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Development of an industry test facility and qualification process for ILI technology and Evaluation Enhancements

Final Report - ILI Trials and Performance Evaluation Phase

NDE-4F

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Prepared for the

Operations and Integrity Technical Committee

of the Pipeline Research Council International, Inc.

and the Department of Research and Development of PHMSA

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Abstract

The project "Development of an Industry Test Facility and Qualification Processes for in-line inspection (ILI) technology Evaluation and Enhancements" aims to expand knowledge of ILI technology performance and identify gaps where new technology is needed. Additionally, this project aims to provide a continuing resource for ILI technology developers, researchers and pipeline operators to have access to test samples with a range of pipeline integrity threats and vintages and in-line technology test facilities at the Pipeline Research Council International, Inc. (PRCI) Technology Development and Deployment Center (TDC), a PRCI managed facility available for future industry and PHMSA research projects.

An ILI pull test facility was designed and constructed as part of this project based on industry state-of-the-art and opportunities for capability improvement. The major ILI technology providers, together with pipeline operator team members, reviewed the TDC sample inventory and designed a series of ILI performance tests illustrating one of multiple possible research objectives, culminating in 16 inch and 24 inch nominal diameter test strings. The ILI technology providers proposed appropriate inspection tools based on limited knowledge of the integrity conditions in the test strings, a series of pull tests of the provided ILI tools were performed and the technology providers delivered reports of integrity anomaly location and physical dimensions for performance evaluation.

PRCI engaged Blade Energy Partners, Ltd. (Blade) to conduct the evaluation of the ILI data obtained from repeated testing on the 16 and 24 inch pipeline strings at the TDC. Blade Energy was also requested by the PRCI Project Team to incorporate prior work concerning the development of the PRCI ILI test facility to serve as a final report for the PRCI project. The resulting data was analyzed, aligned, compared to truth data and evaluated by Blade, with the findings presented in this report. Quantitative measures of detection and sizing performance were disclosed in-confidence to the individual ILI technology providers. For instances where ILI predictions were outside of claimed performance, the vendors were given a limited sample of actual defect data to enable re-analysis, thus demonstrating the potential for improved integrity assessment with validation measurements.

Project Team Members

Company	PRCI Member Level
Australian Pipelines & Gas Association	Technical Program Associate Member
Baker Hughes, Pipeline Inspection	Technical Program Associate Member
Baoshan Iron & Steel Co., Ltd.	Technical Program Associate Member
Boardwalk Pipeline	Pipeline Member
Buckeye Partners, L.P.	Pipeline Member
Chevron Pipe Line Company	Pipeline Member (Team Lead)
China Petroleum Pipeline Bureau	Associate Member
Colonial Pipeline Company	Pipeline Member
ConocoPhillips	Pipeline Member
Electric Power Research Institute	Pipeline Industry Organization
ENGIE	Pipeline Member
Eni S.p.A.	Pipeline Member
Enterprise Products	Pipeline Member
ExxonMobil Pipeline Company	Pipeline Member
Gassco A.S.	Pipeline Member
GE Oil & Gas	Associate Member
Kinder Morgan	Pipeline Member
Marathon Pipe Line LLC	Pipeline Member
N.V. Nederlandse Gasunie	Pipeline Member
National Fuel Gas Supply Corporation	Pipeline Member
National Grid	Pipeline Member
NDT Global	Technical Program Associate Member
Operations Technology Development	Pipeline Industry Organization
Pacific Gas and Electric Company	Pipeline Member
Phillips 66 Pipeline LLC	Pipeline Member
RCP Inc.	Associate Member
Shell Global Solutions (US) Inc.	Contractor
Shell Pipeline Company LP	Pipeline Member
T.D. Williamson, Inc.	Technical Program Associate Member
The ROSEN Group	Technical Program Associate Member
TransCanada PipeLines Limited	Pipeline Member
TransGas Limited	Pipeline Member
Williams Companies, Inc.	Pipeline Member

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List of Acronyms

PRCI	Pipeline Research Council International
TDC	Technology Development Center (PRCI's)
DOT	Department of Transportation (United States of America)
PHMSA	Pipelines and Hazardous Materials Safety Administration
CFR	Code of Federal Regulations (United States of America)
NTSB	National Transportation Safety Board
ASME	American Society of Mechanical Engineers
API	American Petroleum Institute
POF	Pipeline Operators Forum
ILI	In Line Inspection
NDE	Non Destructive Evaluation
IP	Intellectual Property
MFL	Magnetic Flux Leakage
EMAT	Electro Magnetic Acoustic Technology
ML	Metal loss
IML	Internal Metal Loss
EML	External Metal Loss
GW	Girth Weld
GWA	Girt Weld Anomaly
SME	Subject Matter Expert
EDM	Electrical Discharge Machining
CNC	Computer Numeric Control Machining
RMS	Root Mean Square
UIN	PRCI's Unique Identification Number
HAZ	Heat Affected Zone
POD	Probability of Detection
POI	Probability of Identification

List of Nomenclature

OD	Outside or external diameter
ID	Inside or internal diameter
in or ”	Inch/es
mm	Millimeter/s
ft	Foot/Feet
lbs	Pound/s
mph	Miles per hour
d	Feature depth in absolute units
d%	Feature depth in relative units
L	Feature Length
W	Feature Width
A	The greater of Wall Thickness or 10 mm (0.4”) in the POF diagram
GENE	General Corrosion/Metal Loss
CIGR	Circumferential grooving
CISL	Circumferential slotting
AXGR	Axial grooving
AXSL	Axial slotting
PITT	Pitting
PINH	Pinhole
e	Difference (or error) between measurements
$\delta(d\%)_{ILI}$	Depth Tolerance for an ILI system
$\sigma(d\%)_{NDE}$	Depth standard deviation for an NDE system
δe_{comb}	Combined tolerance

1. Executive Summary

The Pipelines and Hazardous Materials Safety Administration (PHMSA) hosted the Government and Industry Pipeline Research & Development Forum in Arlington, Virginia in July 2012. The workshop resulted in a common understanding of current research efforts, a listing of key challenges facing government and industry, and a compilation of potential research areas whose exploration will assist with meeting these challenges and should therefore be considered in the development of new research and development applications. PHMSA pipeline safety representatives determined a need and solicited major research areas including support for the evaluation and improvement of in-line inspection (ILI) technology to identify and characterized pipeline features.

The Pipeline Research Council International, Inc. (PRCI) submitted a proposal on behalf of its membership and research partners for a research project aiming to establish a test facility and a standardized process for evaluating In-Line Inspection (ILI) technologies for the energy pipeline industry. Successful PHMSA co-funding in 2013 enabled the PRCI project NDE-4F "Development of an Industry Test Facility and Qualification Processes for In-Line Inspection technology Evaluation and Enhancements", which provides a continuing resource for ILI technology developers, researchers and pipeline operators to have access to test samples with a range of pipeline integrity threats and vintages, in-line technology test facilities at the PRCI Technology Development and Deployment Center, and demonstrated test protocols. This PRCI managed facility is available for future industry and PHMSA research projects.

The ILI pull test facility, designed and constructed as part of this project, is based on industry state-of-the-art and opportunities for capability improvement. The facility targets both hardware and software improvements in the context of detection, characterization and sizing capabilities of ILI systems[*]. BMT Fleet Technologies, under a separate PRCI research contract, engaged with the five PRCI associate members who are ILI technology providers to gather information regarding the characteristics, advantages and limitations of industry ILI test facilities. The major ILI technology providers, together with pipeline operator team members, reviewed the PRCI TDC sample inventory and designed a series of ILI performance tests illustrating one of multiple possible research objectives, culminating in 16 inch and 24 inch nominal diameter test strings. ILI technology providers proposed appropriate inspection tools based on limited knowledge of the integrity conditions in the test strings. Due to limitations in the project budgets, magnetic flux leakage based ILI metal loss technologies from the two participating ILI technology providers was identified for testing by the PRCI project team.

PRCI engaged Blade Energy Partners, Ltd. (Blade) to conduct the evaluation of the ILI data obtained from repeated testing on the 16 and 24 inch pipeline strings at the TDC. A series of pull tests of the provided ILI tools following the team's defined protocol were performed at the TDC, and the technology providers analyzed the data for metal loss and dents and delivered reports of integrity anomaly location and physical dimensions.

The resulting ILI data was aligned, compared to truth data and evaluated by Blade for conformance with the full detailed performance specification for the tested technology, with the findings presented in this report. Quantitative measures of detection and sizing performance for metal loss

[*] ILI System = tool hardware/sensors + analysis algorithms + analysis team

features were disclosed in-confidence to the individual ILI technology providers. For instances where ILI predictions were outside of vendor claimed performance, the vendors were given a limited sample of actual defect data to enable re-analysis, thus demonstrating the potential for improved integrity assessment with validation measurements.

The identity of the ILI technology providers tested is held confidential and not disclosed in this report by prior agreement within the full PRCI project team as a condition of participation.

The documentation and ILI performance cases studies contained in this report illustrate the design and execution of testing applicable to the wide variety of future ILI research and practical qualification opportunities.

The test protocol consists of an initial trial (Test Trial 1) where ILI tools are pulled through the TDC test strings with only parametric string information revealed to the ILI technology providers. The ILI tool data was analyzed and the report delivered to Blade Energy for correlation, where the ILI system performance is measured and compared with the vendor's established performance specifications.

MFL tools with similar resolution, in general, claim similar detection and discrimination, with the exception of pin holes. However, the depth sizing performance (i.e., ±15%, ±10%, ±8%) can be very different between technology providers for similar ILI systems. ILI performance requirements are pipeline application specific and outside the scope of this project.

The comparison of the Test Trial 1 with the actual flaws concluded both ILI technologies were within their claimed performance specification for detection and identification of metal loss features. The results also demonstrated that the MFL technologies tested performed generally within their claimed sizing specifications, with the exception of some specific metal loss shape geometries with instances of bias or random error. The potential for this behavior is well known within the industry, and forms the basis for the discovery processes found in Codes, Standards and Regulations related to pipeline integrity. The Pipeline Safety Trust saw API 1163 incorporating several process steps critical to effective discovery, including the receipt and validation of ILI data, feedback and continual improvement. These discovery processes form the basis for the design, by the project team, of the specific test protocol used in this project demonstrating the improvement in the understanding of true ILI performance possible by incorporating effective feedback to the ILI providers.

The vendors indicated their ability to correct systemic errors for their sizing analysis based on the return by Blade of limited truth data sample for the defect shape classifications near or out of claimed specification. The vendors documented the fact that ILI system detection and discrimination performance is the sum of mechanical tool performance and data analysis. In the absence of an actual ILI tool failure, (defined as mechanical, electronic or operator error) there is no value in re-pulling the tools and gathering new raw data. The re-analysis correcting discrimination based on the limited truth data returned to the vendor for those defect categories that were out of their claimed specification constituted the Trial 2 for this project.

It is not possible, within the scope of this project, to make head to head comparison of performance between the ILI systems used in this project; only the comparison with their individual claimed specifications is possible.

The comparison of the revised ILI results (Test Trial 2) with the actual flaws shows both ILI technologies are within their claimed performance specification for detection, discrimination and sizing. The Project process and results effectively demonstrates a current industry integrity assessment approach where ILI system integrity assessment performance can be improved when a sample of truth data is returned to the vendors to improve the ILI data analysis.

2. Introduction

Pipeline Research Council International (PRCI) Project NDE-4F was initiated in 2013 to support the evaluation and improvement of in-line-inspection (ILI) technology to identify and characterize pipeline features. This US DOT – PHMSA and PRCI cooperative research program draws upon the expertise of ILI technology development, pipeline operating companies and ILI subject matter experts (SME's) to develop a testing protocol and modular pull test facility at the PRCI Technology Development Center (TDC) in Houston, TX, USA, to evaluate ILI technology performance and opportunities for improvement.

The project plan was developed by the PRCI team members, consisting of funding pipeline operators and associate members (including ILI technology providers), with contracting scope of work directed to PRCI for contract management.

PRCI engaged BMT Fleet Technology (BMT) to conduct a study of the industry's state-of-the-art on facilities to do full scale testing of ILI tools, to design and manage the construction of an ILI pull test facility and to develop operational protocols. PRCI also engaged Blade Energy Partners, Ltd. (Blade) to conduct the ILI performance evaluation of the data obtained from testing on the 16" and 24" pipeline strings at the TDC. Blade was then engaged to:

- Compile the availability of features with known/measured dimensions in the 16" and 24" strings at the TDC in a format compatible for comparison with In Line Inspections.
- Review the ILI Pull-through Testing Protocol that was prepared for the pull-through tests and propose recommendations for changes as needed.
- Witness and supervise the ILI pull-through runs to ensure feature and ILI data anonymity, the monitoring of the key run parameters and appropriately blind tests for the tool run trials.
- Evaluate the resulting pull-through ILI data and statistically validate the ILI tool performance in terms of their capabilities, limitations and potentials in detection, discrimination and characterization.
- Act as the custodian of the defect and ILI data databases to ensure their accessibility to PRCI members with the appropriate anonymity and IP protection, and
- Prepare and present technical briefings and reports for technical review meetings and deliverables.

The PRCI project team, consisting of both pipeline operators and ILI technology providers, defined the test specific objectives and developed a test specific protocol based on pipe samples available through PRCI and the TDC.

3. Value to Members

The documentation and ILI performance case studies contained in this report illustrate the design and execution of ILI systems testing applicable to the wide variety of future ILI research and practical qualification opportunities.

4. Project NDE-4F

4.1 Project Background

The Government and Industry Pipeline Research & Development Forum was held in Arlington, Virginia, USA, in July 2012. The workshop resulted in a common understanding of current research effort, the listing of key challenges and a compilation of potential research areas whose exploration would assist with meeting those challenges. Included in that list was research on anomaly detection and characterization in pipelines that was subsequently reflected in a Pipelines and Hazardous Materials Safety Administration (PHMSA) research announcement [1]. The Pipeline Research Council International proposed to PHMSA the development of an industry test facility and the qualification process for in-line inspection technology evaluation, and the enhancements to improve industry understanding of pipeline anomaly detection and characterization. A contract was awarded by PHMSA in 2013 that subsequently was incorporated into PRCI's project NDE-4F.

In accordance with the API Standard for in-line inspection system qualification [2], the methodology used to qualify the performance specification is based on at least one of the following methods:

a) verified historical data;
b) large-scale tests from real or artificial anomalies; and/or
c) small-scale tests, modeling, and/or analyses.

ILI Performance specifications define the ability of the ILI system to detect, locate, identify, and size pipeline anomalies, components, and features when run in a specific pipeline configuration.

The validation of ILI performance specifications based on full scale tests is routinely [3] performed by some ILI technology providers and private industry research organizations and is the focus of this Project. However, this capability requires both a physically capable facility and the access to relevant calibrated samples. For some performance measures such as probability of detection and limits of detection, full scale tests provide accurate data based on a fully know population whereas validation based on excavation data can only provide estimates based on a finite number of samples.

The project also noted a limited availability of ILI test facilities in North America that were accessible to all ILI technology providers and that could provide a full range of test samples correlated or calibrated to the wide range of integrity conditions seen in field data. To address the gap in capability, PRCI developed the industry-wide* test facility located at the PRCI Technology Development Center (TDC) located in Northwest Houston, Texas, USA (see Figure 1).

Given the advent of the TDC facility and the availability of an inventory of recovered line pipe samples with a variety of integrity conditions, large scale tests of ILI systems is the focus of the PRCI proposal to PHMSA and of this PRCI project.

The PRCI project represents the combined efforts of two principal researchers for the following work scope in conjunction with the efforts of the PRCI staff and PRCI members serving on the

* Open to all the pipeline operators and all the technology providers, including ILI and NDE.

Project Team including pipeline operators and associate members, both ILI technology providers and technical consultants.

Figure 1: Location of the PRCI's Technology Development Center*

4.2 The Phases of Project NDE-4F

The PRCI project NDE-4F was executed in four phases:

* 6410 Langfield Road, Building J, Houston, TX 77092, USA (https://goo.gl/maps/oa3EshPuJMJ2)

Email: TDC@prci.org - Phone +1 (281) 846-7570 - https://www.prci.org/

4.2.1 Design and Construction of a Pull Test Facility

The PRCI Project Team evaluated the design feasibility for both liquid and air coupled test facilities based on the state of the art study performed by BMT fleet. The team concluded that air coupled (pull test) facilities provided the best flexibility for testing both Magnetic Flux Leakage (MFL) and Electro Magnetic Acoustic (EMAT) ILI tool technologies under the range of pipeline diameters and run parameters known to affect ILI system performance.

The design criteria for the test facility was determined from a series of engagements with ILI technology providers who were also PRCI associate members, with the final design incorporating the state-of-the-art where possible and aimed to increase the physical capabilities of the PRCI pull test facility compared to other similar industry facilities.

The design and construction was managed by PRCI and BMT Fleet Technology, with commissioning in June of 2015. Appendix A summarizes of the design basis development, design details and capabilities of the pull test facility.

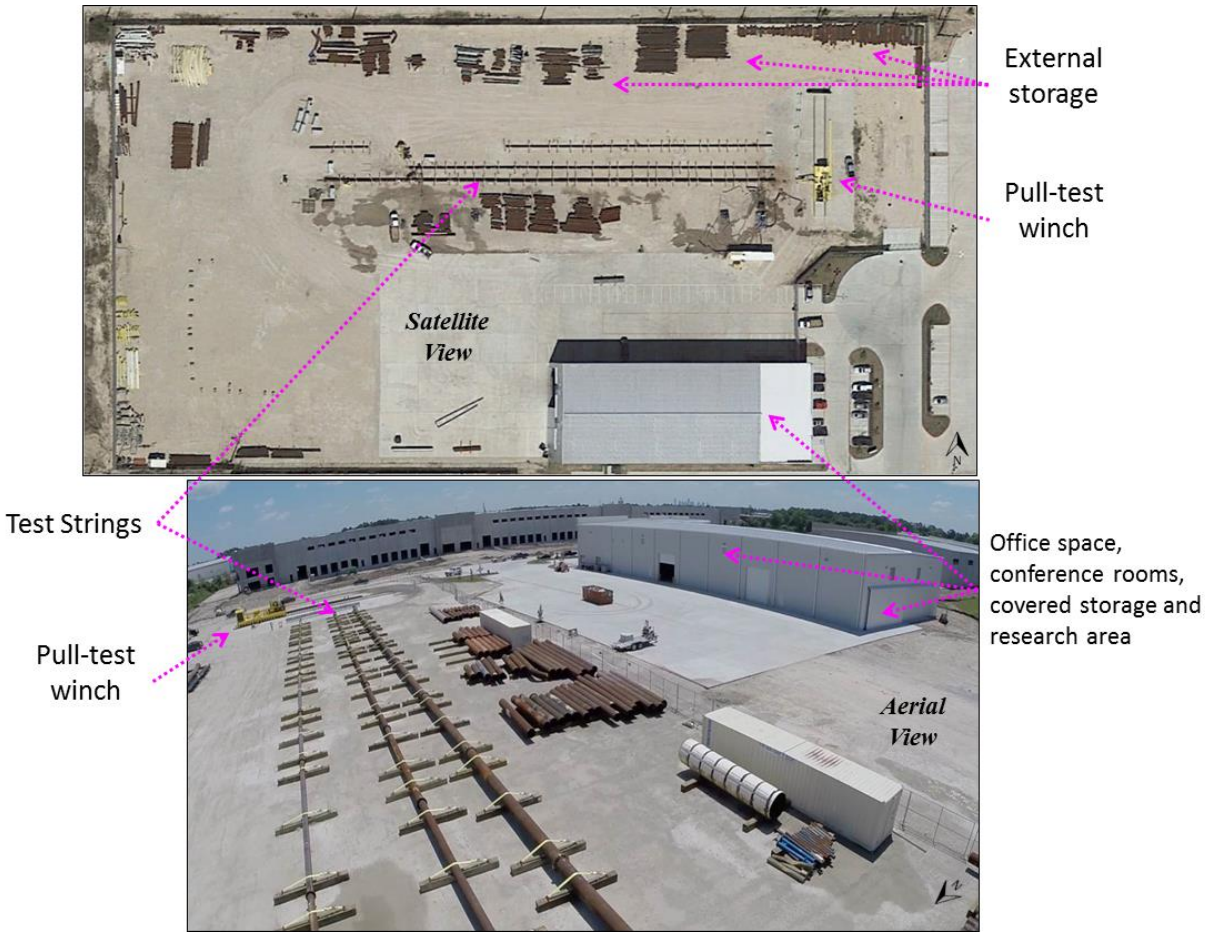

Figure 2: Satellite and aerial view of the TDC

Propulsion of ILI tools through test strings is accomplished by pulling tools using a motor powered winch, see Figure 3. The winch can pull up to 40,000 lbs-force (18,144 Kg-force, or 18.1 ton-force), and the operation of the pull tests (start and end location and speed control) is soft-

ware controlled. The pull speed range is from 0.5 to 11 mph (0.22 to 4.9 m/s) in 0.5 mph (0.22 m/s) increments.

As of the date of this report (2016) the facility has been utilized to test a total of seven different ILI technologies across four different research projects (PRCI and private member research).

Figure 3: Pull test winch

4.2.2 Design of Testing Protocols

A test specific protocol must be developed that addresses the desired objectives or results anticipated from the test. The PRCI Project Team (pipeline operators, associate members, ILI technology providers and industry experts) identified the following three possible types of performance specification qualification test for selection based on the test objectives:

- **Blind Tests:** Blind tests are a type of test where the actual size (or truth data) of the features in the test samples is not disclosed to the ILI technology provider being tested. The criteria used to evaluate the technology performance can either be the performance specification from the technology provider or the specification required by a pipeline operator. In either case, the types of integrity conditions* that are part of the test population must be disclosed because ILI systems their processes and related performance capabilities are not universal.
- **Semi Blind Tests:** Semi blind tests are similar in design to fully blind tests, except that there is partial disclosure of the frequency of integrity conditions with the actual sizing for the purposes of calibration or process improvement. The acceptance criteria can be either the pipeline operator specification or the technology provider performance specification.
- **Full Open Tests:** In full open tests, the full truth data relating to type, location, frequency and severity of integrity conditions is disclosed to the ILI technology provider. The objectives for this type of test are used to fully develop or to improve a performance specification.

For the demonstration protocol in this NDE-4F project, the Project Team selected a blind test (Test Trial 1) followed by a semi-blind test (Test Trial 2).

The test protocol considered the testing of three types of magnetic flux leakage ILI tools from two ILI providers in test strings between 300 and 400 feet in length, with nominal pipe sizes of

* But not their locations and sizes.

16 and 24 inches. The ILI technology providers were provided attribute data for the two test strings limited to the pipe diameter, nominal wall thicknesses, pipe grade and indication that the test strings may contain volumetric metal loss defects as well as unspecified mechanical damage features.

4.2.3 Test Samples

The test samples used in a qualification test of a performance specification must address the objectives of the test protocol. The line pipe used to construct the test strings is sourced from the TDC inventory.

PRCI operating members continue to donate to PRCI a significant quantity of pipe in the range of 8 to 24 inches recovered from operating pipelines or from previous PRCI research where they are known to contain various examples of a variety of integrity conditions, metal loss, cracks and mechanical damage. There are multiple levels of characterization (pipe and defect attributes) of PRCI samples employed by PRCI depending on the needs of research:

Level 1 (All Pipe)

- Pipe received with supporting NDE data (ILI, dig data) validating threats present in pipe
    - *Decision: Enter pipe into inventory that has PRCI relevant defects and supporting data or scrap. Diameter, nominal wall, type and grade, source, predominate threat are logged.*

Level 2 ("The pipe we keep")

- Confirmed presence of predominant threat by NDE screening
    - *Visual, magnetic particle inspection MPI, pit gauge, spot UT thickness gauging*
- Defect location map by relative distance, clock and marking of reference features on the pipe.
- More than 1133 pipe samples.

Level 3 ("The pipe we use in research")

- Fully characterized to requirements of individual PRCI project objectives
    - *E.g. testing metal loss tools; Level 3 limited to mapping of metal loss and dent depth, length, widths. Crack tool evaluation requires crack profiling. Mechanical property projects require mechanical testing, etc.*
- Over 75 samples.

For the test protocol objectives employed in this project, Level 2 and Level 3 characterization is employed to meet the detailed specification developed jointly by the project team and Blade Energy. The integrity conditions in the test samples require characterization by direct examination NDE to a least the level of discrimination cited by the ILI technology provider in their performance specification. What this meant for the test protocol developed and demonstrated in this project is the truth data obtained by PRCI requires detection, location and sizing of thru wall depth, or remaining wall, length and width for metal loss using direct examination technologies with possible error at least equivalent to that claimed for the ILI systems.

The design of the test strings involved the assembly of individual pipe joints containing integrity features by welding into approximately 40 foot long flanged test spools. The absolute and relative axial distances and circumferential orientations for each metal loss or mechanical damage defect together with relative distance, through-wall depth, axial length, circumferential width and orientation measurements together with the details regarding the NDE method used constituted the "truth" data for the test strings. More than 60% of the individual samples with metal loss features were taken from Level 1 and Level 2 to the Level 3 required for this project enabled by the funding available through this PHMSA project.

As the natural metal loss features found in the pipes available did not cover all the ranges of depth, length and width necessary for the test, one flanged section was fabricated using new pipe with machined (artificial) metal loss features. This joint with artificial metal loss features was also built under this funding.

The artificial metal loss features were fabricated by two methods. For the internal metal loss, Electrical Discharge Machining (EDM) was employed. EDM is limited by surface area for portable equipment and therefore the number of artificial internal features was limited. For the external artificial metal loss, end mill Computer Numeric Control Machining (CNC) method was employed. For the larger general metal loss a constant depth bottom profile was specified with a surface roughness no greater than 250 microinches RMS. No special treatment was specified for internal and external corner radii.

The design, construction and final characterization of the test strings began in September of 2014 and were completed in 2016, representing the combined efforts of PRCI staff, the PRCI Project Team and the principal researchers Blade Energy and BMT Fleet Technology.

The final characteristics of the strings used are:

- Nominal Wall Thickness: 0.250 to 0.500 inch
- Seamless and seam-welded pipe
- 14 samples with different UIN[*] from the TDC inventory were used in the 16 inch while 29 were installed in the 24 inch string
- A number[†] of Natural and Artificial (manufactured) Integrity Threats, see Figure 4 and Figure 5.

[*] UIN = PRCI's Unique Identification Number, the number that identifies each pipe sample at the TDC.

[†] The number, distribution and actual sizing of the features of these strings are held confidential until other PRCI projects using them allow its release.

Figure 4: Example of artificial and natural metal loss features

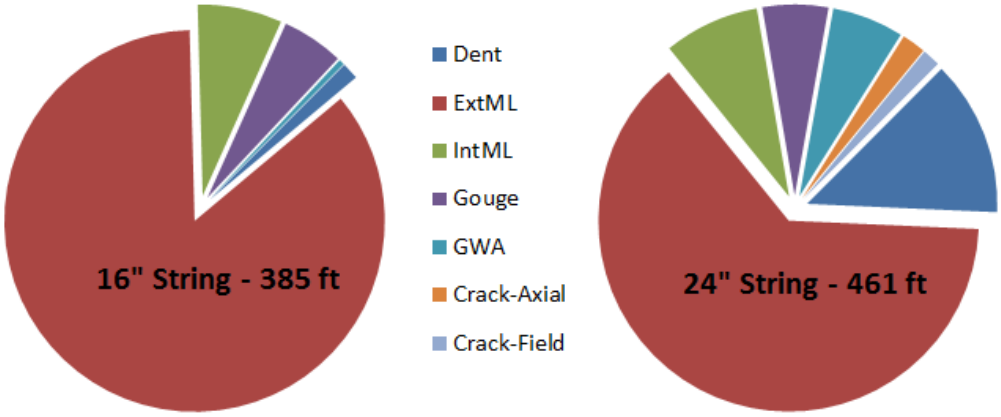

Figure 5: Distribution of Integrity Threats per string

4.2.4 ILI Tool Performance Research

Once the ILI tools were run, the ILI vendor provided an ILI report for each of the repeated runs done. In the work scope by Blade Energy, the ILI results are aligned with the TDC truth data and the findings evaluated in terms of detection, identification and sizing and conformance with the claimed specifications for the respective ILI systems.

This report focuses in this phase of the project.

5. Considerations for Design of ILI System Qualification Tests

5.1 Why We Test

Pipeline integrity is subject to a wide array of threats. The Code of Federal Regulations[4] states that an operator must identify and evaluate all potential threats to each pipeline segment as listed in ASME/ANSI B31.8S, which are grouped under the following four categories:

1. Time dependent threats such as internal corrosion, external corrosion, and stress corrosion cracking;
2. Static or resident threats, such as fabrication or construction defects;
3. Time independent threats such as third party damage and outside force damage; and
4. Human error.

The risk of the first 3 type of threats can be minimized by using Hydrostatic Testing (HT), In Line Inspection (ILI), Direct Assessment (DA) or "other technology", and a pipeline operator must select the method or methods best suited to address the identified threats. This work focuses on immediate and future threats that can be addressed and reported by ILI.

As mentioned in API 1163[2], the process of successfully performing an ILI integrity assessment begins with the operator defining inspection goals, objectives and the pipeline system characteristics to define the performance of the ILI systems regarding classification, characterization, location and coverage capabilities for the anomalies of interest and the pipeline to be inspected.

Threats such as metal loss, cracks and deformations can manifest themselves in terms of physical dimensional characteristics that may (or may not) be within the documented performance capability of an ILI system due to the limitations of the physics of the non-destructive technology used, in the state-of-the-art of the available technologies and in commercial market demands. Therefore, a written performance specification for the chosen ILI system in a particular pipeline setup is required.

The Pipeline Safety Trust sees[5] API 1163 as a positive step in addressing many of the shortcomings in smart pigging that less experienced companies may not yet understand. They identified the critical steps or processes that pigging systems need to incorporate: 1) Identify risk of concern on each pipeline segment, 2) Choose the right ILI tool, 3) Use the appropriate tool appropriately, 4) Receive and validate ILI data, 5) Integrate the ILI data with the pipeline system data, and 6) To provide feedback and continual improvement. All 6 critical steps were applied to the work done in this project NDE-4F.

Furthermore, the post San Bruno NTSB Accident Report[6] mentions that "pigging still provides operators the most information from actual examination of the pipe wall" while the post Marshal Michigan NTSB Accident Report[7] "recommends that the Pipeline Research Council International conduct a review of various in-line inspection tools and technologies—including, but not limited to, tool tolerance, the probability of detection, and the probability of identification—and provide a model with detailed step-by-step procedures to pipeline operators…", both important drivers for the creation and use of the TDC facility in projects as NDE-4F.

In addition, the API standard defines the qualification of ILI systems as the process of validating the performance specifications of an ILI system through test and analysis. The validation of the

performance specification can be accomplished by application of one of three typical approaches:

- Validation Based on Small-scale Tests, Modeling and Analyses; Data from small scale tests, modeling, and/or analyses may be used to demonstrate that the performance of a system or component, such as a type of sensor, is consistent with data used for qualifying performance specifications.
- Validation Based on Historic Data; where dimensions and characteristics have been physically measured after ILI anomalies have been exposed, such as with direct examination Non Destructive Examination (dig data).
- Validation Based on Full-scale Tests; Data from full-scale tests on real or artificial anomalies may be used for qualification of a performance specification provided the data are correlated or calibrated to field data. An example of a full-scale test is a pull test.

PRCI proposed to PHMSA this project employs the option for full scale tests based on the strength of the organization to supply and manage pipeline samples and their ability to serve the largest range of possible system test objectives.

5.2 The Basics of ILI and the Essential Variables for MFL ILI

An ILI assessment of a particular pipeline section using an ILI technology consists of "the inspection tool run" followed by the issue of "the ILI report" to the pipeline operator. The final ILI deliverable, then, reflects the following hardware, data and evaluation components:

1. The physical data gathering system (the tool, with its specific sensing technology* and specific sensors, batteries, storage and electronics attached to a carrier body that propels it through the pipeline to inspect)
2. The specialized data and signal processing methods and analysis algorithms (the analysis software)
3. The team of Subject Matter Experts who analyze and interpret the outputs of the analysis software and produces and compiles the inspection report (the analyst / analysis team) and the processes to ensure the quality of the outcome.

The final product, usually a list of detected features with their characterization and dimensions, is then the result of all 3 parts working together and will be referred in this project as "the inspection system". The distinction between a tool and a system is important because it is only at the "system" level that any ILI technologies deliver detection and discrimination results to a pipeline operator; ILI tools record and deliver data, ILI systems deliver actionable results.

Each of these 3 parts are influenced by a number of factors or variables that may change the outcome of the inspection report, with particular interest in this work in the accuracy of the resulting feature sizing.

Essential variables within any test are those elements that, when changed, can have a significant influence on the results of a test. This chapter focuses on what are the variables embodied in ILI

* Typical ILI technologies: Axial MFL, transverse MFL, Ultrasonic - wall measurement, Angular Ultrasonic (including Phase Array Ultrasonic,

tool design or in the design of a test protocol that can significantly affect the outcome or conclusions. This project focused on the use of Magnetic Flux Leakage (MFL) technologies that were proposed by the ILI providers as most suitable for the integrity threats present in the test strings (see Chapter 6).

5.2.1 The Magnetic Flux Leakage Technique

The physics surrounding the detection and discrimination of metal loss by Magnetic Flux Leakage (MFL) principle is well documented [8,9,11]. MFL techniques detect and measure the change in the magnetic flux applied onto the pipeline wall. In the basics, see Figure 6, a pipeline wall with no metal loss will conduct all of the magnetic field from the North magnetic pole to the South magnetic pole of the magnetic circuit applied, and none of the magnetic field will leave the wall. On the other hand, when a magnetic discontinuity feature is present, part of the magnetic field cannot be conducted and it comes out of the wall (it "leaks") creating a signal in the sensor.

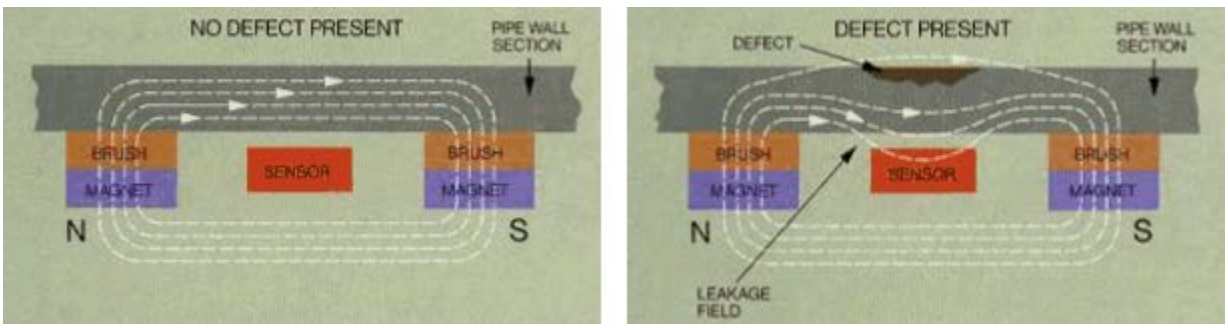

Figure 6: The basics of MFL signals – Figure reproduced from reference[8]

The basic magnetic discontinuity to be detected with this technology is a volumetric metal loss, like the one associated with both internal and external corrosion, and the MFL technology has become the most popular one to address these (most common) threats.

5.2.2 Shape Influence of the Metal Loss Feature on MFL Signal Responses

Magnetic Flux leakage signals are influenced by the size and shape of the metal loss feature within the magnetic field as well as possible physical property changes in line pipe as well as of the geometric effects (shape) of the discontinuities.

Defect shape and orientation within the magnetic field imposed on the pipe wall by the MFL tools significantly affects the strength and character of the leaked magnetic fields due to volumetric defects [9]. In the example shown in Figure 7 the imposed magnetic field is axially oriented; orientations other than axial may be seen in specific ILI tool configurations. The ILI providers can be contacted directly for tool configuration details.

For an isolated metal loss feature the resulting magnetic leakage field is not linearly proportional, neither in amplitude nor in shape, to the feature's depth and shape, and algorithmic techniques of signal interpretation are required to produce a set of estimated dimensions (typically reported depth d, length L and width W).

In addition, when different metal loss features are close enough to each other, the magnetic leakage produced by one of them will potentially affect the magnetic response of the others, increas-

ing the complexity of the resulting magnetic field and its interpretation in order to produce an accurate set of estimated dimensions.

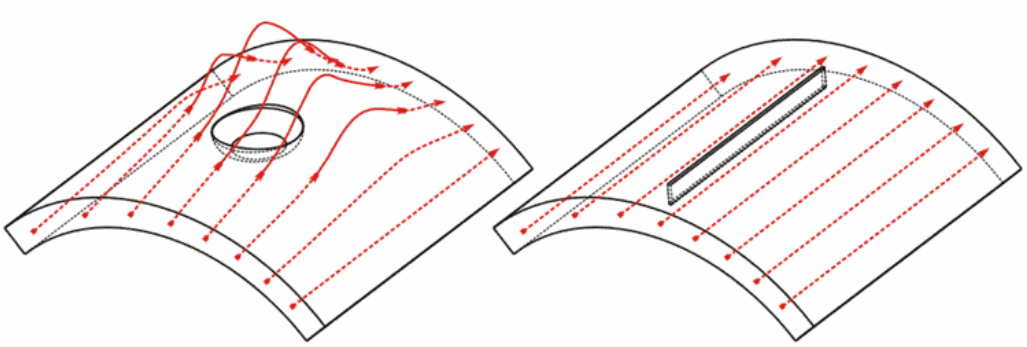

Figure 7: Example of signal strength affected by feature geometry

Therefore, the analysis of these signals requires specialized signal processing software (Analysis Software/Analysis Algorithms) and Subject Matter Expert (SME) personnel (Analyst). This combination of analysis algorithms with SME personnel used by ILI technology providers to evaluate MFL signals collected by the ILI tools represents fundamental intellectual property of the technology providers and comprises an ILI system compared with the sensor technologies that make up the ILI tool. The behaviors of MFL signals affected by defect, size, shape and interaction must be considered by SME's when they are correlating MFL predictions with defects.

5.2.3 The Basics of ILI Reporting

The ultimate pipeline integrity objective is to identify those features that are not suitable for safe operation in order to act on them before a failure condition (rupture or leak) is reached.

The objective of an MFL inspection is to identify all the areas with potential metal loss in a pipeline section, and to report the physical geometric dimensions that can be used to better characterize them and evaluate their significance in terms of the integrity of the pipeline. As the failure conditions are directly or indirectly* based on the dimensions of the ML features, there is a direct relationship between sizing accuracy of the ML features and increased probability to characterize their significance on integrity.

The main outputs of an ILI system are:

- A written report that describes the run (technology or tool used, identification of the pipeline, operator, date, operating conditions et cetera), and
- A list of all detected features (valves, girth welds, attachments, anomalies) in spreadsheet format.
- A signal viewer, a software package able to display and scroll a representation of the collected ILI signals.

This listing includes the significant sizes estimated for each metal loss feature, and in the case of an MFL one the process to obtain that list is described below.

* Leak condition is usually based on peak depth, while Rupture condition is based on the estimated failure pressure of the feature, which is mostly based on the depth and length of the feature or in its depth profile along its length in a more sophisticated (iterative) assessment.

5.2.3.1 Individual Metal Loss Features (Boxing/Pitting)

As described in 5.2.1, when there is an area with metal loss, the MFL sensors see a change in the magnetic flow and a change in the signal is recorded for each sensor crossing the area. The process is repeated for every area that can be individually distinguished in the signals and each of those individual areas can be identified by its location (distance and orientation) and its estimated dimensions (length, width, depth). Different ILI vendors have different names within their internal processes for these individual features, for the purposes of this report they will be called either "boxes" or "pits". Each box will then be assigned an individual axial length (L), a circumferential width (W) and a peak depth (d).

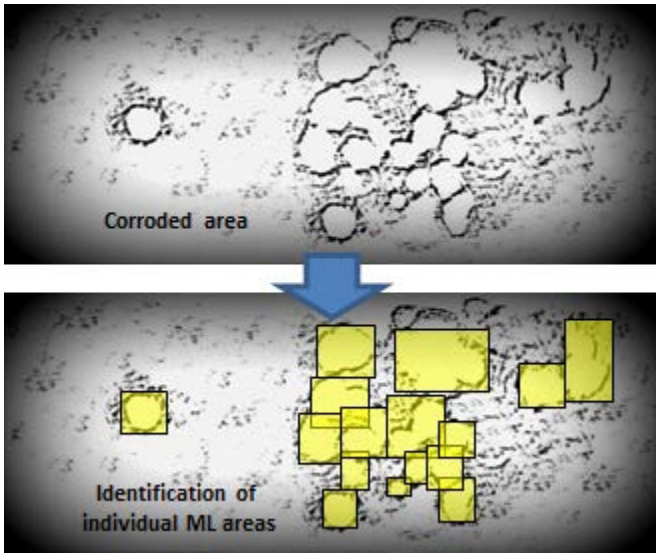

Figure 8: Identifying individual ML features

Isolated pitting areas will then be comprised by single boxes or pits, while more complex corroded areas will have a higher number of individual ML features, as illustrated in Figure 8.

The algorithms and methods for converting MFL signals to approximations of volumetric metal loss are varied, and the performance accuracies achieved represent the intellectual property of the ILI technology providers.

5.2.3.2 Group of Metal Loss Features (Clustering/Grouping)

The next step is to define when individual ML areas belong to the same corrosion feature in order to estimate its total length and width.

The boxes that share common areas can be grouped together as belonging to the same corroded area. However, as the system is not capable of detection below the detection threshold, the areas between the boxes may have low level corrosion that is not boxed and some of the non-touching boxes may belong to the same corroded area, resulting in the under call of the length of the ML feature. To better estimate the actual length of these multi-box metal loss areas, a process called clustering or grouping is used. This process groups together any box that is "close-enough" to the next one, i.e. that the axial or circumferential distance between them is shorter than a defined

threshold*. Figure 9 illustrates the results of the clustering/grouping process for the individual features in Figure 8, with the green areas showing the resulting clusters/groups and the red area on the right cluster showing the deepest box in that cluster.

The data is finally processed and a cluster length and width is calculated for each group of boxes, along with its peak depth (the deepest box/pit), as shown in Figure 10. Each cluster/group is then assigned a distance and an orientation and the final combination of distance, orientation, depth, length and width becomes a reported metal loss feature included in the ILI system listing.

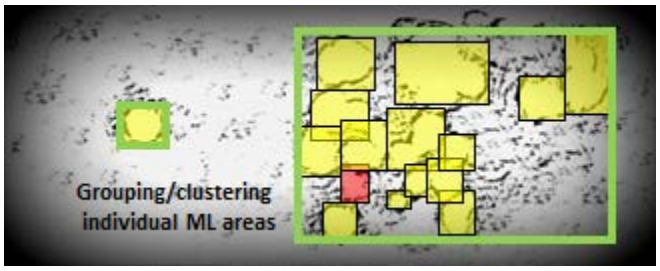

Figure 9: Clustering/grouping

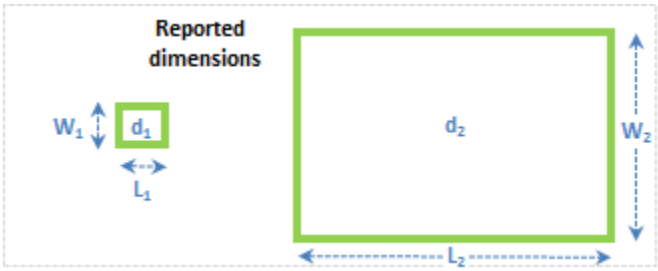

Figure 10: Cluster/Group dimensions

Different ILI vendors use different reporting rules when it comes to how the cluster dimensions are reported. For instance, each cluster's distance may be reported at the beginning of the cluster, at its center or at the distance of the deepest box, while orientation could be related to the top, center, bottom of the cluster or the one from the deepest box, as illustrated in Figure 11.

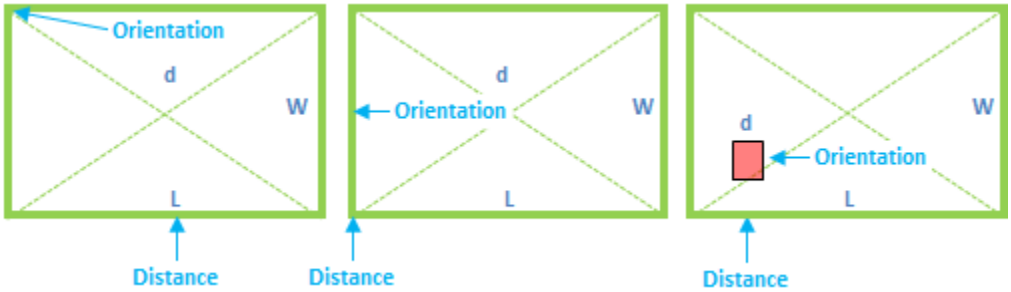

Figure 11: Different reporting rules

In addition, both the reported distance and orientation could be subject to numerical rounding (to the closest inch, to the closest decimeter, to the closest quarter of hour, for instance).

* The clustering/grouping criterion may be defined by the ILI vendor or agreed between the ILI vendor and the pipeline operator.

Moreover, different vendors have different criteria for inclusion of boxes/pits and cluster/groups in the provided listings. All of them include the clusters/groups in the final listings, some include both the box/pits and cluster/groups, some others generate separate listings for cluster/groups and boxes/pits, and in all cases attention need to be paid to understand the contents of each ILI listing.

As the description of most of these reporting criteria is not usually included in the ILI system report, each ILI vendor needs to be consulted to clarify them before any in-ditch or pull-through comparison is made.

5.2.3.3 Thresholds (Magnetic, Boxing, Reporting)

The different stages of magnetic data analysis have different reporting thresholds[2]. At the most basic stage of the data signal processing, the minimum amount of change in sensor readings to be considered above the signal/noise ratio (and therefore a potential metal loss feature) is one of these thresholds, and a fundamental intellectual property of each ILI vendor. In general, the number and distribution of boxes/pits depends on how the signals are processed, filtered and their thresholds defined, and once the signal data is initially processed and the spurious calls eliminated, the resulting boxing/pitting distribution remains constant.

On the other hand, the clusters/groups mostly depend on what clustering/grouping rule is used, and a single boxing/pitting array may result in a significantly different number and distribution of clusters/groups that make it to the report listing, as illustrated in Figure 12.

On the other end of the analysis process, clusters/groups below a certain depth may not be included in the final listing, especially useful for those cases in which the number of spreadsheet rows is limited or widespread low level corrosion.

Once again, the user needs to work closely with the ILI vendor to understand if reporting thresholds and the type of clustering criterion that were applied to the final resulting listing and their potential to affect pipeline integrity decisions.

