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Human Centric Approach to Improve Pipeline Non-Destructive Evaluation (NDE) Performance and Reliability: Phase 2 and 3 Final Report

Pipeline and Hazardous Materials Safety Administration
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Human Centric Approach to Improve Pipeline Non-Destructive Evaluation (NDE) Performance and Reliability: Phase 2 and 3 Final Report

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List of Acronyms

2D	Two-Dimensional
3D	Three-Dimensional
AP	Accomplished Performers
DOT	Department of Transportation
EDM	Electrical Discharge Machining
ID	Inside Diameter
IDI	In-depth Interviews
IWEX	Inverse Wave Field Extrapolation
MPI/MT	Magnetic Particle Testing
MWM	Meandering Winding Magnetometer
NDE	Non-Destructive Evaluation
NDT	Non-Destructive Testing
NTSB	National Transportation Safety Board
OD	Outside Diameter
PHMSA	Pipeline and Hazardous Materials Safety Administration
PSF	Performance Shaping Factor
R&D	Research and Development
RFP	Request for Proposal
RT	Radiographic Testing
SCC	Stress Corrosion Cracking
SQL	Structured Query Language
UT	Ultrasonic Testing

Abstract

The United States of America is critically dependent on natural gas and petroleum liquids transported through pipelines. The infrastructure that currently transports these energy resources is aging, with a significant fraction being more than fifty years old. While new pipelines are being planned and constructed, pipeline operators typically plan on continued operation of the vast majority of existing pipeline mileage. Assuring the long-term integrity and security of these existing pipelines is essential.

Recognizing these facts, the U.S. Department of Transportation (DOT), Pipeline and Hazardous Materials Safety Administration (PHMSA), Office of Pipeline Safety designed a process to emphasize the importance of continuing pipeline-related research and development (R&D). As part of that overall effort, a DOT PHMSA PHP Research Announcement, #DTPH5615RA00001, was issued.

Battelle entered into a Transaction Agreement, #DTPH5615T00010, "Human Centric Approach to Improve Pipeline Non-Destructive Evaluation (NDE) Performance and Reliability" to apply a phased approach to first identify major human performance shaping factors of NDE measurements and then identify high-impact human and technology interventions to reduce identified negative influences on performance.

Keywords: human error, human reliability, human factors, performance shaping factors, non-destructive evaluation (NDE), non-destructive testing (NDT), inspection, human performance, inspection performance, training.

Executive Summary

Three partner organizations (Mistras Group, JENTEK, and Applus RTD) developed a variety of human (phase 2) and technology (phase 3) interventions with the goal of improving NDE pipeline inspector performance and reliability.

Mistras Group implemented a variety of human interventions across their laboratories in Heath, OH and Long Beach, California. Applus and JENTEK made modifications and improvements to their respective scanning technologies. Applus modified their inverse wave field extrapolation (IWEX) scanner and JENTEK modified their eddy current scanner. Each intervention was designed to address one performance shaping factor (PSF) that was identified in phase 1 as having either a positive or negative impact on inspector performance (see table below).

Table 1. Performance Shaping Factors (Executive Summary)

Partner	Phase	Planned Intervention(s)
Mistras Group	2	• Additional employee training/Mentoring program • Improved Traveler Form • Wellness program/Online training webinars • Lessons learned webinars • Improved employee recognition program
ApplusRDT	3	• Improvements to Applus IWEX technology to improve identification and interpretation of inspection images
JENTEK Sensors	3	• Improvements to JENTEK stress corrosion cracking (SCC) mapping and crack depth analysis tool to improve speed and accuracy of inspection

Mistras's additional training and mentoring program provided evidence that shows positive effects on participants in the program in multiple performance categories at the Heath lab. However, the Long Beach lab showed limited impact due to the program. The updated traveler document (i.e. the document that contains all job information) did not show a significant change in customer satisfaction, on-time delivery, and reporting errors over the course of the evaluation period. However, though some improvements in customer satisfaction and reporting errors were observed, a longer evaluation period and more data points may be necessary to further evaluate the impact of the updated traveler on technician performance. The expanded online training experienced significant difficulties with implementation from Mistras management and was not implemented until late in phase 3. As a result, the effect of the online training webinars and wellness program was not apparent on inspector performance. The effect of the lessons learned is not apparent on inspector performance. However, this intervention was highly linked to the mentoring program, as the seminars were implemented at the end of the program as a culmination of the mentor and mentee's time together. Lastly, the improved employee recognition program was never implemented due to lack of customer feedback.

The updates applied to the IWEX tool during phase 3 comprise improved automated calibration to facilitate data acquisition and image production, inclusion of a decision tree for the inspection procedure, and improved processor software to facilitate detection, classification, and sizing of field scan image data. Applus conducted a series of inspection tests with three employee technicians prior to any modifications being made to the IWEX scanner. The first test was intended to determine how long it takes to set up and conduct an inspection with the legacy IWEX system. After the modifications to the IWEX scanner were complete, Applus conducted the same series of inspection tasks with the updated scanner. The table below highlights the efficiency improvements made by the technicians while using the new scanner.

Table 2. Updated IWEX Scanner Time Results (Executive Summary)

Operator/Technician	Time to set up		Time to calibrate		Time to collect data/avg per sample		Time to analyze data		Time to report	
	Before	After	Before	After	Before	After	Before	After	Before	After
Technician 1	40min	20min	55min	15min	3min	3min	6hr	45min	1day	2min
Technician 2	1hr	25min	1hr	20min	3min	3min	2hr	30min	1day	2min
Technician 3	2hr	25min	2hr	18min	3min	3min	8hr	45min	1day	2min

JENTEK applied updates to their SCC tool during phase 3 that were comprised of a more automated scanning system to facilitate the physical inspection process, a modified software to improve the user interface and increase data processing speed, and modified calibration and operating procedures to reduce use errors. JENTEK performed testing of their new automated scanner alongside an equivalent test of the legacy manual scanner at a customer location in November 2017. The customer provided access to an SCC sample, as well as technicians familiar with the use of the manual system. These technicians also had familiarity with the automated scanner, but not all the procedural upgrades. The table below summarizes the test results for some of the major steps for setup, calibration, and scanning that were investigated.

Table 3. Updated Eddy Current Time Results (Executive Summary)

	Manual Scanner (minutes:seconds)	Automated Scanner (minutes:seconds)
Calibration Time	3:15	1:25
Cycles on the sensor connection	2 count	0 count
Scanner Setup	5:00	9:00
Pipe setup/marking	30:00	None
Calibration Verification	No	Yes
Scan Time	6:00	5:30
Example Crack Depth Data Processing Time	2:22	0:02
In-process Crack Depth Processing	Not possible due to data processing time	Yes
Reporting	Not automated/not performed	1:30 Automated

1 Project Background

Petroleum liquids and natural gas remain the primary energy source around the globe and transporting these products in an efficient and safe manner is more critical than ever. The infrastructure that transports these resources is aging, with a significant fraction of pipelines more than fifty years old. In 2014 alone, U.S. pipeline incidents were responsible for over $300 million in property damage, 19 fatalities, and 97 injuries.[1] Though the nation's pipeline infrastructure continues to age, these same pipelines will continue to be relied on to operate for decades into the future.

One critical method in monitoring and maintaining this infrastructure is via non-destructive evaluation (NDE), which may lack vital accuracy and reliability due to unintentional human error. Often pipeline operators feel that they can trust only one individual inspector. This uneasiness in NDE is warranted as human error poses a significant threat to safe and efficient pipeline operations. While human factors typically are not attributed as the sole source of pipeline incidents, they contribute substantially to incident prevalence and severity. For, example, of high consequence pipeline accidents between 1992 and 2004, the National Transportation Safety Board (NTSB) found human factor involvement in 10 of the 13 incidents.[2]

This project (#644)[3] was designed to produce insight into the conduct of successful NDE inspector performance and support the mission of the Pipeline and Hazardous Materials Safety Administration (PHMSA) to ensure the long-term integrity of natural gas and liquid petroleum pipelines. The critical outputs of an inspection task and the positive and negative influences (i.e., performance shaping factors) on those outputs identified through directed in-depth interviews conducted with accomplished inspectors in phase 1 provided knowledge that led to the proposed development of actionable human (phase 2) and technology (phase 3) interventions supporting improved inspector performance.