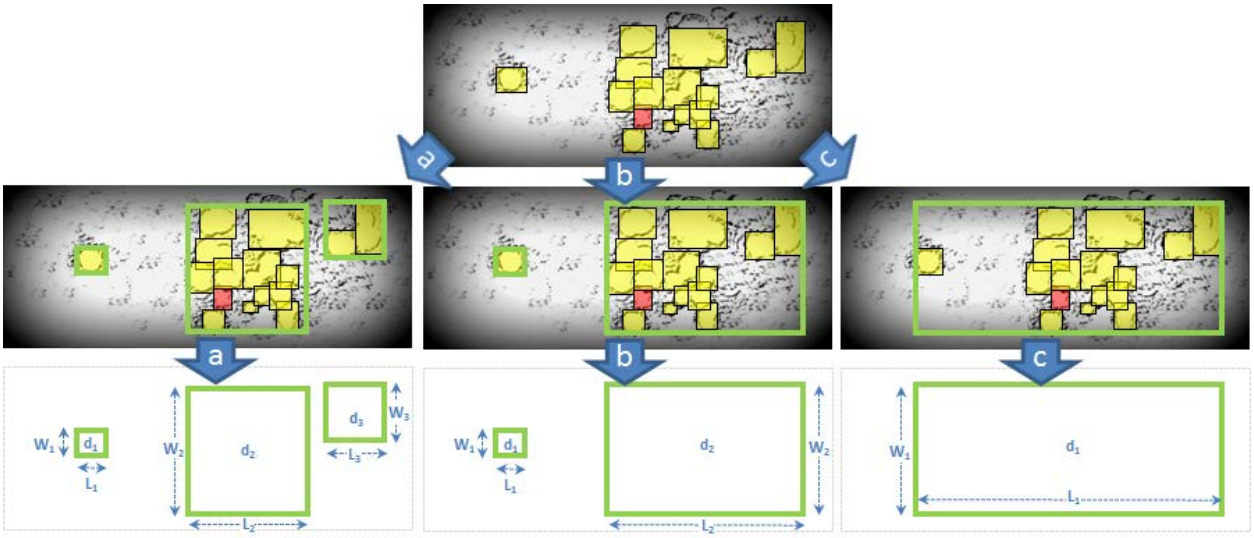

Figure 12: Different listing results from different clustering/grouping criteria

5.2.4 Magnetic Saturation – Wall Thickness – Tool Speed

An MFL inspection system able to detect and size metal loss features requires that the magnetic response of the pipe wall has a lineal behavior [10] when compared with the sensor readings. This magnetization response can only be achieved at high magnetization levels, where it is sensitive to wall thickness changes or to the presence of metal loss features.

Magnetization levels below the lineal behavior are more sensitive to material variations and are used in other MFL applications [11] for discrimination of damage associated to geometrical features (Mechanical Damage). However, they show degraded detection and sizing accuracy capabilities for metal loss feature in comparison to higher magnetization levels.

Such high magnetization levels are achieved through the high magnetic strength of the magnets used in the tool and the design of the magnetizers, both parameters that are part of the intellectual property of each ILI vendor.

Another way of ensuring the high magnetization levels are achieved is by controlling the maximum wall thickness of the pipeline to be inspected. The thicker the wall section, the higher the magnetic field strength required for full saturation.

The travel speed of the ILI tool along the pipe also plays a role in the ability of a given magnetic field strength to fully saturate the pipe wall. The higher the speed, the lower is the time of the steel exposed to the magnetic field and the higher the chances of achieving levels of magnetization acceptable for this application.

Therefore, a complete ILI performance specification must address the applicable pipe wall thickness range for its performance specification and the maximum travel speed permitted in order to achieve full saturation at the extreme end of the wall thickness specification.

Typical MFL acceptable speeds are below 4 m/s (9 mph) with typical wall thickness not exceeding 1” (25mm)[12]. However, each vendor must be consulted for the applicability of each different MFL technology to be used and magnetization levels should be carefully reviewed when the pipe wall exceeds 0.500” (12.7mm).

5.3 The Pipeline Operator Forum Specification

The Pipeline Operator Forum[13] (POF) has formalized basic classifications of metal loss shapes as a basis of inspection performance evaluation of MFL based on their relative ability to disturb pipe wall magnetic flux*.

The POF metal loss diagram for defect shape and orientation has formed the de facto basis for detection and discrimination performance of ILI technologies against the size and shape of metal loss feature (see Figure 13, where W is the circumferential width of a feature, L its axial length and A, a normalizing parameter based on the wall thickness† of the pipe).

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* Assuming the tools used are achieving acceptable levels of magnetization of the pipe wall through the control of the maximum wall thickness and maximum speed during the tool run.

† A = the greater of Wall Thickness or 10 mm (0.4”)

The areas and shapes defined by the POF diagram and the abbreviations that are used in this report are:

- General Corrosion (GENE)
- Circumferential grooving (CIGR)
- Circumferential slotting (CISL)
- Axial grooving (AXGR)
- Axial slotting (AXSL)
- Pitting (PITT), and
- Pinhole (PINH)

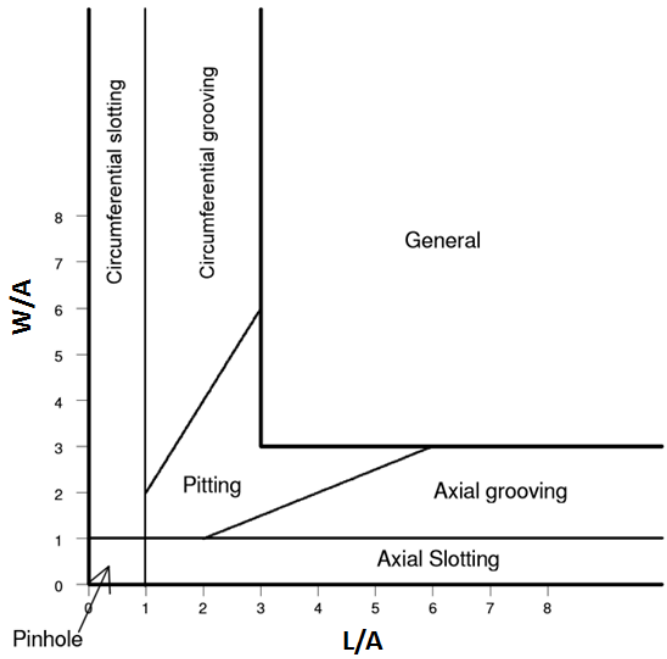

Figure 13: POF diagram – generic form – Figure from reference [13]

For commercialized ILI technologies specialized in the detection and sizing of metal loss features, the system performance specification can be illustrated superimposed on the POF diagram and showing the overall detection and sizing capabilities of the system*.

Figure 14 is an illustration of generalized full tool performance specification envelopes for different MFL technologies superimposed on the POF generic form diagram. Figure 14a shows the generalized tool performance for a generic high-resolution MFL system where the lower bound detection and sizing limits are around 0.5A (i.e. the system is capable of detecting and sizing ML features longer than 0.5A and wider than 0.5A).

* System = ILI tool + analysis algorithms + analysis team

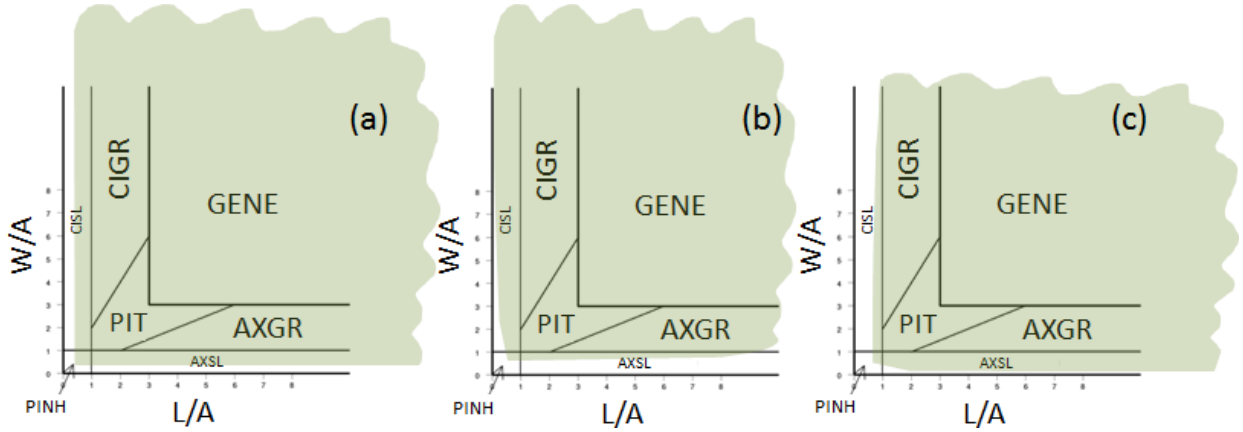

Figure 14: Typical general performance envelopes in terms of the POF diagram

Depending on the configuration of specific ILI tools (magnetic field orientation or sensor types), different performance specifications may be claimed as illustrated in Figure 14b and Figure 14c respectively.

Within the performance capability envelope depicted in Figure 15, the detailed performance specification from the ILI provider may cite different certainty and tolerance for individual POF shape categories.

In the same way, different sizing accuracy may be claimed in the performance specification for ML features in the pipe body* of plate-steel† than in the pipe body of seamless steel‡. The same effect may occur when the sizing of ML features happens near the girth welds, the seam-weld or their heat affected zones (HAZ), where the magnetic properties of the metal is significantly modified by the welding process resulting in areas with higher magnetic noise and reduced detection and sizing capabilities.

A complete performance specification lists the detection and discrimination performance for the ILI system for metal loss Length, Width and Depth for each POF shape category with an accuracy tolerance (in distance units or % WT) and an associated certainty (in %). ILI performance specifications may be further detailed considering tool speed and wall thickness as appropriate for the application.

The industry's most often quoted performance of MFL based ILI for the depth of a common metal loss is +/- 10%t metal loss depth with 80% certainty[14,15,16].

Some ILI performance specifications cite both 80% and 90% certainty but in this project only conformance with the claimed 80% certainty for anomaly depth, length and width is used. The associated sizing tolerance specifications vary from 8%t to as much as 30%t depending on line pipe physical attributes, defect shape and severity or ILI technology used.

From the specifications provided for this project, out of the combined 80 sizing categories similar to those shown in Figure 15 for both technologies, only 3 were actually +/-10%t.

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* away from welds and heat affected zones

† seam-welded pipe fabricated from steel plate, resulting in a minimal variation in the nominal wall thickness

‡ pipe fabricated via steel extrusion, resulting in a greater nominal wall thickness variation

Therefore, a complete or full ILI performance specification is expressed in the format shown in Figure 15, where the Probability of Detection, limits of detection and sizing accuracy are individually specified by the ILI technology providers.

Tool name:	**Magnetic Flow Leakage T**																
Vendor:	**Vendor V**																
Pipetype	**Longseam**							Pipetype	**Longseam**								
Location	**Joint**							Location	**HAZ, Girth Weld**								
Corrosion	**INT, EXT**							Corrosion	**INT, EXT**								
POF class		**GENE**	**PITT**	**AXGR**	**CIGR**	**PINH**	**AXSL**	**CISL**	POF class		**GENE**	**PITT**	**AXGR**	**CIGR**	**PINH**	**AXSL**	**CISL**
Confidence level		80%	80%	80%	80%	80%	80%	80%	Confidence level		80%	80%	80%	80%	80%	80%	80%
Depth at POD=90% [%nwt]									Depth at POD=90% [%nwt]								
Depth sizing [%nwt]									Depth sizing [%nwt]								
Length sizing [mm]									Length sizing [mm]								
Width sizing [mm]									Width sizing [mm]								
Pipetype	**Seamless**							Pipetype	**Seamless**								
Location	**Joint**							Location	**HAZ, Girth Weld**								
Corrosion	**INT, EXT**							Corrosion	**INT, EXT**								
POF class		**GENE**	**PITT**	**AXGR**	**CIGR**	**PINH**	**AXSL**	**CISL**	POF class		**GENE**	**PITT**	**AXGR**	**CIGR**	**PINH**	**AXSL**	**CISL**
Confidence level		80%	80%	80%	80%	80%	80%	80%	Confidence level		80%	80%	80%	80%	80%	80%	80%
Depth at POD=90% [%nwt]									Depth at POD=90% [%nwt]								
Depth sizing [%nwt]									Depth sizing [%nwt]								
Length sizing [mm]									Length sizing [mm]								
Width sizing [mm]									Width sizing [mm]								
Pipetype	**Unknown**							Pipetype	**Unknown**								
Location	**Joint**							Location	**HAZ, Girth Weld**								
Corrosion	**INT, EXT**							Corrosion	**INT, EXT**								
POF class		**GENE**	**PITT**	**AXGR**	**CIGR**	**PINH**	**AXSL**	**CISL**	POF class		**GENE**	**PITT**	**AXGR**	**CIGR**	**PINH**	**AXSL**	**CISL**
Confidence level		80%	80%	80%	80%	80%	80%	80%	Confidence level		80%	80%	80%	80%	80%	80%	80%
Depth at POD=90% [%nwt]									Depth at POD=90% [%nwt]								
Depth sizing [%nwt]									Depth sizing [%nwt]								
Length sizing [mm]									Length sizing [mm]								
Width sizing [mm]									Width sizing [mm]								

Figure 15: Example of a complete ILI performance specification

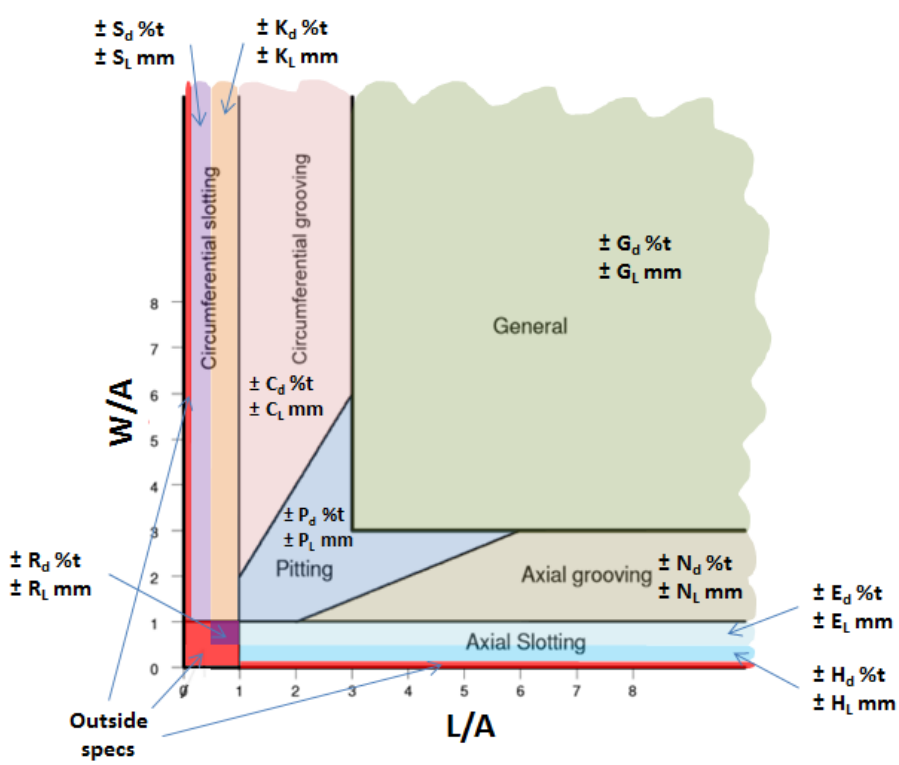

Figure 16: POF diagram depicting the different sizing specs for different type of ML features

Moreover, the ILI system capabilities for features shorter and/or narrower than the typical lower limits shown here (0.5A) may also be addressed in higher detail depending of the ILI systems selected or the vendor capability.

Therefore, a single type of pipe (seam-welded, for instance) will have different sizing specs that need to be taken into account when evaluating an ILI system, as illustrated in Figure 16.

The POF diagram, and the ILI sizing specifications based on it, do not have defined upper limits for defect length (left) or width (up), i.e. metal loss features infinitely long or infinitely wide can still be characterized in terms of the POF metal loss classifications.

In addition, the POF category defect types are purely based on the length and width of an idealized feature and do not discriminate by feature shape complexity. Based on the overall dimensions, a large (long and wide) metal loss area may be considered "general" irrespective of its river bottom profile but still would be evaluated with the "general" specifications. Large corroded areas with small areas of deep metal loss (as in pitting or the pinhole POF types) as detectable by the ILI system may not be dimensioned (if at all) in a given POF defect category where further analysis is needed to accomplish a suitable comparison. This gap is not addressed in this project but has been identified and can be found on the PRCI I&I roadmap.

These characteristics will be further discussed later in this report (see chapter 7 below).

5.4 Consideration of ILI and NDE Performance Errors

5.4.1 Location Matching

As described in 5.2, MFL-based ILI predicts the dimensions and locations of abstract "boxes" meant to approximate actual corrosion as derived from the interpretation of magnetic flux leakage signals associated with pipe wall metal loss. The derivation of these boxes, and interacting boxes forming clusters, depends on proprietary signal processing algorithms and their correlation with actual metal loss features located on a pipe during direct examination requires consideration of the fundamental tool design and signal/data processing by the SME conducting the correlations.

The spatial association of ILI features with actual corrosion was accomplished by correlating the position coordinates from the ILI tool with measurements taken on the pipe from fixed references such as girth welds and top center of pipe. When metal loss features are relatively isolated and well defined, the correlation of predictions from the ILI feature log with observations during direct examination have nil distance correlation error, in which case the in-ditch error is limited direct measurement error.

In addition, direct examination can result in detection of other actual metal loss outside the reliable detection limits for ILI technologies as described by the Pipeline Operator Forum. The Locating conventions used by ILI to define the positions of the reported features (top, center, bottom, deepest point, as described at the end of 5.2.3) can also vary between ILI vendors. These issues can cause difficulties in correlating ILI features with metal loss detected by direct examination representing a significant opportunity for in-ditch error.

To overcome difficulties with correlating ILI predictions to direct examination observations, computer algorithm pattern matching techniques are available where a match in the overall patterns for both ILI predictions and actual corrosion (as obtained by in the ditch techniques) have

proven to be more reliable than by distance based locating of individual features from reference points for some metal loss morphologies[17]. These more advanced tools for correlating ILI predictions with direct examination observations are more useful when correlating length based criteria such as burst pressures or for metal loss features with complex bottom profiles and did not have application for the depth based correlations performed in this project.

5.4.2 Combined Measurement Errors

To validate ILI results, reported ILI measurements are compared to corresponding field measurements, also mentioned as truth data. In an ideal situation, the reference (field) measurement error is small enough to be considered zero when compared with the ILI measurement to more easily distinguish the source of error and evaluation of ILI performance. However, in-field direct examination measurements do have practical errors of magnitudes near the ILI that need to be taken into account in a way that the apparent error observed when comparing in-ditch observations of actual metal loss depth with ILI predictions represents a combination of the true ILI error and the in-ditch errors[2,18].

As stated in API 1163, whose guidance will be used in this project, for a given anomaly (like a metal loss feature), the difference (or error e) between the ILI and the field measurements is given by

$$e = Measurement_{ILI} - Measurement_{Field}$$

Since the sizing difference e reflects the sizing error from both the ILI and the direct examination field measurements, it is not appropriate to compare the sizing error implied by the e values obtained for a number of matched field and ILI measurements to the sizing error that can be inferred from the ILI performance specification. Instead, the sizing error implied by the e values must be compared to the total combined sizing error that reflects the both the sizing error implied by the ILI performance specification and the sizing error inherent in the field measurements.

In the case of MFL inspection, ILI depth measurements are reported directly in units of relative metal loss. In contrast, ultrasonic techniques measure the general wall thickness or the remaining pipe wall directly, while other techniques measure absolute metal loss depth directly. Therefore, ILI and field measurements need to be expressed in consistent terms in order to be comparable.

On the other hand, distance and length/width measurements are reported in absolute units for both the ILI and Field systems.

For the comparison purposes of this project, the depth of the metal loss features to evaluate were all converted to relative units, i.e. they are expressed as a percentage of the wall thickness for both the ILI and the Field (or truth) data:

d% = absolute ML depth / wall thickness

Therefore, the difference (or error) of the relative depth measurements between the ILI and the Field measurement systems can be expressed as:

$$e = d\%_{ILI} - d\%_{Field}$$

For the purposes of the comparisons used in this project, the depth measurements of the ILI and Field systems are considered independent and normally distributed, and the standard deviations (σ) of each measurement can be approximated in terms of tolerances (δ) at a certain confidence

level. Following API 1163 guidance, the tolerance of the combined measurement for an 80% certainty level (1.28 factor) can be expressed as

$$\delta e_{comb} \leq \sqrt[2]{[\delta(d\%)_{ILI}]^2 + [\mathbf{1.28}\ \sigma(d\%)_{NDE}]^2}$$

and an individual ILI measurement can then be considered out of tolerance if

$$|e| > \delta e_{comb}$$

As an example, if the stated ILI specification tolerance for a certain type of metal loss feature is ±10%t at 80% certainty and the Field NDE standard deviation is 5%t, the acceptable depth difference between ILI and Field depth measurements results in 11.9%t.

$\delta(d\%)_{ILI}$	$\sigma(d\%)_{NDE}$	δe_{comb}
10	5	11.9
15	5	16.3
20	5	21.0
25	5	25.8

Figure 17: Example of acceptable depth error for different ILI tolerances and Field NDE variation

For the purposes of the NDE-4F research the "truth or reference" measurements of the metal loss and mechanical damage features were obtained by a variety of methods, namely; pit gauges, ultrasonic measurements, surface replicas or laser profilometry. Detailed deviation estimates for each method used are not available for this project, however PRCI previously conducted research characterizing the errors inherent in the measurement of pit depth for these common Non-Destructive Examination techniques in Project EC-4-2[19], concluding that when all are applied to relatively isolated metal loss features on round, straight pipe they all exhibited errors of approximately +/-5% nominal wall thickness. This result is comparable with Blade findings[38] in the evaluation of new in-ditch methods for measurement and assessment of external corrosion, therefore the standard deviation of error of the Field measurement was established in 5%t for this project.

6. The ILI Tool Performance Research

6.1 Understanding the ILI Systems for NDE-4F

6.1.1 ILI Technology Used

Individual inspection technologies as provided by vendors have varied detailed performance specifications with respect to the detection and discrimination of metal loss.

There are multiple reasons for this, recognizing that the technologies and their capabilities have developed over time, and that different or specialized performance capability may be required by operators to respond to actual pipeline service conditions and integrity threats.

Within the context of public performance trials such is the case for this NDE-4F research, and for reasons related to intellectual property, competitive advantage and a wide range of performance specifications available to industry, some of the ILI technology team members requested the actual full detection and discrimination specifications of ILI systems not be published in this

report. The ILI technology providers participating in this project have advised the project team that consumers of ILI technologies can directly request them the full performance specifications.

The technologies of the two vendors evaluated were both MFL based metal loss sensors with integrated caliper. The two MFL technologies presented by the participating member providers for test under NDE-4F were field-proven high resolution axial field magnetization tools with ID/OD discrimination and in a configuration combined with geometric (caliper) internal diameter (ID) measurements, and generically identified as “High Resolution Axial MFL with caliper”.

The actual depth accuracy claims vary between the technologies and for the defect shape categories, as described in 5.3.

6.1.2 Specs and Protocols

The ILI vendors provided their detailed metal loss performance specification under confidentiality agreement to Blade.

In addition, Blade separately contacted each of the ILI vendors participating in this project to understand the specifications provided and to clarify and agree the overall process for measurement comparison and acceptance or rejection of measurements.

As the agreed testing protocol was defined to be done within the acceptable speed ranges for each ILI system, 5 different run speeds within the TDC winch capability were discussed with each ILI vendor and selected for each test. The performance specification speed ranges for the two ILI technologies were not the same. As is the case with the detection and discrimination performance specifications the individual vendors should be consulted for the speed ranges as a function wall thickness and defect shape category.

6.1.3 ILI Reporting Criterion

As part of the testing protocol, the ILI vendors were requested to provide the results of the run trials in a reporting format that follows their standard reporting procedures for their most-common customer, i.e. no special or ad-hoc reporting spec was used for this project.

In the conversations held with the ILI vendors participating in this project, Blade requested that within their standard reporting format, the minimum amount of thresholding was applied to the boxing/pitting process, that the clustering/grouping criterion was 6t[*], that the signal data was made available for location checkup purposes, and that a separate list of boxes/pits was included as a spreadsheet if the standard reporting procedures did not include them in the resulting ILI listings.

One of the ILI vendors preferred not to provide signal data, otherwise the ILI reports received fulfilled these conditions.

[*] Two boxes are clustered together if the axial or circumferential distance between them is shorter than 6 times the nominal wall thickness of the pipe.

6.2 The ILI Runs

6.2.1 Overall

Three tools from two ILI technology providers were run for this project, 2 in the 24” string, one in the 16” string.

The ILI technologies were pulled through 5 times at 5 different speeds, all within the range of travel speeds cited by their performance specification in the test strings and previously agreed with each ILI vendor. The speed ranges for the two ILI technologies tested were not the same.

Blade coordinated and supervised the ILI runs performed at the PRCI’s Technology Development Center. The run supervision included the pre-run pipe string preparation (anchoring, ID cleanliness), the review of the winch control parameters (acceleration, deceleration and constant speed times and distances), the tool hook-up safety and the preparation for recovery procedures (in case of abnormal test termination). The operation guide [20] prepared during the construction phase of this project (see 4.2) was used as a guideline during the runs.

Figure 18 illustrates part of the ILI run operations: a) recovery line hook-up, b) main line hook-up, c) reception of the ILI tool and placing on the tool tray, d) an overall view of the 24” string from the launch side, where the launch pipe and the string anchoring system can be observed in more detail, and e) the transportation of the ILI tool with its tray to the launching area.

Figure 18: Images of the ILI runs at the TDC

The winch instant speed and instant applied force was also reviewed, an example of the change in these variables across one of the TDC strings is illustrated in Figure 19, and correlated with the variation of the string wall thickness.

After each test run, the speed, force and wall thickness data was provided to the ILI vendors for feedback purposes.

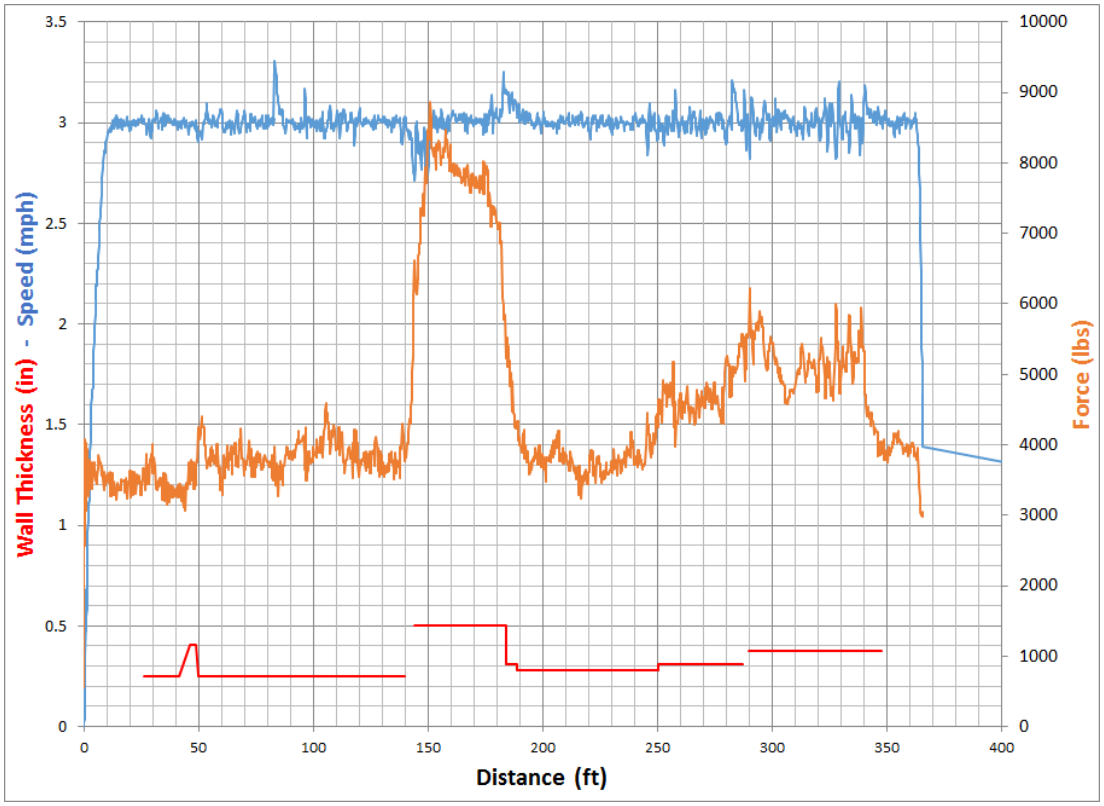

Figure 19: Example of variation of run speed, winch force and string WT versus winch distance

6.2.2 Run Failures

One ILI run was declared a failure by the ILI vendor after the careful review of the sizing repeatability of the resulting initial ILI reports and the review of the mechanical condition of the ILI tool. The ILI vendor internal investigation of the run failure determined that part of the sensor carrier was mechanically damaged, impacting the reliability of the measurements.

The project team worked with the ILI vendor to evaluate the potential causes of the sensor damage and the configuration of the strings was reviewed in detail to minimize events that could lead to a repeated damage. It also worked to reschedule a second run that fitted the project's schedule.

The second run was scheduled and the operations initiated, however they had to be cancelled due to winch speed control problems. Appleton Marine was contacted and a technician was sent to the TDC facility to repair the winch.

A third run was then scheduled and a successful one was achieved, with the ILI data analyzed and finally used for the comparisons in this project.

Experience shows that run failures are infrequent but inevitable. In general, the probabilities of achieving a first run success increase with the maturity of an ILI technology and the experience of the pipeline operator in running inspection tools though their lines. In the case of tools with MFL technologies, first run success ratios are usually high (greater than 90-95%).

There are extensive published guidelines to increase the chances of an ILI run success[21,22,23], the joint work between the operator and the ILI vendor to identify the causes and minimize the risks is one of the key measures.

6.3 The TDC Strings

6.3.1 TDC Truth Data Custodial Status

Blade was entrusted by PRCI with the custody of the truth data of the 16" and 24" strings used for this project, and is only released by explicit instructions from the PRCI team.

This truth data will remain confidential at least until the end of this project NDE-4F, pending notice from the PRCI Research Team as the strings are also used for other ongoing PRCI research projects involving blind comparison exercises.

6.3.2 Distribution of Metal Loss Sizes

The 24 inch string contains 139 machined and natural metal loss features over 321 feet of pipe, while the 16 inch string contains 194 features on 215 feet, in both cases covering depth range between 3%t and through-wall and a wide range of lengths and widths. Figure 20 below shows a partial example* of length and width feature distribution in terms of the POF definitions.

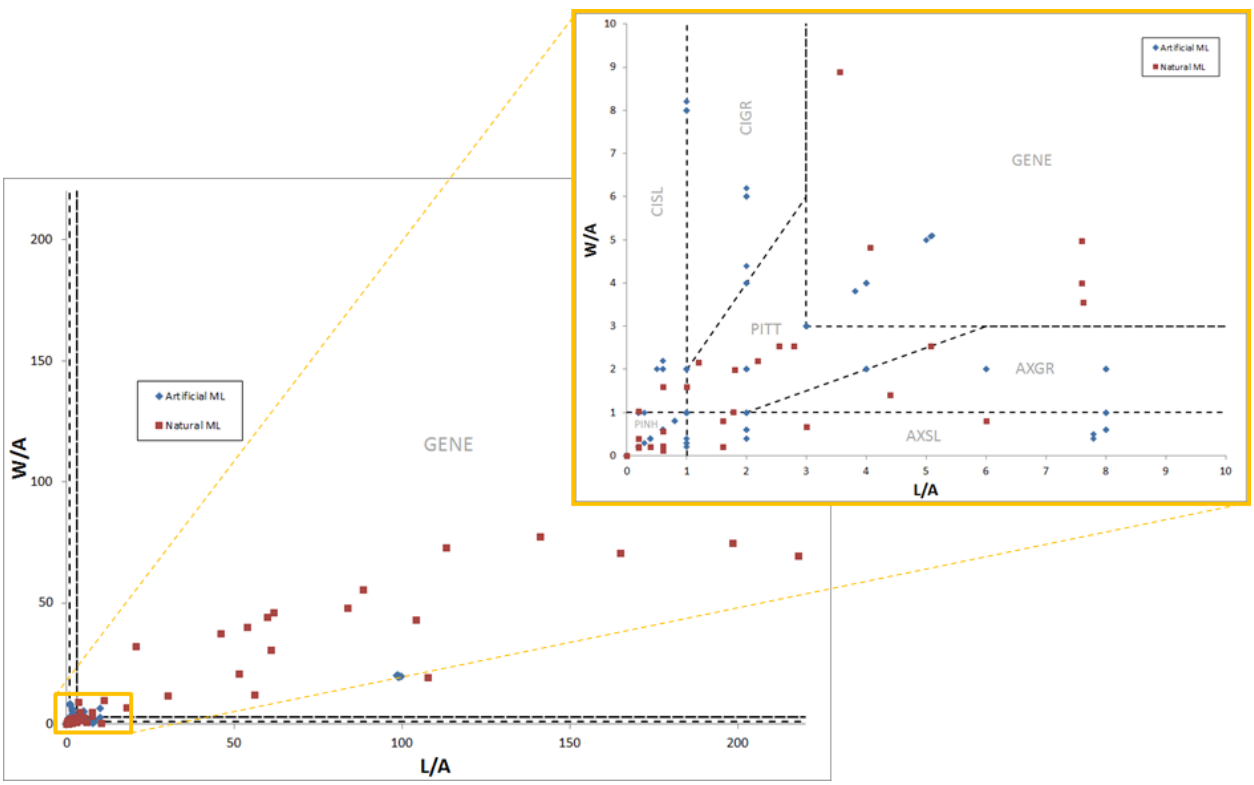

Figure 20: Example of metal loss features length and width distribution

* The figures show a partial example of the existing features, the complete distribution of feature's depth, length and width is kept confidential while other PRCI projects using blind tests are in progress.

6.3.3 Other Features

The strings also contained mechanical damage (gouges, plain dents, dents with gouges, dents with corrosion and cracks) and girth weld anomalies, however, they were not compared and evaluated in this project as there are no published specifications for these types of features.

6.4 The Comparisons

6.4.1 Data Alignment and Feature Matching

The features reported by the ILI were manually aligned with the truth data available from the TDC strings and their dimensions compared.

The first step in this process is to identify benchmarking features (also called hard references) like flanges, girth welds and main attachments in both the TDC and the ILI records for the preliminary distance matching. Figure 21 shows an example of identification and correlation of these main features, shown in a joint containing artificial (man-made) metal loss features. The bottom part of the figure shows rectangles representing the length and width of the features as evaluated by NDE at the TDC string and used as the truth data for this comparison. The Y axis shows their circumferential orientation while the X axis is the distance along the pipe string.

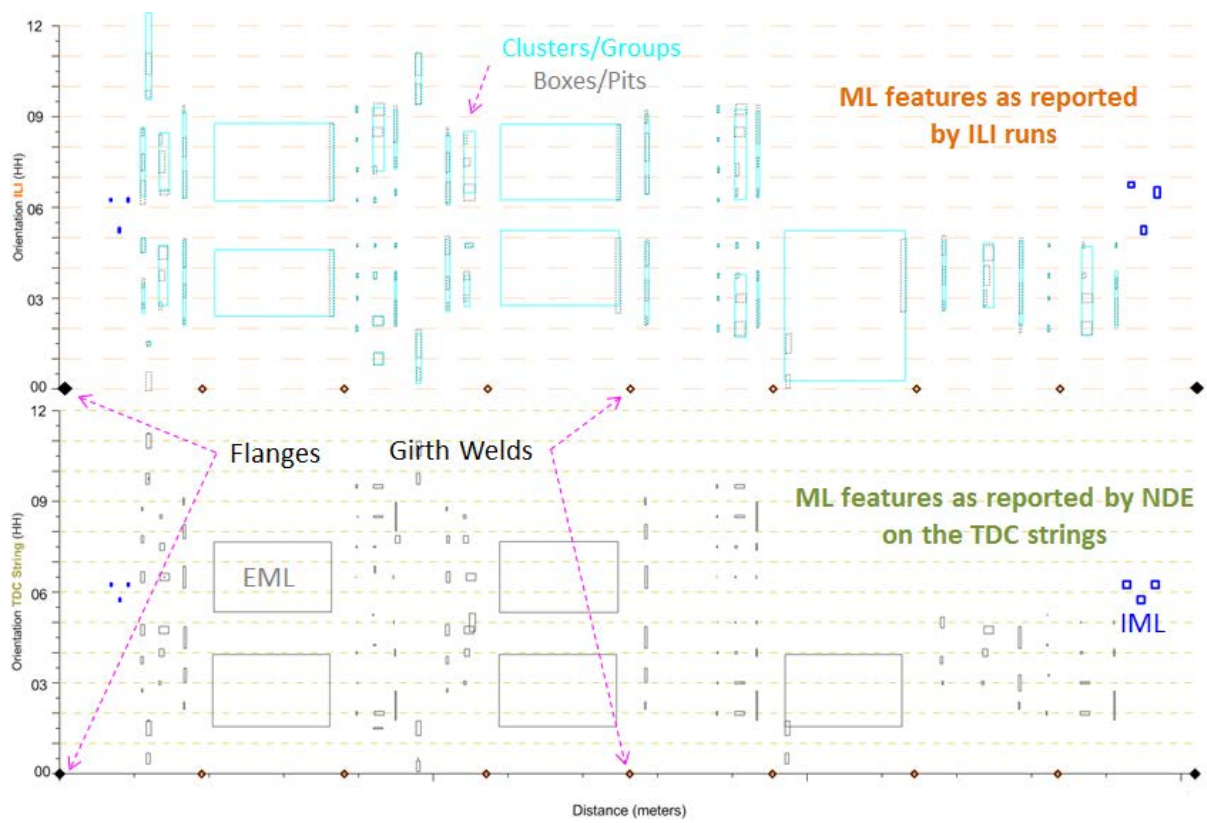

Figure 21: Example of distance correlation of hard references

The following abbreviations are used:

- EML = External metal loss

- IML = Internal Metal Loss
- GW = Girth (circumferential) weld
- Flange = Flange connection joining two separate pipe joints, it acts as a non-welded full circumferential marker

The next step is to match the hard references and identify the main feature patterns, in which any possible odometer slippage is identified and adjusted for the detailed feature alignment.

Finally, each area is compared in detail and each feature reported by the ILI is manually matched with its best TDC counterpart for sizing comparison, and also identifying the features that were not detected or reported by the ILI.

As mentioned in 4.2.3 and illustrated in Figure 4, the strings contained both artificial (man-made) metal loss and natural corrosion features. The artificial features created here have constant depth (flat bottom profile) and well defined edges, and therefore well-defined lengths and widths that simplify the matching process. The matching process is not straightforward where the features are natural corrosion, where the edges are not well defined and/or may fall below the stated system detection capability, as illustrated in Figure 22.

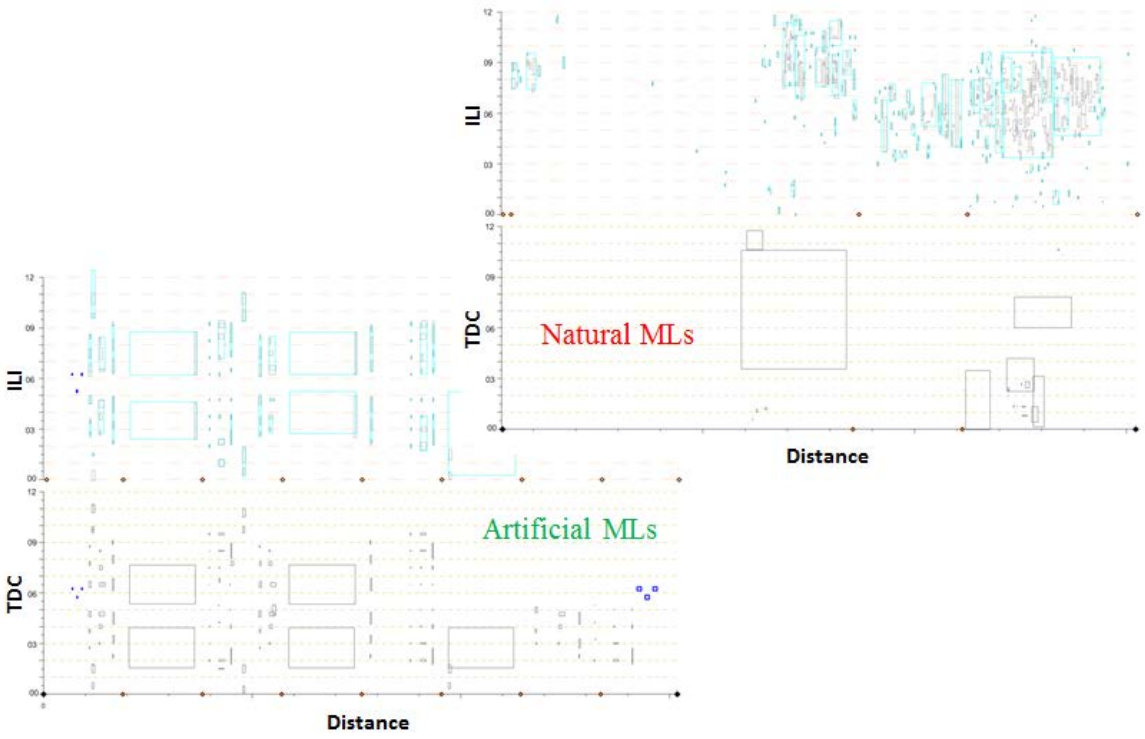

Figure 22: Matching of artificial and natural ML features

6.4.2 Performance Metrics

The basic evaluation of an ILI system* performance consists of a number of separate measures[24], Probability of Detection (POD), Probability of Identification (POI) and Sizing ac-

* ILI System = what results of a combination of an ILI tool, the analysis algorithms and the SME (analysis team)

curacy. POD is the measure of the system's ability to detect an anomaly of a given size and type, while POI is the measure of the system's ability to properly identify the type of anomaly: corrosion, inclusion, or crack. Sizing accuracy is the measure of the system's ability to correctly report the dimensions (depth, length, width) of a given anomaly.

Methods to estimate POD, POI and sizing accuracy for comparisons based on limited size samples using binomial confidence intervals[25,26] and the Clopper-Pearson method[26,27] are well documented and have been used extensively both inside[28,29] and outside PRCI's research[30,31]. However, as the total population of features for the strings is known, the probability measures were calculated as direct rates (number of correct calls / number of possible cases).

6.4.3 Sizing Comparisons

For evaluation of the ILI tool pull through-test performance, the ILI pull-through results were reviewed to make them fully consistent with the existing documented features. The review includes:

- Boxing and clustering rules applied
- Detection threshold and reporting threshold
- Axial and circumferential correction

The predictions from the ILI technologies and methods with the validation data sources were compared. Validation data sources were the available data compiled by PRCI before this project. Additional sources of validation data (like further NDE with different methodologies not available with the TDC documentation) were also evaluated. The key variables for each defect/feature evaluated on the test string included:

- NDE method used for characterization of each type of the features on the test string
- Key parameters such as length, width, boxing and clustering rules, and maximum depth of the features

All the metal loss features in the TDC string were then categorized into the POF classifications (General Corrosion GENE, Circumferential grooving CIGR, Circumferential slotting CISL, Axial grooving AXGR, Axial slotting AXSL, Pitting PITT, and Pinhole PINH, see 5.3 in page 18) and each classification was assigned its corresponding detailed ILI depth sizing specification as per Figure 16.

The test protocol reflected 5 pull tests at multiple travels speeds, all within the tool limits for achieving the performance specification. The ILI technology providers delivered a single Run Report describing the runs and provided ILI listings for each of the 5 test runs at each pull speed.

Measurement or sizing errors, as described in 5.4.2 for each performance category, were calculated and ordered by magnitude. The actual ILI performance is identified at the position in the ordered errors corresponding to the proportion of the correlation sample population that meet the certainty from the claimed performance specification. Blade compared the detailed claimed specifications with the comparisons of the ILI reports (considering NDE error) with the truth data and compared the direct correlation rates (number of correct calls / number of opportunities) with the vendor's stated certainty (80%) and characterized the predictions in the following categories:

- In accordance with the claimed specification

- Out of specification but within a rounding margin of error (5%)
- Out of specification but on the conservative side of the sizing (no immediate integrity threat)
- Clearly outside of the claimed specification
- No claimed performance specification for the particular technology

Unity plots, as described in API 1163, were created for each performance specification category to aid in discussions with the ILI vendors illustrating the behavior of the validation distributions and the conformance with the claimed performance. A hypothetical* example of a unity chart is shown in Figure 23. Those unity charts are not included in this report by prior agreement within the PRCI project team to maintain the blind integrity of the test strings, and respect the confidentiality of their quantitative performance specifications cited by the ILI vendors as a pre-condition for participation in this project. The ILI vendors indicate that they will disclose their quantitative full claimed ILI performance specifications to others subject to individual agreements.

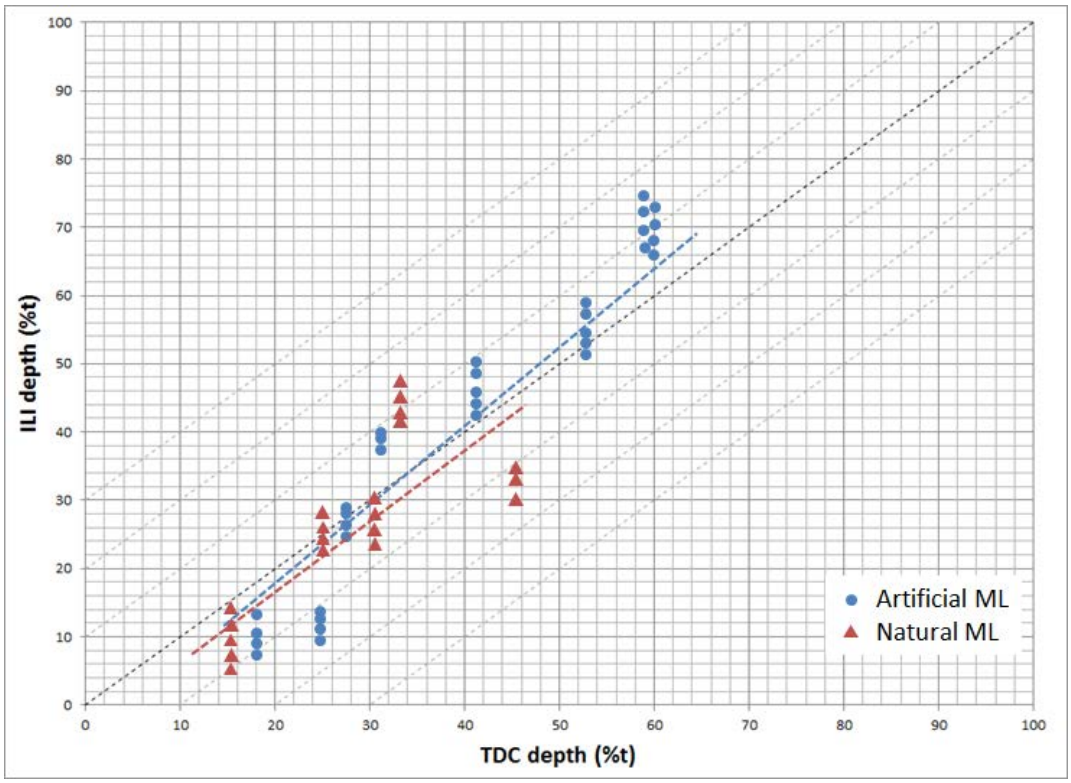

Figure 23: Example of unity chart

For the purposes of reporting the results of testing in this Project, a color matrix with the classifications mentioned above was prepared for each of the 3 ILI technologies in this project, focusing on metal loss feature depth and length, see Figure 24.