2 Project Objectives

The overall *Human Centric Approach to Improve Pipeline NDE Performance and Reliability* project (#DTPH5615T00010) has three objectives:

- Identify human performance shaping factors' influence on in-the-ditch NDE inspector performance
- Identify and validate high-impact human interventions to improve NDE inspector performance
- Identify and validate high-impact technology interventions to improve NDE inspector performance

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[1]https://hip.phmsa.dot.gov/ analyticsSOAP/saw.dll?Portalpages Accessed March 24, 2015.

[2]http://www.phmsa.dot.gov/pv_obj_cache/pv_obj_id_751C99B2334D7A0B306F740B0559696E3B580000/filename/Control%20Room%20Management%20Human%20Factors.pdf Accessed 06 January 2016

[3] https://primis.phmsa.dot.gov/matrix/PrjHome.rdm?prj=644&s=CAC8CF221D2143B2ABB6524C05BF6D25

Battelle proposed an investigative approach staged in three (3) phases, with each objective having a dedicated milestone for a clear go/no-go decision to enter the subsequent phase.

Phase 1 was completed in September 2016. The primary objective of that phase was to extract job performance shaping factor information from designated NDE inspector accomplished performers (APs; i.e. expert inspectors) through coordinated in-depth interviews (IDIs). The results of that phase are summarized in Section *4 Summary of Phase 1 Results* of this report.

Phases 2 and 3, the subject of this report, were dedicated to identifying, developing, and testing valuable human interventions (e.g. training, personnel selection, incentives) and technology interventions (e.g. increased automation), respectively, to eliminate or otherwise reduce detrimental factors that hinder NDE performance and reliability.

3 Project Report Scope

This project report summarizes the approach, analysis activities, and results of the effectiveness of the interventions that were proposed, developed, and implemented by partnering organizations during phase 2 and phase 3 of this project.

4 Summary of Phase 1 Results

This section summarizes the results of the phase 1 efforts in the U.S. DOT PHMSA #DTPH5615T00010 program (Project #644). A complete description of the phase 1 technical approach and results can be found in the Battelle document *Human Centric Approach to Improve Pipeline Non-Destructive Evaluation (NDE) Performance and Reliability: Phase 1 Final Report* (dated September 30, 2016).

Twenty-four (24) APs from three partner organizations (Mistras Group [Mistras], JENTEK® Sensors, Inc. [JENTEK], and Applus RTD [Applus]) participated in extensive interviews and task observations. Mistras identified APs in Magnetic Particle Testing (MPI/MT), X-Radiograph inspection (X-ray), and Ultrasonic Testing (UT) weld inspection. Applus identified APs in Inverse Wave Field Extrapolation (IWEX). JENTEK identified APs in Meandering Winding Magnetometer (MWM) eddy current sensors. Interviews comprised structured questioning about the pipeline NDE inspection process and more general, open-ended questioning regarding positive and negative influences on the inspection process. A subset of APs was provided a pipe sample and asked to demonstrate the inspection process as part of the interview process.

Analysis of the structured data gathered in phase 1 suggested a close alignment among APs regarding the overall target job accomplishment of an NDE inspector and the skills and major accomplishments (i.e. outputs of value that make up the overall job accomplishment) required to produce the expected outcome (see Figure 1).

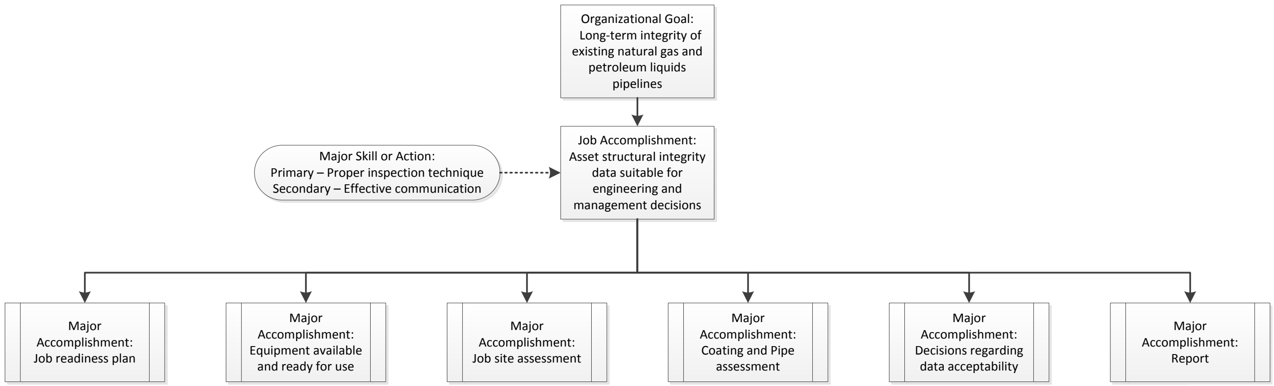


Figure 1. NDE inspector skills and job accomplishment output captured in phase 1.

The major accomplishments shown in Figure 1 are defined as follows:

- Job readiness plan → a plan is developed to gather the data needed to complete a given job.
- Equipment available and ready for use → the appropriate equipment for a given inspection is identified and gathered.
- Job site assessment → the job site is evaluated with respect to overall safety, access to the test specimen, environmental factors (e.g. weather, noise), and accuracy of the job traveler.
- Coating and pipe assessment → the test specimen is assessed.
- Decision(s) regarding data acceptability → the raw data is inspected to determine its acceptability (i.e. repeatable with all faults identified).
- Report → the data is compiled and delivered in a final report to the client.

APs rated each major accomplishment above on two scales: difficulty and importance (1 = low; 5 = high) (see Figure 2).

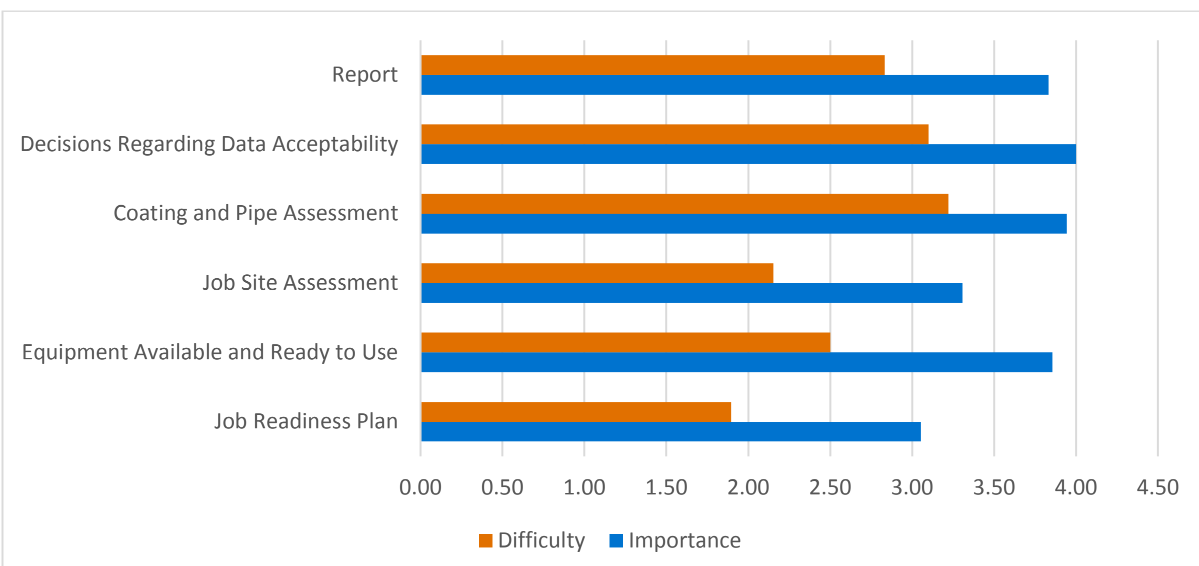


Figure 2. Average importance and difficulty ratings for summary major accomplishments.

Analysis of the combined difficulty and importance ratings indicate that APs place the greatest emphasis on (1) decisions regarding data acceptability, (2) the coating and pipe assessment, and (3) production of the final report. A complete description of the scale content and questioning approach is in the phase 1 final report.

APs were also asked to identify both positive and negative influences on the quality of the inspection process. Their responses were used to organize and prioritize documented performance shaping factors (PSFs)[4] into seven (7) key categories as provided in the list below.

PSF1. Organizational

a. Organizational structure (authority, communication channel(s))
b. Actions by supervisors, coworkers
c. Rewards, recognitions, benefits
d. Team structure and communication
e. Plant policies
f. Feedback of results
g. Threats (of failure, loss of job)

PSF2. Operational

a. Procedures required
b. Work methods
c. Plant policies
d. Training provided

PSF3. Work Task

a. Work hours/breaks
b. Work methods
c. Task speed
d. Task load
e. Task frequency and repetitiveness
f. Task complexity
g. Work risk
h. Monotonous work
i. High vigilance
j. Distractions

PSF4. Technology

a. Availability and adequacy of equipment/tools
b. Man-machine interface factors

PSF5. Physiological/Cognitive

a. Long- and short-term memory
b. Calculating requirements
c. Interpretation requirements
d. Stress (onset and duration)
e. Fatigue
f. Pain or discomfort

PSF6. Personality

a. Intelligence
b. Motivation and attitude
c. Emotional state
d. Group identification

PSF7. Environmental

a. Temperature
b. Humidity
c. Air quality
d. Lighting
e. Noise
f. Vibration
g. Degree of general cleanliness
h. Movement constriction

[4] J.D. Moré, A.S. Guimaraes, G.B. Xexéo and R. Tanscheit (2007). A fuzzy approach to the evaluation of human factors in ultrasonic nondestructive examinations. *Journal of Industrial Engineering International*, Vol.3, No.5, 41-52

This prioritized PSF list, and the relative ranking of major accomplishments by importance and difficulty, formed the basis for decisions regarding the interventions that were proposed, developed and investigated by the three partner organizations during the phase 2 and 3 portions of this program. The interventions developed, how they were implemented and evaluated, and the results related to influencing inspector performance are summarized in the remainder of this report. Details for each of the interventions are found in the partner final reports as referenced in the sections below.

5 Phase 2 and 3 Management Approach

Upon PHMSA approval to proceed into the next phases of the project in October 2016, Battelle issued a phase 1 final report and a request for proposal (RFP) to each partnering organization (Mistras, Applus, and JENTEK). The RFP sought proposals to implement and evaluate human or technology interventions that had the potential to improve inspection/inspector performance. The RFP indicated interventions were to be created with a systems approach that included time for analysis, design, development, implementation, evaluation and reporting within a project period of performance ending June 2018.

Derived from phase 1 results, each RFP outlined broad areas for potential interventions related to (1) improved client service provider communication, (2) improved or new training resources, (3) improved or new inspector work engagement resources, and (4) inspection technology improvements. However, bidders were invited to respond with interventions having the potential to improve inspection performance in any category of PSFs listed in Section *4 Summary of Phase 1 Results* of this report.

Through this process, contract awards were made to each of the partner organizations for development and evaluation of interventions as shown in Table 4.

Table 4. Proposed interventions by partner, phase, and PSF addressed.

Partner	Phase	Planned Intervention(s)	PSF Addressed
Mistras Group	2	• Additional employee training/Mentoring program • Improved Traveler Form • Wellness program/Online training webinars • Lessons learned webinars • Improved employee recognition program	PSF1c, d, f PSF2a, d PSF5d PSF6c
ApplusRDT	3	• Improvements to Applus Inverse Wave Field Extrapolation (IWEX) technology to improve identification and interpretation of inspection images	PSF2a PSF3d, f, i PSF4b PSF5b, c
JENTEK Sensors	3	• Improvements to JENTEK Stress Corrosion Cracking (SCC) mapping and crack depth analysis tool to improve speed and accuracy of inspection	PSF2a PSF3b, c, d, e, f, h, i PSF4b PSF5a, b, c, e, f PSF7h

Summaries of the approach, implementation, evaluation, and results for each of the planned interventions shown in Table 4 are provided in the following sections. In some instances, the interventions proposed were either not fully implemented or implemented late in the schedule due to unforeseen organizational complexities. These circumstances and outcomes are noted in the appropriate sections below.

6 Human Interventions

This section summarizes Mistras' human intervention results. The content contains excerpts from the draft Mistras final report. A complete description of Mistras phase 2 can be found in their final report, *Human Centric Approach to Improve Pipeline NDE Performance and Reliability, Mistras Project: R17-087*.

In the initial phase of this project, Mistras Group, Inc. represented common practice NDE methods (magnetic particle testing (MT) and ultrasonic (UT) methods) and their application for detecting and sizing cracks in seam welds found in pipelines. During phase 2, Mistras proposed and deployed human-based interventions (e.g., training) to reduce detrimental human factors that hinder NDE performance and reliability that were identified during phase I of the project. The areas identified as needing improvement corresponded to: client-service provider communication, training for employees, and employee engagement.

During phase 2, Mistras promoted and verified awareness of Mistras inspection procedures and identified sources of improvements to their "Traveler Form". Training for employees was approached by delivering online seminars/training dealing with pipeline site protocol, customer expectations and communication and professionalism. Mistras also conducted "lessons learned" style discussions to present case studies and deployed an active mentoring program. Finally, employee engagement, was addressed by devoting effort to increasing visibility and diffusion of existing employee recognition programs with customers, by offering the employees webinars and access to online support, as well by distributing materials with guidelines for healthy living and stress management.

Mistras expected that improvements provided by the planned interactions listed above would have a positive correlation between increased inspection quality and improved key performance indicators (KPIs). The methodology has not been able to clearly identify the effect of each intervention of the KPIs or other employee performance improvements produced by any training delivered during the program.

Access to the technicians was limited throughout phase 2 due to the availability of technicians and the schedule of inspections. This impacted the schedule to complete and implement the interventions in the program. Having most of the activities delivered electronically via online training, webinars, videos, and conference calls helped the technicians participate while they had down time between inspections. For the Long Beach lab, this was the only method to deploy a program. The Heath Lab management was able to gather technicians together with more ease than the Long Beach Lab, that was likely possibly due to the lighter work load and bigger personnel group.

As part of this program some modifications to the traveler were implemented. The quality of the work observed by KPI's of the Labs seems to have seen an improvement in the Heath Lab, and not very clearly on the Long Beach, CA lab.

The participants considered the time investment on the activities a useful practice. Good working and personal relationships were developed between mentor and mentee pairs. The training provided about organizational skills, and time management was well received by the technicians. The training related to introduction to pipeline operation was better received by less experienced technicians than the more experienced technicians. The mentoring program was also well received and was identified that it was a good time and effort investment for the mentees.

The presentations helped newer technicians identify the important factors to pay attention to during an inspection. However, preparing a presentation was an unfamiliar task to most technicians.

6.1 Performance Shaping Factors Addressed

Participants from Mistras took part in one of the proposed interventions shown in Table 4 during phase 2. Each intervention had a unique objective and was evaluated by metrics specific to each intervention as described in the following sections.