Mechanical Damage features and Failure Pressure calculations were not included in the analysis for this report due to no equivalent industry definitions of mechanical damage defect types and no resulting claimed performance by the vendors. As such, they were considered outside the

* The chart does not show actual TDC features to keep the truth data confidential.

primary objective of the project. These topics are found in the PRCI I&I roadmap for future research.

	GENE	PITT	PINH	AXSL	AXGR	CISL	CIGR
POD							
POI							
Sizing Spec (d)							
Sizing Spec (L)							
Sizing Spec (FP)							

References
Inside specification
Close to specification
Outside specification (Conservative)
Outside specification

Figure 24: Specification comparison matrix (empty)

6.4.4 Test Trial 1: Blind Tests

The testing protocol called for an initial blind test (Test 1) followed by a semi-blind test (Test 2), as described in 4.2.2. The ILI Technology providers ran their tools knowing the basic parameters of the TDC strings (diameter, wall thickness, type of pipe) and the indication that the test strings may contain volumetric metal loss defects as well as unspecified mechanical damage features.

The 3 ILI reports were aligned, compared and analyzed as described above, and the results for 3 runs during Test 1 are summarized as follows:

- POD and POI achieved and exceeded the stated specifications of both vendors as all the string metal loss features were detected and properly identified. In addition, the detection and identification capabilities of small (short and narrow) features below the detection capability were better than stated, and the sizing capabilities of small features (sub-pinhole, sub-circumferential slotting and sub-axial slotting) were observed to have improved from previous MFL comparison experiences.
- No significant differences were observed in the results for the range of speeds selected (within the tools operative range for each technology used) and of wall thicknesses available at the strings (0.250 to 0.500”).
- In the same way, the feature length for the artificial metal loss features achieved and exceeded the stated specifications of both vendors. The matching correlation for length of the natural corrosion features resulted in out-of-specification results, mostly due to the no-thresholding of the Field NDE total length measurement criterion. In consequence, length matching for natural ML features was not deemed possible with the current Field NDE level of detail. This finding is consistent with other length comparison experiences in the industry, including the ones done for dents [34] and cracks [29]. In other words, the length results are out of the stated ILI specifications but the ILI runs cannot be rejected based on these comparisons. This effect could be minimized in future projects by increasing the level of detail of the Field measurement of length with the use of more sophisticated measuring techniques [38].
- For the depth accuracy evaluations, an 80% certainty was used against each of the vendor’s stated sizing specifications for all the metal loss feature categories (without discrimination of characteristics). The GENE category was observed to have more results outside specification. A closer examination of the results showed the influence of very large features (length and/or width in excess of 10A in the POF diagram) in the results of the comparisons.

Figure 25, Figure 26 and Figure 27 summarize the results as a color coded matrix:

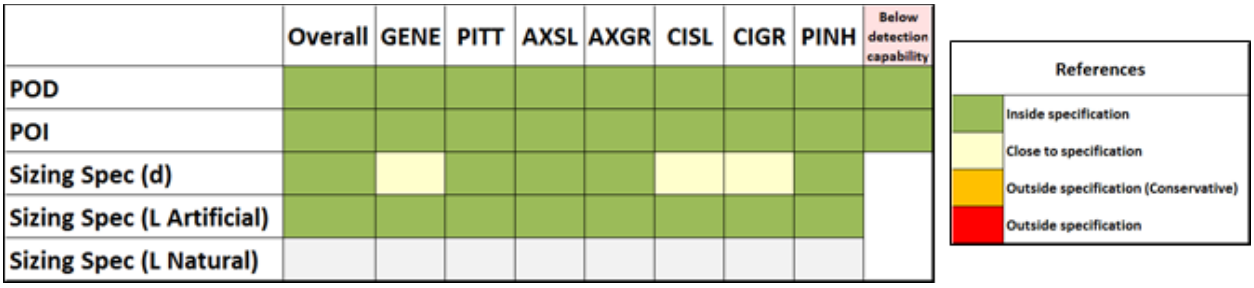

Figure 25: Summary of Results for Test 1 - Vendor 1 – 16"

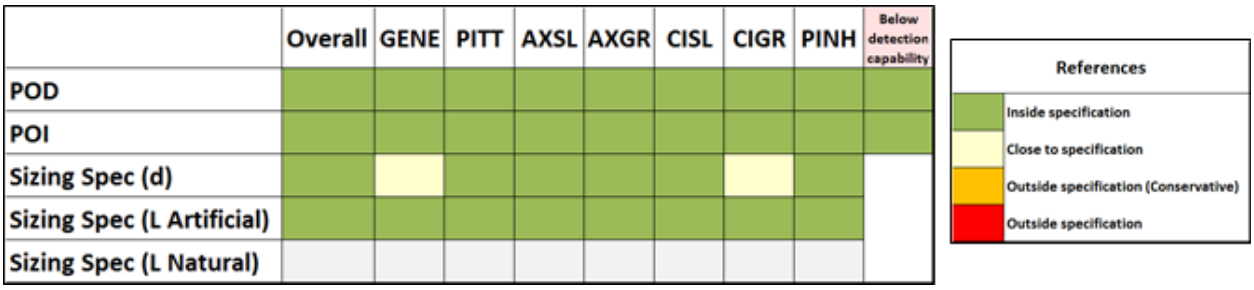

Figure 26: Summary of Results for Test 1 - Vendor 1 – 24"

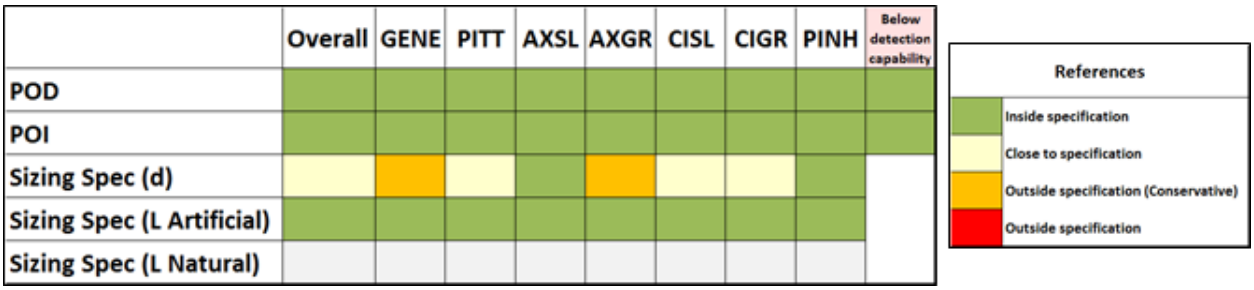

Figure 27: Summary of Results for Test 1 - Vendor 2 – 24"

These results are not intended and cannot be used for head-to-head comparison between the participating technologies and vendors, as their stated specifications are different.

They were separately discussed with the ILI Technology providers, and the potential causes of the deviations reviewed.

6.4.5 Test Trial 2: Repeat Semi-Blind Tests

The findings of the comparison of Test 1 and a more detailed explanation of the morphologies of the metal loss features were separately discussed with each of the ILI Technology providers. The need for new tool runs with the same or with other technology or tool configuration was addressed, with the conclusion that no further improvement was possible with a tool rerun within the context of the research objectives and that a regrade of the existing inspections based on the partial disclosure of the truth data (as following API 1163 guidelines) would be a more suitable solution.

Figure 28 illustrates a unity chart for a hypothetical* situation where the correlations show a non-conservative tendency for the validation population where the corresponding sizing tolerance 80% of the time is not validated. In this case, the ILI vendors recognize the potential within their data analysis system process to make changes.

When coupled with an observation of the bias and random error, together with the actual measurement specifics from a small sample of defects, then enables an accurate comparison of the ILI predictions for the purpose of improvement in discrimination performance and the regrading of those ILI predictions.

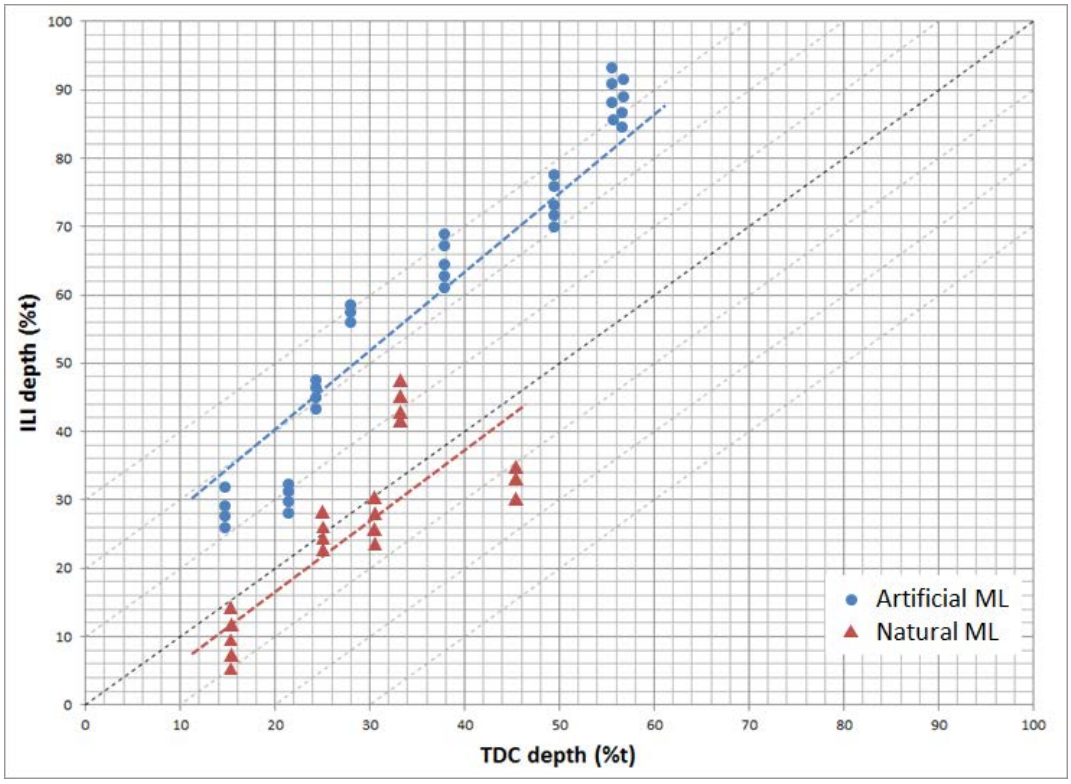

Figure 28: Example of unity chart

Furthermore, the morphologies of the artificial features, and differences due to the natural corrosion features in the assumptions used by the ILI sizing algorithms were also discussed and addressed with the ILI vendors. While differences in measurement performance were noted between natural corrosion and machined analogs, in the case of this validation experiment, those differences did not result in the tested technologies validating outside of their claimed performance specifications.

In this regard, API 1163 presents a process to verify that the reported inspection results have been meet and are consistent with the performance specification for the pipeline being inspected. Samples of truth data or validation measurements from the pull test strings were returned to the ILI technology providers, similar in concept to the process outlined in Section 8.2 of API 1163 for the purposes of revision of the performance specification, taking into account the properties

* The chart does not show actual TDC features to keep the truth data confidential.

of the actual integrity conditions for the re-analysis of the ILI data to correct errors or acceptance of decrepit performance as a statistical outlier.

The ILI vendors regraded their ILI reports based on this limited feedback, with the summarized results shown in Figure 29, Figure 30 and Figure 31.

Once again, these results are not intended and cannot be used for head-to-head comparison between the participating technologies and vendors, as their stated specifications are different.

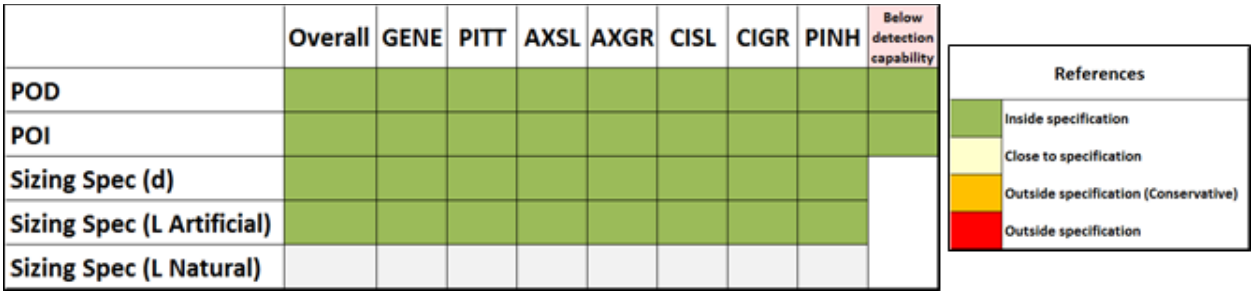

Figure 29: Summary of Results for Test 2 - Vendor 1 – 16"

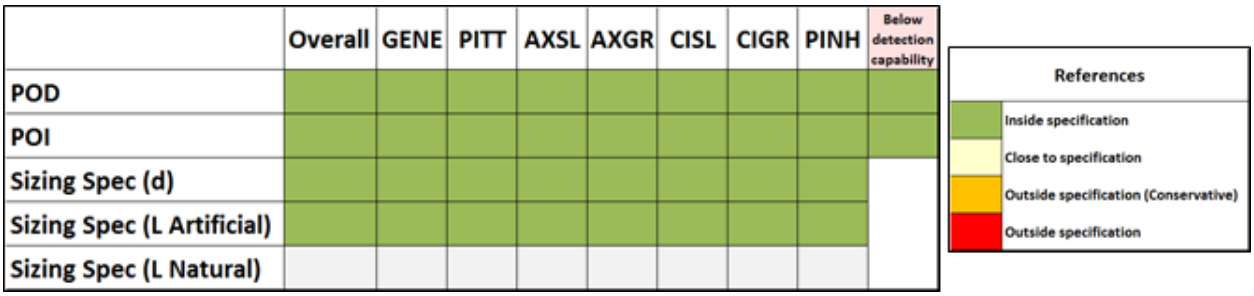

Figure 30: Summary of Results for Test 2 - Vendor 1 – 24"

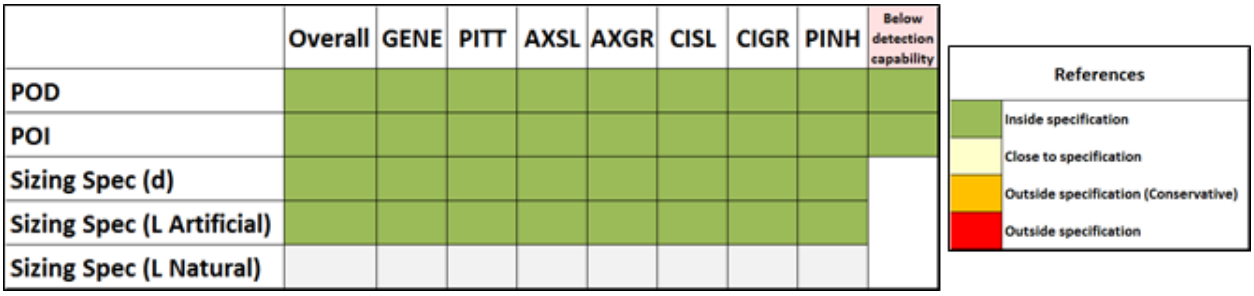

Figure 31: Summary of Results for Test 2 - Vendor 2 – 24"

6.5 Other Findings - Mechanical Damage

6.5.1 Background

Mechanical damage is normally divided into two categories, dents and gouges, which are deformations in the pipe wall that serve as failure initiation sites. Dents typically result from a purely radial deformation. A pipe impinging on a rock may result in a dent. If the pipe also slides on the rock, a dent with a gouge may result. Third-party mechanical damage, caused during construction and excavation, is a common cause of gouges. A gouge normally results in a highly deformed, work hardened surface layer and may involve metal removal. Undetected mechanical

damage to pipelines from outside forces can lead to leaks or ruptures, and mechanical damage can result in either immediate or delayed failure.

As mentioned in prior PRCI research [28] a majority of the anomalies caused by outside forces do not have dire consequences. However, a few prominent pipeline failures have been attributed to mechanical damage [32]. While dents are common, failures from dents alone (i.e., dents without additional surface mechanical damage such as scratches and gouges) are relatively rare. Dents with additional surface mechanical damage result in immediate failure approximately 80 percent of the time [33]. In the remainder of mechanical damage events, damage is not severe enough to cause immediate failure but it may lead to delayed failure if the internal pressure is raised sufficiently, if corrosion or cracking develops in the damaged material, or if there is pressure-cycle fatigue.

The utilization of MFL tools, along with caliper/deformation tools, allows operators to identify co-incident damage. In addition, there are MFL tools that exhibit potential to characterize dents without caliper data, and also identify co-incident crack like defects. However, there is a lack of a consistent view of the capabilities of current ILI technologies to discriminate and quantify mechanical damage and the lack of a definition as to compare against. Hence the issues with the understanding of ILI technologies are how well a combination of tools can characterize the shape and size of dents and other mechanical damage features and discriminate the presence of corrosion/gouge/crack in dents.

Previous research [28,34] by PRCI concluded that:

- MFL technologies demonstrated capability to detect metal loss within dents with either a strict application of the Subject Matter Expert Analysis (SMEA) or combined assessment of MFL and Caliper data.
- None of the ILI vendors made performance claims relating to coincident feature sizing (metal loss, corrosion or gouge within dents) or probability of detection and minimum threshold for detection and reporting for current MD Technologies.
- The discrimination of gouges from corrosion and from cracks within dents was claimed, however validation data was not sufficient to confirm such claims or to establish a performance specification.

As part of the past research work, it was recommended to obtain line pipe test specimen with MD features (dents and dents with metal loss or gouges) to be subjected to detailed direct examination and to repeated ILI evaluation in order to evaluate the ILI capabilities.

6.5.2 Findings in NDE-4F

As mentioned in 6.3.3, the TDC strings also contained mechanical damage features (gouges, plain dents, dents with gouges, dents with corrosion and cracks) that were not evaluated in this project as there are no published specifications.

Notwithstanding, the dent depths reported by the ILI vendors, along with their characterization or association with other features (corrosion, gouges and cracks), were compared against the existing at the TDC strings.

All 3 ILI systems used in NDE-4F confirmed the dent sizing capabilities estimated in previous research (namely within +/- 1%D for most of the cases) in absence of rerounding and/or rebounding effects typical of in-operation dents and confirmed the technology capability to detect

coincident features within dents. In addition, one of the technologies evaluated showed encouraging capabilities to discriminate cracks from other metal loss features in dents.

The data supports the starting point of defining a characterization specification through pull testing, and discussion with the participating ILI vendors shows their interest in participating in research projects within the scope of future PRCI I&I Roadmap projects.

7. Recommendations

7.1 Length Comparisons

As stated in 6.4.4, length matching for natural ML features was not deemed possible with current Field NDE level of detail. In other words, the ML length results for natural features are out of the stated ILI specifications but the ILI runs cannot be rejected based on these comparisons.

This effect could be minimized in future projects by increasing the level of detail of the Field measurement of length with the use of more sophisticated (Level 3) measuring techniques [38].

An alternative more in line with the PRCI roadmap objectives in the pipeline integrity (as stated in 5.2.3) would be to aim to the comparison of burst pressure estimations via Effective* Lengths[35,36] in lieu of total length estimations[37], consistent with future research identified on the PRCI roadmap.

7.2 Review and Expansion of the POF Definitions

As stated in section 5.3, the POF defect categories and the related ILI sizing specifications based on them, do not have upper limits in defect length or width, i.e. metal loss features infinitely long or infinitely wide can still be technically characterized in terms of the POF metal loss classifications.

However, some of the findings in this project suggest the specifications cannot be clearly validated for very long / very wide metal loss features, as illustrated in Figure 32.

The ILI vendors recognized that their testing and validation has limitations in the sizing of these very extended metal loss areas but the data available is not sufficient to establish a clear line for the end of the valid specification area. The direct NDE examination of extended defects is not limited to metal loss but also when extended to deformations and cracking, is also compromised when the width and particularly the length exceed certain levels, a condition also recognized in other research [34,38] but with limited quantification. ILI qualification testing to investigate the limits or extent of a singular general metal loss category is indicated as a gap in current MFL based ILI performance specifications and should be reflected in the PRCI I&I roadmap for future research.

Further validation of ILI systems should include the quantification of the sizing capability degradation both the ILI system and the Field NDE system.

* The ones obtained by iterative corrosion assessment methods.

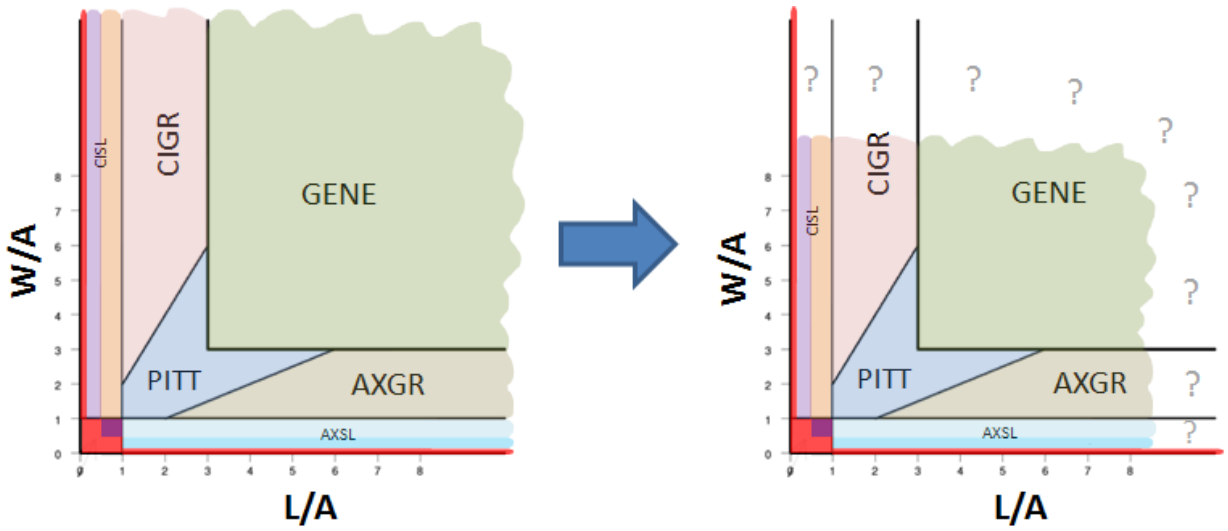

Figure 32: Limitation in POF definitions

7.3 Natural vs Artificial ML Features

As stated in 4.2.3, the artificial metal loss features were fabricated by EDM and end mill CNC methods.

As mentioned in 6.4.5, the morphologies of the artificial features (flat bottom profiles with very well defined edges) were observed to be different in their signal responses from the natural corrosion features. On the other hand, the ILI systems make assumptions of metal loss morphology that is then used in the ILI sizing algorithms.

It was reported from one ILI provider that surface roughness and corner radii can affect MFL patterns but no quantified criteria are available in the public domain. Performance differences between natural and artificial metal loss were noted in this research but not great enough to affect performance compared with the claimed specifications. In the absence of public domain specifications for the manufacture of fabricated metal loss analogs, this project focused on a manufacturing specification that did not infringe on the intellectual property of the participating ILI providers in this regard. While differences in measurement performance were noted between natural corrosion and machined analogs, in the case of this validation experiment those differences did not result in the tested technologies validating outside of their claimed performance specifications.

A quantitative treatment of the differences in observed performance between real vs machined metal loss features, including length errors, and a more detailed evaluation of some of the machined defects, including the evaluation of potential changes in the material characteristics during their fabrication, should be addressed in future research projects mentioned in the PRCI I&I roadmap.

8. Summary and Conclusions

The comparison of the Test Trial 1 with the actual flaws concluded both ILI technologies were within their claimed performance specification for detection and identification of metal loss features. The results also demonstrated that the MFL technologies tested performed generally within

their claimed sizing specifications, with the exception of some specific metal loss shape geometries with instances of bias or random error. The potential for this behavior is well known within the industry, and forms the basis for the discovery [8,39] processes found in Codes, Standards and Regulations related to pipeline integrity. The Pipeline Safety Trust [5] saw API 1163 incorporating several process steps critical to effective discovery, including the receipt and validation of ILI data as well as feedback and continual improvement. These discovery processes form the basis for the design, by the project team, of the specific test protocol used in this project demonstrating the improvement in the understanding of true ILI performance possible by incorporating effective feedback to the ILI providers.

The vendors indicated their ability to correct systemic errors for their sizing analysis based on the return by Blade of limited truth data sample for the defect shape classifications near or out of claimed specification. The vendors documented the fact that ILI system detection and discrimination performance is the sum of mechanical tool performance and data analysis. In the absence of an actual ILI tool failure, (defined as mechanical, electronic or operator error) there is no value in re-pulling the tools and gathering new raw data. The re-analysis correcting discrimination based on the limited truth data returned to the vendor for those defect categories that were out of their claimed specification constituted the Trial 2 for this project.

The comparison of the revised ILI results (Test Trial 2) with the actual flaws shows both ILI technologies are within their claimed performance specification for detection, discrimination and sizing. The Project process and results effectively demonstrate a current industry integrity assessment approach where ILI system integrity assessment performance can be improved when a sample of truth data is returned to the vendors to improve the ILI data analysis.

9. Acknowledgements

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Appendix A

Catalog No. PR-328-153721-R01 (Appendix A)

Development of an industry test facility and qualification process for ILI technology and Evaluation Enhancements

Appendix A - Design and construction of the Test Facility

NDE-4F

Contract PR-328-153721

Contractor Project Number: PRC-15-023

Prepared for the

Operations and Integrity Technical Committee

of the Pipeline Research Council International, Inc.

Prepared by: BMT Fleet Technology Ltd.

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List of Acronyms

AMI	Appleton Marine Inc.
BMT	BMT Fleet Technology Limited
CCA	Chromated Copper Arsenate
EIPS	Extra Improved Plow Strength
EMAT	Electromagnetic Acoustic Transducer
ET	Eddy current Testing
FLA	Full Load Amperes
HDPE	High Density Polyethylene
ILI	In-line Inspection
IWRC	Independent Wire Rope Core
LOTO	Lock-out/Tag-out
MFL	Magnetic Flux Leakage
NDT	Non-Destructive Testing
OEM	Original Equipment Manufacturer
PLC	Programmable Logic Controller
PRCI	Pipeline Research Council International
TDC	Technology Development Center
UT	Ultrasonic Testing
WLL	Working Load Limit

List of Nomenclature

1 Project Background

1.1 Introduction

The design and construction of a new In-Line Inspection (ILI) Pull-Test Facility for the Pipeline Research Council International (PRCI) has been undertaken to support the evaluation and improvement of ILI technologies used to identify and characterize pipeline features. The ILI Pull-Test Facility is designed to provide operational capabilities not currently available at ILI Vendor facilities. The facility furthers the evaluation of current inspection technologies using challenging test specimens and with extended performance capabilities.

The project identified the different issues (including both equipment and operational requirements) affecting the development of a new facility for technology improvement, including:

- Capabilities and limitations with existing ILI technology;
- Requirements for standardized testing protocols;
- Need for a facility to conduct improvement tests, with open trials;
- Need for a facility to conduct ILI technology and capability evaluations, with blind trials; and,
- Gaps and areas for improvement in ILI technology.

This report provides a summary of the design basis for development of the ILI Pull-Test Facility and describes the design details and performance capabilities. An overview of the maintenance and operational procedures for completing a pull test is also provided.

1.2 Scope

In addition to designing the ILI Pull-Test Facility, the NDE-4F project included development of a standardized ILI pull test procedure and related processes to support repeatable and objective testing and reporting of ILI technology performance. That activity has involved:

- Reviewing vendor practices to establish tool tolerance and performance verification;
- Gathering information related to specimen characterization, testing procedures, data reduction, reporting and documentation; and,
- Discussions with ILI Service Providers and site surveys to understand the performance requirements.

This report is focused on describing the design and construction of the ILI Pull-Test Facility and is constrained to the following scope:

1. Project Background

- Provides a brief overview of the project, with important reference documentation identified.

2. Design Basis Development

   - Identifies the key design decisions, with the background data and discussion supporting the decisions.

3. Design Details and Capabilities

   - Describes the as-built pull test facility, including photos.

   - Identifies the equipment (winches, forklift, etc.) and components (Timber Supports, Tie-Down Straps, etc.) required to complete a pull test.

4. Operational Requirements

   - Identifies the operational requirements, including electrical load, fuelling and other activities.

   - Provides an overview of the calibration, maintenance and inspection activities.

5. Preparation and Execution of Pull Testing

   - Provides an overview of the preparation of the pipe specimens, and the test area and equipment.

   - Identifies the role of the ILI Service Provider in testing.

   - Discusses the execution of a pull-test and the post-testing activities.

1.3 Reference Documents

The following documents are referenced in this report and were delivered separately in support of this project. Consult the appropriate documentation for complete details relating to operation and maintenance of the Test Winch System and the health and safety requirements.

- PRCI TDC - ILI System Pull Test Facility Operation Guide – Final – (Revision 04) August 10, 2015

- PRCI TDC - ILI System Pull Test Facility Commissioning Plan – Draft – (Revision 02.1) 15 May 2015

- INSTALLATION MANUAL FOR HIGH SPEED PULL-IN WINCH AND DIESEL HYDRAULIC POWER UNIT (FEBRUARY 2015)

- MAINTENANCE MANUAL FOR HIGH SPEED PULL-IN WINCH AND DIESEL HYDRAULIC POWER UNIT (FEBRUARY 2015)

- OPERATION MANUAL FOR HIGH SPEED PULL-IN WINCH AND DIESEL HYDRAULIC POWER UNIT (JULY 2015)

- HIGH SPEED WINCH OUTLINE DRAWING BMD-0705 REV.1 (15 OCTOBER 2014).

2 Design Basis Development

2.1 Introduction

This section provides a description of the objectives, requirements and other considerations agreed with the project team and applied in the development of the final ILI Pull-Test Facility design.

2.2 Design Objectives

With inputs from ILI Service Providers, the project team identified the following objectives for designing the ILI Pull-Test Facility. The facility will:

- Permit the use of a wide range of pipe geometries including ovalized cross-sections;
- Support random pipe specimen usage, without requiring that pipe specimens be welded permanently to each other;
- Be modular to permit different arrangements of Pipe Test Strings having a range of pipe samples and defect features;
- Be long enough to permit ILI Tools to collect data at higher speeds;
- Permit testing at higher speeds than are currently available at similar industry facilities; and,
- Permit testing with higher line pull forces than are currently available at similar industry facilities.

2.3 Requirements

To achieve the design objectives, the project team defined a set of requirements with respect to the layout of the site; the pull-test capabilities; the pipe test strings; the pull-test winch capabilities; and, safety as described in the following sections.

2.3.1 Site Requirements

Once the project team confirmed the ILI Pull-Test Facility and the PRCI Technology Development Center (TDC) would be located in (Houston, TX), a site was then selected with an area large enough to accommodate a maximum Pipe Test String having a length of approximately 500 ft and a width of approximately 200 ft.

The site includes a cast-in-place reinforced concrete slab to support the pull-testing winch (Winch Concrete Foundation) and with embedded anchorages. The test area around the Pipe Test Strings is large enough to accommodate material handling and storage, and includes sufficient space to ensure safety during testing.

The project team required that the facility consisted, as much as practical, of modular components to allow parts to be stored between usages, for security, safety and to avoid corrosion. The selected site has space available for material storage, whether outside in shipping containers or within the TDC Building warehouse space.

2.3.2 Pull-Test Capabilities

2.3.2.1 Maximum Line Pull and Speed

The project team identified the different types and sizes of ILI tools available in industry for evaluation and improvement. Typically, larger tools are operated at lower speeds. However, a maximum speed of 984 fpm (5.0 m/s) has been used for design since it exceeded the speeds available within industry, as determined from an analysis of existing capabilities.

The required maximum pulling force is then based on the maximum weight of a fully loaded 30 inch diameter ILI tool operating at a moderate speed; and, the weight of a fully load 24 inch diameter ILI tool operating at the maximum design speed. Different ILI Tool weights were collected from industry, and the corresponding line pull forces were estimated. The maximum line pull force equal to 36,000 lbf was discussed with input from the project team and ILI Service Providers. It was agreed that it was sufficiently conservative while also meeting the project design objective for a state-of-the art facility.

A 30 inch diameter magnetic ILI Tool provided the design basis with respect to achieving the maximum speed over the entire length of the Pipe Test String. However, ILI Tools for larger diameter pipe may be tested and may require consideration for longer acceleration lengths, shortening of the Pipe Test String, or lower maximum speeds.

The parameters listed in Table 2.1 supported defining the maximum line pull force requirement equal to 36,000 lbf (160 kN), used in the design for all pull-test components.

Table 2.1: ILI Tool Parameters for Pull-Test Facility Design

Technology Types	Magnetic flux leakage (MFL) Low-Res; High-Res; Extra High-Res Eddy current Testing (ET) NDT Ultrasonic Testing (UT) Electromagnetic Acoustic Transducer (EMAT) Geometry Tools (Caliper Pigs) Self-powered and operated
Mass [lbs]	6000 lbs at 30 inch diameter 4000 lbs at 24 inch diameter 900 lbs at 12 inch diameter
Length [ft]	Min. 6 foot at 24 inch diameter Max. 16.5 foot at 30 inch diameter
Speed [fpm]	20 fpm (0.10 m/s) (min.) 985 fpm (5.0 m/s) (max.)
Maximum required pulling force [lbf]	36,000 lbf

2.3.2.2 Dry Testing

The project team determined that dry testing would be implemented; therefore, the ILI Pull-Test Facility required only adequate pipe supports and non-watertight end-to-end connections. A submerged testing capability may be implemented in later phases. With the dry testing, the loads

on the pipe segments are reduced as compared to a submerged test condition and thus fit-up and alignment of the Pipe Test String is simplified.

2.3.2.3 Pipe Test Strings

With the ILI Pull-Test Facility site defined, the overall length of any Pipe Test String is constrained to approximately 480 ft (146.3 m). Additional space is allocated around the test area to accommodate material handling, the Test Winch System, and all other equipment required for pull-testing.

The project team defined the general arrangement of each Pipe Test String, corresponding to the following segments: (i) launching and loading; (ii) accelerating; (iii) performance testing section; (iv) decelerating; and, (v) receiving and unloading. Based on the total length available, the maximum length of the performance testing section was estimated to be approximately 340 ft (103.6 m) after accounting for the other segments, as follows:

- 20 ft Launching Tray (6.1 m);
- 20 ft Launching Funnel Section (6.1 m);
- 20 ft of pipe for accelerating to the specified test speed (6.1 m);
- 340 ft (maximum) of pipe specimens for performance testing (104 m);
- 80 ft of pipe for decelerating (24.4 m); and,
- 20 ft Receiving End (6.1 m).

For the design basis condition, the overall length of a Pipe Test String will vary depending on the length of each pipe specimen installed in the performance testing section, taken from the PRCI inventory. Shorter acceleration and deceleration segments may be used for smaller or lighter ILI Tools, or when lower test speeds are required.

2.3.2.4 PRCI Specimen Inventory

The existing PRCI inventory was reviewed and evaluated to identify the range of pipe sizes available in support of determining the operational requirements. On that basis, the ILI Pull-Test Facility is developed for pipe specimens having outer diameters of 12 inches (305 mm); 24 inches (610 mm); and, 30 inches (762 mm). (At the time, the PRCI inventory included one pipe specimen having an outer diameter greater than 30 inches (762 mm).)

The facility is not currently designed to reach the maximum design speed within the length of the acceleration section for pipes having an outer diameter of up to 48 inches (1219 mm), as an upper bound. By limiting the design of the facility to pipe specimens having an outer diameter of 30 inches (762 mm), the project team further supported the definition of a maximum line pull force of 36,000 lbf. Larger pipe specimens require larger ILI Tools, having increased weight, which requires increased line pull force for the Test Winch System in order to achieve the same speed profile. ILI Tools for larger diameter pipe may be tested using the facility and may require longer acceleration lengths, shortening of the Pipe Test String, or lower maximum speeds.

2.3.3 Test Winch System Capabilities

The project team identified early that a winch or a mining hoist would be appropriate, and required, to meet the objectives for the ILI Pull-Test Facility. On the basis of the decision to use a maximum line pull force of 36,000 lbf and a maximum line pull speed of 5.0 m/s, several winch and hoist fabricators were contacted in an industry search. Following a search of winch suppliers, and including discussions to rent equipment, it was agreed that a bespoke winch would best meet the winch capability and performance requirements.

Initial quotations were reviewed and a performance specification was prepared, corresponding to a self-contained Test Winch System to include:

- An arm to raise/lower elevation of the wire rope, to adjust to the diameter of the Pipe Test String;
- A self-propelled drive system for lateral positioning and to allow rapid testing of multiple parallel Pipe Test Strings;
- A torsionally resistant wire rope of sufficient capacity to meet the requirements safely (with an appropriate factor of safety);
- A drum sized for the maximum length of Pipe Test String;
- A software control system for inputting test parameters, safety conditions and with data logging and reporting capabilities;
- A fusible link to mitigate risks associated with failure of the wire rope; and,
- Controls to automatically stop the tools and to report the position, speed and time during testing.

Recognizing that failure of the wire rope under tension could cause significant damage and risk of injury, the wire rope was specified to have a safe breaking load in excess of 100,000 lbf with an appropriate factor of safety. The winch manufacturer would supply the appropriate wire rope in accordance with standards for safe design at the factored operating load.

The winch and the software control system would allow definition of a velocity versus time profile for each pull-test consisting of: (i) regimes for accelerating and decelerating the tool; and, (ii) a level plateau along the performance testing section at the specified test velocity. The specification required the pulling speed to be controlled within a tolerance of ±50 fpm (0.25 m/s).

At the conclusion of the industry suppliers, a detailed specification was submitted to Appleton Marine Inc. (AMI) in support of a request for proposal. AMI subsequently submitted a detailed quotation, including a preliminary design drawing.

2.3.4 Pipe Test String Setup

The project team confirmed the general arrangement of components for the setup and configuration of a Pipe Test String, including:

- Launcher tray, being fabricated from non-magnetic materials;
- Launching Funnel;
- Acceleration Section;
- Constant-Speed (Anomalies) Section;
- Deceleration Section; and,
- Receiving End;

These sections would be connected using flanged slip-on end connections, welded on to the pipes and bolted end-to-end, based on the following determinations that bolted flange connections:

- Need not be watertight; need only support the loads;
- Reduce the potential for misalignment to avoid damaging the ILI Tools;
- Ensure axial load transmission between pipes by aligning pipe end contact;
- Align pipes to minimize effect of pipe ovality on transition between pipe samples; and,
- Support loads to minimize pipe lateral movement.

To meet the objective of permitting a modular or flexible arrangement with respect to pipe diameter and length, an approach was adopted to use the self-weight of components to anchor and support the Pipe Test Strings. The pipe specimens and the components would be strapped to wood (being non-magnetic) heavy timbers, rough-cut to measure 12 inches × 12 inches.

The Pipe Test Strings would be stabilized by securing the segments to the timber supports using ratcheting tie-down straps and steel mounting plates attached to the timbers. A minimum safe breaking load capacity of 6,000 lbf was determined to be sufficient for selection of the restraint straps.

Further, a positive anchorage connection at the launching and receiving ends was required to support the axial load transmission of the pipe system and to protect the winch system. At the launching end, the anchorage could be satisfied using concrete anchoring blocks of sufficient dead weight. At the receiving end, engineering anchorages could be embedded in the cast-in-place reinforced Winch Concrete Foundation.

2.3.5 Ancillary Equipment

Other equipment to support operation of the ILI Pull-Test Facility was identified and included:

- A smaller winch with a return line to retrieve the primary wire rope back through pipe to reset the system was included in the design; and,

- A forklift for material handling, including setup and configuration of all components of the Pipe Test String.

2.3.6 Safety Requirements

General considerations regarding the safe setup and operation of the facility are described below. Some have been incorporated directly into the design of the facility and some apply specifically to the safe operating procedures. The following safety requirements subsequently supported defining the performance and operational specifications for the facility and equipment, detailed in Section 3.

- An end stop guard (precast concrete barrier) would be included towards the receiving end of the Pipe Test String to prevent ILI Tools from damaging the Test Winch System;

- A fusible link or shear pin would be provided to protect the Winch Main Wire Rope against failure;

- Space appropriate to the safe operation of the facility must be provided, including operation of all material handling equipment;

- PRCI TDC personnel require training in the safe operation and maintenance of the facility and all equipment;

- Detailed instruction and training, to be supplied by the winch vendor, is required for safe operation of the Test Winch System; and,

- ILI Service Provider personnel will operate the ILI Tools, collect data and interpret the data and thus operational requirements will be defined to ensure safety of non-PRCI TDC personnel.

2.4 Summary of Design Recommendations

By April 2014, the project team had defined the set of recommendations for the facility design listed in Table 2.2.

Table 2.2: Summary of Design Recommendations

Design Issue	Description	Recommendation
Overall Test Area	75 ft wide by 500 ft long	Allows for length up to 460 ft of testing. Provide additional area sufficient for safe operation and material handling.
Pipe Specimens	Outer diameter	Initial capability for 12 inch, 24 inch and 30 inch pipes.
Test Conditions	Dry versus submerged testing	Dry testing initially.
Pipe Test String	Loading Tray	Half section of clean pipe.
	Launching Section	Eccentric funnel.

	Performance Testing Sections	From pipe specimen inventory, of various lengths.
	Deceleration Section	Clean pipe of diameter matching testing sections.
	Receiving End	Half section of clean pipe.
Supports and Connections	Pipe Test String	12 inch × 12 inch heavy timbers; 3 per section.
		4 inch wide ratcheting tie-down straps secured around pipe joint and to timber support with steel plates; 16,200 lbf breaking strength identified.
	Pipe-to-Pipe Connections	Welded slip-on flanges, bolted end-to-end.
	Pipe Section Anchorage	Launching end and receiving end will be anchored; remainder of Pipe Test String will rely on self-weight.
System Anchorage	Launcher End	Concrete anchoring blocks.
	Receiver End	Incorporate anchorages into the cast-in-place concrete foundation, to support the design loads.
Test Winch System	Test Winch System	1 or 2 diesel/electric generator sets with transmission for speed control and a 5 foot to 6 foot diameter wire rope drum; capable of producing at least 1075 raw cable horsepower.
	Mounting	Mounted on a structural frame, on rails to allow lateral movement across the set of test runs; rails supported on cast-in-place concrete foundation.
	Anchoring	Hold-backs to support maximum pull force.
	Wire Rope	Initial recommendations suggested 6X19 Independent Wire Rope Core (IWRC) Extra Improved Plow Steel (EIPS), Right Regular Lay with a nominal breaking strength of 130,000 lbf at 1-1/8” diameter.
	Fairlead or Sheave	Required to align wire rope with pipe longitudinal axis and to control sheaving angle at drum.
Ancillary Equipment	Retrieval Winch	Smaller winch will be used to retrieve main wire rope and return to the launching end.
	Forklift	A forklift is required to fit-up and the Pipe Test Strings and handle materials on site.
Safety	End stop	Precast concrete barriers to protect Test Winch System.
	Winch Main Wire Rope	Include fusible link (shear pin).
	Facility Operation	Provide training in the safe operation and maintenance of the facility and all equipment for all personnel.

3 Design Details and Capabilities

3.1 Introduction

This section provides a description of the as-built ILI Pull-Test Facility and the equipment supplied to support the ILI pull testing.

3.2 As-Built ILI Pull-Test Facility

As-built drawings illustrating the layout of the ILI Pull-Test Facility and the fabricated components are shown in Annex A. The pull-test facility area is located in the northeast area of the lot at the following address:

6410-J Langfield Road
Houston, TX 77092

3.2.1 Winch Concrete Foundation

Annex B illustrates the engineering drawings prepared for the Winch Concrete Foundation, including the embedded anchorages to which the Winch Platform Rails, Winch Anchorage Girder and the Receiving Ends are connected. The Winch Concrete Foundation has been engineered by:

Garza + McLain
Structural Engineers, Inc.
13313 Southwest Freeway, Suite 163
Sugar Land, TX 77478
281-494-1230

The Winch Concrete Foundation is engineered to support the weight of the Test Winch System (approximately 52,750 lbs) and a loaded forklift. The embedded (cast-in-place) Pipe Test String anchorages are engineered to support the full 36,000 lbf maximum pull test load acting at an elevation of 4 feet above grade. All embedded anchorages are galvanized.

The embedded anchorages at the Winch Platform Rails are spaced at 120 inches on centers and are designed to support the full 36,000 lbf maximum pull test load.

Figure 3.1 illustrates the Test Winch System on the Winch Platform Rails at the Winch Concrete Foundation.

3.2.2 Winch Platform Rails

As shown in Figure 3.1, two (2) lines of ASCE-85 Type rails are installed at the Winch Concrete Foundation for transiting of the Test Winch System. The rails are connected and anchored (for tension, bearing or shear) to support a minimum breaking strength of 100,000 lbf.

The Winch Platform Rails are installed straight and parallel, spaced nominally at 131.5 inches on centers. Each line of ASCE-85 Type rails spans a length of 1448.50 inches. Winch Platform Rail segments, drilled at both ends, are spliced end-to-end using a bolted rail connection and splice bars. Rail End Stops on the Winch Platform Rails are installed to prevent the Test Winch System from rolling off the rail ends. The Winch Platform Rails are affixed to the embedded anchorages using welded soleplates, resilient polymer pads, and adjustable crane rail clips. Soleplates have been levelled using a compatible epoxy grout.