Table 5 links the modifications to, or implementation of, the Mistras human interventions to PSFs identified in phase 1 of this program.

Table 5. Performance shaping factors addressed by Mistras human-based interventions.

Description	Performance Shaping Factor(s) Addressed
1. Pipeline 101/Mentor Program Implementation	PSF1a, b, d PSF2b, d PSF5b, c
2. Improved Mistras Job Traveler	PSF1e PSF2a, b, c
3. Online Training Seminars/Employee Wellness Program	PSF2d PSF3a PSF5d, e
4. Lessons Learned Webinars	PSF1a, f PSF6d
5. Employee Recognition	PSF1b, c, f

6.2 Description of Personnel Groups

Seventeen (17) technicians were recruited from two Mistras laboratories (Long Beach, CA and Heath, OH). The laboratory located in Long Beach had a total of N=11 technicians participate in phase 2 of the program. The laboratory located in Heath had a total of N=6 technicians participate in phase 2 of the program. Each cohort of participants was tested against a control group that was tracked and surveyed but did not participate in any interventions.

Participants came from three types of Mistras inspectors:

- **Level I UT/MT Technicians –** customarily these individuals can calibrate and execute test procedures *with* the supervision of a Level II or III technician.
- **Level II UT/MT Technicians –** typically these individuals can calibrate and execute test procedures *without* supervision. They may also conduct test assessments.
- **Level III UT/MT Technicians –** these individuals are experts in their respective technologies and not only calibrate, execute test procedures, and conduct test assessments *without* supervision but are often responsible for training and advising Level I and Level II staff.

6.3 Intervention Metrics

To better evaluate the impact of a given intervention on a specific inspection technique (i.e. magnetic particle testing and ultrasonic testing), the results for each intervention are broken out between the two participating labs where appropriate. The laboratory located in Heath primarily performs pipeline inspections using magnetic particle inspection techniques. The laboratory located in Long Beach primarily performs pipeline inspections using ultrasonic inspection techniques.

As part of their normal operations, Mistras collects and analyzes data to track the effectiveness of their quality assurance program (QAP). This data is referred to as key performance indicators (KPI). The KPIs tracked for each inspection include, but are not limited to the following:

- On time delivery
- Accuracy of reporting
- Customer satisfaction
- Safety and production
- Audit results

To assess, track and compare the technical performance of the technicians participating in the program, Mistras developed a *Technician Score Card*, which is filled out per employee and per inspection and is shown in Appendix A. Each item on the score card is linked back to one of four high level performance metrics and was designed to correlate to the KPIs used to assess the Mistras QAP. The four main items used on the *Technician Score Card* were:

- work quality,
- quantity of work performed,
- work efficiency, and
- organizational skills.

Table 6 describes how the work of each technician was evaluated against the four-performance metrics above:

Table 6. Mistras inspector performance description background.

Quality	Quantity	Efficiency	Organization
Number of reports needing revision	Number of points inspected	Preparation time for an inspection	Time management onsite

Quality	Quantity	Efficiency	Organization
Number or reworked points	Number of reports produced	Time to produce report	Ability to complete pre-inspection and post inspection tasks
Completeness of documentation (traveler, timesheet, permits, other)	Inspections performed per period	Time to complete inspection documentation	Ability to document activities
Calibration/Verification of system and materials for inspection			Ability to communicate status to the team or manager
Technical ability of method being performed			Ensure all proper equipment to perform job correctly/efficiently and is in good working order
Understanding of procedure and acceptance criteria			

As study participants performed their normal work, they were assessed at the end of each project. Scorecards were filled out by Level III inspectors or project managers. The scorecard then became part of the project record. The scorecards were then compiled and used for comparative analysis of the effectiveness of the mentoring program and training. Participants were assessed on a 1 to 10-point scale, with 10 being the highest score per category.

6.4 Additional Employee Training/Mentorship Program

Mistras developed an inspector mentoring program along with additional training that was delivered to select personnel.

6.4.1 Additional Employee Training

Pipeline 101 Course

A special *Pipeline 101* course that was delivered to select personnel. The *Pipeline 101* course was a 1-day seminar that presented Mistras procedures and presented industry requirements for performing radiographic testing (RT) inspections. The *Pipeline 101* course was also used to help guide inspectors and create materials that summarize procedures, standards, and other tasks that should be followed throughout the entire pipeline inspection process. Mistras developed questionnaires and checklists to verify understanding of personnel activities and responsibilities. The Heath laboratory administered the *Pipeline 101* course during November of

2017. The Long Beach laboratory administered their *Pipeline 101* course during February of 2018.

Introduction to Pipeline Operation and Protocol

Mistras developed a special training seminar entitled *"Introduction to Pipeline Operation and Protocol"* and delivered the training to the technicians who were participating in the employee mentorship program. This seminar identified Mistras procedures regarding inspection preparation, traveler preparation, documentation, and reporting. The topics delivered as part of this training were: NDT Techniques for Pipeline Reliability Inspections, Pipeline Site Protocol, Pipeline Terminology, Pipeline NDT Reporting and Documentation, Communication and Professionalism. This training was not focused on a specific NDT technique, but intended to show technicians how to navigate inspections in "the ditch". The training was delivered in person and was recorded and made available to personnel that had to be on a jobsite while the training was provided.

6.4.2 Mentorship Program

Inspectors that completed the Pipeline 101 course were also assigned a mentor to help improve technical knowledge and improve on-the-job learning and retention. Inspectors were paired based on their experience level (e.g. Level I technicians paired with a Level II technician and Level II technicians paired with Level III technicians). Mentorship teams met at least once a month for a period of six (6) months. The topics discussed at each meeting included (but were not limited to) professional advice, technical advice, personal advice, and guidance related to an unclear procedure.

To objectively evaluate the effectiveness of this intervention, Mistras collected performance scorecard data against a control group of inspectors for a period of 6 months at the Heath lab and 3 months at the Long Beach lab. The scorecard data were compiled for comparative analysis of the intervention effectiveness. Inspectors were graded on a 1 to 10-point scale, with 10 being the highest score.

To gain subjective feedback on the effectiveness of the *Pipeline 101* course and the mentorship program, Mistras administered questionnaires to each inspector that participated in the intervention. The results are presented in the sections below.

6.4.3 Subjective Results

Additional Employee Training

The usefulness of the training (from the technician perspective) was assessed via surveys applied to the participants.

Overall, technicians indicated that the material provided (i.e. *Introduction to Pipeline Operation*) was not significantly relevant to highly experienced technicians. Experienced technicians wanted a more technical related training that focused on advanced techniques. Based on the comments, Mistras determined that the training provided as part of this program would be very useful for junior technicians. After the *Introduction in Pipeline Operation* training was delivered, the participants were asked to complete surveys on their opinions of the course. The results of the subjective surveys are shown in Figure 3 and Figure 4.