Between embedded anchorages, intermediate soleplates are anchored to the Winch Concrete Foundation using post-installed concrete anchors. The Winch Platform Rails are supported by the intermediate soleplates with resilient polymer pads and adjustable crane rail clips. Soleplates have been levelled using a compatible epoxy grout. Intermediate soleplates are installed under each rail at approximately 24 inches on centers. Figure 3.2 illustrates and Table 3.1 lists components of the as-built Winch Platform Rails, respectively.

Figure 3.1: Test Winch System with Rails on Concrete Foundation

(a) Rail splice and anchoring

(b) Rail end stop

Figure 3.2: Winch Platform Rails

Table 3.1: Winch Platform Rail Components

Item	Quantity	Description

ASCE-85 Type Standard Grade rail	2× 1448.50 inches	Rails drilled both ends and including splice bars and hardware. Each length measures 1448.50 inches (120 feet plus 8.5 inches).
Gantrex RailLock W15/BJ Weldable Clips	244	Nose J Assembly 85 ASCE Black; 2 required at each soleplate location (Primary and Intermediate).
Primary Soleplates W2 Weld-lok 24-AS85	26	Primed base plates (10 ½ inches × 8 ½ inches × ½ inches) for welding of two Gantrex Raillock W15/BJ crane rail clip lower components. Located at embedded anchorage locations; each rail. Welded in place.
Intermediate Soleplates W2 Weldlok 24-AS85	96	Primed base plates (10 ½ inches × 8 ½ inches × ½ inches) complete with two holes drilled for anchor bolts includes welding of two Gantrex Raillock W15/BJ crane rail clip lower components. Spaced at 2-foot on-centers. Anchored in place to concrete with post-installed anchors.
Post-Installed Concrete Anchors	192	Required for intermediate soleplates installed between embedded anchorage locations; two per soleplate.
Gantrex MK2 Rail Pad 220x125	122	125 mm wide unreinforced pre-formed, resilient polymer pads for discontinuous rail support.
Gantrex K3 Epoxy Grout	16 cu ft.	Gantrex Epoxy Grout K3 formula, in (3) cubic foot unit packaging, complete with resin, hardener and aggregate.

At construction, the embedded anchorages were not installed level and one line of embedded anchorages was lower than the other. The contractor corrected the differences in elevation using 1.5 inch thick base plates. Additional shim plates are included under the 1.5 inch thick base plates and the weld size is increased to fill the root of the base plate to embedded anchorage plate attachment fillet welds.

The Winch Platform Rails and all rail components are supplied by:

Gantrex Inc.
7554 Carriage Cove
Trussville AL 35173
205 335 7663
412-655-3814
www.gantrex.com

3.2.3 Winch Anchorage Girder

The Winch Anchorage Girder is installed as a 73 foot long W14×90 rolled steel W-section at the Winch Concrete Foundation, located 60 inches on centers from the east rail of the Winch Platform Rail pair. The girder has been installed as two sections, spliced at the mid-span.

Steel spacer plates (18 inch wide × 12 inch long × 0.5 inch thick) are welded to the bottom flange of the Winch Anchorage Girder to ensure the bottom flange does not bear on any high points in the Winch Concrete Foundation between embedded anchorages. The spacer plates are located on the bottom flange, aligned with and welded to each embedded anchorage, which are spaced at 8 feet on centers.

The Winch Anchorage Girder includes flange stiffeners aligned with each embedded anchorage (located front side and back side of the girder web) to connect the top and bottom flanges.

The top flange of the Winch Anchorage Girder is drilled with holes to suit ASTM A325 1 inch diameter bolts, spaced longitudinally at 6 inches on centers and transversely at 8 inches on centers. The holes and bolts allow positioning of the Winch Anchorage Braces for testing. Figure 3.3 illustrates the Winch Anchorage Girder.

Figure 3.3: Winch Anchorage Girder and Braces

3.2.4 Winch Anchorage Braces

The two (2) Winch Anchorage Braces shown in Figure 3.3 are positioned, using the forklift and rigging, at the winch anchorage girder and aligned with the winch tie-back cylinders for testing. When fitting up the braces on the Winch Anchorage Girder, shims may be required to ensure proper fit up on the uneven concrete foundation.

Each Winch Anchorage Brace is connected to the Winch Anchorage Girder top flange using four (4) ASTM A325 1.0 inch diameter bolts with hex nuts and washers. Bolts shall be secured to a snug-tight condition, without overtightening. Table 3.2 lists the components of the pair of braces.

Table 3.2: Winch Anchorage Brace Components

Item	Quantity	Description
Lug Attachment	2	1 inch thick lug plate with 2 inch diameter hole drilled to suit chain shackle; welded to Stub Cap Plate.
Stub Cap Plate	2	Cap plate 13 inch × 13 inch × 0.75 inch welded to Stub Girder.
Stub Girder	2	W12×40 section; 12 inches.
Stub Baseplate	2	Baseplate 13 inch × 13 inch × 0.75 inch with slotted holes drilled to suit Girder Bolts.
Bracing Leg	2	HSS 6×6×0.25 A500 Class C; approximately 40 inches long, oriented at approximately 40 degrees to horizontal, to bear on Winch Concrete Foundation.
Bracing Leg Bearing Plate	2	Bearing plate 13 inch × 13 inch × 0.75 inch welded to Bracing Leg.
Girder Bolts and Nuts	8	ASTM A325 1 inch diameter bolts (4 required per Girder Lug Base Plate).
Girder Washers	8	Over the slotted holes in the Girder Lug Base Plate, an ASTM F436 washer or 5/16 inch thick common plate washer is used to cover the hole.

3.2.5 Winch Anchor Linkages

For each test, the Winch Platform is moved into position such that the Test Winch System is aligned with a Pipe Test String. Once in position, the Winch Platform is anchored by connecting the Winch Anchor Linkages at the Winch Hold-Back Cylinders to the Winch Anchorage Braces. The Winch Hold-Back Cylinders are hydraulically actuated to engage the linkages and to take up all slack in the chain. Figure 3.4 illustrates the pair of linkages connected to the Winch Hold-Back Cylinders.

Figure 3.4: Winch Anchor Linkages with Hold-Back Cylinders

Each winch tie-back linkage consists of the following components:

- Two (2) Crosby Bolt-Type Anchor Shackles, 1.5 inch (37,478 lbs WLL);
- Crosby Grade 100 Alloy ¾ inch 18/20 Chain (35,300 lbs WLL);
- Two (2) Crosby A-1337 Lok-A-Loy Connecting Links (35,300 lbs WLL);
- Link plate, 1 inch thick with 2 inch diameter holes for securing; and,
- Cylinder pin by AMI, 2 inch diameter solid steel pin.

The minimum working load limit (WLL) of any component of the Winch Anchor Linkages is 35,000 lbf. The ultimate load is at least four (4) times the working load limit for any component.

3.3 Test Winch System

This section provides an overview of the Test Winch System design and supplied by Appleton Marine Inc. (AMI).

Appleton Marine Inc.
3030 E. Pershing St.
Appleton, WI 54911
Phone: (920) 738-5432
Fax: (920) 738-5435
www.appletonmarine.com

Reference AMI SERIAL NUMBER 19653 for all enquiries.

Refer to the following documentation provided by AMI for detailed instructions and part information.

- INSTALLATION MANUAL FOR HIGH SPEED PULL-IN WINCH AND DIESEL HYDRAULIC POWER UNIT (FEBRUARY 2015)
- MAINTENANCE MANUAL FOR HIGH SPEED PULL-IN WINCH AND DIESEL HYDRAULIC POWER UNIT (FEBRUARY 2015)
- OPERATION MANUAL FOR HIGH SPEED PULL-IN WINCH AND DIESEL HYDRAULIC POWER UNIT (JULY 2015)

Annex C illustrates the winch outline drawings prepared by AMI. Printed copies of the reference documentation are filed at the TDC.

3.3.1 Overview

The diesel hydraulic powered winch with operator cabin, shown in Figure 3.5, is a self-powered, rail-mounted, high speed winch. The winch is designed for service in an outdoor environment. Power for the unit is derived from a Cummins 665 HP diesel hydraulic power unit.

Figure 3.5: Test Winch System

The Test Winch System is capable of achieving 15,000 lbs line pull force at 5.0 m/s (982 fpm); and, 40,000 lbs line pull force at no specified speed.

The winch drum is driven by four (4) variable displacement axial piston hydraulic motors. Two (2) motors are mounted on each side of the winch and drive a dual input gearbox. The winch frame houses the winch drum, which rides on spherical roller bearings. The winch frame also contains the winch levelwind, which controls the wrapping of the wire rope. A pressure roller is mounted on the back side of the winch drum to apply pressure to the wire rope while it is being paid out and hauled in.

One (1) torque arm is mounted between each gearbox and trolley frame. Each torque arm contains a load pin, which is used to calculate the amount of line pull force. A rotary encoder is mounted to the winch frame and driven from a gear mounted to the winch drum. The information is used by the Programmable Logic Controller (PLC). A rotary limit switch is also mounted to the winch frame and driven off of the same drum gear.

3.3.2 Winch Hold-Back Cylinders

During testing operation two (2) hold-back cylinders are engaged by the operator to prevent the Winch Platform from overturning. Each Winch Hold-Back Cylinder is designed to pre-tension to 7,350 lbs and to hold a maximum capacity of 44,000 lbs. Each cylinder has a 5.0 inch bore with a 14 inch stroke. The Winch Hold-Back Cylinders are shown in Figure 3.4.

3.3.3 Winch Platform

The total dead load of the Test Winch System is approximately 52,750 lbs. The plan dimensions of the Winch Platform are 144 inches wide by 424 inches long.

The Winch Platform includes an A-Frame comprised of fabricated steel HSS tube with a guide sheave assembly mounted at the end to align with the centerline axis of the Pipe Test String. The A-Frame is pinned to the Winch Platform and is raised or lowered using a pair of 5.0 inch bore × 14 inch stroke hydraulic cylinders. This provides adjustable operation heights between 6 inches

and 48 inches above the ground surface. A tensioner sheave assembly and a fixed sheave assembly are mounted to the A-Frame and contain anti-friction roller bearings and ride-on heat-treated stainless steel pins.

The Winch Platform is moved along the Winch Platform Rails by a fixed displacement, axial piston hydraulic motor. The hydraulic motor drives a double enveloping worm gearbox, which drives both sides of the track wheel.

3.3.4 Winch Main Wire Rope

The Test Winch System is supplied with approximately 565 feet of Winch Main Wire Rope with one end seized and the other end having a closed spelter socket. The wire rope and the end spelter socket, shown in Figure 3.6, have the following specifications:

- 1-1/4 inch COMPAC 35 SUPER 2160 non-rotating galvanized (42,000 lbs WLL) wire rope; 225,400 lbs minimum breaking load.
- Closed spelter socket, 136 T ultimate load.

A Crosby swivel can be added to the main wire rope spelter socket so that any twist will be prevented, as might occur when pulling an ILI Tool. Though this is considered unlikely, the swivel will preclude the wire rope from storing any rotational energy.

(a) Wire rope on drum **(b) Wire rope spelter socket**

Figure 3.6: Winch Main Wire Rope and Spelter Socket

3.3.5 Diesel Engine

A Cummins Diesel Model QSX15 six cylinder diesel engine is installed, rated for 665 HP at 2100 RPM for intermittent duty. The engine is equipped with the following:

- 125 F radiator with fan, shroud, and guards;
- Dual hydraulic pump adapter;
- Air cleaner;

- Fuel, coolant, and lube oil filters;
- Industrial muffler and spark arrestor with exhaust insulation;
- Fuel strainer;
- Vibration isolators;
- 24 V starter, alternator, batteries, and cables;
- Automatic shutdowns for high engine temperature, low engine oil pressure, and engine over speed; and,
- Wiring harness for all electrical interfaces.

The Test Winch System requires 250 gallons of diesel fuel to fill the tank mounted on the Winch Platform, under the diesel engine. The fuel tank includes level indicator; supply, return and vent ports; and, inline fuel strainer.

3.3.6 Hydraulics

The hydraulic control valve manifold for operating the Test Winch System winch and auxiliary functions (including the A-Frame, Winch Hold-Back Cylinders and drive system) is mounted on a frame at the Winch Platform.

The Test Winch System requires 1000 gallons of Grade SAE AW46 hydraulic oil to fill the tank mounted on the Winch Platform. The minimum required cleanliness grade must meet 8 to NAS 1638; 6 to SAE; or, 20/17/14 to ISO 4406. The hydraulic oil must be filtered several times as it is pumped from the shipper into the equipment's tank, shown in Figure 3.7.

Figure 3.7: Hydraulic Tank

3.3.7 Operator Cabin

The Winch Platform is fitted with an enclosed, weather-tight cabin in which the operator is seated during testing. The cabin, shown in Figure 3.8, is equipped with the following:

- Tinted safety glass on front;
- Sliding left-hand and right-hand windows;
- Heavy duty, marine style lockable door;
- Anti-skid floor with acoustic insulation;
- Adjustable operator's seat;
- Windshield wiper/washer;
- Ventilation fan and air conditioner;
- Interior cab light;
- Exterior signal light indicating testing is imminent, in operation and complete;
- Function control levers (Test Winch System, Winch Platform, A-Frame and hold-back cylinders);
- Power unit control and alarm functions:
    - Diesel engine ignition start pushbutton and engine run/stop pushbutton;
    - Diesel engine monitor display; and,
    - Gauges for system pressure, pump pressure, cooling pressure and return pressure.
- Alarm indication (audible and visual) for low oil pressure, low engine coolant;
- Cabin light selector switch;
- Dead man foot switch;
- Warning horn;
- Emergency Shutdown Pushbutton;
- Control/monitor display unit, computer CPU and keyboard; and,

- PLC Enclosure.

Figure 3.8: Operator Cabin (Exterior)

3.3.8 Monitoring System

The Test Winch System is equipped with a PLC and dual monitoring system to provide real-time electronic output and data recording. One of the monitors provides operational inputs and outputs, calibration adjustments, setup adjustments, disabling input/output sensors and alarm history; the other provides data recording.

A pair of shear type load pins measure the torque/force generated between the gearbox and the load pin bolted to the Winch Platform frame. The measured force is converted into a 4 mA to 20 mA electric signal. One load pin is mounted to each gearbox and the sum of each electric signal is calculated and displayed as one value in units of pounds (lbs). The load pin material is heat-treated stainless steel.

A multi-turn Ethernet encoder transmits drum speed and position to the PLC system, which is used to display the following data:

- Rope on the drum;
- Rope paid out;
- Current layer of wire rope on the winch drum;
- Wraps of wire rope on the layer of the drum; and,
- Winch speed.

The Test Winch System is equipped with a limit system to prevent the winch from paying out wire rope when there is only five wraps left on the winch drum; and, to prevent the winch from continuing to haul-in wire rope when there is 50 feet of wire rope paid out.

3.4 Pipe Test String Arrangement

The current ILI Pull-Test Facility accommodates up to four (4) Pipe Test Strings within the test area. Since the pipe joints available in the inventory may vary, and also depending on the test objectives, the overall length of any Pipe Test String can differ. However, the general arrangement for each Pipe Test String is the same and will consist of pipe joints connected end-to-end with bolted slip-on flanges, secured to Timber Supports with ratcheting Tie-Down Straps. Each Pipe Test String requires a Launching Funnel; an Acceleration section; a Constant-Speed (Anomalies) section; a Deceleration section; and a Receiving End. This section describes the components required to configure a Pipe Test String, including the Loading Trays used for handling ILI tools. Additional Pipe Test Strings can be lined up in front of the Test Winch System with minor modifications to the anchorage. (For example, a beam can be designed to span the anchorages allowing for more test strings to be positioned).

Annex D illustrates the layout of the ILI Pull Test Facility. Annex E provides a copy of the as-built drawings prepared for illustrating each fabricated and assembled component.

3.4.1 Maximum Length

The maximum overall length of the Pipe Test String is limited to 485 feet, taken as the distance between the start of the Launching Funnel and the end of the Receiving End. Figure 3.9 illustrates a completed Pipe Test String (with ILI Tool loaded), used for the facility commissioning.

3.4.2 Setup

Pipe segments are connected by through-bolting at adjacent pipe slip-on flanges using a minimum of eight (8) ASTM A325 bolts with hex nuts. The bolt diameter must be appropriate for the pipe slip-on flanges. Bolts can be secured to a snug-tight condition, without overtightening.

When fitting up the pipe segments comprising the Pipe Test String, the nylon rope Retrieval Line must be run through before each segment is connected at the slip-on flanges. The Retrieval Line is required to bring the retrieval winch wire rope up to the Receiving End, so that that the Winch Main Wire Rope can be brought to the Launching Funnel end.

Figure 3.9: Test String Configured for Commissioning

3.4.3 Loading Trays

Two Loading Trays have been fabricated using high density polyethylene (HDPE) pipe, sectioned longitudinally and mounted on steel frames. The Loading Trays include lifting slots to accommodate the PRCI forklift for material handling. The Loading Tray, shown in Figure 3.10, may be used for loading and unloading of the ILI Tools, unless a tray is provided by the ILI Service Provider.

Figure 3.10: HDPE Loading Tray

3.4.4 Launching Funnels

Three (3) Launching Funnels supplied, one (1) in each nominal pipe diameters of 12 inch, 24 inch and 30 inch. A Launching Funnel, shown in Figure 3.11, is positioned using the forklift at the launcher end of the Pipe Test String. The Launching Funnel is then secured by through-bolting at the adjacent pipe slip-on flanges using a minimum of eight (8) ASTM A325 bolts with hex nuts. The bolt diameter must be appropriate for the pipe slip-on flanges. Bolts can be secured to a snug-tight condition, without overtightening.

The Launching Funnel is secured to the precast Test Pipe Run Counterweights (Reaction Blocks) with the Launching Funnel Anchorage Chain. Each Launching Funnel shall be secured to a minimum of two (2) Reaction Blocks.

(a) Launching Funnel

(b) Loading cleaning pig

Figure 3.11: Launching Funnel

3.4.5 Acceleration Section

The test string includes an Acceleration Section through which the ILI Tool is accelerating until reaching the target constant velocity. The pipe joints comprising the Acceleration Section are determined from the test objectives and pipe selected from the PRCI inventory. The length of the Acceleration Section and the number of joints required are determined for each test. The pipe joints used may be plain pipe.

3.4.6 Constant-Speed (Anomalies) Section

The Pipe Test String comprises a selection of pipe joints having specific anomalies or features relevant to the test objectives. The ILI Tool travels through the section at constant speed and collects data for the anomalies. The length of the Constant-Speed (Anomalies) Section and the number of joints required are determined for each test.

3.4.7 Deceleration Section

Each Pipe Test String includes a Deceleration Section, within which the ILI Tool decelerates until stopping. The pipe joints comprising the Deceleration Section are determined from the test objectives and pipe selected from the PRCI inventory. The length of the Deceleration Section and the number of joints required are determined for each test. The pipe joints used may be plain pipe.

3.4.8 Receiving Ends

Three (3) Receiving Ends are fabricated and supplied, one (1) in each nominal pipe diameters of 12 inch, 24 inch, and 30 inch. The Receiving End sections are bolted to the Test Run Connection Plates using three (3) ASTM A325 3/4-inch diameter bolts with hex nuts. (The Test Run Connection Plates are welded to the embedded anchorage plates at the Winch Concrete Foundation). Figure 3.12 shows the Receiving End in position at the end of the last Deceleration Section and bolted to the Test Run Connection Plate.

The Receiving End sections are bolted at the slip-on flange connection to the last pipe in the Deceleration Section. Each bolted connection requires eight (8) ASTM A325 bolts. Note that bolts

are not required at all of the bolt holes in the slip-on flanges. The bolt diameter must be appropriate for the pipe slip-on flanges. Bolts can be secured to a snug-tight condition, without over-tightening.

Figure 3.12: Receiving Ends

3.5 Pipe Test String Preparation

The pipe joints used in the Pipe Test Strings are supported on Timber Supports. At each support, the pipe joint is lashed to the Timber Support using ratcheting Tie-down Straps secured to Lashing Plates. This section identifies the equipment required to configure each test string.

3.5.1 Unit Test Pipe Preparation

The pipe ends must be machined square, de-burred and beveled to ensure that the slip-on flanges are welded such that no portion of the pipe will affect the flange-to-flange connection. Note that pipe re-rounding may be required to fit on the slip-on flanges.

WARNING

Damage to the ILI tool sensors may result from gaps or misalignment between slip-on flanges at the end-to-end connections.

Ensure the pipe ends are machined properly and the slip-on flanges are welded flush with the end face of the pipe joint.

Pipe sections can be joined end-to-end by tack welding, in accordance with the typical arrangement illustrated in Figure 3.13.

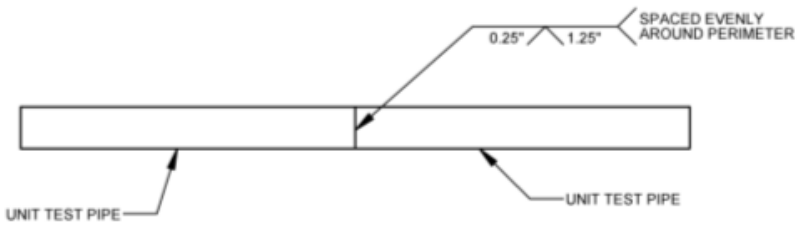


Figure 3.13: Joining Sections of Unit Test Pipe

3.5.2 Slip-On Flanges

The test pipes and components will be connected using slip-on flanges welded to the pipe joints and then bolted together end-to-end. Each slip-on flange is welded to the end of the Pipe Test String joint with one (1) full-perimeter (all-around) fillet weld having a minimum weld throat of 0.125 inches. A completed connection along the Pipe Test String is shown in Figure 3.14.

PRCI purchased 200 slip-on flanges to suit the diameters of the initial arrangement of the Acceleration, Test and Deceleration Pipe joints for commissioning. For each joint in the Pipe Test String, two (2) slip-on flanges are required (one on each end); one (1) slip-on flange is required at the end for each Launching Funnel section; and, one (1) slip-on flange is required at the end for each Receiving End.

For the 24 inch and 16 inch pipes used at facility commissioning, the slip-on flanges are specified as:

CLASS 150 (PN20) Flanges
Forged steel ASTM A-105
ASME/ANSI B16.5
Full face (no raised face)

Figure 3.14: Slip-On Flange Bolted Connection

When bolting the Test Pipe Run components at the slip-on flange connections, each bolted connection requires four (4) ASTM A325 bolts per flange to fasten each flange pair at the 12:00, 3:00, 6:00 and 9:00 clock positions installed in any order. Note that bolts are not required at all of the bolt holes in the Slip-On Flanges. Gaskets are not required when making any flange-to-flange pipe connections.

The high-strength bolts at the pipe slip-on flanges need not be pre-tensioned and can be installed in aligned holes to a snug-tight condition. The snug-tight condition shall bring the plies into firm contact, attained by a few impacts of an impact wrench or the full effort of a worker using an ordinary spud wrench.

3.5.3 Timber Supports

PRCI purchased 280 Timber Supports measuring 12 inch high by 12 inch wide by 12 foot long, illustrated in Figure 3.15. The Timber Supports correspond to "Southern Yellow Pine", No.2 rough cut, treated 0.60 Chromated Copper Arsenate (CCA). The Timber Supports are arranged on site to meet the test objectives.

In general, each pipe joint, including the Acceleration and Deceleration Sections, shall be supported by three (3) Timber Supports, as follows:

- One (1) Timber Support shall be placed at mid-span; and,
- One (1) Timber Support shall be placed within 24 inches of each end of the pipe joint.

Three (3) timber supports are used for each 40 foot long pipe joint. Pipe joints exceeding 40 foot in length should be supported by at least four (4) Timber Supports.

Figure 3.15: Timber Support with Tie-Down Strap and Lashing Plate

The Timber Supports were supplied by:

American Pole & Timber
(800) 716-0636
www.americanpoleandtimber.com

3.5.4 Tie-Down Straps

PRCI purchased 140 ratcheting Tie-Down Straps measuring 4 inches wide by 16 feet long and having a minimum load capacity of 5,400 lbs (minimum breaking strength of 16,200 lbs). The straps are outfitted with a flat hook at each end.

Each ratcheting Tie-Down Strap is secured tightly against the pipe segment, as shown in Figure 3.15. Any extra length of strap is folded neatly and tied to the strap using zip ties to remove any potential tripping hazard.

The Tie-Down Straps were supplied by:

Cargo Equipment Corp.
13700 George Bush Ct
Huntley, IL 60142
847-741-7272
www.cargoequipmentcorp.com

3.5.5 Lashing Plates

At each Timber Support, Lashing Plates, as shown in Figure 3.15, are mounted to fit the flat hook ends of the ratcheting Tie-Down Straps. Each Lashing Plate is capable of providing a minimum safe working load limit of 5,400 lbs (breaking strength of 16,200 lbs) capacity to match the full rated load capacity of a Tie-Down Strap.

Each Timber Support is outfitted with a lashing plate screwed into the Timber Support at 13.5 inches from each end. Each Lashing Plate is connected to the Timber Supports using two (2) lag screws, Grade A307 ¾ inch diameter, 8 inch long with washer.

3.5.6 Winch Main Wire Rope Shackle

The shackles used to secure the ILI Tool to the Winch Main Wire Rope corresponds to the following specification:

- Crosby Bolt-Type Anchor Shackles 2.0 inch (35T WLL).

Figure 3.16 shows the 2.0 inch shackle attached to the Winch Main Wire Rope spelter socket. (In the figure, a load cell is connected in line with the Winch Main Wire Rope and the ILI tool, used during commissioning). Note that additional shackles may be required to downsize from the 2.0 inch shackle to a size that can accommodate the connection at the ILI tool or payload. The TDC Pull Test Coordinator must confirm the load rating required for any such intermediate shackles.

Figure 3.16: Winch Main Wire Rope Shackle (shown with load cell at commissioning)

3.5.7 Shear Pin

A shear pin (i.e., a fusible link) is to be inserted with the 2.0 inch anchor shackle at the spelter socket on the Winch Main Wire Rope. The Shear Pin has a rated load capacity of 90,000 lbs and is designed to fail prior to the Winch Main Wire Rope. The drawing prepared by AMI is included in Annex F.

3.5.8 Anchor Shackles (Retrieval Line)

Ten (10) bolt-type Anchor Shackles are supplied for securing the Winch Main Wire Rope to the Retrieval Winch Wire Rope. The shackles have a load capacity exceeding that of the Retrieval Winch. Figure 3.17 shows the Retrieval Winch Wire Rope attached to the rear of a Cleaning Pig using a bolt-type shackle.

Figure 3.17: Retrieval Line attachment to Rear of Cleaning Pig

3.5.9 Launching Funnel Anchorage Chain

Four (4) sets of chain are supplied in 40 foot lengths and four (4) sets of chain in 25 foot lengths. The chain, hooks and links are required to secure the Launching Funnel to the Pipe Test String Counterweights (Reaction Blocks). The chain, hooks and links are sized to each support a minimum breaking strength of 100,000 lbf. Figure 3.18 shows the arrangement of chains and bolt-type shackles at the Launching Funnel Section and Pipe Test String Counterweights (Reaction Blocks).

Figure 3.18: Launching Funnel Sections Anchorage Chain

3.5.10 Pipe Test String Connection Plates

Four (4) sets of Pipe Test String Connection Plates, consisting of two (2) plates each, are installed at each of four (4) embedded anchorage locations at the Winch Concrete Foundation. The Connection Plates, welded to the embedded anchorage locations, provide a bolted connection to the Receiving Ends capable of carrying the minimum breaking strength of 100,000 lbf.

The Connection Plates secure the Receiving Ends to the Winch Concrete Foundation at the embedded anchorage locations (at the west end of the foundation), as shown in Figure 3.19. The four (4) embedded anchorage locations have been cast-in-place and aligned with each Pipe Test String. The Connection Plates and bolted connections are designed such that the Receiving End, regardless of pipe diameter, is aligned and level with the test run pipe supported on the 12 inch high Timber Supports.

Figure 3.19: Test Run Connection Plates

3.5.11 Pipe Test String Counterweights (Reaction Blocks)

Ten (10) precast concrete Pipe Test String Counterweights (Reaction Blocks), each weighing 21,074 lbs have been fabricated and supplied by:

Locke Solutions
832-804-7062
www.lockesolutions.com

The Pipe Test String Counterweights are positioned at the west end of the ILI Pull-Test Facility and located between each Pipe Test String. The Reaction Blocks are fabricated with lashing points to allow connection to the Acceleration Sections. A minimum of two (2) Pipe Test String Counterweights are positioned at and secured to the Launching Funnel with shackles and chains. The lashing points are designed for a minimum breaking strength of 100,000 lbf.

The arrangement requires the following components:

- Four (4) Crosby Bolt-Type Anchor Shackles 1.25 inch (26,455 lbs WLL) attached through each hole on the launcher attachment plate;

- A minimum of two (2) Crosby Grade 100 Alloy ¾ inch 18/20 chains (30,865 lbs WLL) passed through the launcher anchor plate and shackles;

- Each chain is terminated at each end with a Crosby A-1328 Eye Grab Hook Grade 100 ¾ inch 18/20 (35,300 lbs WLL); and,

- A minimum of two (2) precast concrete anchor blocks measuring 4 foot × 10 foot × 3.5 foot and weighing 21,017 lbs.

The Pipe Test String Counterweights are positioned such that the maximum angle created by the chain as measured from the Pipe Test String longitudinal axis does not exceed 45°. One Reaction Block is positioned similarly and to each side of the Pipe Test String. Figure 3.20 illustrates the minimum arrangement. Figure 3.21 shows the configuration using four (4) anchor blocks.

The first chain is passed through the shackle pair at the launcher anchor plate and hooked onto the first embedded bent #6 rebar at the top of each precast concrete anchor block. The second chain is similarly installed, anchored to the second of three embedded bent #6 rebar at the top of each precast concrete anchor block.

- Maximum angle between chain and axis of pipe test string is 45°;

- Minimum one (1) precast concrete anchor block is required each side, anchored at two (2) locations;

- Position the blocks to allow safe working area at the loading end of Launching Funnel Section; and,

- Do not use recessed utility anchors to anchor the Launching Funnel Section unless arranged to support the maximum design load (66,000 lbs).

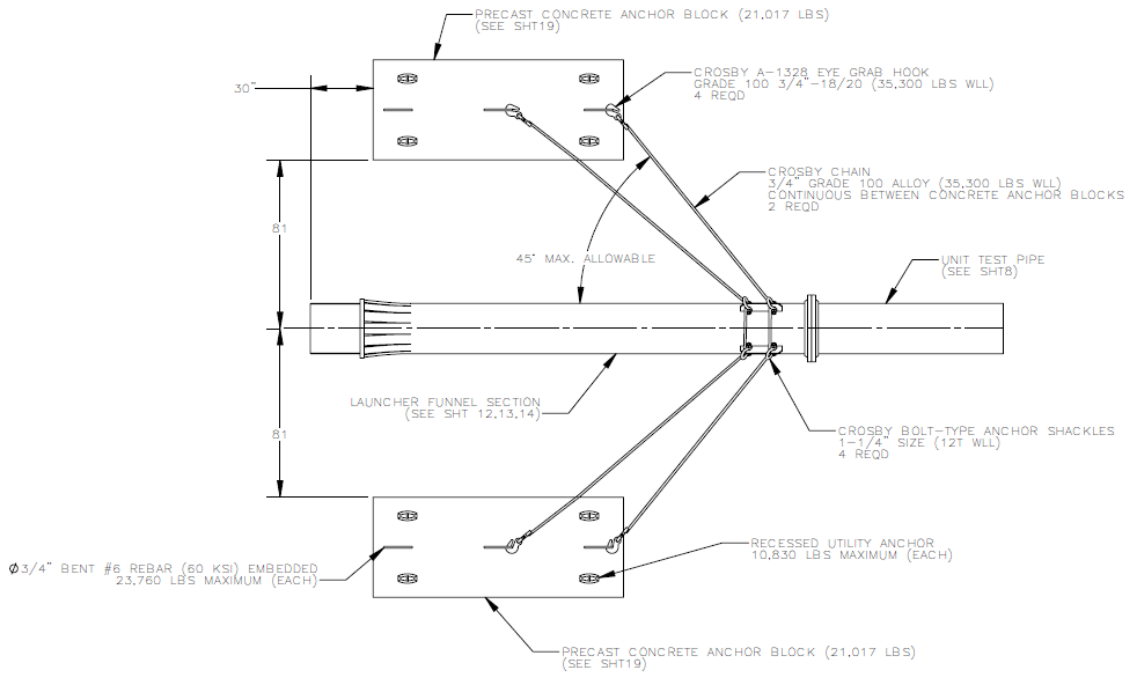


Figure 3.20: Arrangement of Precast Concrete Anchor Blocks

Figure 3.21: Concrete Anchor Blocks

3.5.12 Pre-Cast Concrete Jersey Barriers

Ten (10) precast concrete Jersey (traffic) barriers are supplied to be used to protect the Test Winch System during testing. The precast concrete Jersey barriers are supplied by:

Locke Solutions
832-804-7062
www.lockesolutions.com

A minimum of four (4) precast concrete Jersey barriers are positioned on the Winch Concrete Foundation. The barriers are arranged between the receiver end and the end of the A-Frame on the Test Winch System, positioned closely such that the Winch Main Wire Rope will pass between the ends of the barriers, having an opening of approximately 24 inches.

Figure 3.22: Precast Concrete Jersey Barriers

3.6 Retrieval Winch

The Retrieval Winch is used to bring the Winch Main Wire Rope through the Pipe Test String to the Launching Funnel so that it can be connected to the ILI Tool before testing.

The Retrieval Winch Wire Rope is then connected to the rear of the ILI Tool and the Retrieval Winch clutch is disengaged. During a pull test, as the ILI Tool is moving along the Pipe Test String, the Retrieval Winch Wire Rope is paid out freely.

Bolt-type chain shackles, sized to fit the connections, are used to connect the Retrieval Winch Wire Rope to the Winch Main Wire Rope and to the back end of the ILI Tool or payload.

The Retrieval Winch has a minimum safe working load limit of 7,000 lbf, to support the loads associated with pulling up to 550 feet of the Winch Main Wire Rope. The Retrieval Winch drum has been sized for up to 600 feet of Retrieval Winch Wire Rope. The arrangement includes an adjustable guide to control the elevation of the Retrieval Winch Wire Rope depending on the diameter of the Pipe Test String. The guide is required to prevent the Retrieval Winch Wire Rope from abrading against the walls or edges of the pipe sections.

The Retrieval Winch is comprised of the following components:

- Honda Model gas-powered GX390 Motor;
- Tulsa Winch Model 18G-SL-RFO;
- Permco Model P2100A290MDZA10-14 Hydraulic Pump; and,
- Kulkoni 3/8” 6x26 Warrington Seale with IWRC (SWL 1.51 tons) steel wire rope.

The Retrieval Winch, shown in Figure 3.23, is mounted on a precast concrete anchor block, weighing approximately 5,000 lbs. The precast concrete anchor block is supplied by:

Locke Solutions
832-804-7062
www.lockesolutions.com

Figure 3.23: Retrieval Winch

3.7 Forklift

PRCI purchased a forklift rated with a maximum working load of 22,000 lbf for material handling. Details of the PRCI forklift are:

- Caterpillar DP100NT-D 22,000 lbf Capacity Tier 4 Interim Compliant Diesel Pneumatic Tire Lift Truck, MCFA Configured at 24 inch Load Center.

3.8 Miscellaneous

3.8.1 Protective Shackle Wrap

In order that the pipe joints are not damaged when retrieving the Winch Main Wire Rope, the spelter socket and shackles must be wrapped. A typical shipping blanket secured with several wrappings of duct tape has been used to cover the connected shackles when retrieving the wire rope. Note that the shipping blanket will tear and can be reused approximately 2 to 3 times only and is sacrificial. The wrap is not required during testing, since the connected shackles will lift off the pipe wall under tension.

Figure 3.24: Protective Shackle Wrap

3.8.2 Nylon Rope Retrieval Lines

Four (4) spools of nylon rope are provided to manually retrieve the Retrieval Winch Wire Rope forward to the Test Winch System. Once at the Test Winch System, the Retrieval Winch Wire Rope is secured with shackles to the Winch Main Wire Rope, which is then paid out (with the Retrieval Winch also working to haul in the slack) until it reaches the Launching Funnel.

Figure 3.25: Receiving End with Nylon Rope Retrieval Line Spool

4 Operational Requirements

4.1 Introduction

This section provides a description of the operational requirements associated with the Test Winch System, including the electrical power supply provided via the TDC Building.

An overview of the key maintenance requirements for the Test Winch System is also provided. For complete details and instructions, refer to the following manuals:

- MAINTENANCE MANUAL FOR HIGH SPEED PULL-IN WINCH AND DIESEL HYDRAULIC POWER UNIT (FEBRUARY 2015); and,

- OPERATION MANUAL FOR HIGH SPEED PULL-IN WINCH AND DIESEL HYDRAULIC POWER UNIT (JULY 2015)".

4.2 Electrical Power Supply

The Test Winch System requires 110 VAC at 100 Full Load Amperes (FLA) (or, 12 kW).

A junction box at the Winch Concrete Foundation is installed to complete the electrical power connection to the Test Winch System. At the junction box, the Test Winch System retractable electrical cable is connected, as shown in Figure 4.1. A take-up cable reel is mounted on the end of the Winch Platform and retracts or pays out the cable as the platform transits the Winch Platform Rails. The take-up cable reel is shown in Figure 4.2.

(a) Junction Box

(b) Retractable Cable

Figure 4.1: Test Winch System Junction Box

Figure 4.2: Test Winch System Take-Up Cable Reel

An electrical disconnect is included next to the electrical panel for Lock-out/Tag-out (LOTO), allowing the Test Winch System to be disconnected from inside the TDC Building for safety and security. Figure 4.3 illustrates the electrical schematic for routing the conduit from the connection at the Winch Concrete Foundation to the transformer locating at the South wall within the TDC Building warehouse space.

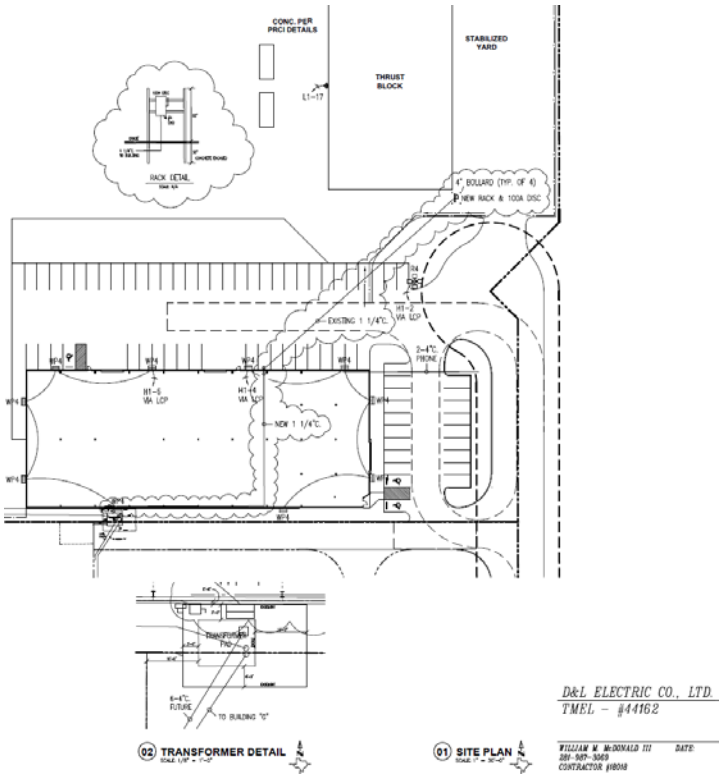


Figure 4.3: Electrical Schematic for Test Winch System Electrical Power Supply

4.3 Test Winch System Fuelling

The Test Winch System requires 250 gallons of diesel fuel to fill the tank mounted on the Winch Platform, under the diesel engine.

4.4 Test Winch System Hydraulic Oil

The Test Winch System requires 1000 gallons of Grade SAE AW46 hydraulic oil to fill the tank mounted on the Winch Platform. The minimum required cleanliness grade must meet 8 to NAS 1638; 6 to SAE; or, 20/17/14 to ISO 4406. The hydraulic oil must be filtered several times as it is pumped from the shipper into the equipment's tank.

4.5 Winch Main Wire Rope Winding

The Winch Main Wire Rope requires a nominal tension on it to pay out properly, so that the wraps on the drum remain tightly and evenly spaced. After manually paying out or hauling in, the wraps need to be checked for consistency and may require resetting.

4.6 Draining Rainwater from Drip Trays

As part of regular operation, the drip trays located under the fuel tank and the hydraulic oil reservoir should be drained of any rainwater that may collect. If the trays contain rainwater with hydraulic or fuel due to any leaks, the mixture shall be disposed of in accordance with environmental regulations.

4.7 Supporting Winch Main Wire Rope

To maintain the integrity of the Winch Main Wire Rope when not in use, it should be hauled in on the drum to the minimum distance with any remaining span supported off the ground.

4.8 Test Winch System Calibration

A load cell installed in-line with the Winch Main Wire Rope is used for calibration of line pull force recorded in the Test Winch System software.

In general, the Test Winch System should be calibrated annually to confirm the accuracy of pull force measurements. Since load cells are calibrated equipment and require their own maintenance and calibration, it was determined that a load cell could be rented on an as-required basis.

4.9 Test Winch System Maintenance

4.9.1 General

The following is a brief summary of the preventative maintenance activities and approximate schedule. Refer to the maintenance manual for complete details associated with replacing filters; oiling and greasing components; checking hoses; and other components. For any assistance regarding maintenance, and for specific part information, contact AMI quoting Serial Number 19653:

Appleton Marine, Inc.
3030 E. Pershing St.
Appleton, WI 54911
Phone: (920) 738-5432

Fax: (920) 738-5435
www.appletonmarine.com

4.9.2 Safety

Unless properly serviced, the Test Winch System can be extremely dangerous.

- Make sure the winch is properly lubricated before operation;
- Disengage the electrical power supply before performing lubrication or maintenance procedures;
- Remove all loads from the winch before performing any maintenance on the unit; and,
- Inspect the winch before and after every use, servicing or replacing any worn or damaged components.

Do not work alone.

- Never attempt to service equipment alone.
  - Someone capable of providing aid in the event of an accident must be present.
- Never attempt servicing while power is applied.
  - Tag and lock out the electrical power supply at the main electrical disconnect, located in the TDC Building.
- Never attempt servicing while the winch is moving or the hydraulic power unit is running.

In order to ensure safety, each person working on the Test Winch System must have the necessary skills, information, tools and equipment. Do not attempt to make adjustments, or perform repairs unless authorized and qualified to do so.

4.9.3 Regular Preventative Maintenance Actions

Table 4.1 lists the preventative maintenance actions, summarized from the maintenance manual.

On the Test Winch System, the levelwind at the winch drum is the most maintenance intensive component, requiring regular greasing using a marine grade, waterproof grease; or, synthetic grease is acceptable. Re-grease the level wind if the grease has dried between uses.

Table 4.1: Summary of Regular Preventative Maintenance Actions

Pressure grease fittings	Lubricate every 8 hours of operation Use marine grade grease, as required.
Planetary gearbox	Check oil level monthly. Add "Shell Omala 220" gear lubricant, as required.
	Drain and refill annually. Capacity is approximately 1.85 gallons (7.0 liters)
Dual input splitter boxes (2)	Check oil level monthly. Add "Shell Omala 220" gear lubricant, as required.
	Drain and refill annually. Capacity is approximately 2.5 gallons (9.6 liters)
Wire rope	Inspect at each use
Crane wheels	Lubricate every 8 hours of operation Use marine grade grease, as required.
Worm Drive Gearbox	Replace the oil annually. Use 1.5 liters of Mobil SHC 634 gear oil or equivalent.
Winch Levelwind	Lubricate every 8 hours of operation, or when dried.
Winch Levelwind Chain	Coat chain and sprockets with a suitable chain lubricant every 100 hours of operation.
Diesel Engine Oil	Change oil after initial 100 hours of operation. Change oil every 250 hours of operation, or sooner based on duty cycle.
Diesel Engine Air Intake Filters	Inspect filters and replace when indicated or annually, whichever occurs sooner.
Diesel Engine Fuel Filters	Change fuel filters every 250 hours of engine operation.
Diesel Engine Coolant	Check periodically to maintain a sufficient level. Drain and refill cooling system every 1500 hours of engine operation.
Hydraulic Unit Return Filters	Change the return filter elements when indicated by the clogged filter alarm on the filter.
Hydraulic Cylinders (A-Frame and Tie-backs)	Do not store winch with hydraulic cylinders extended, exposing the chrome shafts to prevent rusting.
Steel Winch Platform	Apply paint to touch up any contact points to prevent rusting.

4.9.4 Preservation Actions

If the Test Winch System is not to be operated for more than 6 months, it is recommended to complete the following preservation actions:

- Grease all components according to the lubrication chart found in the Maintenance Manual;

- Fill all gearbox levels according to the Maintenance Manual and add a vapor phase inhibitor, such as Cortec Corporation #VCI-322;

- Cover all exposed machined metal surfaces with a rust preventative such as Noccotec 211 or BC Petro Tape;
- Coat the Winch Main Wire Rope wound on the winch drum with a lubricant, such as Dynaguard Blue and cover with a tarp;
- Outfit all electrical enclosures with moisture absorbent packs; and,
- Protect all parts that may be subject to corrosion (including valve adjustment screws; manual selector valves; solenoid manual overrides; etc.) with a removable rust preventative, such as BC Petro Tape.

4.9.5 Other Long-Term Storage Actions

Table 4.2 provides a list of some additional long-term storage actions for good practice.

Table 4.2: Long-Term Storage Actions

Winch Computer	Remove from operating cabin and store inside the TDC Facility.
Winch Computer UPS	Remove from operating cabin and store inside the TDC Facility. Charge prior to using, if left unplugged for an extended period.
System batteries	Check if charging is required.

4.10 Inspections

4.10.1 Wire Rope Inspection

The Winch Main Wire Rope, the Retrieval Winch Wire Rope and all end fittings should be inspected visually prior to commencing any testing to identify any change in condition of the materials and equipment, including:

- Loose, broken or misplaced wires;
- Thinning or any reduction in diameter or cross-section;
- Corrosion;
- Rope deformation;
- Loop formations or nodes;
- Kinks; and,
- Flat areas.

4.10.2 Equipment Inspections

The following equipment should be checked annually for indications of wear, corrosion or deterioration:

- Winch Main Wire Rope spelter socket connection;
- Retrieval Winch Wire Rope end connection and condition;
- All slings used for lifting or material handling;
- All chain, Lok-A-Loy connecting links and end hooks;
- Ratcheting tie-down straps; and,
- Bolts, not to be over-tightened.