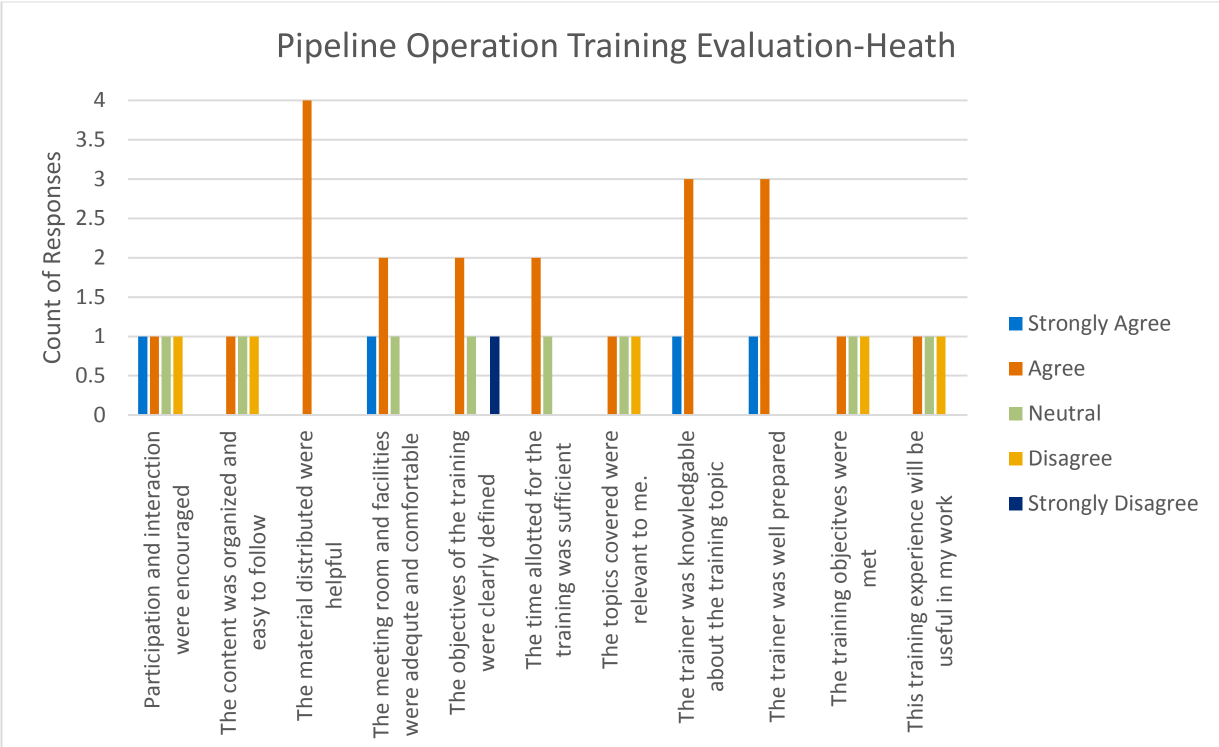


Figure 3. Pipeline Operation Survey Results (Heath)

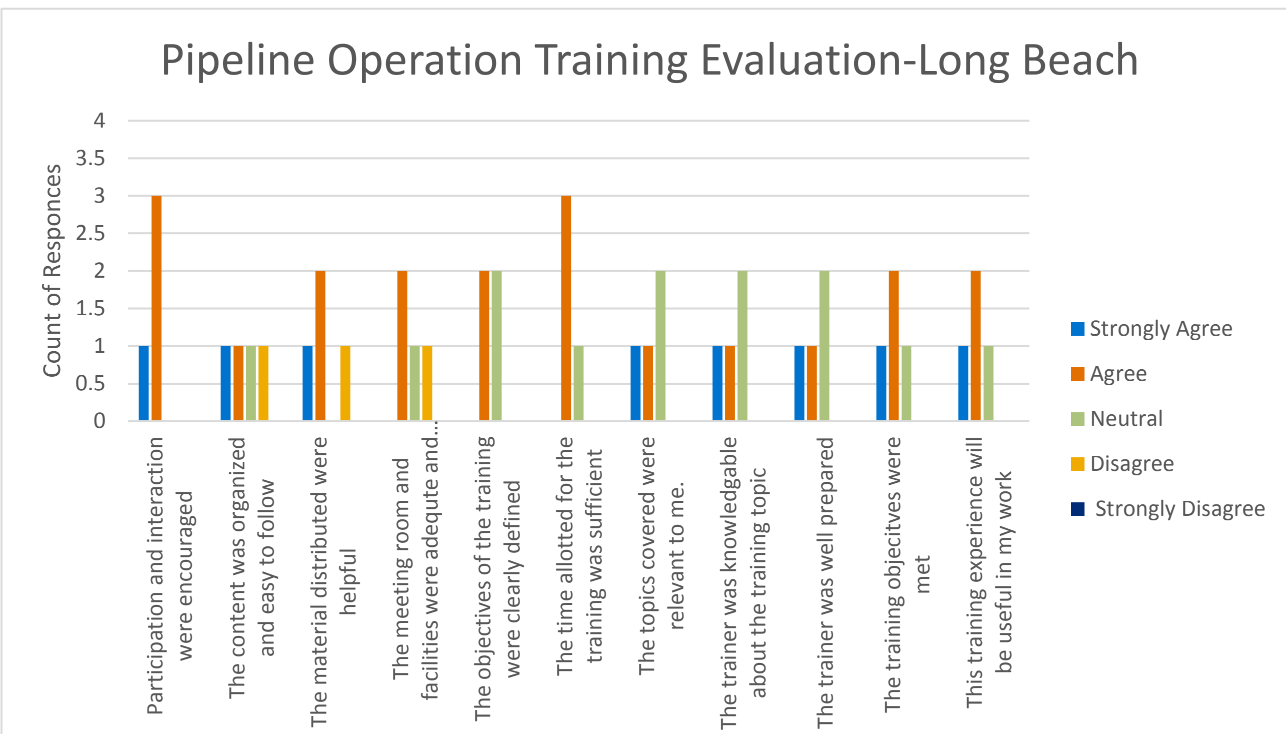


Figure 4. Pipeline Operation Survey Results (Long Beach)

Overall, both the *Introduction to Pipeline Operation* class and the *Pipeline 101* video were well received by the technicians. The most common feedback that was gathered from the participants was the both training would be helpful to get a newly hired technician up to speed and/or serve as a refresher on various inspection aspects for junior technicians. In general, the more experienced the participant was (e.g. Level III) the less value they saw in the training materials provided.

Mentorship Program

The usefulness of the mentorship program (from the technician perspective) was assessed via surveys that were given to every participant who completed the program.

Overall, the mentees rated as the mentorship program as “Good”. On the question *How would you rate the mentorship program*, the Heath lab had a 100% response rate of “Good” and the Long Beach Lab showed a more varied level of response (75% of responses ranged between “good” to “very good”).

The mentors also provided feedback on the program via survey and, in general, found the program to be useful with 100% rating the program “Good” or better and all the mentors felt that the time spent had some benefit to the mentee. Only one respondent showed hesitancy to continue being a mentor.

Using word-frequency mapping, the results show that the most mentioned word was “mentor” followed by “mentoring.” This leads to the conclusion that most of the comments were focused on the process of mentoring as well as on the role of the mentor. The ratio of positive to negative words is 2:1. In context, the positive word occurrences were about the mentor-mentee relationship. As a result, the connotation of the comments was positive and appear to support the conclusion that the program was well received overall.

6.4.4 Heath Performance Results

Each participant was evaluated on 13 categories as detailed in the *Technician Score Card* (Appendix A). Prior to the *Pipeline 101* training class (hence forth called *training*) the only category that the mentee group was statistically significantly different from the control group was the “arrived on-site on time and notified contact” category. After the training was delivered, however, there were many more categories where the mentee group had a statistically significantly higher average than the control group. Of the 13 categories, the mentee group showed a statistically significant improvement in 11 categories. The only categories where no difference was found were “pre-Inspection tasks completed” and “followed all applicable safety protocols.” While these two results are statistically the same, the P-value for the “pre-inspection” result is 0.08 as compared to the critical value of 0.05 (for a 95% confidence) which would indicate that there may be a practical improvement. The “followed all applicable safety protocols” result is to be expected, with the lab placing a significant importance on a safe working environment.

A complete statistical analysis can be found in the Mistras final report. However, it is important to note that while the number of observations is limited (20 total, 7 pre-training and 13 post), as is indicated by the relatively low degree of freedom value in each T-test, what can be inferred from the data is that there is a positive correlation between the mentoring/training program and performance of the technicians in all categories. All the linear regression best fit lines for those in the intervention show a positive slope, indicating that the performance is improving with time. The control groups are either flat or declining over the same period.

The mentee group also shows an overall positive correlation among all categories, which is different from the control group. This lends further credibility to the hypothesis that the mentoring/training is having a positive effect on the program participants.

6.4.5 Long Beach Performance Results

Each participant was evaluated on 11 categories as detailed in in the *Technician Score Card* (Appendix A). Prior to the *Pipeline 101* training class, the only category the mentee group was statistically significantly different from the control group was "punctuality" and "quality". After the training was delivered, the mentee group was not statistically significantly better than the control group in any category. Unlike the findings in the Heath lab, the control group appears to perform as well or better than the mentee group in every in almost every category. A complete statistical analysis can be found in the Mistras final report.

The mentee group does not show a strong correlation among all categories. This would indicate that that there is little change (positive or negative) in time for the categories.

6.4.6 Pipeline 101/Mentorship Conclusion

Each data set consisted of roughly the same number of categories (13 and 11) and are on the same scale of 1-10. The labs are not, however, evaluated on the same criteria due to the difference in methodology employed for each location (magnetic partial vs ultrasonic testing). The mentoring program is also implemented in a different fashion at both labs with a more clearly defined separation of roles in the Heath lab; the Heath lab clearly defined the mentor-mentee relationship between the participants while the Long Beach lab approached the roles with a more fluid view.

Given the data available, there is evidence to show that there have been positive effects on participants in the program in multiple categories at the Heath lab. However, the Long Beach lab shows limited impact due to the program. The Heath lab also shows a strong positive correlation among all categories for the program participants as compared to the control group. The impact is not evident with the Long Beach lab.

6.5 Improved Mistras Job Traveler Form

Currently, Mistras has a special form called the *Job Traveler Form* where all details about the contract, statement of work, safety requirements, and other inspection related details are defined (Figure 5).

MISTRAS Asset Protection Solutions | Services Division

Job Traveler

Customer Number:	Customer Name:
Customer Address:	
Contact:	Phone Number:

Mistras Job Number: 596476	Contract/PO Number. 86576
Work Location:	
Project Start Date: 5-7-2014	Project Start Time: 7:00 am
Projected Completion Time: 7pm	Report Requirements: Turbine reports

Project Description:

Code/Specification/Drawing	Rev/Issue	Procedure/Work Instruction	Rev	Acceptance Criteria
ASME V	N/A	100-MT-001	10	per customer
		100-PT-001	9	
		100-UT-001	10	
		100-UT-002H1	0	
		100-UT-002I	0	
		100-VT-001	4	

Equipment Required	Additional Information
UT,UTT,MT,PT as required UT Scope & transducers,Couplant MT Yoke and 8A Red,14A,MFI,Black light and light meter PT Penetrant,Developer and Remover MT Machine	Proper PPE Hard hat ear protection Safety Glasses Safety Shoes Harness and Lanyard Contract Invokes 10 CFR 50 Appendix B: ☐ Yes ☒ No

Contract Review & Project Authorization:

Operations (sign) (date) | Quality Assurance/Level 3 (when required) (date)

Customer (if applicable):

(company) (name print) (sign) (date)

Project Close Out:
Inspection reports have been completed and reviewed. Nonconformances have been closed. Material/parts are released for shipment.

(sign) (date)

Comments:

Figure 5. Old Mistras job traveler form.

Figure 6 below shows the general procedure followed when a customer requests an inspection.

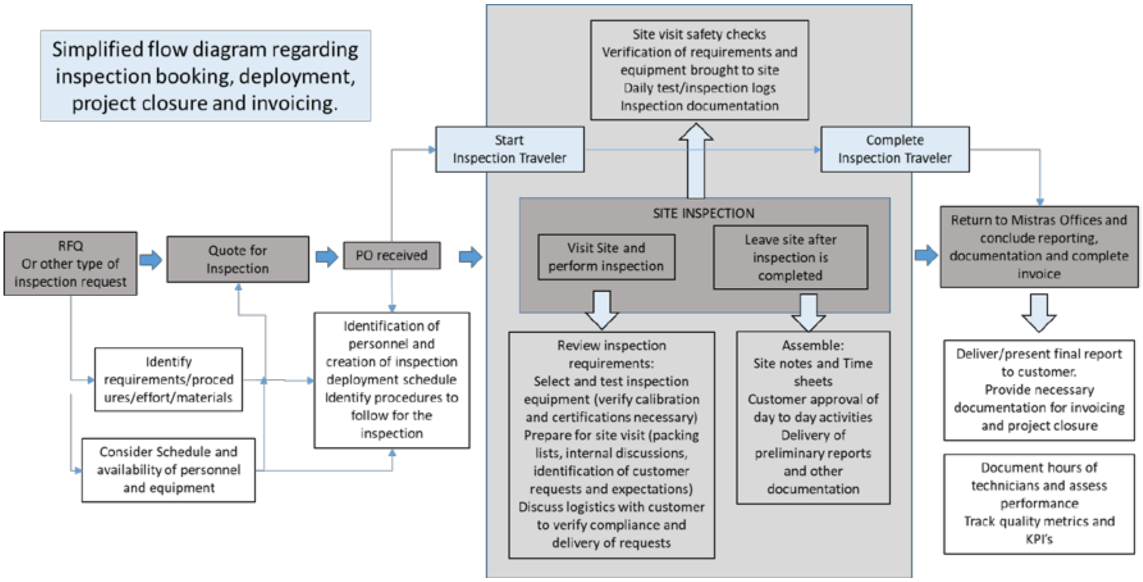
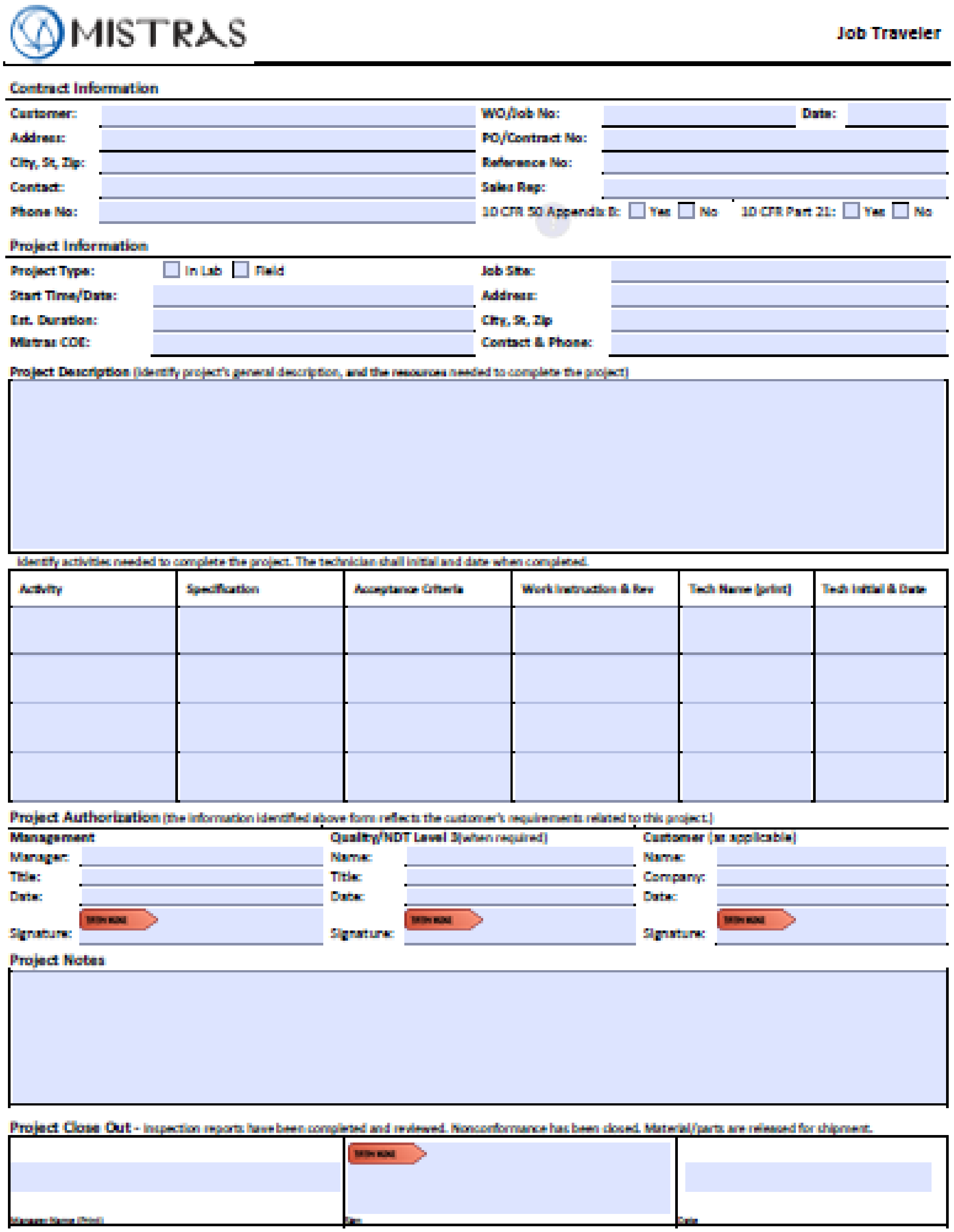