5 PREPARATION AND EXECUTION OF Pull TESTING

5.1 Introduction

This section provides an overview of the actions required to prepare for and execute a pull-test. Refer to "PRCI TDC - ILI System Pull Test Facility Operation Guide" (10 August 2015) for full details, including roles of the participants and the health and safety requirements.

5.2 Preparation

5.2.1 Pipe Test String Maximum Length

The maximum overall length of the Pipe Test String is limited to 485 feet, taken as the distance between the start of the Launching Funnel and the end of the Receiving End.

- The setback distance of the Test Winch System from the end of the Receiving End to the Test Winch System drum is approximately 48 feet.

- The Test Winch System drum holds 565 feet of wire rope; however, the full length of wire rope cannot be paid out. The Test Winch System is configured to ensure that a safe minimum number of dead wraps remain on the drum.

- At commissioning, the Test Winch System demonstrated adequate power with a shorter acceleration length, allowing a length of the constant velocity test segment exceeding 350 feet.

5.2.2 Pipe Test String Configuration

The choice and sequence of test specimens to be included in each of the Pipe Test Strings will be defined as part of the Testing Plan prior to testing. Once the test specimens are connected to form a Pipe Test String, a listing of features is created to confirm the actual test configuration and to document the as-built record.

5.3 Pull Test Area and Equipment

The TDC Pull Test Coordinator is responsible for ensuring the pull test area is maintained and prepared for testing.

The equipment, described previously in Section 3, to be setup and prepared includes:

- Timber Supports with Lashing Plates;

- Receiving End;

- Pipe Test String;

- Tie-Down Straps;

- Launching Funnel;

- Test Winch System;
- Winch Anchorage Braces;
- Winch Anchor Linkages;
- Pipe Test String Counterweights (Reaction Blocks);
- Precast Concrete Jersey Barriers;
- Loading Tray;
- Nylon Rope Retrieval Line;
- Retrieval Winch;
- Winch Main Wire Rope; and,
- Winch Main Wire Rope Shackles with Shear Pin.

5.4 ILI Service Provider

The ILI Service Provider is responsible for the setup and calibration of the ILI Tool and associated inspection technology tools prior to the performance trials. The tool delivery and pre-trial setup and calibration activities are included in the schedule data provided by the ILI Service Provider to the TDC Pull Test Coordinator.

5.4.1 Pre-Run Briefings

At the start of each day of testing, the TDC Pull Test Coordinator conducts a briefing for all personnel involved in the trial program. The briefing includes:

- Objectives of testing;
- Confirmation of ILI Tool and associated inspection technology and test setup;
- Schedule of events for the trial and the test day;
- Roles of individuals including PRCI TDC Staff, PRCI Project Contractors, ILI Service Providers and their representatives, and other participants directly involved in the activities for the referenced trials;
- Equipment and access restrictions;
- Data to be collected;
- Results to be delivered;

- Points of contact; and,
- Job Safety Briefing and Analysis.

A written note outlining the trial briefing is provided to all trial participants.

5.4.2 Test Parameters

The TDC Winch Operator is responsible for enabling the data collection system and inputting the winch testing parameters supplied by the TDC Pull Test Coordinator for the test run.

A schedule of runs is provided to the TDC Winch Operator at the beginning of the trial program and reviewed each day. The schedule includes definition of the test parameters required for each trial.

5.4.3 Pull Test Personnel Responsibilities

Responsibilities of all personnel are outlined in the Operations Guide. The scope of work includes operating the Test Winch System; setting up and operating auxiliary equipment (e.g., forklift and manipulating the Winch Main Wire Rope); logistics support; and, interfacing with the ILI Service Provider personnel in providing the support requested in advance of the trial program.

The ILI Service Provider personnel are responsible for operating the ILI Tool and all accompanying equipment, including download and confirmation of data collected.

The activities of all non-essential personnel, including observers, are managed by the TDC Pull Test Coordinator or their designate.

5.4.4 Logistics and Scheduling

Detailed schedules for all activities starting from preparation of the TDC Facility to final reporting are established and managed by the TDC Pull Test Coordinator. The logistics and coordination of material deliveries to the TDC Facility and acceptance of these materials is managed by the TDC Pull Test Coordinator.

The trial program general schedule is managed by the TDC Pull Test Coordinator with input from the PRCI Project Team and ILI Service Provider personnel. The trial schedule covers timelines and defines deadlines for all stages of a particular performance trial, from preparation, execution, processing of data and results and reporting.

The daily test schedule is established to cover all activities during operating hours and storage of equipment. The daily schedule is managed by the TDC Pull Test Coordinator with input from the PRCI Project Team and the ILI Service Provider.

Modifications to schedules and logistics details are documented by the TDC Pull Test Coordinator, with support from the PRCI Project Team, and confirmed in writing with the ILI Service Provider.

5.5 Testing – Execution

Checklists to support documentation and uniform reporting of each step in the testing process, as well as additional detail regarding setting up and completing testing, are included in "PRCI TDC - ILI System Pull Test Facility Operation Guide" (10 August 2015).

5.5.1 Operational Procedure

A performance trial is completed as follows:

- Using the forklift, move the ILI Tool to the loading area on the vendor supplied tray, positioned such that it can be transferred to the test facility Loading Tray.
    - The ILI Service Provider personnel are permitted to make any final inspections, adjustments and issue operational commands to the ILI Tool at this time.
    - After the ILI Tool has been transferred to the Loading Tray, the unloaded forklift relocates to the winch end of the Pipe Test String. The forklift remains in position until after the pull test to keep sightlines clear.
- The TDC Pull Test Technician attaches the Winch Main Wire Rope to the leading end of the ILI Tool.
- The TDC Pull Test Technician attaches the Retrieval Winch Wire Rope to the trailing end of the ILI Tool.
    - Connections to the ILI Tool are checked and the connection process confirmed with the ILI Service Provider staff to ensure appropriate connections are made.
- The TDC Pull Test Technician disengages the clutch on the Retrieval Winch so it can pay out line freely.
- TDC Pull Test Coordinator signals the TDC Winch Operator to move the ILI Tool at low speed through the Loading Funnel into the first test segment.
    - This operation does not commence until all hands are confirmed clear of the ILI Tool, wire rope and Launching Funnel to avoid injury.
    - The TDC Pull Test Technician signals to the TDC Pull Test Coordinator that a successful loading is completed.
    - The TDC Pull Test Coordinator relays the signal to the TDC Winch Operator (via the TDC Pull Test Technician located within the operator cabin).
- When the TDC Pull Test Coordinator confirms that all personnel are clear of the test system and the ILI Tool is fully within the launcher funnel section, the system is ready to test. The TDC Pull Test Coordinator signals the TDC Winch Operator to commence the test.

- The TDC Winch Operator is responsible for enabling the data collection system and inputting the winch testing parameters supplied by the TDC Pull Test Coordinator for the test run.

- The TDC Winch Operator confirms the test parameters are input correctly before testing.

- The Test Winch System is engaged to pull the ILI Tool through the Pipe Test String.

- The test is complete when any one of the following conditions occurs:

  - The maximum test pull distance is reached, as measured by the winch control system.

  - The painted segments of the pull wire are sighted by the TDC Winch Operator or the TDC Pull Test Coordinator.

  - Any of the personnel involved in the trial program issues the command to stop the trial due to a safety concern. The TDC Winch Operator will activate the emergency stop.

  - The tension on the pull rope exceeds the safe operating load limit.

- Once the ILI Tool comes to a complete stop, the forklift is moved into position at the Receiving End of the Pipe Test String to receive the ILI Tool.

  - With the forklift and loading tray in position, the TDC Pull Test Technician signals the TDC Winch Operator to move the ILI Tool out of the Receiving End and onto the Loading Tray.

  - The rope connections are free to enter the pipe run. A roller or a piece of well-supported wood should be placed so that the wire rope does not ride against the edge of the pipe.

  - All personnel are clear of the pipe ends while the ILI Tool is removed.

  - The ILI Service Provider personnel are permitted to inspect, adjust and issue operational commands to the ILI Tool at this time, as required.

  - All shackled wire rope connections are removed from the ILI Tool at this time by the TDC Pull Test Technician(s).

  - The forklift moves the ILI Tool away from the receiver end of the Pipe Test String.

- The Winch Main Wire Rope is connected to the Retrieval Winch Wire Rope by the TDC Pull Test Technician.
    - Prior to retuning the Winch Main Wire Rope to the Launching Funnel, the TDC Pull Test Technician ensures that the wire ropes are firmly connected.
    - A sacrificial shipping blanket or other material is used to wrap the wire rope shackles and sockets to prevent damage while recovering the Winch Main Wire Rope.
    - The TDC Winch Operator sets the winch to return mode. The Winch Main Wire Rope requires some nominal tension on it to pay out properly so that the wraps on the drum are spaced tightly. The TDC Winch Operator operates the controls to ensure the Winch Main Wire Rope carries the required tension.

5.5.2 ILI Tool Handling

The forklift is used to move the ILI Tool around the test area. The handling equipment and procedures used in the trial are reviewed and approved by the ILI Service Provider prior to starting.

The ILI Tool shall not be handled or moved in a manner deemed to be unacceptable to the ILI Service Provider. The ILI Service Provider approves all lift points, rigging and tools if procedures used differ from those defined in standard TDC procedures.

5.5.3 ILI Tool Operation

All pre-run preparation and calibration of the ILI Tool is the responsibility of the ILI Service Provider.

Post-run calibration checks of the ILI Tool inspection and adjustments are the responsibility of the ILI Service Provider.

The retrieval of test data and data checks to assess test run success are the responsibility of the ILI Service Provider.

5.5.4 Test Winch System Operation

The Test Winch System is operated only by personnel approved by PRCI.

The TDC Winch Operator is supported by a TDC Pull Test Technician within the winch operating cabin during a trial for the purposes of relaying communications to/from the TDC Pull Test Coordinator.

When hauling in the Winch Main Wire Rope back onto the winch drum, it is critical to maintain tension on the wire rope to ensure proper wrap. Winch haul in operations are not recommended with little to no line tension due to spooling issues on the drum that occur.

The Winch Main Wire Rope requires some nominal tension on it to pay out properly, so that the wraps on the drum are spaced tightly. The wraps shall be checked for consistency.

Shutting down the diesel engine after each step in the testing reduces the life of the ignition starter. Between testing stages, the diesel engine is left idling.

5.5.5 Pull-Test Data Recording

The TDC Winch Operator is responsible for collecting and saving the winch system direct measurement results of each pull trial to a data file.

The TDC Pull Test Coordinator provides direction regarding file naming conventions and any pull test annotations to add to the file. When complete, the data is stored in the PRCI TDC Facility database.

5.5.6 ILI Data Recording

Recording and storage of ILI data from each of the pull tests included in an ILI Performance Trial are the responsibility of the ILI Service Provider.

The ILI Service Provider defines the schedule for data collection and checking with the TDC Pull Test Coordinator. The ILI Service Provider is responsible for completing and documenting all ILI System pre- and post- pull test operational and calibration checks. Records and confirmation of these checks are provided to PRCI as part of the trial run acceptance process.

Details of this reporting are discussed with the TDC Pull Test Coordinator prior to testing.

5.5.7 Acceptance of Runs

At the completion of each ILI Performance Trial, a decision is made whether the test runs were performed successfully, based on the criteria defined in the documents and tables developed for the program, including:

- Operationally successful completion as confirmed by both the ILI Service Provider and the TDC Pull Test Coordinator;
- Covered range of inspection speeds as defined by the TDC Winch Operator and the TDC Pull Test Coordinator;
- Quality of recorded data as defined by the ILI Service Provider, the TDC Winch Operator and the TDC Pull Test Coordinator; and,
- ILI System calibration and operational condition of the ILI Tool will be documented and confirmed by the ILI Service Provider.

A summary report is developed and issued to the PRCI Project Team by the TDC Pull Test Coordinator. The final decision on achieving a successful ILI Performance Trial is the responsibility of the PRCI Project Team.

If a performance trial is not considered complete or acceptable by the PRCI Project Team, the ILI Service Provider and other participants of the performance trial are consulted to evaluate options for further testing.

5.6 Post-Testing

5.6.1 Test Winch System Shutdown

The TDC Pull Test Coordinator ensures the TDC Winch Operator completes the recommended pre-shutdown checks, follows the shutdown procedures and that the winch is in good working order upon completion of a pull test. Any anomalies or maintenance concerns are documented and reported to PRCI TDC Facilities Manager.

- The required procedures are outlined in the AMI Winch Operating Manual.
- All electrical disconnects on the winch platform and in the operating cabin are switched off.
- The TDC Winch Operator hauls in the Winch Main Wire Rope manually, with over-rides engaged as required, so that the end spelter socket and wire rope are supported off of the ground at the A-Frame.
- The TDC Pull Test Coordinator ensures that all equipment is switched off and that no lines are in tension.

5.6.2 Test Winch System Main Electrical Disconnect

The main electrical disconnect for the Test Winch System, located within the PRCI TDC Building, is switched off to prevent unauthorized or unsafe use.

5.6.3 Clean-Up

As a result of pull testing, corrosion particulate is pushed out of the Receiving End. TDC Pull Test Technicians collect and dispose of the particulate safely. Respiratory and eye protection is required to minimize the risk of personal injury.

5.6.4 Retrieval Line

Each prepared pipe test string must always have a line running through the full length. The line may be any of the Winch Main Wire Rope; the Retrieval Winch Wire Rope; or, the Nylon Retrieval Line.

The Retrieval Line is required to bring the Retrieval Winch Wire Rope up to the Receiving End so that that Winch Main Wire Rope can be brought to the Launching Funnel.

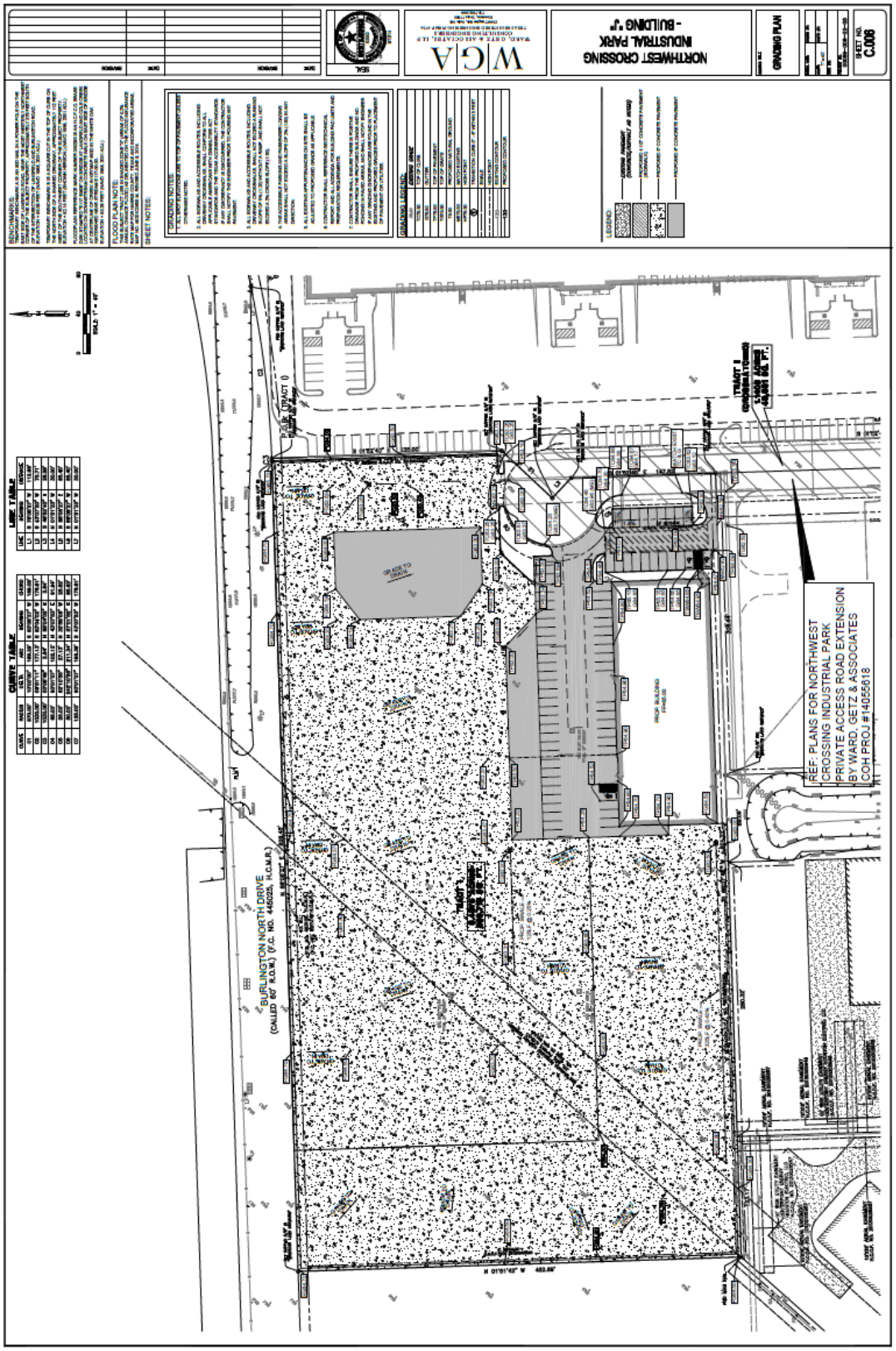
At the completion of testing, the Pipe Test String is arranged with the Retrieval Line running the full length.

5.6.5 Test Winch System Computers and Equipment

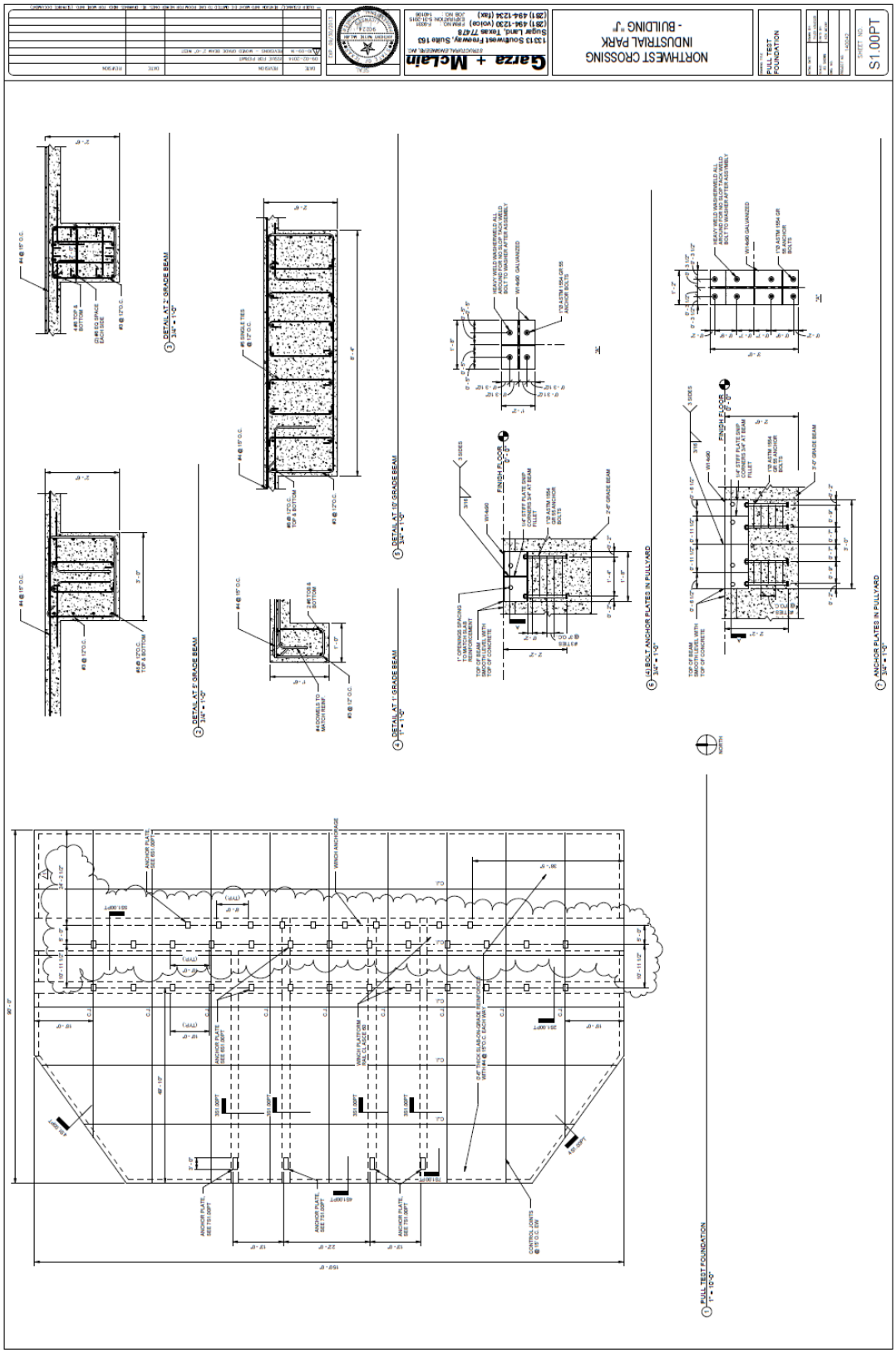
The security of the Test Winch System operating cabin and the electronics is maintained by ensuring that the operating cabin is locked while not in use.

The Test Winch System computer and display screens are safeguarded by storing in the PRCI TDC Building when not in use.

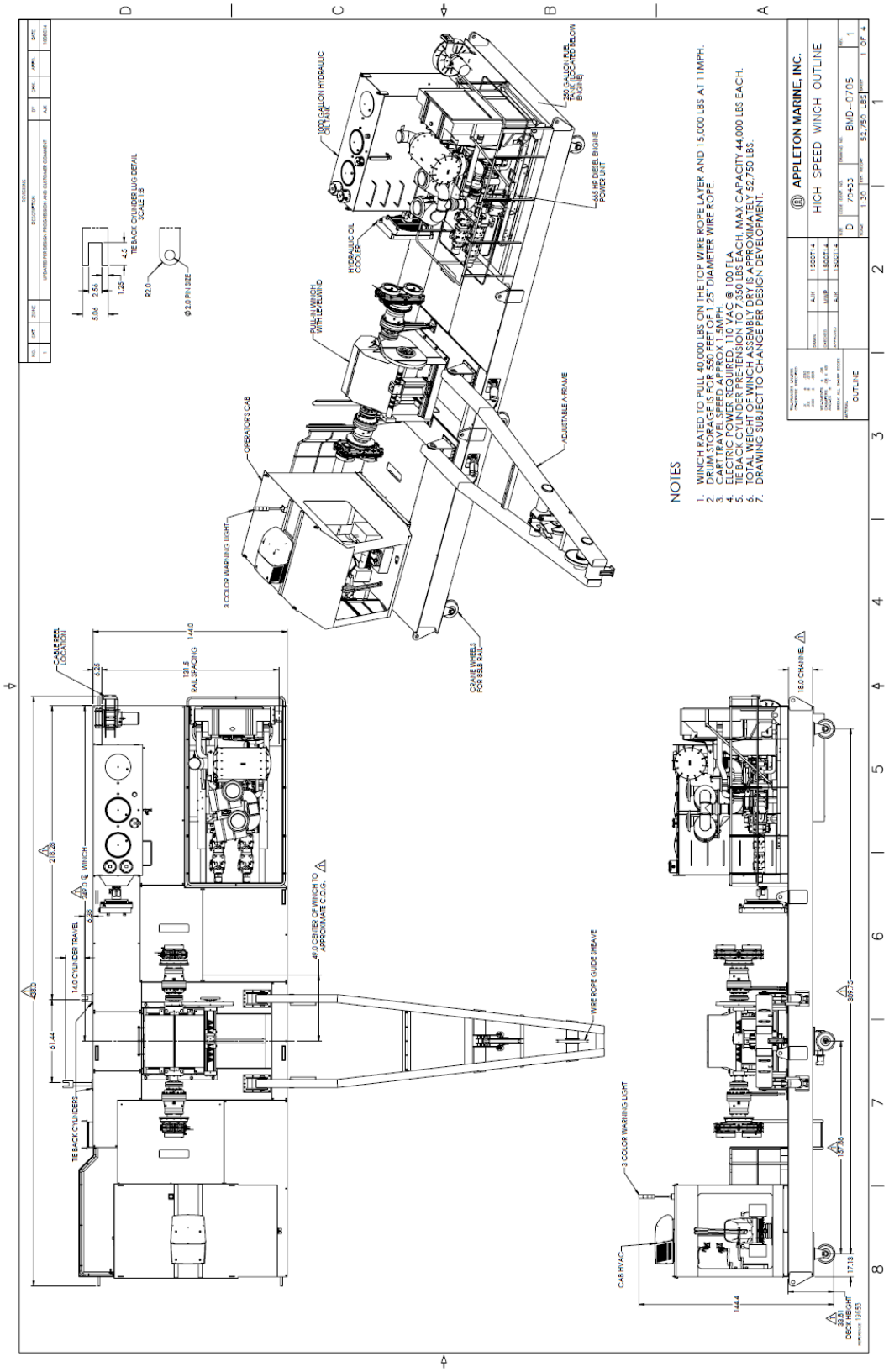
ANNEX A – GENERAL SITE LAYOUT AND GRADING PLAN

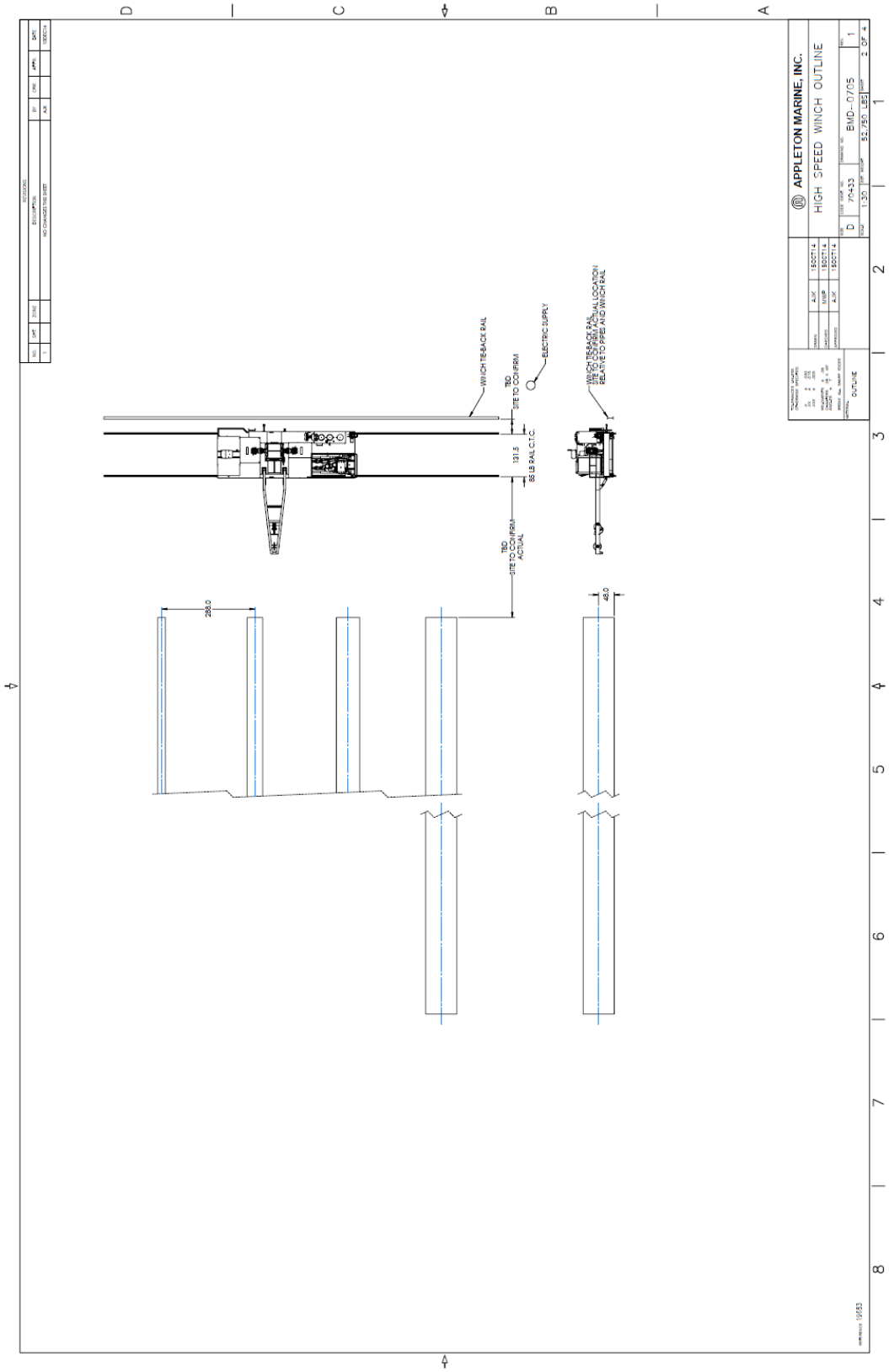

NORTHWEST CROSSING
INDUSTRIAL PARK
- BUILDING "J"
GRADING PLAN
C.006
W|G|A
BURLINGTON NORTH DRIVE
(CALLED 60' R.O.W.) (F.C. NO. 440026, O.P.R.M.C.)
REF: PLANS FOR NORTHWEST
CROSSING INDUSTRIAL PARK
PRIVATE ACCESS ROAD EXTENSION
BY WARD, GETZ & ASSOCIATES
COH PROJ #14055618

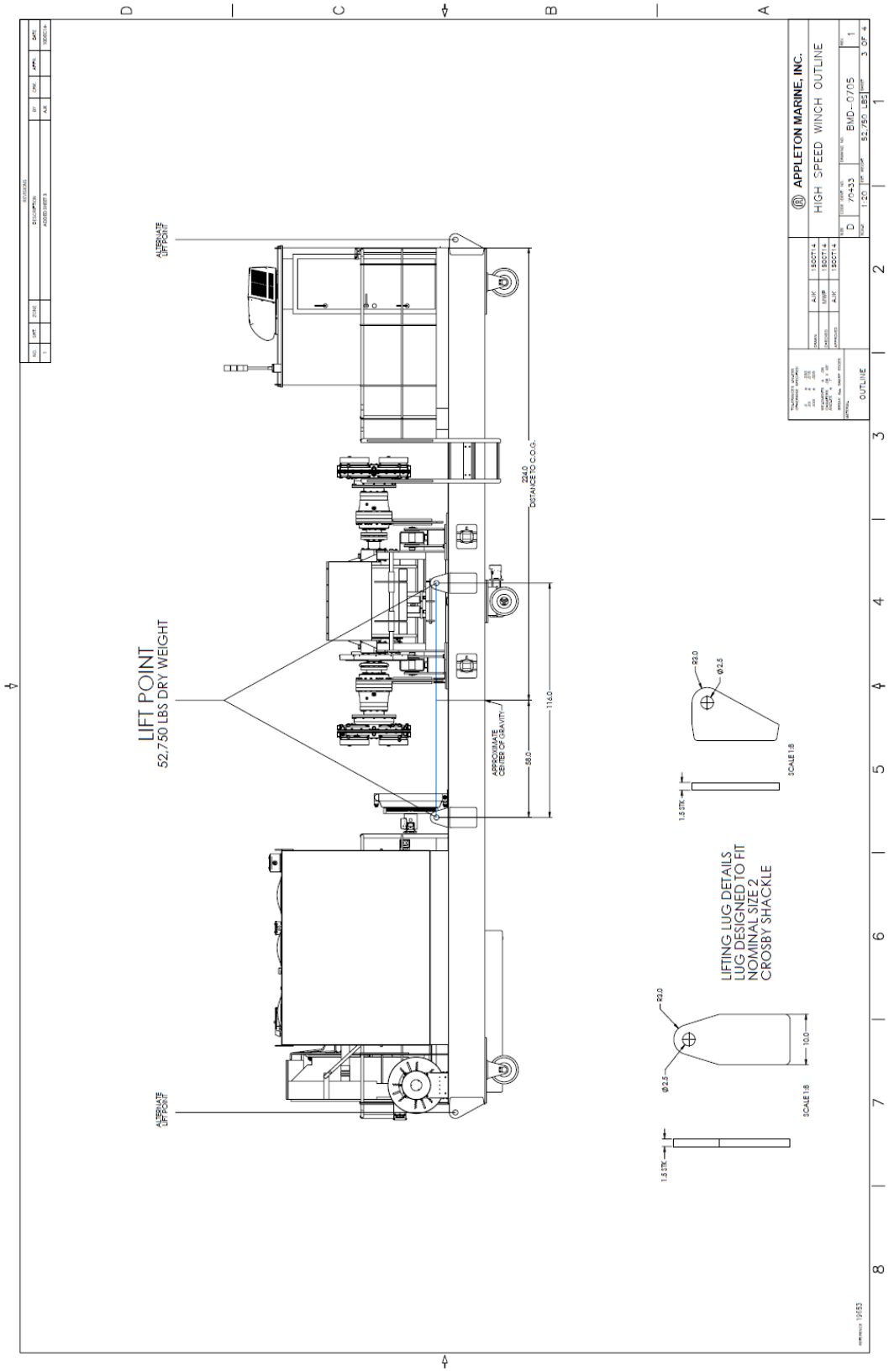
ANNEX B – WINCH CONCRETE FOUNDATION

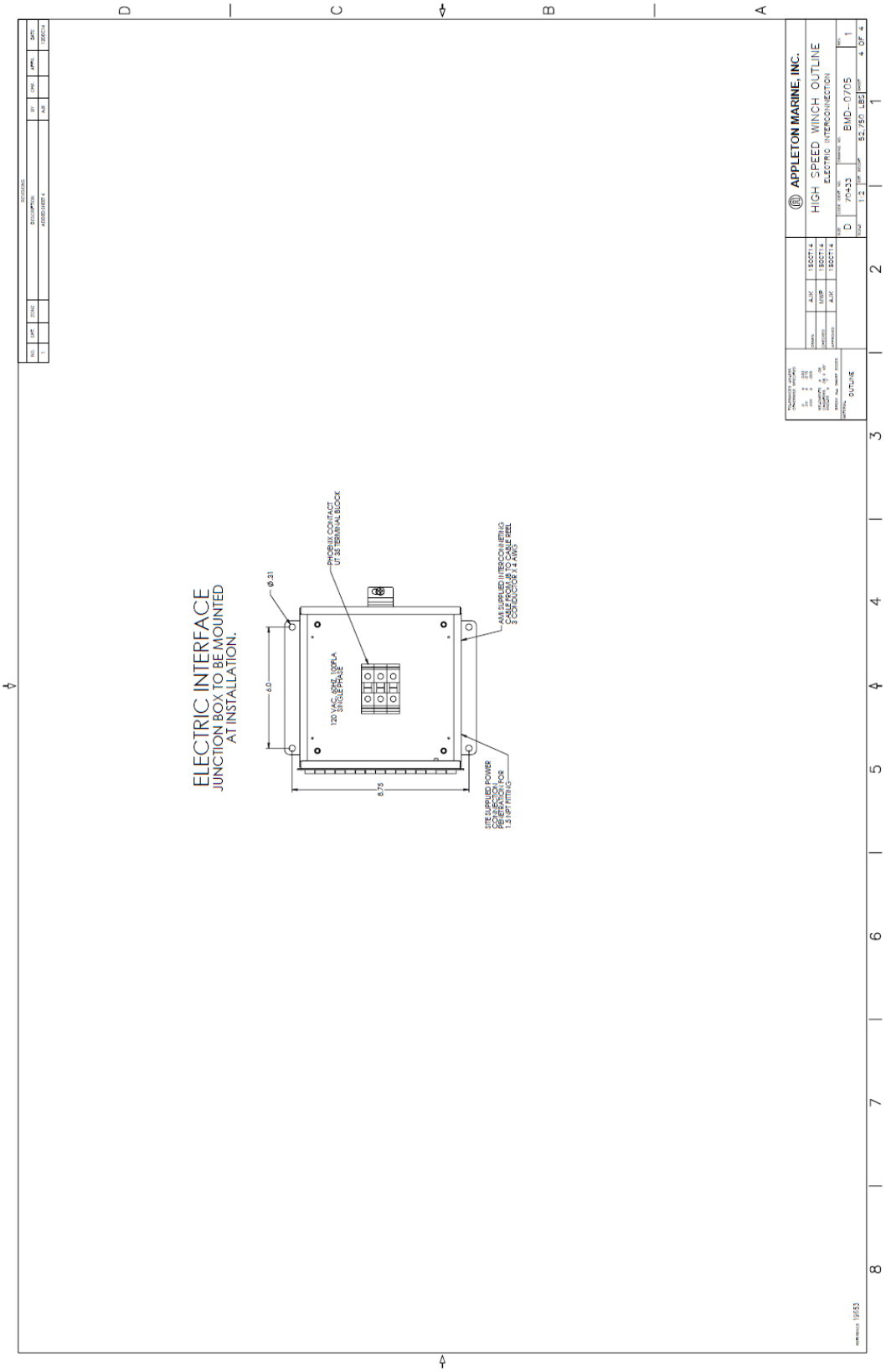

NORTHWEST CROSSING
INDUSTRIAL PARK
- BUILDING "J"
PULL TEST FOUNDATION
S1.00PT
Garza + McLain
DETAIL AT 2' GRADE BEAM
DETAIL AT 1' GRADE BEAM
J-BOLT ANCHOR PLATES IN PULLYARD
ANCHOR PLATES IN PULLYARD
PULL TEST FOUNDATION

ANNEX C - TEST WINCH SYSTEM OUTLINE DRAWING

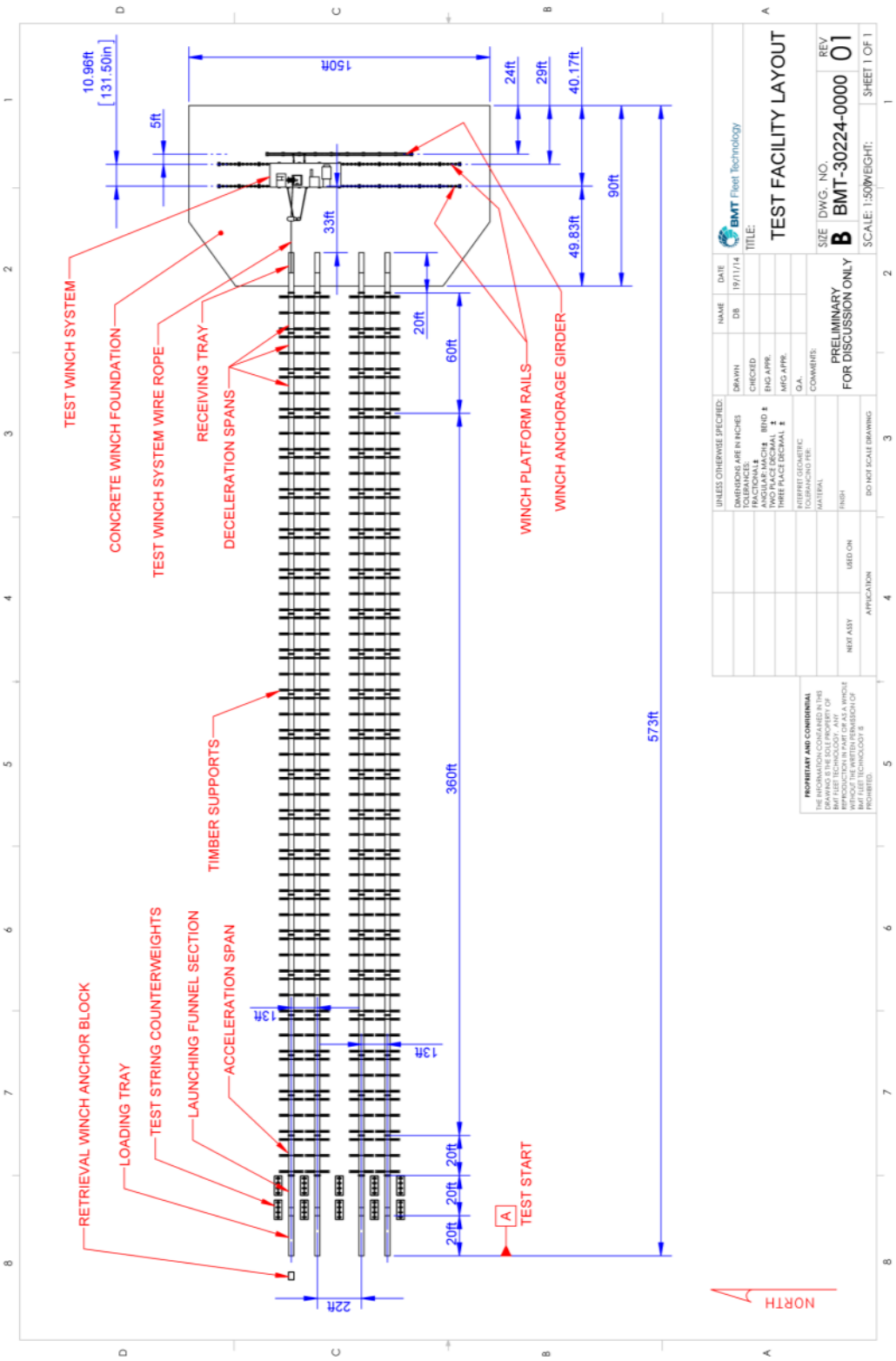

NOTES
1. WINCH RATED TO PULL 40,000 LBS ON THE TOP WIRE ROPE LAYER AND 15,000 LBS AT 11MPH.
2. DRUM STORAGE IS FOR 550 FEET OF 1.25" DIAMETER WIRE ROPE.
3. CART TRAVEL SPEED APPROX 1.5MPH.
4. ELECTRIC POWER REQUIRED, 110 VAC @ 100 FLA.
5. TIE BACK CYLINDER PRE-TENSION TO 7,350 LBS EACH, MAX CAPACITY 44,000 LBS EACH.
6. TOTAL WEIGHT OF WINCH ASSEMBLY DRY IS APPROXIMATELY 52,750 LBS.
7. DRAWING SUBJECT TO CHANGE PER DESIGN DEVELOPMENT.
APPLETON MARINE, INC.
HIGH SPEED WINCH OUTLINE
BMD-0705
52,750 LBS
OUTLINE
3 COLOR WARNING LIGHT
OPERATOR'S CAB
PULL-IN WINCH WITH LEVELWIND
HYDRAULIC OIL COOLER
1000 GALLON HYDRAULIC OIL TANK
250 GALLON FUEL TANK LOCATED BELOW ENGINE
445 HP DIESEL ENGINE POWER UNIT
ADJUSTABLE A-FRAME
CRANE WHEELS FOR SELF RAIL
TIE BACK CYLINDER LUG DETAIL SCALE 1:8
CABLE REEL LOCATION
RAIL SPACING
49.0 CENTER OF WINCH TO APPROXIMATE C.O.G.
WIRE ROPE GUIDE SHEAVE
TIE BACK CYLINDER
1.4 CYLINDER TRAVEL
18.0 CHANNEL
CAB HVAC
DECK HEIGHT


APPLETON MARINE, INC.
HIGH SPEED WINCH OUTLINE
BMD-0705
WINCH TIE-BACK RAIL
ELECTRIC SUPPLY
TBD
SITE TO CONFIRM
131.5
SS B RAIL C.T.C.
TBD
SITE TO CONFIRM
ACTUAL
288.0
48.0


APPLETON MARINE, INC.
HIGH SPEED WINCH OUTLINE
BMD-0705
OUTLINE
LIFT POINT
52,750 LBS DRY WEIGHT
ALTERNATE LIFT POINT
ALTERNATE LIFT POINT
DISTANCE TO C.O.G.
APPROXIMATE CENTER OF GRAVITY
LIFTING LUG DETAILS
LUG DESIGNED TO FIT
NOMINAL SIZE 2
CROSBY SHACKLE
SCALE 1:8
SCALE 1:8


ELECTRIC INTERFACE
JUNCTION BOX TO BE MOUNTED
AT INSTALLATION.
Ø.31
6.0
8.75
PHOENIX CONTACT
UT 35 TERMINAL BLOCK
120 VAC 60HZ 100MLA
SINGLE PHASE
AAM SUPPLIED INTERCONNECTION
CABLE ASSEMBLY WITH 4 PAIR
8 CONDUCTOR X 4 AWG
SITE SUPPLIED POWER
CONNECTION
PENETRATION FOR
1.5 NPT FITTING
APPLETON MARINE, INC.
HIGH SPEED WINCH OUTLINE
ELECTRIC INTERCONNECTION
D
79433
BMD-0705
1
1:2
52,750 LBS
4 OF 4
OUTLINE
AJK
15OCT14
MMP
15OCT14
AJK
15OCT14