Figure 6. General steps necessary to complete a job traveler form and perform an inspection.

This intervention focused on simplifying the job traveler form and format the form to combine several existing fields into one field called “Project Description.” The rationale for the simplification is that the materials, certification requirements, and equipment needs are clearly stated in the work procedures. The format change forces the technician verify the work procedure rather than rely on a limited description of requirements and equipment that was provided as on the old form. The updated form is shown in Figure 7.


MISTRAS Job Traveler

Contract Information

Customer: | WO/Job No: | Date:
Address: | PO/Contract No:
City, St, Zip: | Reference No:
Contact: | Sales Rep:
Phone No: | 10 CFR 50 Appendix B: Yes No | 10 CFR Part 21: Yes No

Project Information

Project Type: In Lab Field | Job Site:
Start Time/Date: | Address:
Est. Duration: | City, St, Zip
Mistras COE: | Contact & Phone:

Project Description (Identify project's general description, and the resources needed to complete the project)

Identify activities needed to complete the project. The technician shall initial and date when completed.

Activity	Specification	Acceptance Criteria	Work Instruction & Rev	Tech Name (print)	Tech Initial & Date

Project Authorization (the information identified above form reflects the customer's requirements related to this project.)

Management | Quality/NDT Level 3(when required) | Customer (as applicable)
Manager: | Name: | Name:
Title: | Title: | Company:
Date: | Date: | Date:
Signature: | Signature: | Signature:

Project Notes

Project Close Out - Inspection reports have been completed and reviewed. Nonconformance has been closed. Material/parts are released for shipment.

Manager Name (Print) | Sign | Date

Figure 7. New Mistras job traveler form.

As part of this project the time sheets, field notes and any inspection specific check lists are attached to the documentation. Mistras hypothesized the new information would provide:

1. Improved technician time tracking under specific codes, which is critical for maintaining certification records,
2. Reduced billing errors, and
3. Timely revision of the specific work orders and procedures before getting to site, to pack and prepare for the inspection appropriately.

6.5.1 Improved Traveler Results

Changes to the traveler and the activities associated with this program began in June of 2017. Mistras KPI data, which is calculated every six months, was used to assess the effectiveness of the traveler changes. It should be noted that improvements might also be the effect of the training that was delivered throughout phase 2, as well as gained experience of technicians. However, since the updated traveler was distributed to every technician in each lab, the influences of other interventions are expected to be minimal.

A summary and comparisons of data from 2016 and 2017 is shown in Figure 8, where an increase in customer satisfaction can be observed.

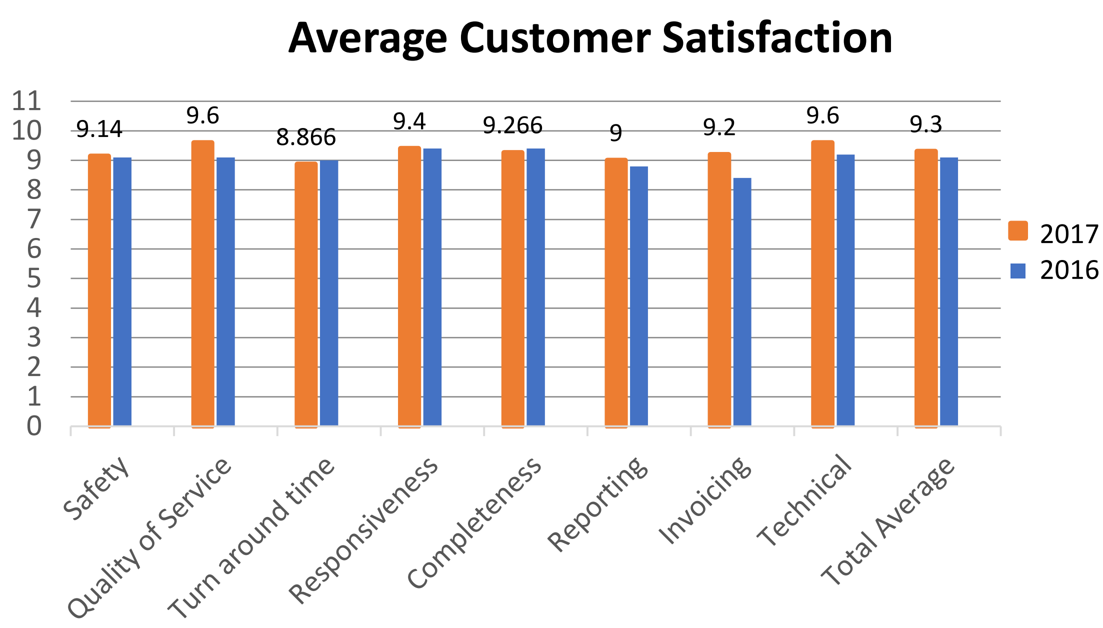


Figure 8. Average Customer Satisfaction

Figure 9 shows on-time delivery rates per technique. The figure compares the first half of 2017 and the second half of 2017 (after the updated traveler was implemented). This figure shows that on-time delivery improved for some techniques (PT and MT) over the course of 2017. However, UT and RT experienced a reduction in on-time delivery over the same time. Mistras hypothesizes that the overall reduction in on-time delivery might be a combination of technician absences (due to medical and family leaves) and an increased complexity in the inspection type booked during the second half of 2017. The data does not indicate that the new traveler had any impact on on-time delivery.

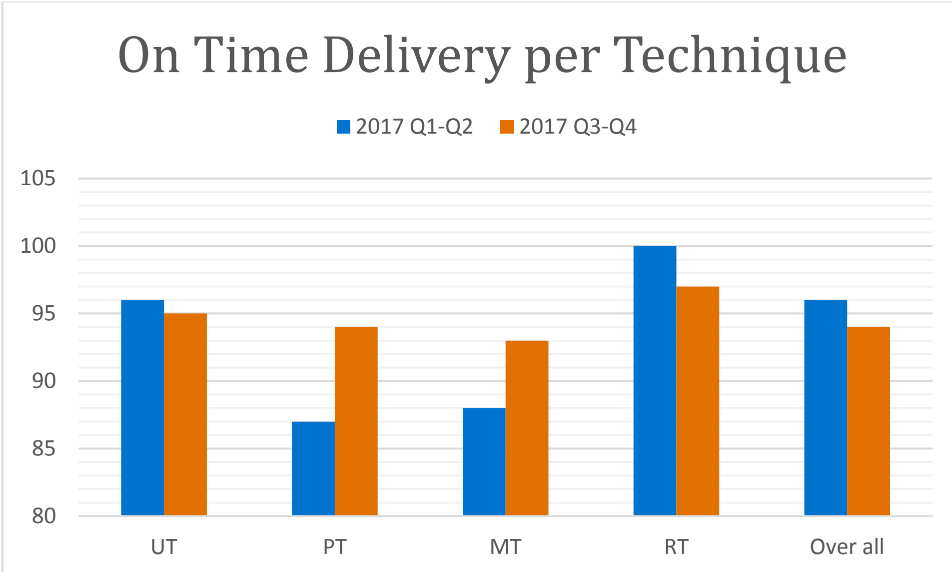


Figure 9. On-time Delivery per Technique

Figure 10 shows a comparison of reporting errors found for all inspections performed during the first part of the year and the second part of the year (i.e. after the updated traveler was implemented). The figure shows the errors that were caught before the reports were sent to customer (i.e. Errors Caught) and the errors that were caught by the customer (i.e. Not Caught). Overall, Mistras experienced a reduction in reporting errors, but the variation between the first and second half of the year is small. It is not apparent that the updated traveler had any impact on reducing reporting errors.