ANNEX D – TEST FACILITY LAYOUT


TEST WINCH SYSTEM
CONCRETE WINCH FOUNDATION
TEST WINCH SYSTEM WIRE ROPE
RECEIVING TRAY
DECELERATION SPANS
WINCH PLATFORM RAILS
WINCH ANCHORAGE GIRDER
TIMBER SUPPORTS
RETRIEVAL WINCH ANCHOR BLOCK
LOADING TRAY
TEST STRING COUNTERWEIGHTS
LAUNCHING FUNNEL SECTION
ACCELERATION SPAN
TEST START
NORTH
10.96ft
[131.50in]
5ft
150ft
24ft
29ft
40.17ft
90ft
49.83ft
33ft
20ft
60ft
360ft
573ft
13ft
13ft
20ft
20ft
20ft
22ft
BMT Fleet Technology
TITLE:
TEST FACILITY LAYOUT
SIZE B
DWG. NO. BMT-30224-0000
REV 01
SCALE: 1:500
WEIGHT:
SHEET 1 OF 1
PRELIMINARY
FOR DISCUSSION ONLY
DRAWN DB 19/11/14
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
FINISH
DO NOT SCALE DRAWING
NEXT ASSY
USED ON
APPLICATION
PROPRIETARY AND CONFIDENTIAL
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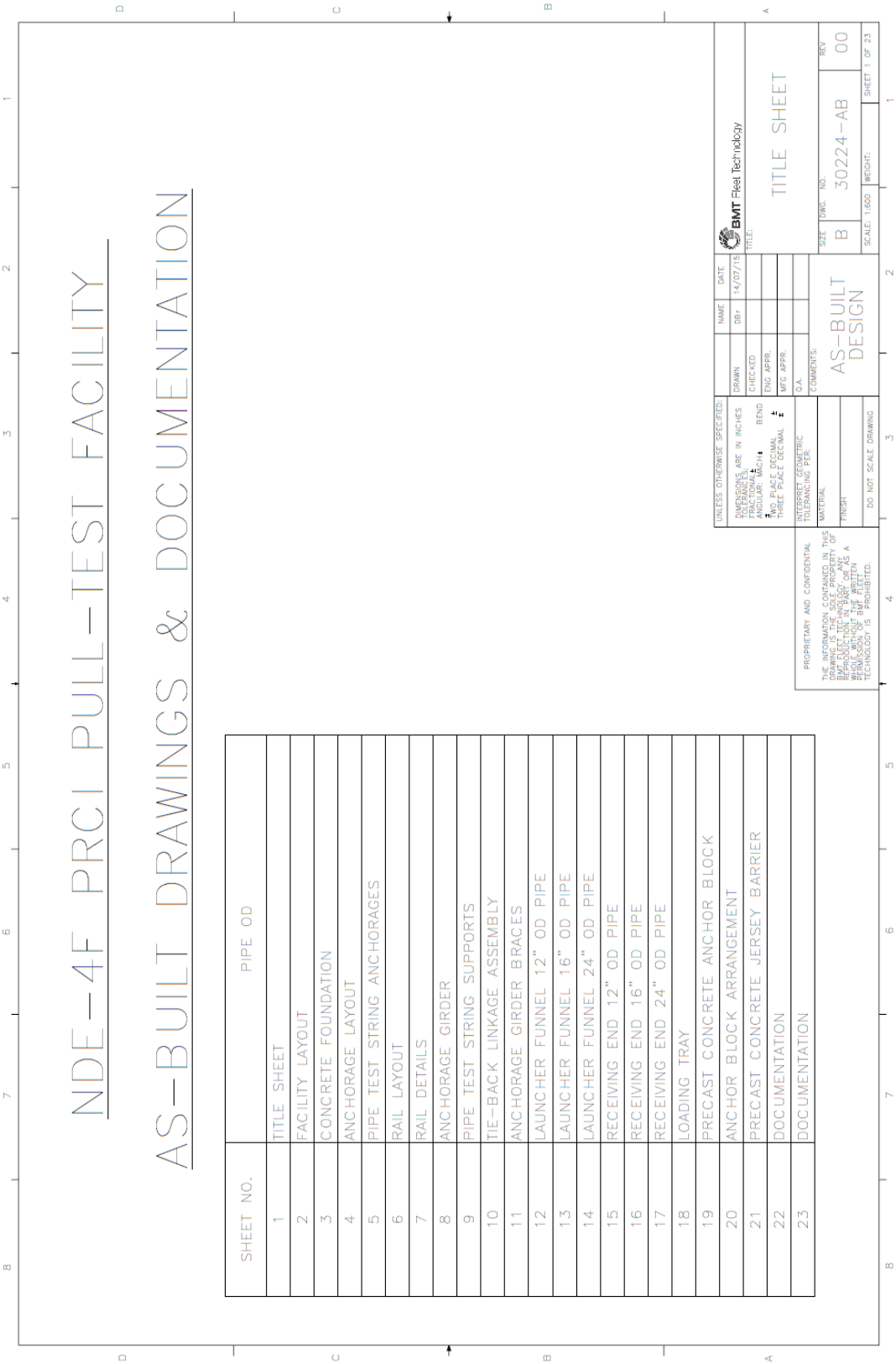
ANNEX E – AS-BUILT DRAWINGS


NDE-4F PRCI PULL-TEST FACILITY
AS-BUILT DRAWINGS & DOCUMENTATION
SHEET NO.
PIPE OD
1 TITLE SHEET
2 FACILITY LAYOUT
3 CONCRETE FOUNDATION
4 ANCHORAGE LAYOUT
5 PIPE TEST STRING ANCHORAGES
6 RAIL LAYOUT
7 RAIL DETAILS
8 ANCHORAGE GIRDER
9 PIPE TEST STRING SUPPORTS
10 TIE-BACK LINKAGE ASSEMBLY
11 ANCHORAGE GIRDER BRACES
12 LAUNCHER FUNNEL 12" OD PIPE
13 LAUNCHER FUNNEL 16" OD PIPE
14 LAUNCHER FUNNEL 24" OD PIPE
15 RECEIVING END 12" OD PIPE
16 RECEIVING END 16" OD PIPE
17 RECEIVING END 24" OD PIPE
18 LOADING TRAY
19 PRECAST CONCRETE ANCHOR BLOCK
20 ANCHOR BLOCK ARRANGEMENT
21 PRECAST CONCRETE JERSEY BARRIER
22 DOCUMENTATION
23 DOCUMENTATION
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
FINISH
DO NOT SCALE DRAWING
NAME
DATE
DRAWN DBF 14/07/15
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
AS-BUILT DESIGN
PROPRIETARY AND CONFIDENTIAL
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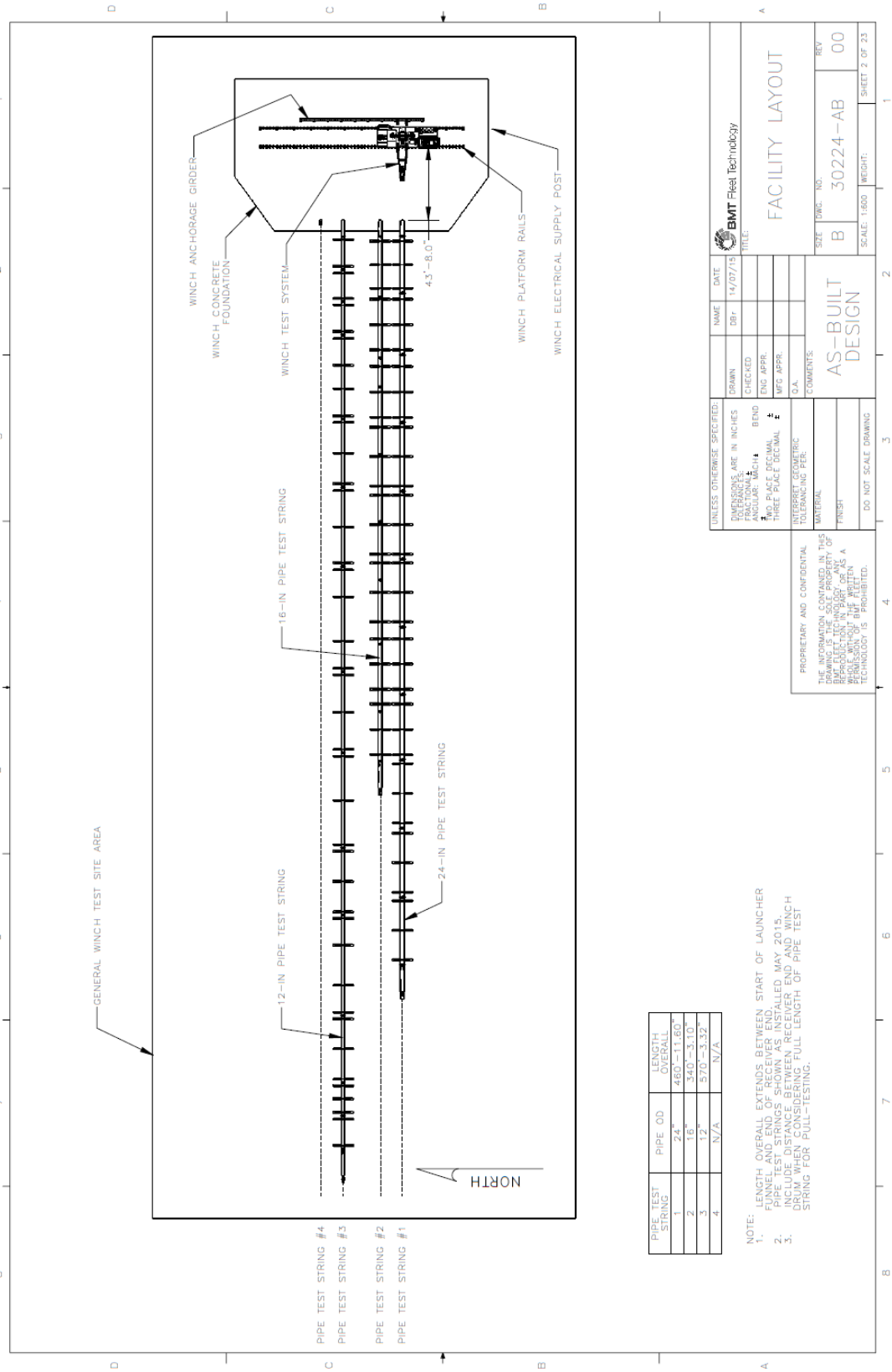
BMT Fleet Technology
TITLE:
TITLE SHEET
SIZE B
DWG. NO. 30224-AB
REV 00
SCALE: 1:600
WEIGHT:
SHEET 1 OF 23


WINCH ANCHORAGE GIRDER
WINCH CONCRETE FOUNDATION
WINCH TEST SYSTEM
4.3'-8.0"
WINCH PLATFORM RAILS
WINCH ELECTRICAL SUPPLY POST
16-IN PIPE TEST STRING
24-IN PIPE TEST STRING
12-IN PIPE TEST STRING
GENERAL WINCH TEST SITE AREA
NORTH
PIPE TEST STRING #4
PIPE TEST STRING #3
PIPE TEST STRING #2
PIPE TEST STRING #1
PIPE TEST STRING | PIPE OD | LENGTH OVERALL
1 | 24" | 460'-11.60"
2 | 16" | 340'-3.10"
3 | 12" | 570'-3.32"
4 | N/A | N/A
NOTE:
1. LENGTH OVERALL EXTENDS BETWEEN START OF LAUNCHER FLANGE AND OPERATOR END.
2. PIPE TEST STRINGS SHOWN AS INSTALLED MAY 2015.
3. INCLUDE DISTANCE BETWEEN RECEIVER END AND WINCH DRUM WHEN CONSIDERING FULL LENGTH OF PIPE TEST STRING FOR PULL-TESTING.
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
FINISH
DO NOT SCALE DRAWING
DRAWN DB+ 14/07/15
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
AS-BUILT DESIGN
PROPRIETARY AND CONFIDENTIAL
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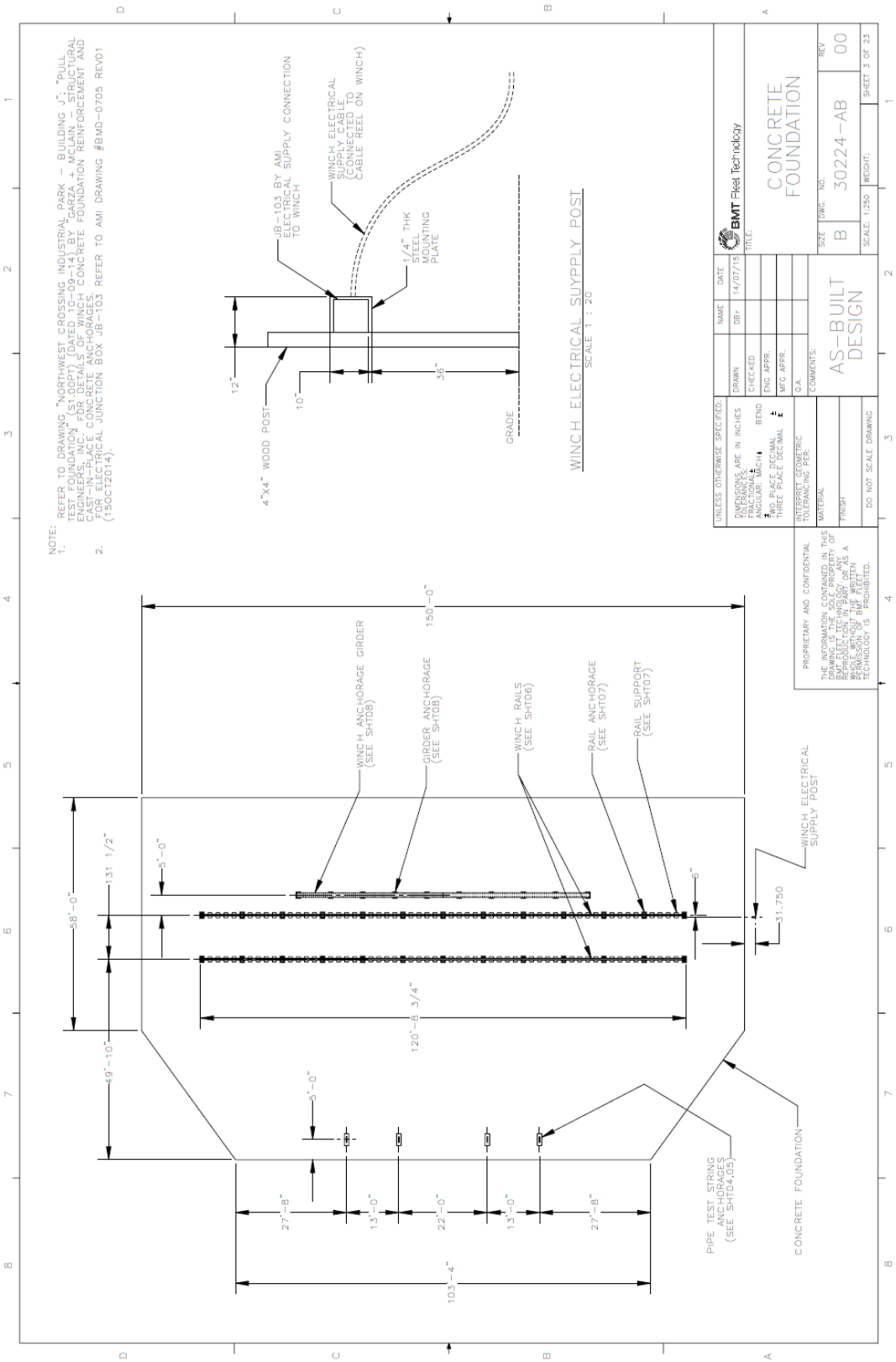
BMT Fleet Technology
TITLE:
FACILITY LAYOUT
SIZE B
DWG. NO. 30224-AB
REV 00
SCALE: 1:600
WEIGHT:
SHEET 2 OF 23


NOTE:
1. REFER TO DRAWING "NORTHWEST CROSSING INDUSTRIAL PARK – BUILDING J", "PULL-TESTING FOUNDATION" (SHEET 1 OF 3) (150CT2014) PREPARED BY STRUCTURAL ENGINEERS, INC., FOR DETAILS OF WINCH CONCRETE FOUNDATION REINFORCEMENT AND CAST-IN-PLACE CONCRETE ANCHORAGES.
2. FOR ELECTRICAL JUNCTION BOX JB-103 REFER TO AMI DRAWING #BMD-0705 REV01 (150CT2014).
JB-103 BY AMI ELECTRICAL SUPPLY CONNECTION TO WINCH
WINCH ELECTRICAL SUPPLY CABLE (CONNECTED TO CABLE REEL ON WINCH)
1/4" THK STEEL MOUNTING PLATE
4"X4" WOOD POST
12"
10"
36"
GRADE
WINCH ELECTRICAL SUYPPLY POST
SCALE 1 : 20
WINCH ANCHORAGE GIRDER (SEE SHT08)
GIRDER ANCHORAGE (SEE SHT08)
WINCH RAILS (SEE SHT06)
RAIL ANCHORAGE (SEE SHT07)
RAIL SUPPORT (SEE SHT07)
150'-0"
58'-0"
131 1/2"
5'-0"
6"
31.750
120'-8 3/4"
49'-10"
3'-0"
27'-8"
13'-0"
22'-0"
13'-0"
27'-8"
103'-4"
WINCH ELECTRICAL SUPPLY POST
PIPE TEST STRING ANCHORAGES (SEE SHT04,05)
CONCRETE FOUNDATION
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
LINEAR: ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
FINISH
DO NOT SCALE DRAWING
NAME
DATE
DRAWN
DBr
14/07/15
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
AS-BUILT DESIGN
PROPRIETARY AND CONFIDENTIAL
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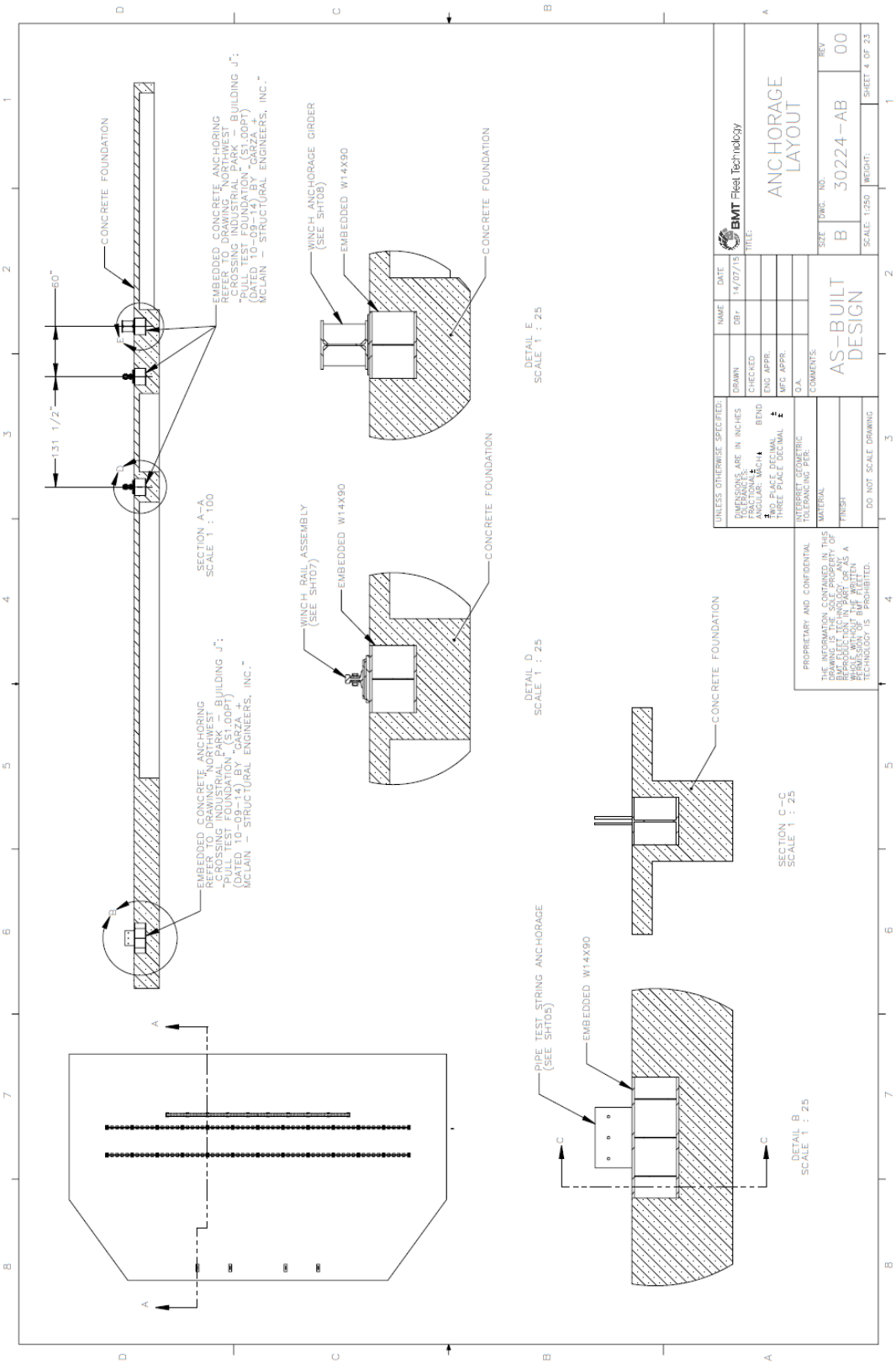
BMT Fleet Technology
TITLE:
CONCRETE FOUNDATION
SIZE
B
DWG. NO.
30224-AB
REV
00
SCALE: 1:250
WEIGHT:
SHEET 3 OF 23


CONCRETE FOUNDATION
60"
131 1/2"
EMBEDDED CONCRETE ANCHORING
REFER TO DRAWING "NORTHWEST
CROSSING INDUSTRIAL PARK - BUILDING J";
"PULL TEST FOUNDATION" (S1.00PT)
(DATED 10-09-14) BY "GARZA +
MCLAIN - STRUCTURAL ENGINEERS, INC."
SECTION A-A
SCALE 1 : 100
WINCH ANCHORAGE GIRDER
(SEE SHT08)
EMBEDDED W14X90
CONCRETE FOUNDATION
DETAIL E
SCALE 1 : 25
WINCH RAIL ASSEMBLY
(SEE SHT07)
DETAIL D
SCALE 1 : 25
SECTION C-C
SCALE 1 : 25
PIPE TEST STRING ANCHORAGE
(SEE SHT05)
DETAIL B
SCALE 1 : 25
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ± 1/16
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±
INTERPRET GEOMETRIC
TOLERANCING PER:
MATERIAL
FINISH
DO NOT SCALE DRAWING
DRAWN DBr 14/07/15
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
AS-BUILT DESIGN
PROPRIETARY AND CONFIDENTIAL
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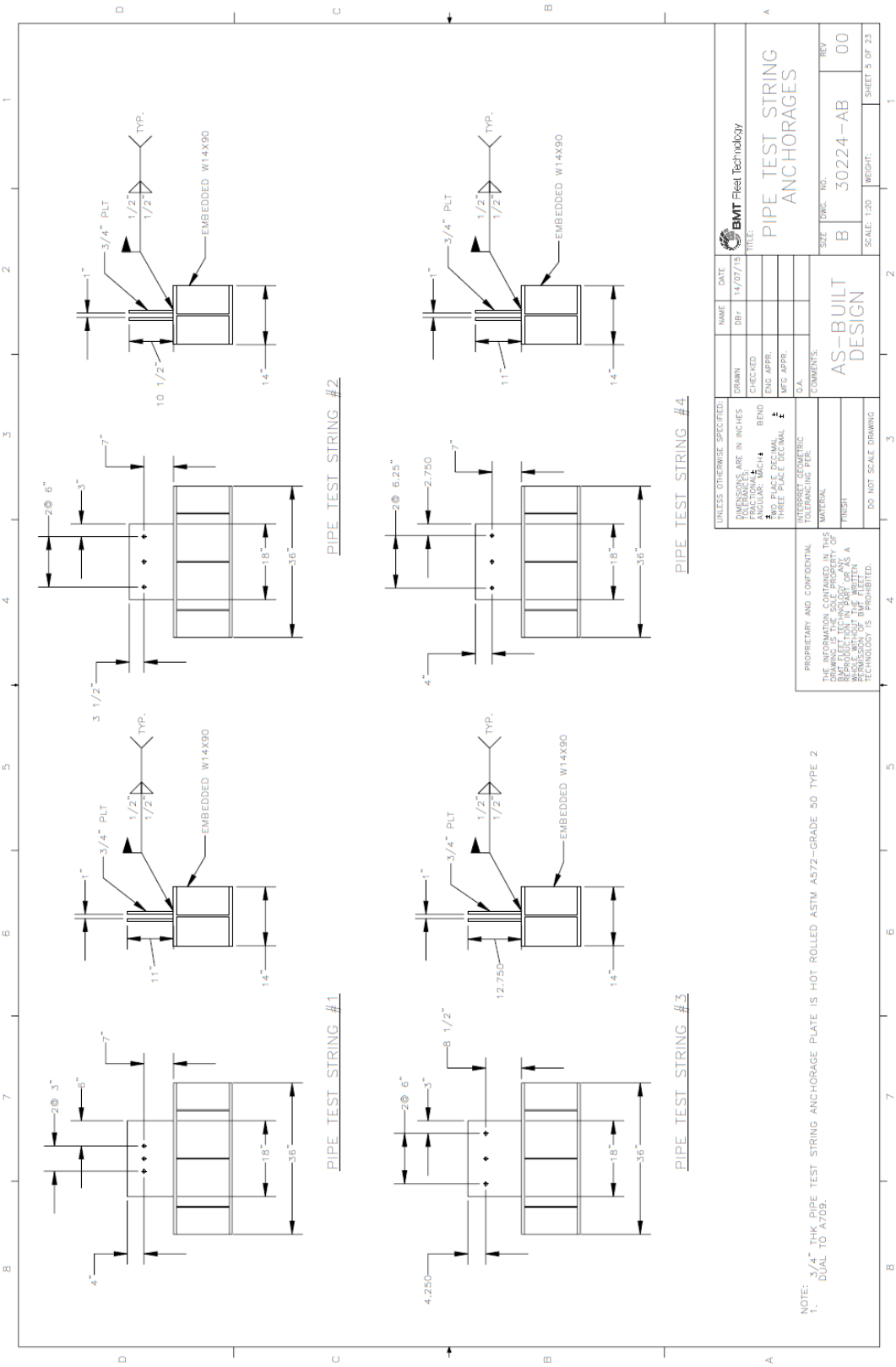
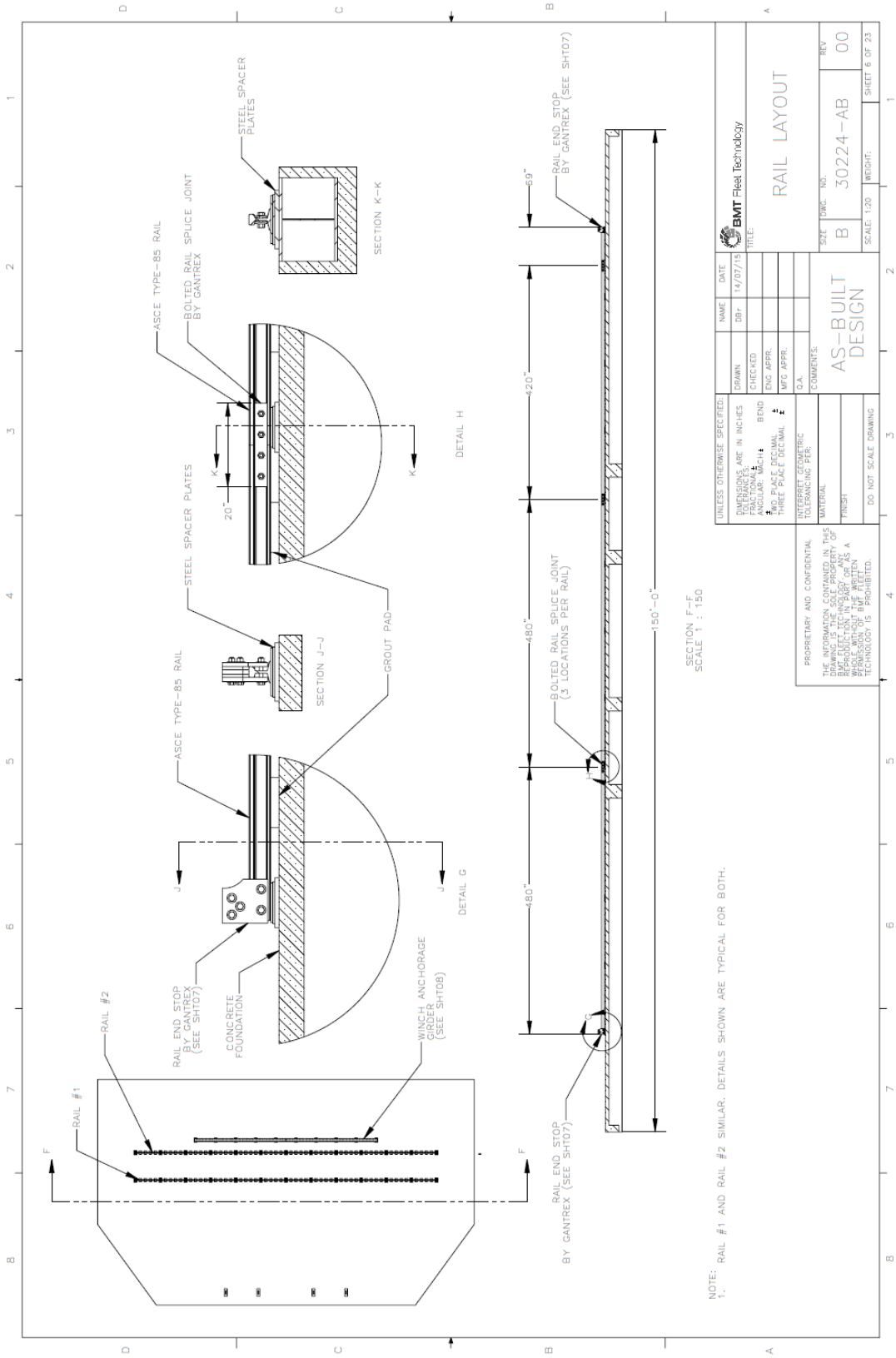
BMT Fleet Technology
TITLE:
ANCHORAGE LAYOUT
SIZE B
DWG. NO. 30224-AB
REV 00
SCALE: 1:250
WEIGHT:
SHEET 4 OF 23


PIPE TEST STRING #1
PIPE TEST STRING #2
PIPE TEST STRING #3
PIPE TEST STRING #4
3/4" PLT
EMBEDDED W14X90
TYP.
BMT Fleet Technology
PIPE TEST STRING ANCHORAGES
30224-AB
AS-BUILT DESIGN
NOTE:
1. 3/4" THK PIPE TEST STRING ANCHORAGE PLATE IS HOT ROLLED ASTM A572-GRADE 50 TYPE 2 DUAL TO A709.


ASCE TYPE-85 RAIL
BOLTED RAIL SPLICE JOINT BY GANTREX
STEEL SPACER PLATES
SECTION K-K
DETAIL H
STEEL SPACER PLATES
20"
GROUT PAD
SECTION J-J
ASCE TYPE-85 RAIL
DETAIL G
RAIL END STOP BY GANTREX (SEE SHT07)
CONCRETE FOUNDATION
WINCH ANCHORAGE GIRDER (SEE SHT08)
RAIL #2
RAIL #1
RAIL END STOP BY GANTREX (SEE SHT07)
59"
420"
480"
480"
BOLTED RAIL SPLICE JOINT (3 LOCATIONS PER RAIL)
150'-0"
SECTION F-F
SCALE 1 : 150
NOTE:
1. RAIL #1 AND RAIL #2 SIMILAR. DETAILS SHOWN ARE TYPICAL FOR BOTH.
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
FINISH
DO NOT SCALE DRAWING
DRAWN
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
NAME
DATE
DBF
14/07/15
AS-BUILT DESIGN
PROPRIETARY AND CONFIDENTIAL
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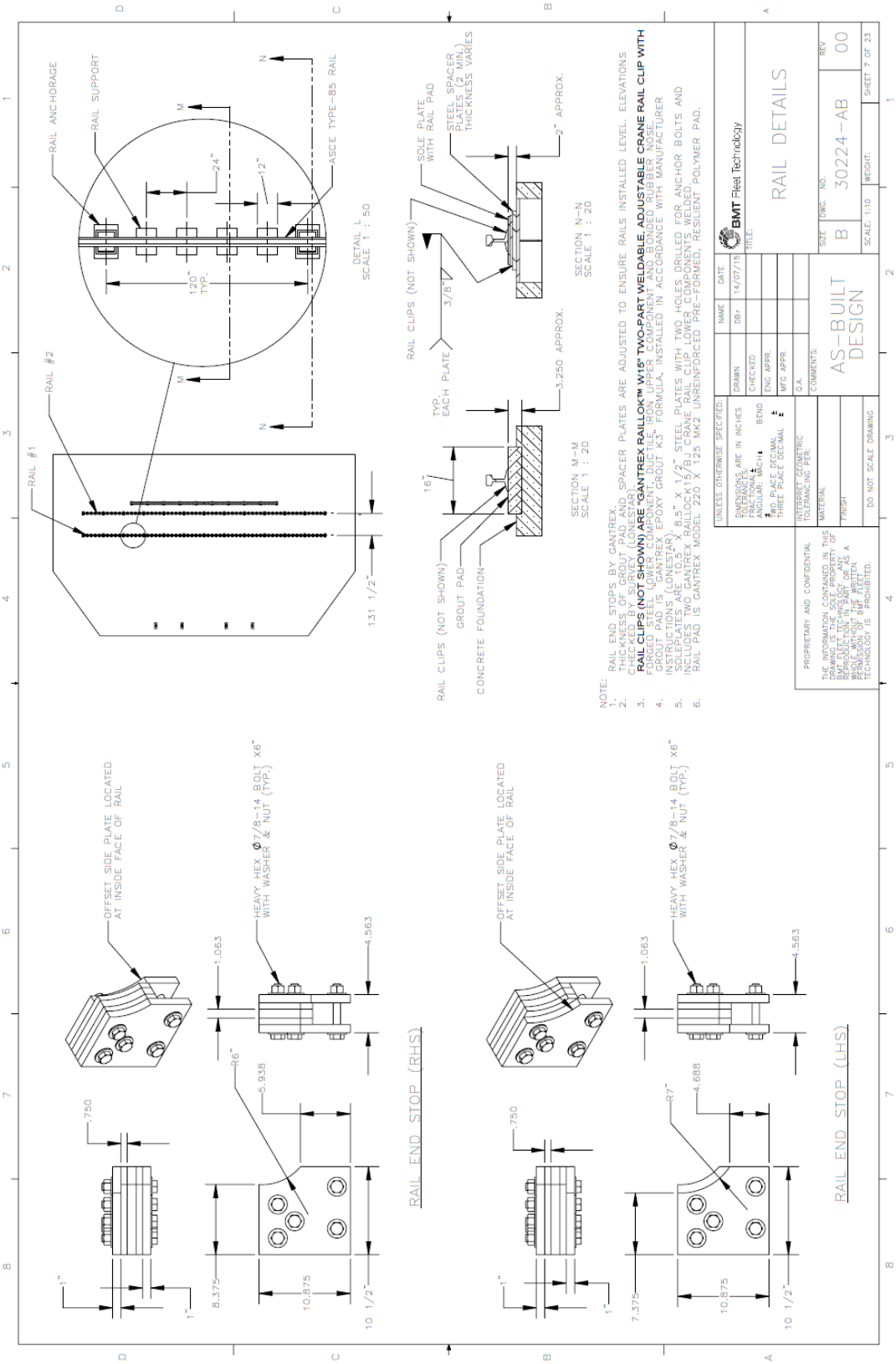
BMT Fleet Technology
TITLE:
RAIL LAYOUT
SIZE
B
DWG. NO.
30224-AB
REV
00
SCALE: 1:20
WEIGHT:
SHEET 6 OF 23


RAIL ANCHORAGE
RAIL SUPPORT
RAIL #2
RAIL #1
ASCE TYPE-85 RAIL
24"
12"
120" TYP.
131 1/2"
DETAIL L
SCALE 1 : 50
SOLE PLATE WITH RAIL PAD
STEEL SPACER PLATES (2 MIN.) THICKNESS VARIES
2" APPROX.
RAIL CLIPS (NOT SHOWN)
3/8"
TYP. EACH PLATE
3.250 APPROX.
16"
RAIL CLIPS (NOT SHOWN)
GROUT PAD
CONCRETE FOUNDATION
SECTION M-M
SCALE 1 : 20
SECTION N-N
SCALE 1 : 20
NOTE:
1. RAIL END STOPS BY GANTREX.
2. THICKNESS OF GROUT PAD AND SPACER PLATES ARE ADJUSTED TO ENSURE RAILS INSTALLED LEVEL. ELEVATIONS VALIDATED BY SURVEY (LEVELING) AT FIELD INSTALLATION.
3. RAIL CLIPS (NOT SHOWN) ARE "GANTREX RAILLOK™ W15" TWO-PART WELDABLE, ADJUSTABLE CRANE RAIL CLIP WITH FORGED STEEL LOWER COMPONENT, DUCTILE IRON UPPER COMPONENT AND BONDED RUBBER NOSE.
4. GROUT PAD IS "GANTREX EPOXY GROUT K5" FORMULA, INSTALLED IN ACCORDANCE WITH MANUFACTURER INSTRUCTIONS (LONESTAR).
5. INCLUDES ARCHORS 8 x 8 x 1/2" STEEL PLATES WITH TWO HOLES DRILLED FOR ANCHOR BOLTS AND INCLUDES WELDED GANTREX RAILLOCK15/8 CRANE RAIL CLIP LOWER COMPONENTS.
6. RAIL PAD IS GANTREX MODEL 220 X 125 MK2 UNREINFORCED PRE-FORMED, RESILIENT POLYMER PAD.
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
FINISH
DO NOT SCALE DRAWING
NAME
DATE
DRAWN
DB
14/07/15
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
AS-BUILT DESIGN
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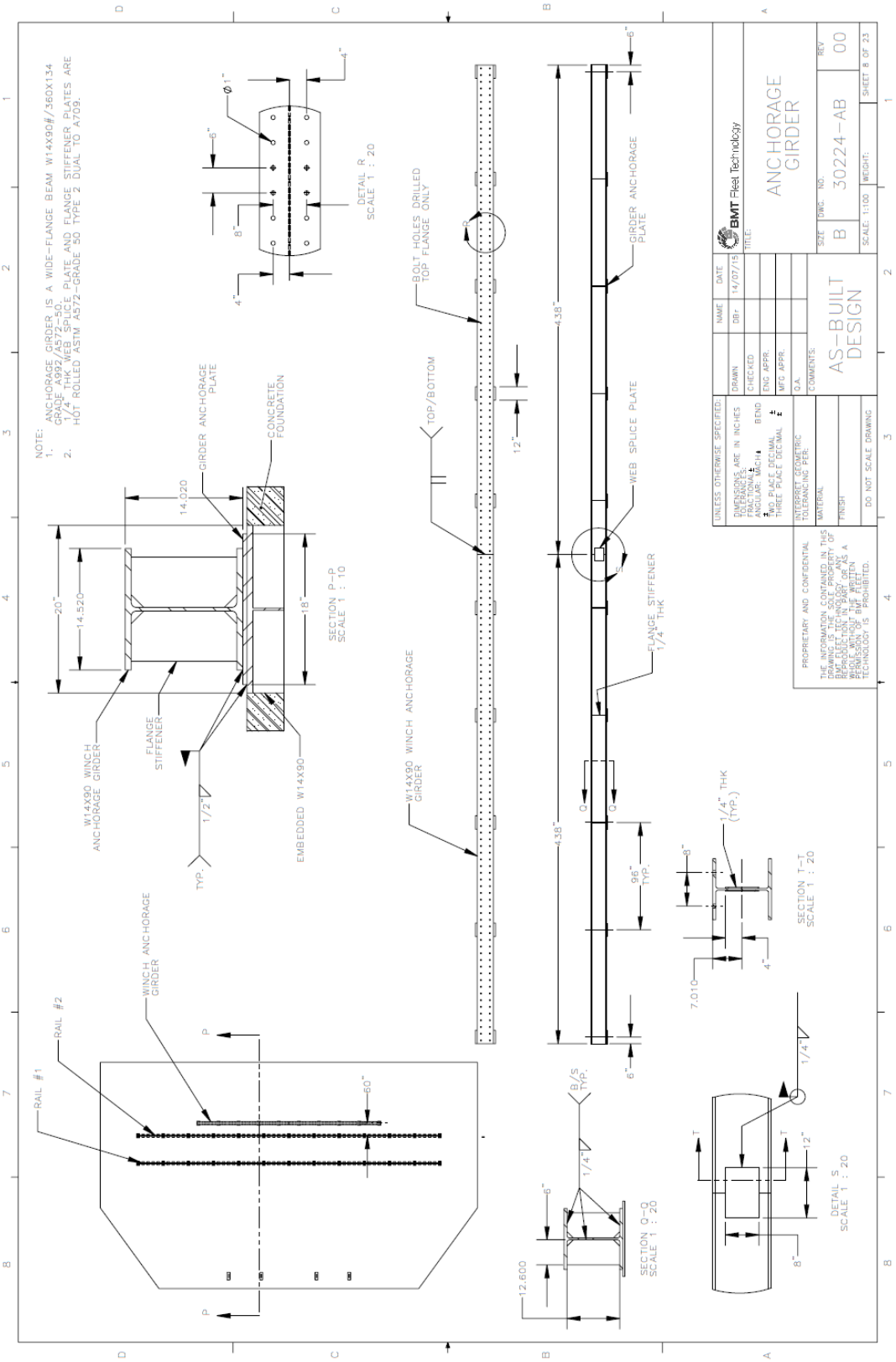
BMT Fleet Technology
TITLE:
RAIL DETAILS
SIZE B
DWG. NO. 30224-AB
REV 00
SCALE: 1:10
WEIGHT:
SHEET 7 OF 23
OFFSET SIDE PLATE LOCATED AT INSIDE FACE OF RAIL
HEAVY HEX Ø7/8-14 BOLT X6" WITH WASHER & NUT (TYP.)
1.063
4.563
.750
R6"
5.938
8.375
10.875
10 1/2"
1"
RAIL END STOP (RHS)
OFFSET SIDE PLATE LOCATED AT INSIDE FACE OF RAIL
HEAVY HEX Ø7/8-14 BOLT X6" WITH WASHER & NUT (TYP.)
1.063
4.563
.750
R7"
4.688
7.375
10.875
10 1/2"
1"
RAIL END STOP (LHS)


NOTE:
1. ANCHORAGE GIRDER IS A WIDE-FLANGE BEAM W14X90#/360X134 GRADE A992/A572-50 1/4" THK WEB SPLICE PLATE AND FLANGE STIFFENER PLATES ARE HOT ROLLED ASTM A572-GRADE 50 TYPE 2 DUAL TO A709.
2.
DETAIL R
SCALE 1 : 20
BOLT HOLES DRILLED TOP FLANGE ONLY
GIRDER ANCHORAGE PLATE
CONCRETE FOUNDATION
14.020
20"
14.520
18"
SECTION P-P
SCALE 1 : 10
TOP/BOTTOM
12"
4.38"
WEB SPLICE PLATE
FLANGE STIFFENER 1/4" THK
W14X90 WINCH ANCHORAGE GIRDER
FLANGE STIFFENER
EMBEDDED W14X90
1/2"
TYP.
96" TYP.
1/4" THK (TYP.)
SECTION T-T
SCALE 1 : 20
7.010
WINCH ANCHORAGE GIRDER
RAIL #1
RAIL #2
60"
B/S TYP.
1/4"
12.600
SECTION Q-Q
SCALE 1 : 20
DETAIL S
SCALE 1 : 20
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
DECIMALS ± .
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
FINISH
DO NOT SCALE DRAWING
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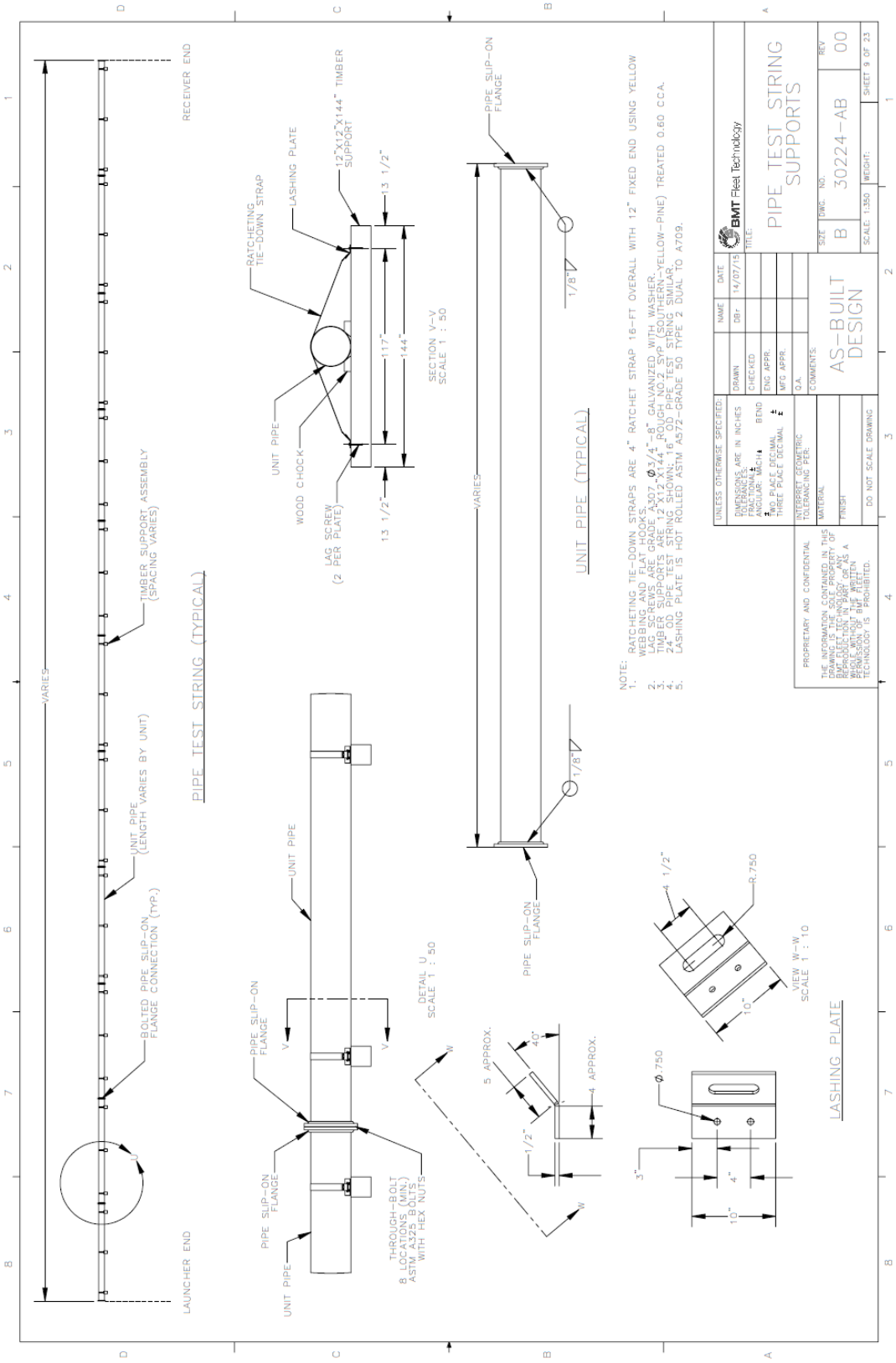
DRAWN DBr 14/07/15
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
AS-BUILT DESIGN
BMT Fleet Technology
TITLE:
ANCHORAGE GIRDER
SIZE B
DWG. NO. 30224-AB
REV 00
SCALE: 1:100
WEIGHT:
SHEET 8 OF 23


PIPE TEST STRING (TYPICAL)
LAUNCHER END
RECEIVER END
VARIES
BOLTED PIPE SLIP-ON FLANGE CONNECTION (TYP.)
UNIT PIPE (LENGTH VARIES BY UNIT)
TIMBER SUPPORT ASSEMBLY (SPACING VARIES)
RATCHETING TIE-DOWN STRAP
LASHING PLATE
12"X12"X144" TIMBER SUPPORT
13 1/2"
117"
144"
UNIT PIPE
WOOD CHOCK
LAG SCREW (2 PER PLATE)
SECTION V-V SCALE 1 : 50
PIPE SLIP-ON FLANGE
UNIT PIPE (TYPICAL)
1/8"
DETAIL U SCALE 1 : 50
THROUGH-BOLT 8 LOCATIONS (MIN.) ASTM A325 BOLTS WITH HEX NUTS
5 APPROX.
4 APPROX.
40°
1/2"
4 1/2"
R.750
10"
VIEW W-W SCALE 1 : 10
Ø.750
3"
4"
LASHING PLATE
NOTE:
1. RATCHETING TIE-DOWN STRAPS ARE 4" RATCHET STRAP 16-FT OVERALL WITH 12" FIXED END USING YELLOW WEBBING AND FLAT HOOKS.
2. LAG SCREWS ARE GRADE A307, Ø3/4"-8" GALVANIZED WITH WASHER.
3. TIMBER SUPPORTS ARE 12"X12"X144" ROUGH NO.2 SYP (SOUTHERN-YELLOW-PINE) TREATED 0.60 CCA.
4. 24" OD PIPE TEST STRING SHOWN, 16" OD PIPE TEST STRING SIMILAR.
5. LASHING PLATE IS HOT ROLLED ASTM A572-GRADE 50 TYPE 2 DUAL TO A709.
PROPRIETARY AND CONFIDENTIAL
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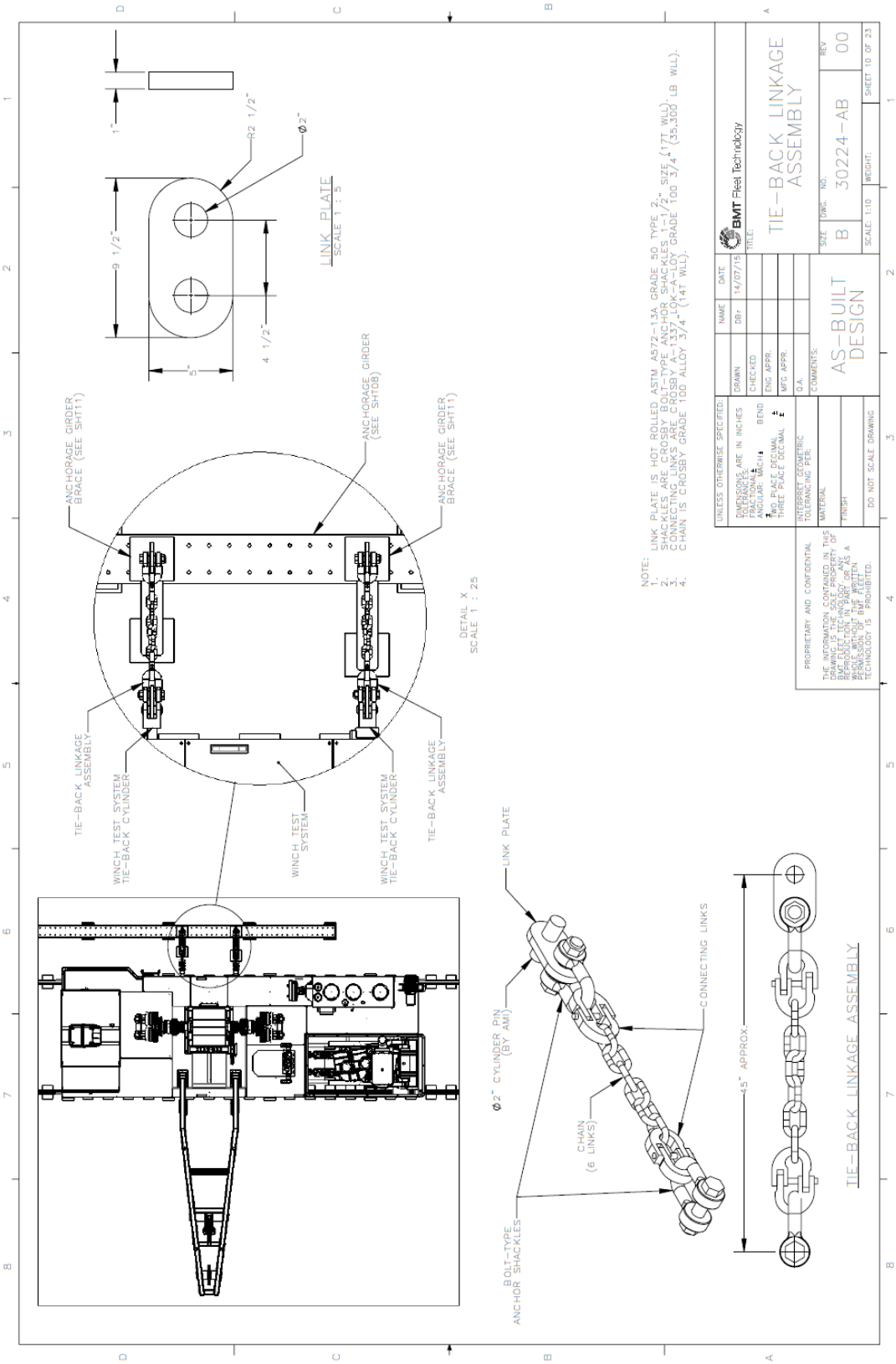
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
FINISH
DO NOT SCALE DRAWING
DRAWN DBr 14/07/15
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
AS-BUILT DESIGN
BMT Fleet Technology
TITLE:
PIPE TEST STRING SUPPORTS
SIZE B
DWG. NO. 30224-AB
REV 00
SCALE: 1:350
WEIGHT:
SHEET 9 OF 23


LINK PLATE
SCALE 1 : 5
R2 1/2"
Ø2"
9 1/2"
4 1/2"
1"
5"
ANCHORAGE GIRDER BRACE (SEE SHT11)
ANCHORAGE GIRDER (SEE SHT08)
DETAIL X
SCALE 1 : 25
TIE-BACK LINKAGE ASSEMBLY
WINCH TEST SYSTEM TIE-BACK CYLINDER
WINCH TEST SYSTEM
NOTE:
1. LINK PLATE IS HOT ROLLED ASTM A572-13A GRADE 50 TYPE 2.
2. SHACKLES ARE CROSBY BOLT-TYPE ANCHOR SHACKLES 1-1/2" SIZE (17T WLL).
3. CONNECTING LINKS ARE CROSBY A-1337 LOK-A-LOY GRADE 100 3/4" (35,300 LB WLL).
4. CHAIN IS CROSBY GRADE 100 ALLOY 3/4" (14T WLL).
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
FINISH
DO NOT SCALE DRAWING
NAME DATE
DRAWN DBr 14/07/15
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
AS-BUILT DESIGN
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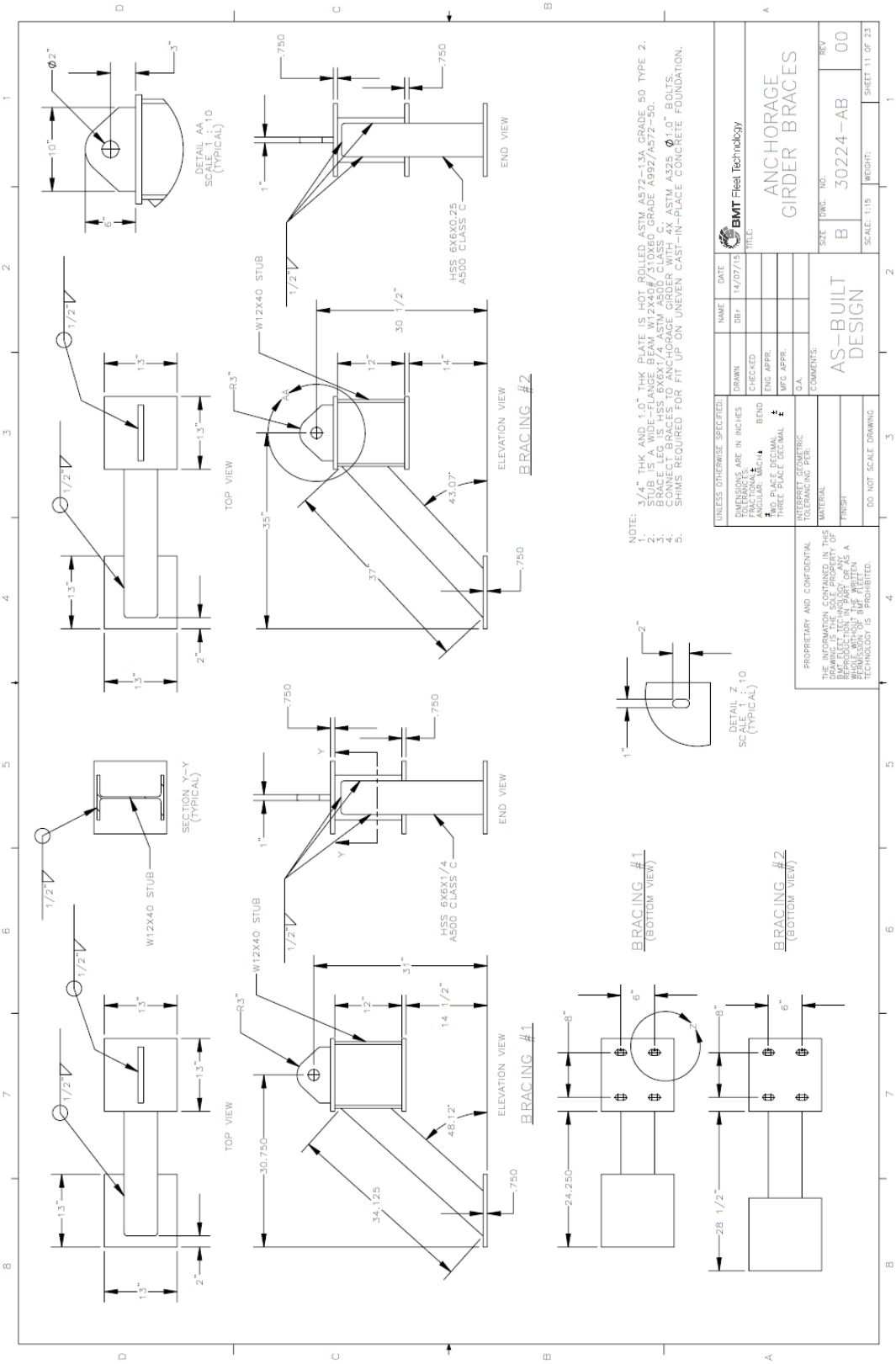
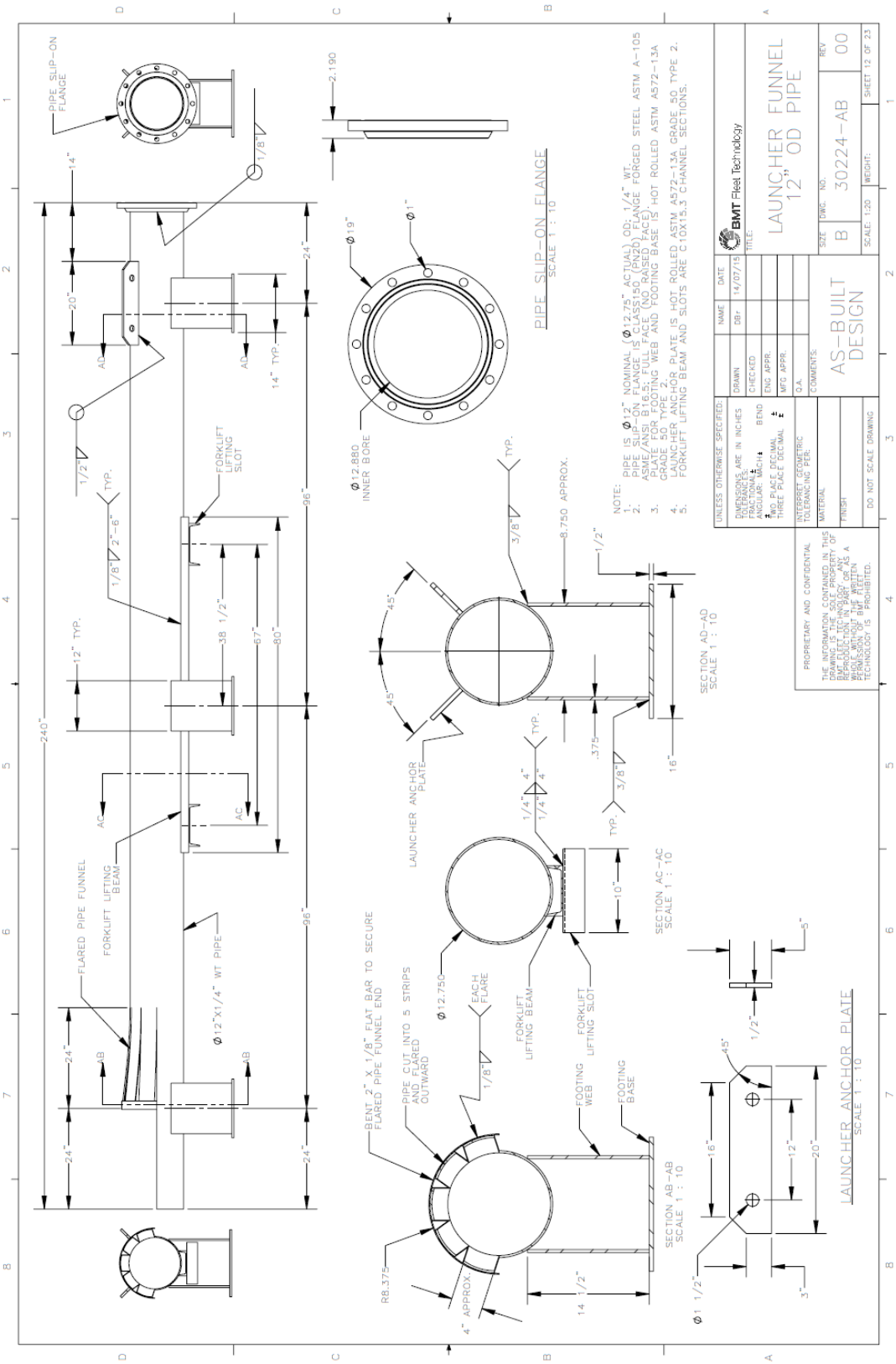
BMT Fleet Technology
TITLE:
TIE-BACK LINKAGE ASSEMBLY
SIZE B
DWG. NO. 30224-AB
REV 00
SCALE: 1:10
WEIGHT:
SHEET 10 OF 23
Ø2" CYLINDER PIN (BY AMI)
LINK PLATE
CONNECTING LINKS
CHAIN (6 LINKS)
BOLT-TYPE ANCHOR SHACKLES
45" APPROX.
TIE-BACK LINKAGE ASSEMBLY


NOTE:
1. 3/4" THK. AND 1.0" THK PLATE IS HOT ROLLED ASTM A572-13A GRADE 50 TYPE 2.
2. STUB IS A WIDE-FLANGE BEAM W12X40#/310X60 GRADE A992/A572-50.
3. BRACE LEG IS HSS 6X6X1/4 ASTM A500 CLASS C.
4. CONNECT BRACES TO ANCHORAGE GIRDER WITH 4X ASTM A325 Ø1.0" BOLTS.
5. SHIMS REQUIRED FOR FIT UP ON UNEVEN CAST-IN-PLACE CONCRETE FOUNDATION.
BRACING #1
BRACING #2
TOP VIEW
ELEVATION VIEW
END VIEW
W12X40 STUB
HSS 6X6X0.25 A500 CLASS C
HSS 6X6X1/4 A500 CLASS C
SECTION Y-Y (TYPICAL)
DETAIL AA SCALE 1 : 10 (TYPICAL)
DETAIL Z SCALE 1 : 10 (TYPICAL)
BRACING #1 (BOTTOM VIEW)
BRACING #2 (BOTTOM VIEW)
BMT Fleet Technology
ANCHORAGE GIRDER BRACES
AS-BUILT DESIGN
30224-AB
00
SHEET 11 OF 23
PROPRIETARY AND CONFIDENTIAL
DO NOT SCALE DRAWING


PIPE SLIP-ON FLANGE
FLARED PIPE FUNNEL
FORKLIFT LIFTING BEAM
FORKLIFT LIFTING SLOT
Ø12"X1/4" WT PIPE
240"
96"
80"
67"
38 1/2"
PIPE SLIP-ON FLANGE
SCALE 1 : 10
Ø12.880 INNER BORE
Ø19"
Ø1"
2.190
NOTE:
1. PIPE IS Ø12" NOMINAL (Ø12.75" ACTUAL) OD; 1/4" WT.
2. PIPE SLIP-ON FLANGE IS CLASS150 (PN20) FLANGE FORGED STEEL ASTM A-105
ASME/ANSI B16.5; FULL FACE (NO RAISED FACE)
3. PLACE FOOTING WEB AND FOOTING BASE IS HOT ROLLED ASTM A572-13A
GRADE 50 TYPE 2.
4. LAUNCHER ANCHOR PLATE IS HOT ROLLED ASTM A572-13A GRADE 50 TYPE 2.
5. FORKLIFT LIFTING BEAM AND SLOTS ARE C10X15.3 CHANNEL SECTIONS.
LAUNCHER ANCHOR PLATE
SECTION AD-AD
SCALE 1 : 10
SECTION AC-AC
SCALE 1 : 10
SECTION AB-AB
SCALE 1 : 10
BENT 2" X 1/8" FLAT BAR TO SECURE FLARED PIPE FUNNEL END
PIPE CUT INTO 5 STRIPS AND FLARED OUTWARD
Ø12.750
EACH FLARE
FOOTING WEB
FOOTING BASE
R8.375
4" APPROX.
14 1/2"
LAUNCHER ANCHOR PLATE
SCALE 1 : 10
Ø1 1/2"
BMT Fleet Technology
LAUNCHER FUNNEL 12" OD PIPE
30224-AB
00
SHEET 12 OF 23
SCALE: 1:20
AS-BUILT DESIGN
DO NOT SCALE DRAWING
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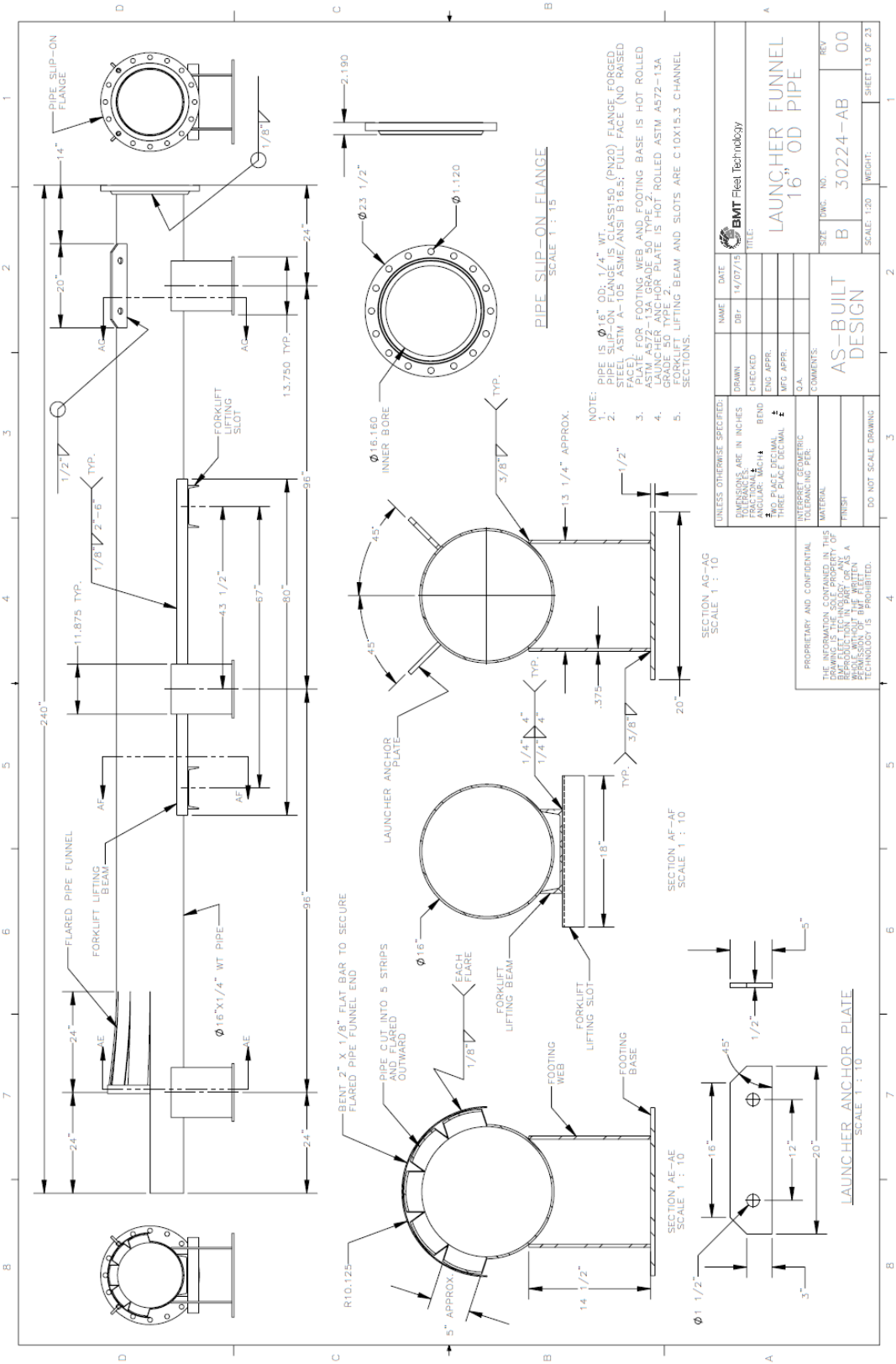
PIPE SLIP-ON FLANGE
FLARED PIPE FUNNEL
FORKLIFT LIFTING BEAM
FORKLIFT LIFTING SLOT
Ø16"X1/4" WT PIPE
BENT 2" X 1/8" FLAT BAR TO SECURE FLARED PIPE FUNNEL END
PIPE CUT INTO 5 STRIPS AND FLARED OUTWARD
R10.125
5" APPROX.
Ø16.160 INNER BORE
Ø23 1/2"
Ø1.120
2.190
LAUNCHER ANCHOR PLATE
FOOTING WEB
FOOTING BASE
PIPE SLIP-ON FLANGE
SCALE 1 : 15
NOTE:
1. PIPE IS Ø16" OD; 1/4" WT.
2. SLIP-ON FLANGE IS CLASS150 (PN20) FLANGE FORGED STEEL, ASTM A-105 ASME/ANSI B16.5; FULL FACE (NO RAISED FACE).
3. PLATE FOR FOOTING WEB AND FOOTING BASE IS HOT ROLLED ASTM A572-13A GRADE 50 TYPE 2.
4. LAUNCHER ANCHOR PLATE IS HOT ROLLED ASTM A572-13A GRADE 50 TYPE 2.
5. FORKLIFT LIFTING BEAM AND SLOTS ARE C10X15.3 CHANNEL SECTIONS.
SECTION AC-AC
SCALE 1 : 10
SECTION AF-AF
SCALE 1 : 10
SECTION AE-AE
SCALE 1 : 10
LAUNCHER ANCHOR PLATE
SCALE 1 : 10
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
FINISH
DO NOT SCALE DRAWING
DRAWN DB+ 14/07/15
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
AS-BUILT DESIGN
PROPRIETARY AND CONFIDENTIAL
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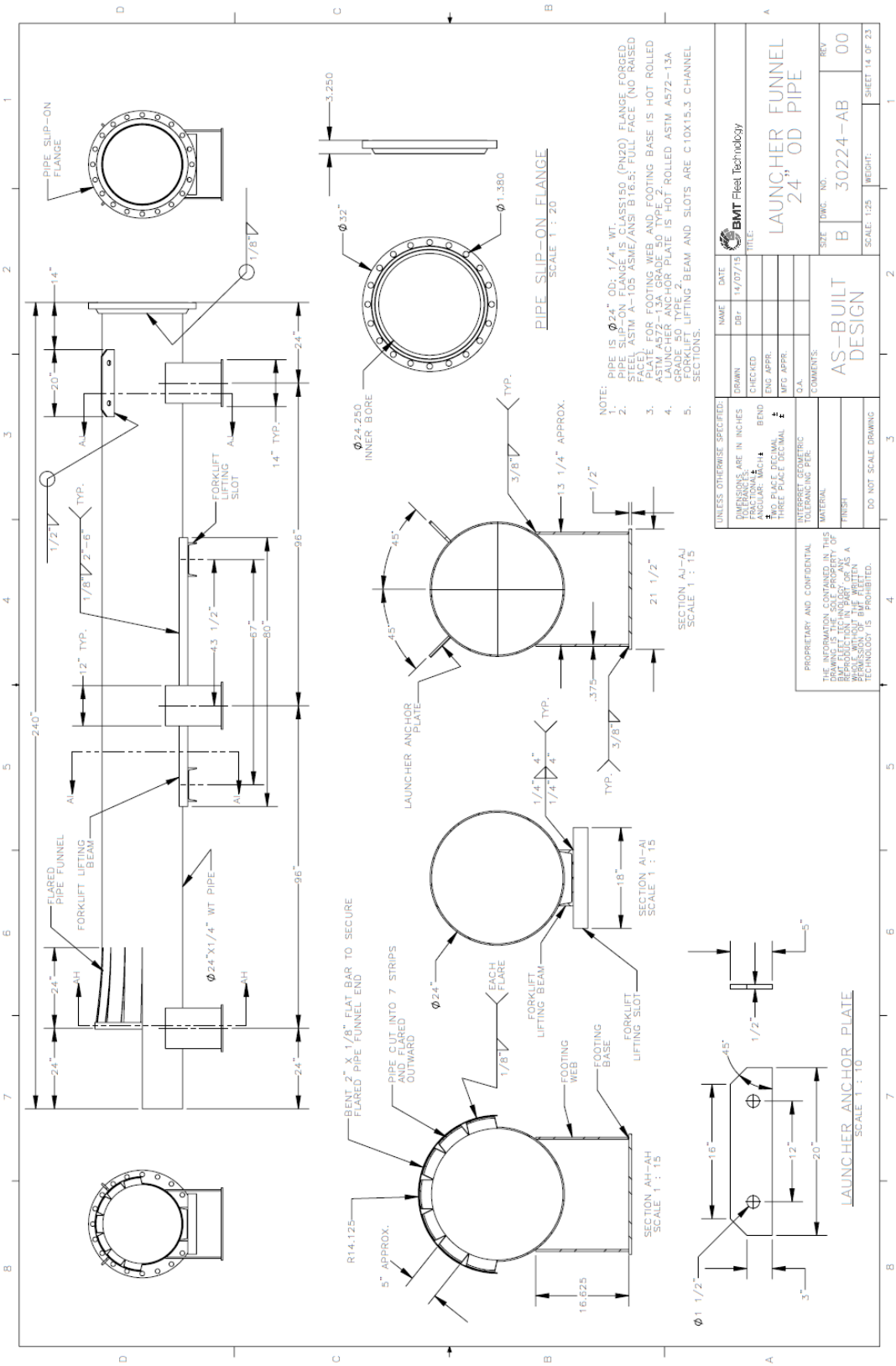
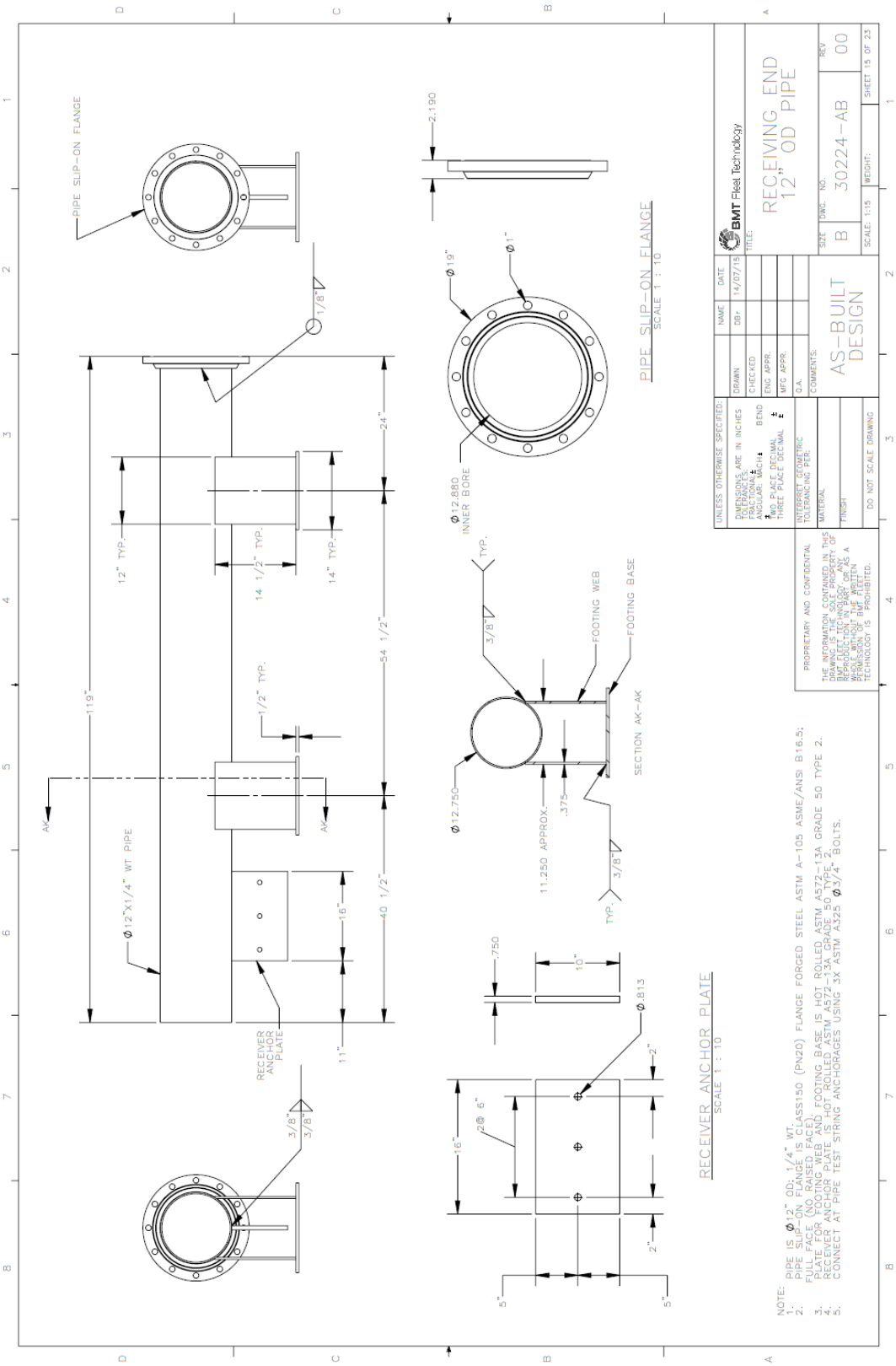
BMT Fleet Technology
TITLE:
LAUNCHER FUNNEL 16" OD PIPE
SIZE B
DWG. NO. 30224-AB
REV 00
SCALE: 1:20
WEIGHT:
SHEET 13 OF 23


PIPE SLIP-ON FLANGE
FORKLIFT LIFTING SLOT
FLARED PIPE FUNNEL
FORKLIFT LIFTING BEAM
Ø24"X1/4" WT PIPE
BENT 2" X 1/8" FLAT BAR TO SECURE FLARED PIPE FUNNEL END
PIPE CUT INTO 7 STRIPS AND FLARED OUTWARD
R14.125
5" APPROX.
16.625
SECTION AH-AH SCALE 1 : 15
FOOTING WEB
FOOTING BASE
FORKLIFT LIFTING SLOT
FORKLIFT LIFTING BEAM
EACH FLARE
Ø24"
SECTION AI-AI SCALE 1 : 15
LAUNCHER ANCHOR PLATE
13 1/4" APPROX.
SECTION AJ-AJ SCALE 1 : 15
Ø24.250 INNER BORE
Ø32"
Ø1.380
PIPE SLIP-ON FLANGE
SCALE 1 : 20
NOTE:
1. PIPE IS Ø24" OD, 1/4" WT.
2. PIPE SLIP-ON FLANGE IS CLASS150 (PN20) FLANGE FORGED STEEL ASTM A-105 ASME/ANSI B16.5; FULL FACE (NO RAISED FACE).
3. PLATE: FOR FOOTING WEB AND FOOTING BASE IS HOT ROLLED ASTM A572-13A GRADE 50 TYPE 2.
4. LAUNCHER ANCHOR PLATE IS HOT ROLLED ASTM A572-13A GRADE 50 TYPE 2.
5. FORKLIFT LIFTING BEAM AND SLOTS ARE C10X15.3 CHANNEL SECTIONS.
LAUNCHER ANCHOR PLATE
SCALE 1 : 10
BMT Fleet Technology
LAUNCHER FUNNEL 24" OD PIPE
30224-AB
AS-BUILT DESIGN
PROPRIETARY AND CONFIDENTIAL
DO NOT SCALE DRAWING


PIPE SLIP-ON FLANGE
1/8"
12" TYP.
14 1/2" TYP.
14" TYP.
24"
119"
54 1/2"
1/2" TYP.
AK
Ø12"X1/4" WT PIPE
16"
40 1/2"
11"
RECEIVER ANCHOR PLATE
3/8"
3/8"
2.190
Ø19"
Ø1"
Ø12.880 INNER BORE
PIPE SLIP-ON FLANGE
SCALE 1 : 10
TYP.
3/8"
FOOTING WEB
FOOTING BASE
SECTION AK-AK
Ø12.750
11.250 APPROX.
.375
TYP.
3/8"
.750
10"
Ø.813
2@ 6"
16"
2"
2"
5"
5"
RECEIVER ANCHOR PLATE
SCALE 1 : 10
NOTE:
1. PIPE IS Ø12" OD. 1/4" WT.
2. PIPE SLIP-ON FLANGE IS CLASS150 (PN20) FLANGE FORGED STEEL ASTM A-105 ASME/ANSI B16.5;
FULL FACE (ONLY FACED FOR GASKET).
3. PLATE FOR FOOTING WEB AND FOOTING BASE IS HOT ROLLED ASTM A572-13A GRADE 50 TYPE 2.
4. RECEIVER ANCHOR PLATE IS HOT ROLLED ASTM A572-13A GRADE 50 TYPE 2.
5. CONNECT AT PIPE TEST STRING ANCHORAGES USING 3X ASTM A325 Ø3/4" BOLTS.
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
FINISH
DO NOT SCALE DRAWING
NAME
DATE
DRAWN DBr 14/07/15
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
AS-BUILT DESIGN
PROPRIETARY AND CONFIDENTIAL
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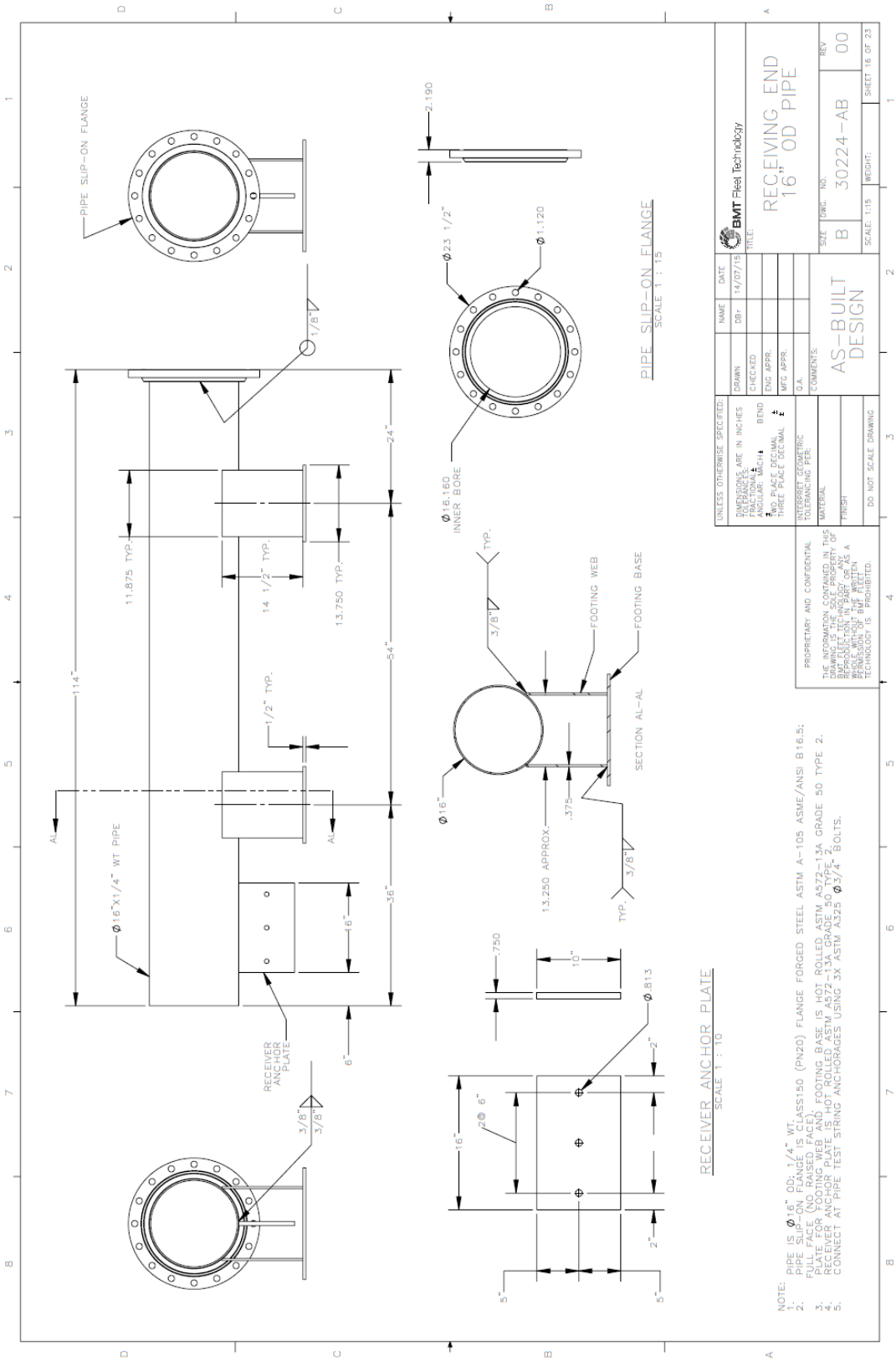
BMT Fleet Technology
TITLE:
RECEIVING END 12" OD PIPE
SIZE B
DWG. NO. 30224-AB
REV 00
SCALE: 1:15
WEIGHT:
SHEET 15 OF 23


PIPE SLIP-ON FLANGE
1/8"
114"
11.875 TYP.
14 1/2" TYP.
13.750 TYP.
24"
54"
36"
16"
6"
1/2" TYP.
AL
Ø16"X1/4" WT PIPE
RECEIVER ANCHOR PLATE
3/8"
3/8"
2.190
Ø23 1/2"
Ø1.120
Ø16.160 INNER BORE
PIPE SLIP-ON FLANGE
SCALE 1 : 15
TYP.
3/8"
FOOTING WEB
FOOTING BASE
SECTION AL-AL
Ø16"
13.250 APPROX.
.375
.750
10"
Ø.813
2@ 6"
16"
2"
5"
RECEIVER ANCHOR PLATE
SCALE 1 : 10
NOTE:
1. PIPE IS Ø16" OD; 1/4" WT.
2. PIPE SLIP-ON FLANGE IS CLASS150 (PN20) FLANGE FORGED STEEL ASTM A-105 ASME/ANSI B16.5; FULL FACE (NO RAISED FACE).
3. PLATE FOR FOOTING WEB AND FOOTING BASE IS HOT ROLLED ASTM A572-13A GRADE 50 TYPE 2.
4. RECEIVER ANCHOR PLATE IS HOT ROLLED ASTM A572-13A GRADE 50 TYPE 2.
5. CONNECT AT PIPE TEST STRING ANCHORAGES USING 3X ASTM A325 Ø3/4" BOLTS.
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
FINISH
DO NOT SCALE DRAWING
DRAWN
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
AS-BUILT DESIGN
NAME
DATE
DBr
14/07/15
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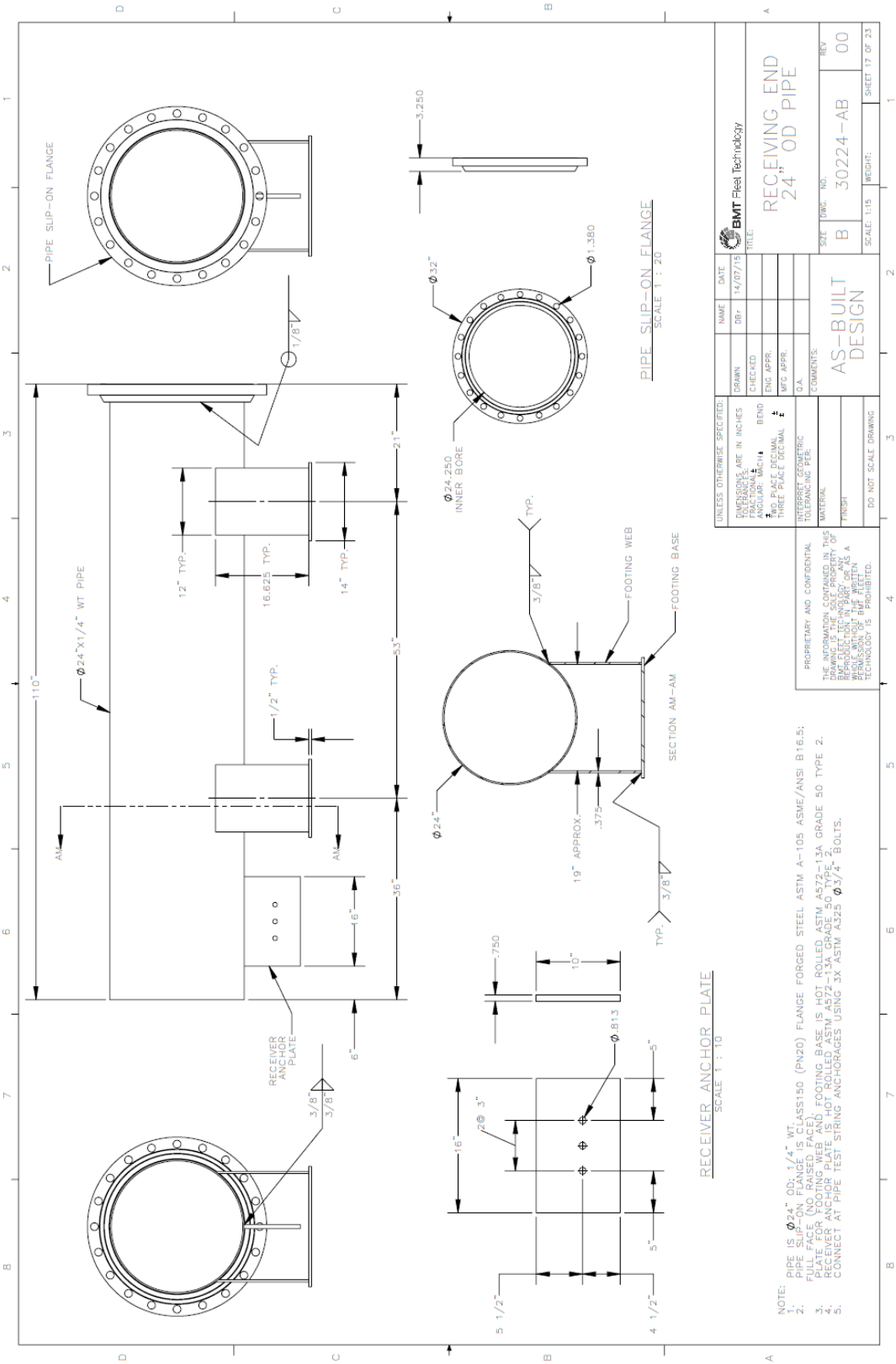
BMT Fleet Technology
TITLE:
RECEIVING END
16" OD PIPE
SIZE
B
DWG. NO.
30224-AB
REV
00
SCALE: 1:15
WEIGHT:
SHEET 16 OF 23


PIPE SLIP-ON FLANGE
1/8"
Ø24"X1/4" WT PIPE
110"
12" TYP.
16.625 TYP.
14" TYP.
1/2" TYP.
21"
53"
36"
6"
A
A
RECEIVER ANCHOR PLATE
3/8"
3/8"
3.250
Ø32"
Ø1.380
Ø24.250 INNER BORE
PIPE SLIP-ON FLANGE
SCALE 1 : 20
TYP.
3/8"
FOOTING WEB
FOOTING BASE
Ø24"
19" APPROX.
.375
SECTION AM-AM
TYP.
3/8"
.750
10"
Ø.813
2@ 3"
16"
5"
5"
5 1/2"
4 1/2"
RECEIVER ANCHOR PLATE
SCALE 1 : 10
NOTE:
1. PIPE IS Ø24" OD; 1/4" WT.
2. PIPE SLIP-ON FLANGE IS CLASS150 (PN20) FLANGE FORGED STEEL ASTM A-105 ASME/ANSI B16.5;
FULLFACED (COVERED).
3. PLATE FOR FOOTING WEB AND FOOTING BASE IS HOT ROLLED ASTM A572-13A GRADE 50 TYPE 2.
4. RECEIVER ANCHOR PLATE IS HOT ROLLED ASTM A572-13A GRADE 50 TYPE 2.
5. CONNECT AT PIPE TEST STRING ANCHORAGES USING 3X ASTM A325 Ø3/4" BOLTS.
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
FINISH
DO NOT SCALE DRAWING
NAME
DATE
DRAWN
DB
14/07/15
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
AS-BUILT DESIGN
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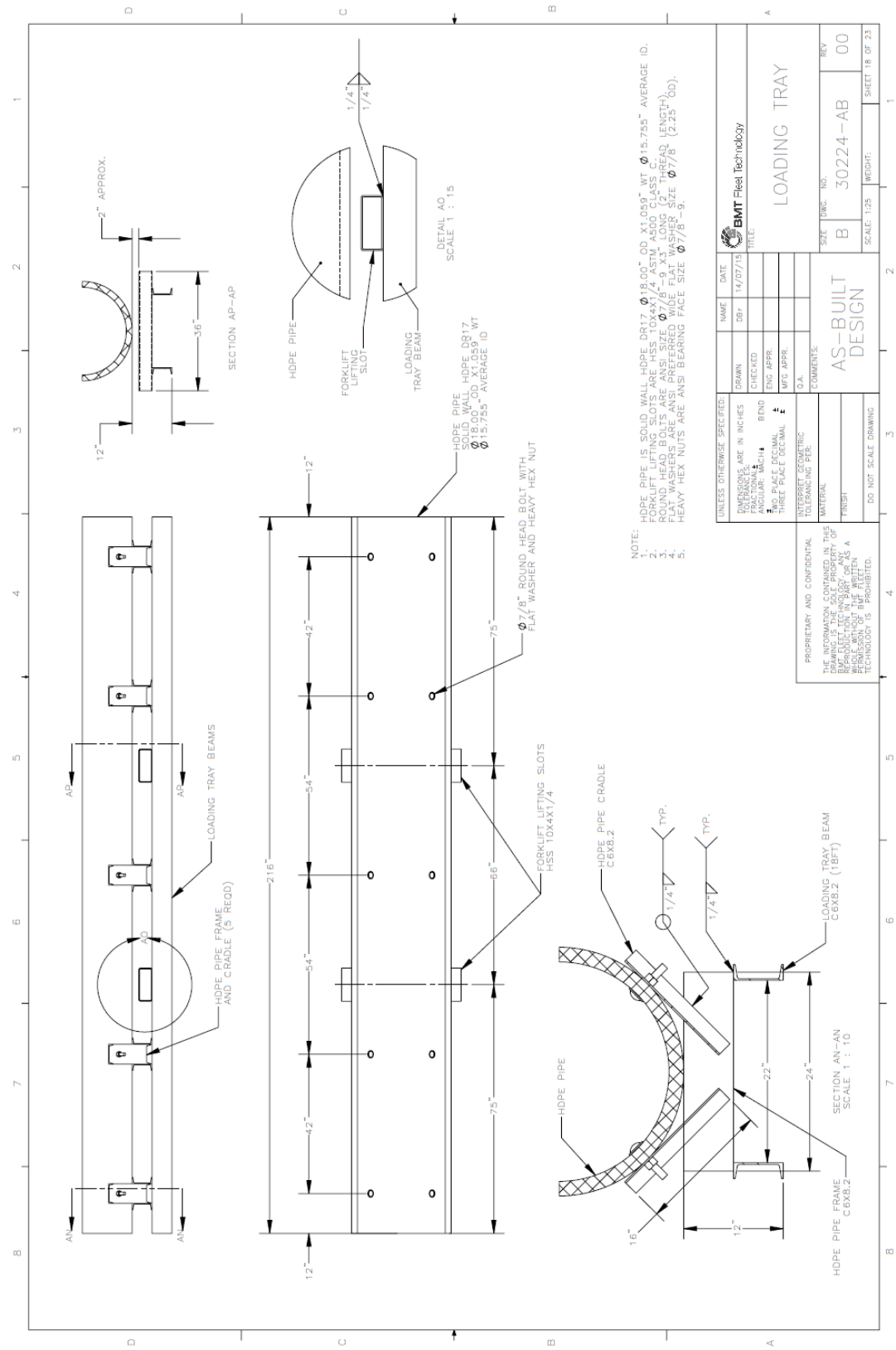
TITLE:
RECEIVING END 24" OD PIPE
SIZE
B
DWG. NO.
30224-AB
REV
00
SCALE: 1:15
WEIGHT:
SHEET 17 OF 23


SECTION AP-AP
2" APPROX.
36"
12"
DETAIL AQ
SCALE 1 : 15
HDPE PIPE
FORKLIFT LIFTING SLOT
LOADING TRAY BEAM
1/4"
HDPE PIPE SOLID WALL HDPE DR17 Ø18.00" OD X1.059" WT Ø15.755" AVERAGE ID
Ø7/8" ROUND HEAD BOLT WITH FLAT WASHER AND HEAVY HEX NUT
FORKLIFT LIFTING SLOTS HSS 10X4X1/4
LOADING TRAY BEAMS
HDPE PIPE FRAME AND CRADLE (3 REQD)
216"
42"
54"
75"
66"
12"
HDPE PIPE CRADLE C6X8.2
TYP.
LOADING TRAY BEAM C6X8.2 (18FT)
SECTION AN-AN
SCALE 1 : 10
HDPE PIPE FRAME C6X8.2
22"
24"
16"
NOTE:
1. HDPE PIPE IS SOLID WALL HDPE DR17 Ø18.00" OD X1.059" WT Ø15.755" AVERAGE ID.
2. FORKLIFT LIFTING SLOTS ARE HSS 10X4X1/4 ASTM A500 CLASS C.
3. ROUND HEAD BOLTS ARE ANSI SIZE Ø7/8"-9 X3" LONG (2" THREAD LENGTH).
4. FLAT WASHERS ARE ANSI PREFERRED WIDE FLAT WASHER SIZE Ø7/8" (2.25" OD).
5. HEAVY HEX NUTS ARE ANSI BEARING FACE SIZE Ø7/8"-9.
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
ANGULAR: ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±
BEND ±
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
FINISH
DO NOT SCALE DRAWING
DRAWN DBr 14/07/15
CHECKED
ENG APPR.
MFG APPR.
Q.A.
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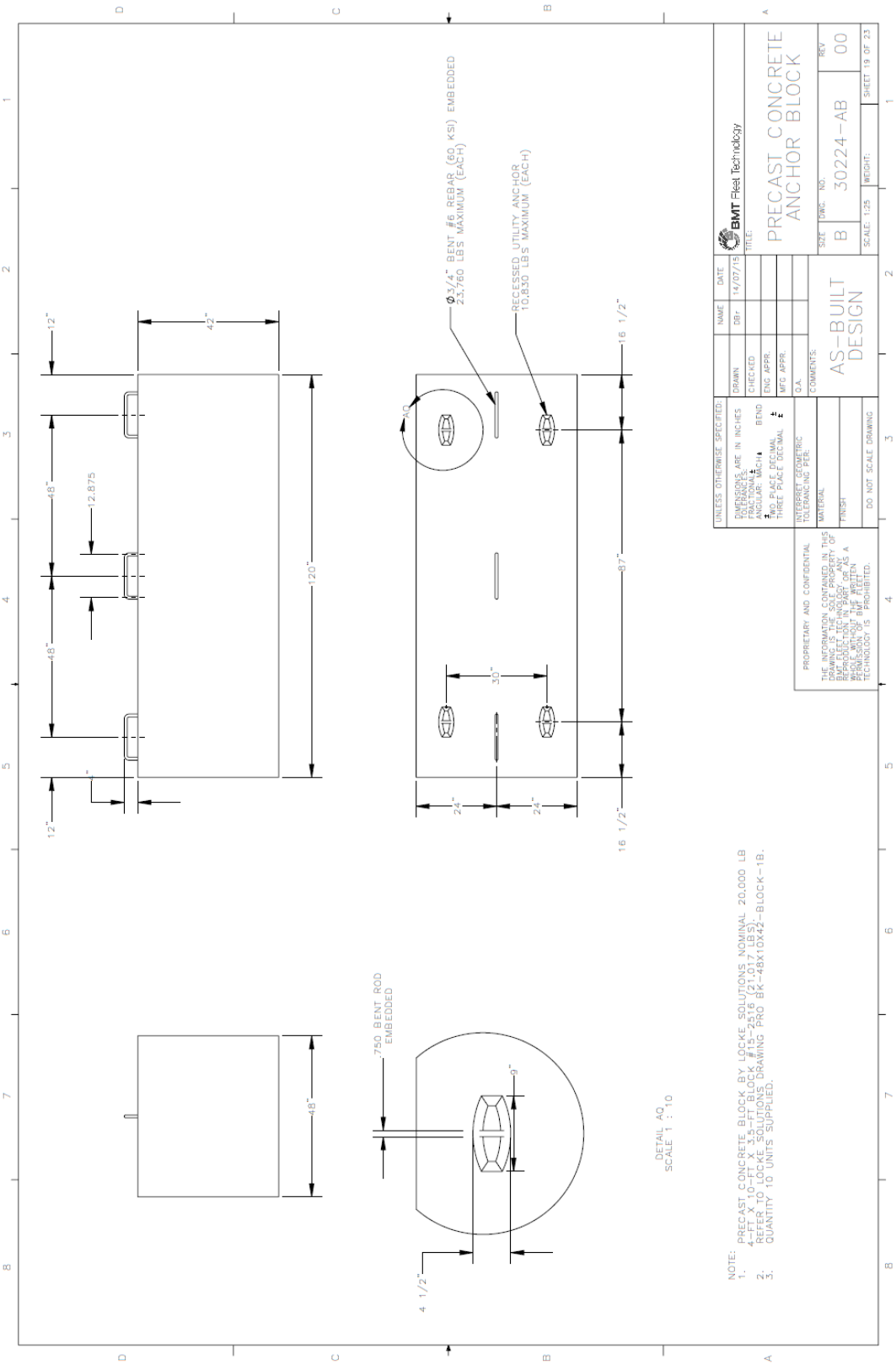
TITLE:
LOADING TRAY
SIZE B
DWG. NO. 30224-AB
REV 00
SCALE: 1:25
WEIGHT:
SHEET 18 OF 23


Ø3/4" BENT #6 REBAR (60 KSI) EMBEDDED
23,760 LBS MAXIMUM (EACH)
RECESSED UTILITY ANCHOR
10,850 LBS MAXIMUM (EACH)
12"
42"
48"
12.875
48"
120"
12"
1"
AQ
24"
30"
24"
16 1/2"
87"
16 1/2"
48"
.750 BENT ROD
EMBEDDED
9"
4 1/2"
DETAIL AQ
SCALE 1 : 10
NOTE:
1. PRECAST CONCRETE BLOCK BY LOCKE SOLUTIONS NOMINAL 20,000 LB
4 FEET X 10 FEET X 3.5 FEET BLOCK #15-2516 (21.01 LBS).
2. REFER TO LOCKE SOLUTIONS DRAWING PRO BK-48X10X42-BLOCK-1B.
3. QUANTITY 10 UNITS SUPPLIED.
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
FINISH
DO NOT SCALE DRAWING
DRAWN DBr 14/07/15
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
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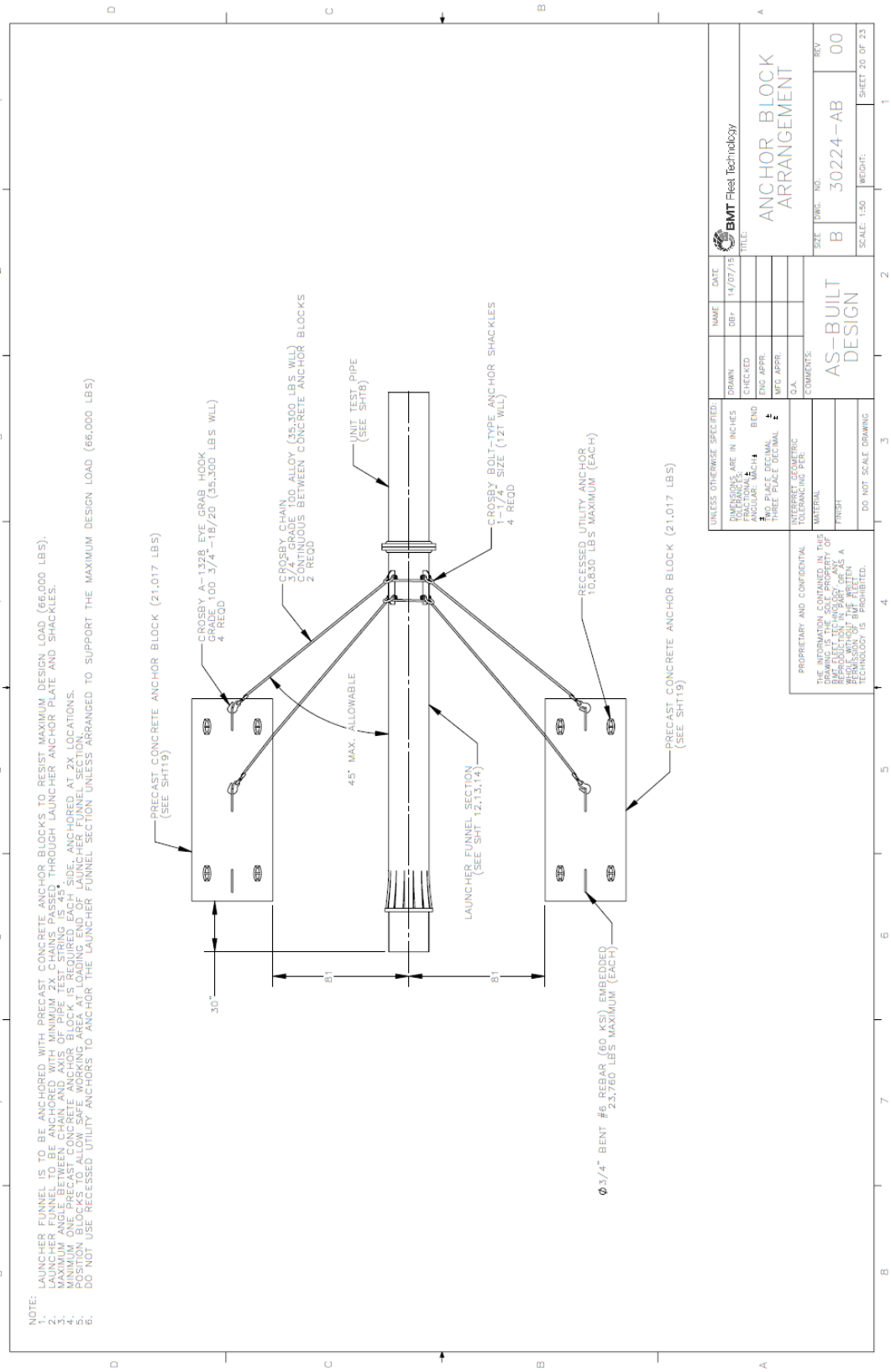
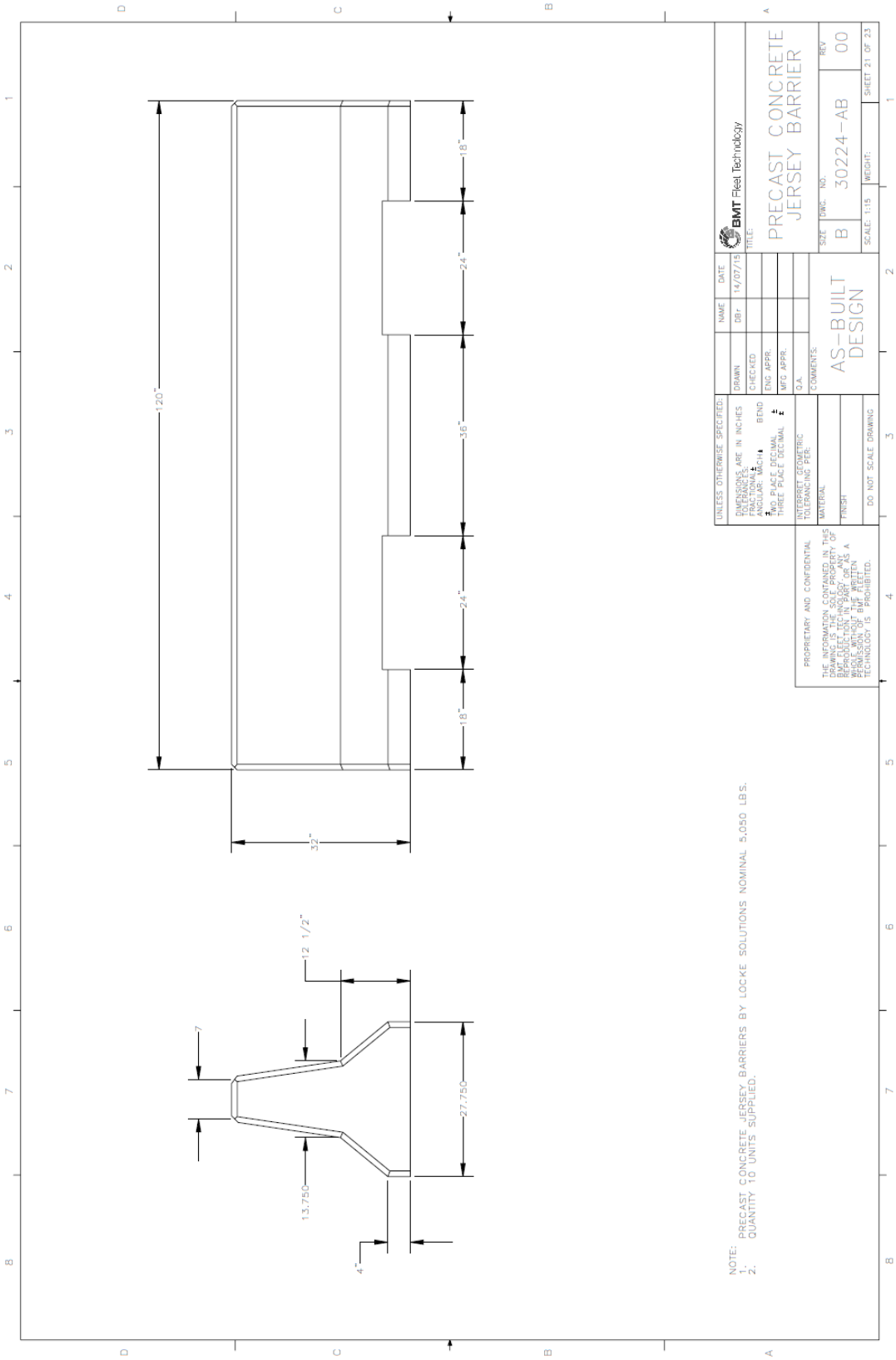
BMT Fleet Technology
TITLE:
PRECAST CONCRETE ANCHOR BLOCK
SIZE B
DWG. NO. 30224-AB
REV 00
SCALE: 1:25
WEIGHT:
SHEET 19 OF 23


NOTE:
1. LAUNCHER FUNNEL IS TO BE ANCHORED WITH PRECAST CONCRETE ANCHOR BLOCKS TO RESIST MAXIMUM DESIGN LOAD (66,000 LBS).
2. LAUNCHER FUNNEL TO BE ANCHORED WITH MINIMUM 2X CHAINS PASSED THROUGH LAUNCHER ANCHOR PLATE AND SHACKLES.
3. MAXIMUM ANGLE BETWEEN CHAINS AND AXIS OF PIPE IS 45°.
4. MINIMUM ONE PRECAST CONCRETE ANCHOR BLOCK IS REQUIRED EACH SIDE, ANCHORED AT 2X LOCATIONS.
5. POSITION BLOCKS TO ALLOW SAFE WORKING AREA AT LOADING END OF LAUNCHER FUNNEL SECTION.
6. DO NOT USE RECESSED UTILITY ANCHORS TO ANCHOR THE LAUNCHER FUNNEL SECTION UNLESS ARRANGED TO SUPPORT THE MAXIMUM DESIGN LOAD (66,000 LBS)
PRECAST CONCRETE ANCHOR BLOCK (21,017 LBS)
(SEE SHT19)
CROSBY A-1328 EYE GRAB HOOK
GRADE 100 3/4"-18/20 (35,300 LBS WLL)
4 REQD
CROSBY CHAIN
3/4" GRADE 100 ALLOY (35,300 LBS WLL)
CONTINUOUS BETWEEN CONCRETE ANCHOR BLOCKS
2 REQD
UNIT TEST PIPE
(SEE SHT8)
CROSBY BOLT-TYPE ANCHOR SHACKLES
1-1/4" SIZE (12T WLL)
4 REQD
RECESSED UTILITY ANCHOR
10,830 LBS MAXIMUM (EACH)
45° MAX. ALLOWABLE
LAUNCHER FUNNEL SECTION
(SEE SHT 12,13,14)
PRECAST CONCRETE ANCHOR BLOCK (21,017 LBS)
(SEE SHT19)
30"
81
81
Ø3/4" BENT #6 REBAR (60 KSI) EMBEDDED
23,760 LBS MAXIMUM (EACH)
BMT Fleet Technology
ANCHOR BLOCK ARRANGEMENT
AS-BUILT DESIGN
SIZE B
DWG. NO. 30224-AB
REV 00
SCALE: 1:50
WEIGHT:
SHEET 20 OF 23
DO NOT SCALE DRAWING
PROPRIETARY AND CONFIDENTIAL


120"
18"
24"
36"
24"
18"
32"
12 1/2"
7
13.750
27.750
4"
NOTE:
1. PRECAST CONCRETE JERSEY BARRIERS BY LOCKE SOLUTIONS NOMINAL 5,050 LBS.
2. QUANTITY 10 UNITS SUPPLIED.
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
FINISH
DO NOT SCALE DRAWING
NAME
DATE
DRAWN
DB+
14/07/15
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
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BMT Fleet Technology
TITLE:
PRECAST CONCRETE JERSEY BARRIER
SIZE
B
DWG. NO.
30224-AB
REV
00
SCALE: 1:15
WEIGHT:
SHEET 21 OF 23

A. DEAD LOADS
TOTAL DEAD WEIGHT (DRY) – 52,750 LBS
VOLUME OF DIESEL FUEL (FULL) – 250 GAL (@6.94 LBS/GAL)
VOLUME OF HYDRAULIC OIL (FULL) – 1,000 GAL (@7.237 LBS/GAL)
DEADWEIGHT OF FLUIDS – 9,000 LBS (APPROX.)
TOTAL DEAD WEIGHT (FULL) – 61,750 LBS
B. LIVE LOADS
MAXIMUM PULL FORCE IS – 40,000 LBS ON THE TOP WIRE ROPE LAYER AND 15,000 LBS AT 11MPH.
LIVE LOAD FACTOR FOR DESIGN – 1.6 (UNITED STATES)
FACTORED MAXIMUM PULL FORCE FOR DESIGN – 66,000 LBS (294 KN)
C. CONCRETE FOUNDATION
REFER TO EMBEDDED ANCHORAGE DESIGNED TO RESIST FACTORED MAXIMUM PULL FORCE – 66,000 LBS (SHEAR + MOMENT)
D. WINCH TIE-BACK CYLINDERS
MAXIMUM PULL FORCE PER CYLINDER – 0.50X 66,000 LBS – 33,000 LBS (147 KN)
CAPACITY OF EACH CYLINDER – 44,000 LBS; PRE-TENSION TO 7,350 LBS EACH
E. PIPE TEST STRING ANCHORAGES
BOLTS – 3@ Ø3/4" ASTM A325
SHEAR PLATE THICKNESS – 3/4" (19 MM) ASTM A572 GRADE 50
LIMITING FACTORED RESISTANCE OF BOLT GROUP (SHEAR) – 3X 2X 79 KN/BOLT/SHEAR PLANE – 474 KN (106,559 LBS)
MINIMUM WELD IS AT RECEIVER ANCHOR PLATE TO RECEIVER END – 2X 3/8" FILLET X 16" (406 MM)
LIMITING FACTORED RESISTANCE OF WELD (SHEAR) – 2X 1.48 KN/MM X 406MM – 1203 KN (270,445 LBS)
F. WINCH TIE-BACK LINKAGES
MAXIMUM PULL FORCE PER LINKAGE – 0.50X 66,000 LBS – 33,000 LBS
MAXIMUM SWL RATING OF LINKAGE – 75 TON
ANCHOR SHACKLES – 1 1/2" WLL, SIZE 35T WLL (70,000 LBS) EACH
CONNECTING LINKS – 3/4" LOK-A-LOY 16T (35,300 LBS) EACH
LINK PIN
LINK PIN AT WINCH – Ø2.0" GRADE 50 STEEL
FACTORED SHEAR RESISTANCE OF LINK PIN – 383 KN (86,100 LBS)
LINK PLATE AT WINCH – 1.0" THK GRADE 50 STEEL
FACTORED SHEAR RESISTANCE OF LINK PLATE – 183 KN (41,100 LBS) (NET SECTION TEAR-OUT: ASSUMING SINGLE SHEAR PATH; CONSERVATIVE)
FACTORED BEARING RESISTANCE OF LINK PLATE – 1394 KN (313,384 LBS)
G. ANCHORAGE GIRDER BRACES
MAXIMUM PULL FORCE PER BRACE – 0.50X 66,000 LBS – 33,000 LBS
TIE-BACK LINKAGE LUG – 1.0" THK GRADE 50 STEEL
FACTORED RESISTANCE OF LUG – 244 KN (54,824 LBS) (NET SECTION TEAR-OUT: ASSUMING SINGLE SHEAR PATH; CONSERVATIVE)
FACTORED BEARING RESISTANCE OF LUG – 1394 KN (313,384 LBS)
WELD LUG TO STUB STOP – 2X 1/2" FILLET X 10" (254 MM)
FACTORED WELD RESISTANCE – 2X 1.12 KN/MM X 254MM – 1006 KN (226,158 LBS)
BRACE LEG HSS 6X6X1/4 ASTM A500 CLASS C
BRACE LEG MAXIMUM UNSUPPORTED SPAN – 37" (940 MM)
FACTORED COMPRESSIVE RESISTANCE OF BRACE LEG – 994 KN (223,460 LBS) (USING UNSUPPORTED SPAN OF 1200 MM; CONSERVATIVE)
H. BOLTED CONNECTION AT ANCHORAGE GIRDER BRACE TO ANCHORAGE GIRDER
MAXIMUM PULL FORCE AT CONNECTION (SHEAR) – 0.50X 66,000 LBS – 33,000 LBS
MAXIMUM PULL FORCE AT CONNECTION (TENSION) – (35/31)X 33,000 LBS – 37,260 LBS (TAKING MOMENT ABOUT BRACE LEG BEARING ON CONCRETE)
BOLTS – 4@ Ø1.0" ASTM A325
ANCHORAGE GIRDER – W14X90 ASTM A572 GRADE 50
STUB BOTTOM PLATE THICKNESS – 3/4" (19 MM)
GIRDER TOP FLANGE THICKNESS – 0.71" (18 MM)
SHEAR PLANES
LIMITING FACTORED RESISTANCE OF BOLT GROUP (SHEAR) – 4X 1X 141 KN/BOLT/SHEAR PLANE – 564 KN (126,792 LBS)
TENSILE RESISTANCE OF BOLT GROUP – 4X 251 KN – 1004 KN (56,427 LBS)
I. ANCHORAGE GIRDER
MAXIMUM SHEAR FORCE AT 2 LOCATIONS (SPACING – 64") – 33,000 LBS EACH APPLIED LATERALLY
ANCHORAGE GIRDER – W14X90 ASTM A572 GRADE 50
GIRDER TOP FLANGE THICKNESS – 0.71" (18 MM)
GIRDER WEAK-AXIS ELASTIC SECTION MODULUS – 817,000 MM³
GIRDER WEAK-AXIS SHEAR AREA (2X FLANGES) – 13,284 MM²
CONSIDER ANCHORAGE GIRDER AS 3-SPAN CONTINUOUS BEAM OVER SIMPLE SUPPORTS SPACED AT 96" (2440 MM) (CONSERVATIVE)
MAXIMUM MOMENT AND MOMENT OCCUR FOR LOAD APPLIED AT MID-SPAN OF THE END SPAN
MAXIMUM FACTORED SHEAR/REACTION – 0.725X 294 KN – 213.2 KN (47,929 LBS)
MAXIMUM FACTORED MOMENT – 0.200X 294 KN X 2.44 M – 143.5 KN (105,840 LBF-FT)
CONSIDER FULL LOAD APPLIED AT A SINGLE SUPPORT ANCHORAGE (CONSERVATIVE)
MAXIMUM FACTORED SHEAR/REACTION – 1.0X 294 KN – 294 KN (66,000 LBS)
CALCULATED FACTORED RESISTANCES (WEAK-AXIS)
ANCHORAGE GIRDER SHEAR RESISTANCE – 2511 KN (564,495 LBS)
ANCHORAGE GIRDER MOMENT RESISTANCE – 257.4 KNM (189,848 LBF-FT)
CALCULATED WELD RESISTANCE AT GIRDER CONNECTION TO ANCHORAGE PLATE
WELD GIRDER FLANGE TO ANCHORAGE PLATE – 2X 1/2" FILLET X 10" (254 MM)
FACTORED WELD RESISTANCE OF FLANGE AT ANCHORAGE PLATE – 1006 KN (226,158 LBS)
J. PIPE TEST STRING
THE PIPE TEST STRINGS ARE STABILIZED FROM LATERAL OR VERTICAL BUCKLING
A VERTICAL OR LATERAL MISALIGNMENT OF 24" IS ASSUMED FOR DESIGN AT THE MAXIMUM FACTORED PULL FORCE (66,000 LBS)
GEOMETRY OF PIPE SUPPORTS APPLIES 5% OF PULL FORCE AS LATERAL/UPLIFT FORCE
MAXIMUM FACTORED UPLIFT FORCE FOR DESIGN – 3300 LBS (WITH LATERAL FORCE – 1692 LBS)
MAXIMUM FACTORED LATERAL FORCE FOR DESIGN – 3300 LBS (WITH UPLIFT FORCE – 1692 LBS)
MAXIMUM FACTORED TENSION FORCE IN TIE-DOWN STRAP FOR DESIGN – 3709 LBS
TIE-DOWN STRAPS
RATCHETING TIE-DOWN STRAPS – 5,400 LBS WLL
LASHING PLATES
LASHING PLATES – 1/2" THK GRADE 50 STEEL
FACTORED SHEAR RESISTANCE OF LASHING PLATE – 101.3 KN (22,773 LBS) (NET SECTION TEAR-OUT)
FACTORED BEARING RESISTANCE OF LASHING PLATE – 405.4 KN (91,138 LBS)
LAG SCREW CONNECTION TO TIMBER SUPPORTS
MAXIMUM FACTORED LATERAL FORCE FOR DESIGN – 3300 LBS
MAXIMUM REACTION AT LAG SCREW FOR DESIGN – 3300 LBS
TIMBER SUPPORT BEAMS ARE 12"X12"X144" LONG GRADE A307 WITH WASHER
CALCULATED FACTORED WITHDRAWL RESISTANCE – 28.7 KN (6452 LBS)
CALCULATED LATERAL RESISTANCE – 16 KN (3597 LBS)
K. SLIP-ON FLANGES
WELD AT EACH SLIP-ON FLANGE – SINGLE, ALL-AROUND 1/8" FILLET (FULL PERIMETER)
UNIT PIPES ARE CONNECTED BY THROUGH-BOLTING AT SLIP-ON FLANGES – 8@ ASTM A325 BOLTS
BOLT DIAMETER DETERMINED BY SIZE OF PIPE SLIP-ON FLANGE
NOTE: BOLTS CARRYING SHEAR (LATERAL) LOAD – 8
MINIMUM BOLT DIAMETER – Ø1.0" (FOR 12" OD PIPE SLIP-ON FLANGE)
MINIMUM FACTORED SHEAR (LATERAL) RESISTANCE OF BOLTED CONNECTION – 8X 1X 141KN/BOLT/SHEAR PLANE – 1128 KN (253,585 LBS) (BASED ON Ø1.0" BOLTS; CONSERVATIVE)
ONLY 2 OF 8 BOLTS CARRYING THE FACTORED MAXIMUM PULL FORCE FOR DESIGN (66,000 LBS)
MINIMUM FACTORED TENSILE RESISTANCE OF BOLTED CONNECTION – 2X 251 KN/BOLT – 502 KN (112,854 LBS) (BASED ON Ø1.0" BOLTS; CONSERVATIVE)
L. PIPE TEST STRING ANCHORING
LAUNCHER FUNNEL AT EACH PIPE STRING TO BE ANCHORED TO PRECAST CONCRETE ANCHOR BLOCKS FOR PULL-TESTING.
MAXIMUM ANGLE BETWEEN CHAIN AND AXIS OF LAUNCHER FUNNEL – 45°
REQUIRES CROSBY BULK 1/2" ANCHOR SHACKLES (15 TON SIZE WLL)
CONNECTING LINKS 3/4" LOK-A-LOY (35,300 LBS WLL) ATTACHED CROSBY A-1337 GRADE 100 3/4"-18/20 (35,300 LBS WLL)
CAPACITY IS GOVERNED BY Ø3/4" BENT #6 REBAR (23,780 LBS)
REFER TO SHT19 FOR POSITIONING OF PRECAST CONCRETE ANCHOR BLOCKS.
M. WINCH TEST SYSTEM
REFER TO AMI DRAWING BMD-0705 REV01 (150CT2014) FOR WINCH TEST SYSTEM DETAILS.
PLATFORM TRANSIT SPEED APPROX 1.5MPH.
ELECTRIC POWER REQUIRED: 110 VAC @ 100 AMP, 1-PHASE, 60 HZ, FLA (SINGLE-PHASE)
WINCH COLOR IS TRAFFIC YELLOW RAL 1023.
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FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
FINISH
DO NOT SCALE DRAWING
DRAWN DBr 14/07/15
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
AS-BUILT DESIGN
BMT Fleet Technology
TITLE:
DOCUMENTATION
SIZE B
DWG. NO. 30224-AB
REV 00
SCALE: 1:25
WEIGHT:
SHEET 22 OF 23

LOAD RATED COMPONENTS

- CROSBY BOLT-TYPE ANCHOR SHACKLES AT WINCH TEST SYSTEM MAIN WIRE ROPE - 2.0" SIZE (35T WLL) PN:G1019677 (QTY. 2)
- CROSBY BOLT-TYPE ANCHOR SHACKLES AT CONCRETE ANCHOR BLOCKS - 1-1/4" SIZE (12T WLL) PN:1019597 (QTY. 20)
- CROSBY BOLT-TYPE ANCHOR SHACKLES AT WINCH TIE-BACK CYLINDERS - 1-1/2" SIZE (17T WLL) PN:1019631 (QTY. 4)
- CROSBY CLOSED SPELTER SOCKET AT MAIN WIRE ROPE END - G-417 GALVANIZED 1-1/4" - 1-3/8" SIZE (136T ULTIMATE LOAD) PN:G-417-1040055
- CROSBY CHAIN AT WINCH TIE-BACK CYLINDERS - 3/4" GRADE 100 ALLOY (35,300 LBS WLL) PN:1210160
- CROSBY CHAIN AT PRECAST CONCRETE ANCHOR BLOCKS - 3/4" GRADE 100 ALLOY (35,300 LBS WLL) PN:1210160
- CROSBY A-1328 EYE GRAB HOOKS AT PRECAST CONCRETE ANCHOR BLOCKS - GRADE 100 3/4"-18/20 (35,300 LBS WLL) PN:1026214 (70T ULTIMATE LOAD)
- CROSBY A-1337 LOK-A-LOY CONNECTING LINK - 3/4" (35,300 LBS WLL) PN:1015154
- **WINCH TEST SYSTEM MAIN WIRE ROPE = 1-1/4" COMPAC 35 SUPER 2160 NON-ROTATING GALVANIZED (42,000 LBS WLL); MANUFACTURED IN KOREA TO API-9A; 225,400 LBS MINIMUM BREAKING LOAD (PROOF LOAD** TESTED TO 2X WLL); LENGTH - 565' TOTAL (550' ON DRUM + 5 WRAPS).
- RETRIEVAL WINCH WIRE ROPE - 3/8" 6X26 @600'
- RATCHETING TIE-DOWN STRAPS - 4" WIDE X 16' RATCHET STRAPS WITH FLAT HOOKS (5,400 LBS WLL) (16,200 LBS BREAKING STRENGTH)

CONCRETE

- PRECAST CONCRETE ANCHOR BLOCKS - 21,017 LBS (4'X10'X3'-6")
- PRECAST CONCRETE RETRIEVAL WINCH MOUNTING BLOCK - 4,989 LBS (50"X96"X12")
- PRECAST CONCRETE JERSEY BARRIER - 5,050 LBS (10')

ASTM A325 HIGH-STRENGTH BOLTS AND HEX NUTS FACTORED RESISTANCES

- Ø3/4" SIZE: SHEAR - 79 KN/BOLT/SHEAR PLANE; TENSILE - 141 KN/BOLT; BEARING - 20.57 KN/MM/BOLT WITH A572 GRADE 50
- Ø1.0" SIZE: SHEAR - 141 KN/BOLT/SHEAR PLANE; TENSILE - 251 KN/BOLT; BEARING - 27.43 KN/MM/BOLT WITH A572 GRADE 50
- Ø1-1/4" SIZE: SHEAR - 193 KN/BOLT/SHEAR PLANE; TENSILE - 345 KN/BOLT; BEARING - 34.29 KN/MM/BOLT WITH A572 GRADE 50

RESISTANCE FACTORS FOR LIMIT STATES DESIGN

- STEEL MATERIAL - 0.90
- SHEAR AREA - 0.60
- BOLTS - 0.80
- WELDS - 0.60

CALCULATED FACTORED UNIT WELD RESISTANCES (SHEAR)

- 1/8" THROAT - 0.49 KN/MM
- 1/4" THROAT - 0.99 KN/MM
- 3/8" THROAT - 1.48 KN/MM
- 1/2" THROAT - 1.98 KN/MM
- BASED ON Fu - 450 MPA AND Xu - 490 MPA

PROPRIETARY AND CONFIDENTIAL

THE INFORMATION CONTAINED IN THIS DRAWING IS THE SOLE PROPERTY OF BMT FLEET TECHNOLOGY. ANY REPRODUCTION IN PART OR AS A WHOLE WITHOUT THE WRITTEN PERMISSION OF BMT FLEET TECHNOLOGY IS PROHIBITED.

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±

INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
FINISH
DO NOT SCALE DRAWING

	NAME	DATE
DRAWN	DBr	14/07/15
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		

COMMENTS:
AS-BUILT DESIGN

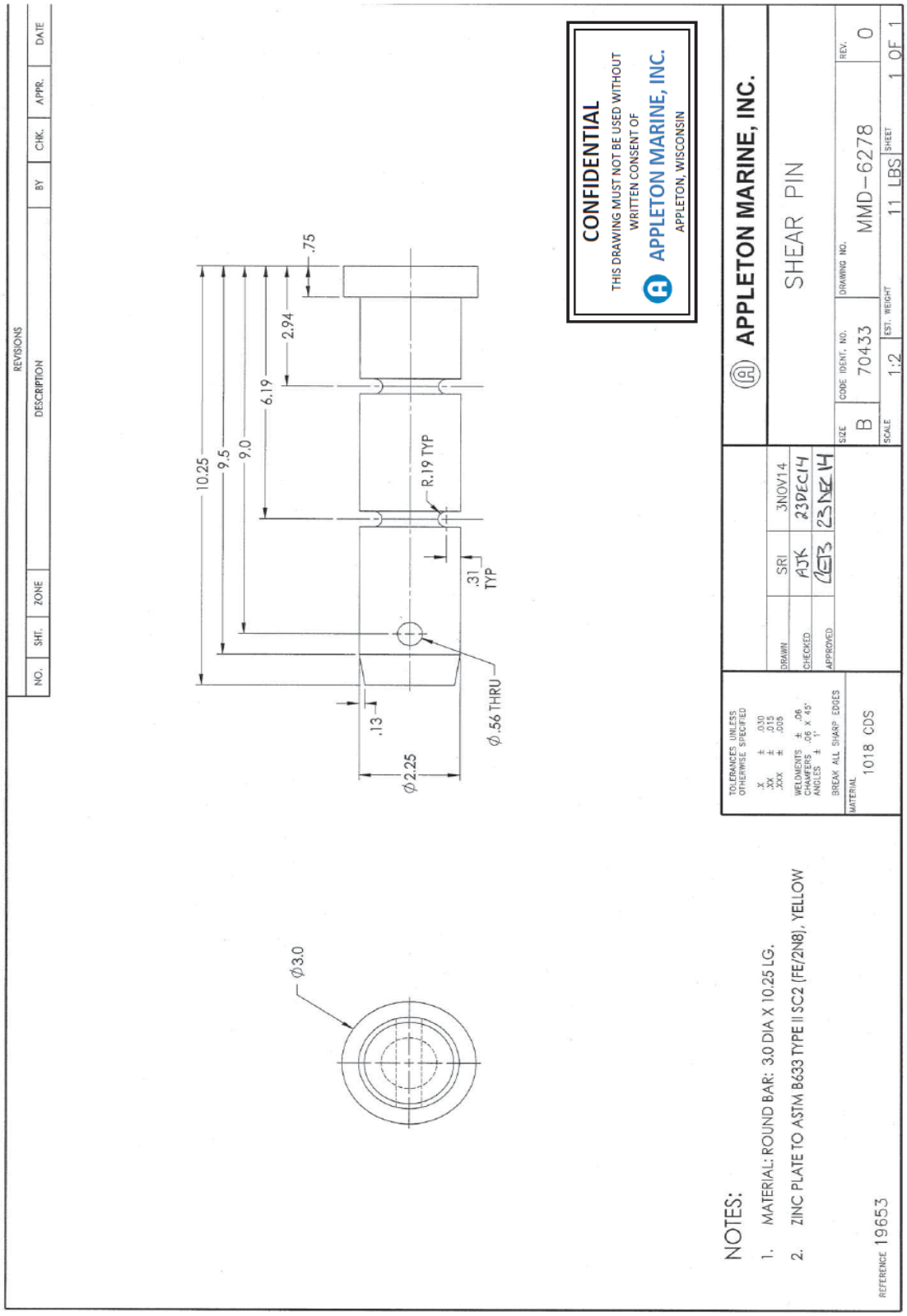
BMT Fleet Technology

TITLE:
DOCUMENTATION

SIZE	DWG. NO.	REV
B	30224-AB	00

SCALE: 1:25 | WEIGHT: | SHEET 23 OF 23

ANNEX F – SHEAR PIN DRAWING



Appendix B

WELCOME TO THE TECHNOLOGY DEVELOPMENT CENTER!

The Technology Development Center (TDC) opened in July 2015 and today is a cornerstone of the PRCI pipeline research model. The preeminent feature of the TDC is the large collection of pipe samples containing a vast array of manufacturing defects, mechanical damage, internal corrosion, external corrosion, stress corrosion cracking, and other defect types.

The TDC provides a unique opportunity for operators and technology providers to collaborate in an open forum and bring new advances in technology to market at a much more rapid pace. This site has been designed by the pipeline industry for the pipeline industry, and is a critical tool as we continue to strive for zero failures.

ABOUT PRCI

PRCI is a community of the world's leading pipeline companies, and the vendors, service providers, equipment manufacturers, and other organizations supporting our industry. PRCI executes a member-directed R&D portfolio addressing critical pipeline integrity, environmental compliance and operating efficiency needs.

PRCI

LEADING PIPELINE RESEARCH

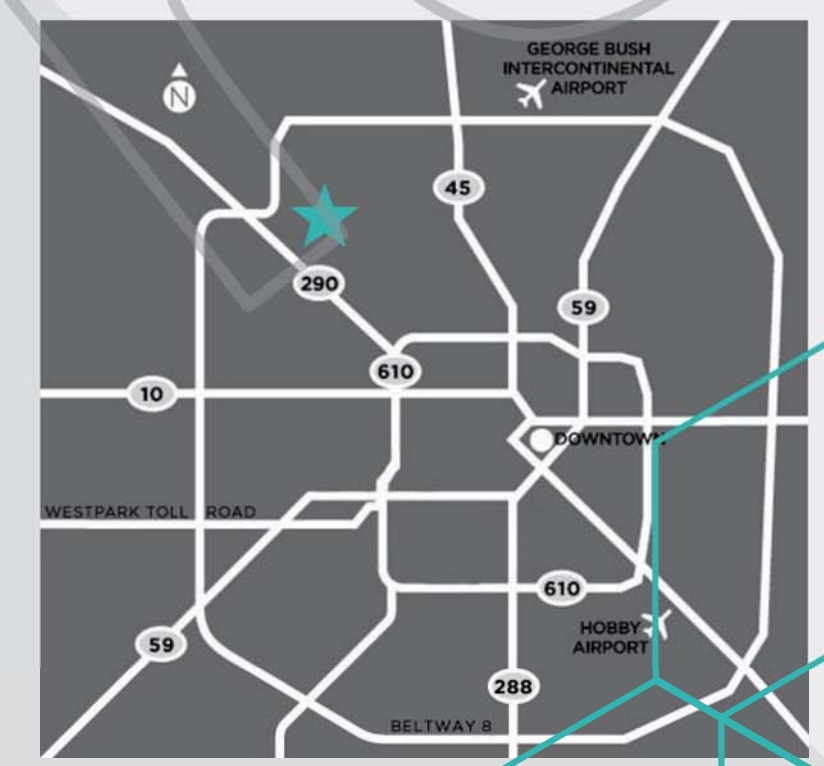
HOURS OF OPERATION

Monday to Friday	8:00am - 5:00pm
Saturday & Sunday	Closed

LOCATION & CONTACT

6410 Langfield Road, Building J
Houston, TX 77092 U.S.A.

+1 (281) 846-7570
TDC@prci.org | www.prci.org



PRCI

TECHNOLOGY DEVELOPMENT CENTER

Home of Global Pipeline Research & Development

PIPELINE RESEARCH COUNCIL INTERNATIONAL

PROOF

STATE-OF-THE-ART PULL TEST FACILITY

- 24-inch, 16-inch & 12-inch pipe strings containing hundreds of fully characterized real & manufactured defects.
- Main winch is capable of running consistent velocities from 1 mph to 11 mph while pulling over 5,000 lbs.
- The 24-inch & 16-inch strings are equipped to run liquid tools.

LIQUID TEST LOOP

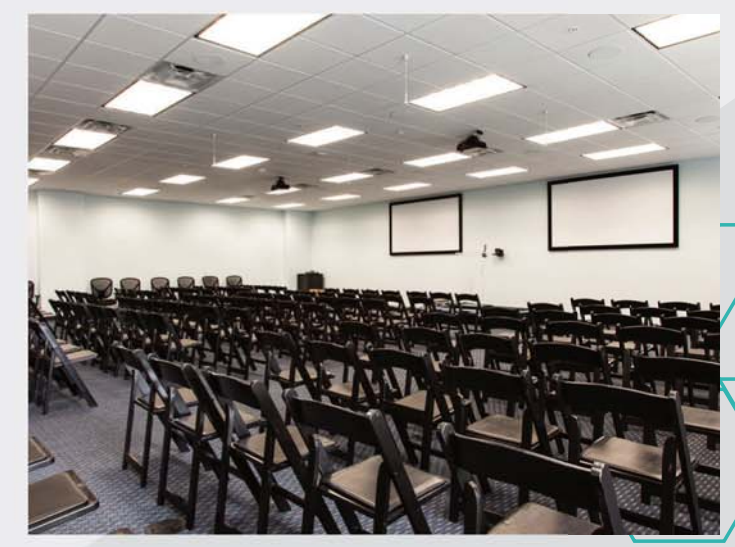
- 6-inch & 12-inch nominal pipe utilizing water as the liquid medium.
- Variety of pipeline configurations ranging from easily piggable to "difficult to inspect."
- Design incorporates the ability for continuous test cycles at a pressure of ANSI Class 150 (285 psi).

PIPE INVENTORY & WAREHOUSE

- Over 20,000 square feet of indoor warehouse space to conduct testing, NDE evaluations & storage.
- Access to over 1,100 pipe samples with various defect types & dimensions.
- Third party pipe surface preparation, welding, cutting & moving services available upon request.

HOW YOU CAN GET INVOLVED

All services at the TDC are available to PRCI's member companies and all interested pipeline operating companies, service providers & industry organizations. PRCI members receive special rates & priority for utilizing the facility. We are continually working to expand our capabilities to meet the needs of the industry. Please don't hesitate to ask if you have any special requests beyond the listed services.



MEETING ROOMS

- A large conference room accommodating up to 127 people & a small conference room accommodating up to 55 people.
- Two large screens in each room for presentations.
- Web conferencing systems with built-in ceiling speakers & microphones.
- Quick access to pipe samples in the warehouse.