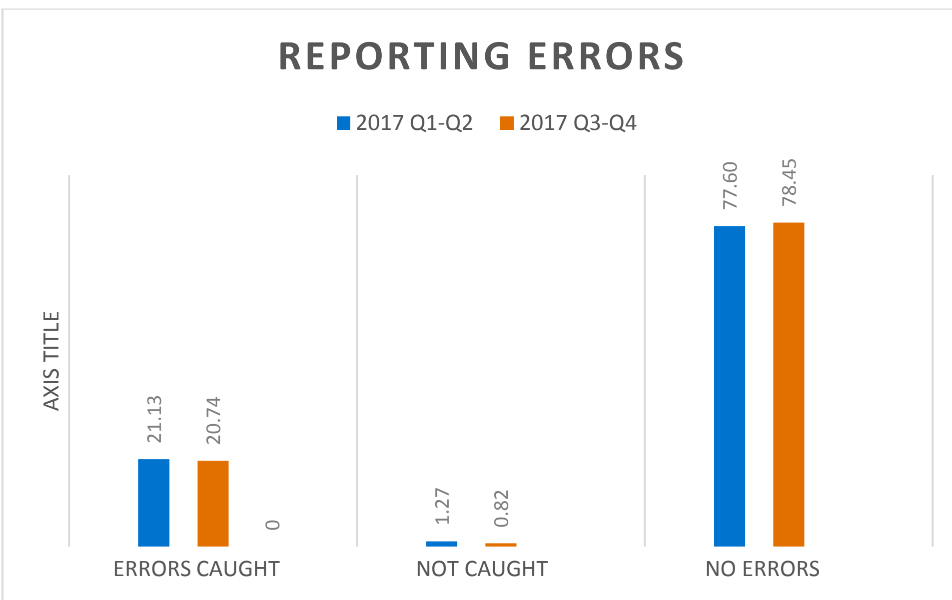


Figure 10. Reporting Errors

6.5.2 Improved Traveler Conclusion

Modifications to the traveler were intended to simplify the effort of filling-out the document by reducing the amount of detail needed and guide the technicians in charge. The new traveler was intended to direct the technician to consult the specific inspection procedure(s) needed for the given job. However, the updated traveler did not show a significant change in customer satisfaction, on-time delivery, and reporting errors over the course of the evaluation period.

Considering that some improvements in customer satisfaction and reporting errors were observed, a longer evaluation period and more data points may be necessary to further evaluate the impact of the updated traveler on technician performance.

6.6 Employee Wellness Program / Online Training Seminars

To help provide inspectors with information regarding wellness plans and available benefits that are not fully exploited by personnel, Mistras offered online tools with guidelines for healthy living and managing stress. Mistras also provided short information sessions that discussed diet, exercise, relaxation and mindfulness practices for inspectors.

The activities above were intended to increase employee engagement and employee satisfaction, as well as provide inspectors with the tools to improve their organizational skills, time management skills, ability to deal with frustration, and improve the capability of focusing on relevant work-tasks.

Members of the labs completed two types of assessments, an initial assessment of their current emotional wellbeing and a survey inquiring into the desired activities to improve the participants overall wellbeing. The initial assessment involved identifying the stress levels of each program participant via the initial assessment survey. The initial assessment survey asked participants to grade how much the experienced various stress related emotions on a Likert-based scale in the last four (4) weeks. The second survey focused on what types of wellness activities each technician would like to see as part of a Mistras provided wellness program. Typical responses included sports/exercise programs, health and dietary advice, and personal development programs.

After technicians completed both surveys, they began participation in the program. The program involved the presentation of the following topics:

- Organizational Skills: "Tactics for Time Management and Organizational Skills”
- Stress Management: “Practical Stress Management: A Mind-Body Approach”
- Social Intelligence: “Golden Book: How to Win Friends and Influence People”
- Work Life Balance: "Increasing Your Happiness"
- Well Being as a Skill: "Creating Resilience in Times of Extremes", and
- Mindfulness: "How mindfulness can help you to live in the present"

The information above was provided as handouts, videos, podcasts, and webinars. The materials could be reviewed by the program participants on their own time.

The Mistras Human Resources department did not want to limit the wellness program to a select number of participants (i.e. any wellness program would have to be offered to the entire company). As a result, implementation of this intervention was delayed until April 2018, and no performance-based data are available. However, the surveys of the activities performed do indicate that employees want to be involved in programs that focus on organization, maintaining healthy practices, and creating mindfulness practices. Inspectors who participated in the intervention have requested to share information provided with others and to make the wellness program a companywide program. Additionally, the technicians who presented at the *Lessons Learned* webinars anecdotally brought up how a successful inspection was linked to the items above.

6.6.1 Employee Wellness Program Literature Review

A review of the published literature on wellness programs was conducted to better evaluate the potential impact of corporate based wellness programs on employee performance.

A representative, though not exhaustive, list of keywords and phrases used to conduct the wellness program literature search is provided in the list below. Secondary searches were also conducted for literature cited in reviewed documents.

- Wellness Program
- Employee Performance
- Employee Productivity
- Health
- Presenteeism
- Corporate Social Responsibility
- Stress
- Social Well-being
- Culture
- Health Promotion
- Cost Savings

There is a large body of literature on the relationship between healthy employees and employee job performance. Overall, opinions on the effectiveness of employee wellness programs are mixed.

Some studies show evidence that employees who participate in an employee wellness program experience a 25% reduction in sick leave. The implication being that reduced absenteeism leads to an increase in productivity. Another study showed that employees who actively participated in employee wellness programs and saw an improvement in their overall health displayed increased productivity of about 10%. However, Gallup researchers suggest that it takes more than simply making a wellness program available to employees to see positive results. Gallup researchers that say that a company must embrace a *Culture of Wellness.* That is, company leaders need to ensure that it is acceptable for employees to perform self-care during the workday (e.g. workout, leave early to participate in a charitable function, etc.). Additionally, company leaders need to regularly communicate the value of the wellness program, help their team members set and track goals related to their well-being, and be an active participant in the wellness program themselves.

Several studies also show evidence that employee wellness programs typically do not experience an improvement in overall health and/or productivity. A study done with employees at the University of Illinois at Urbana-Champaign found that the most likely employees to take advantage of a company offered wellness program are those who are already relatively healthy. Additionally, the study found that those with worse health were less likely to participate in a wellness program. Other studies have found that wellness programs can take as long as three years to yield any measurable benefits.

6.6.2 Conclusion

The effect of the online training webinars and wellness program was not apparent on inspector performance. Given the results of the literature review, Mistras would likely require the total corporate buy-in and the investment of significant time and resources to put in place a wellness program for a long enough period (e.g. 2-3 years) to see measurable results on inspector performance.

6.7 Lessons Learned Webinars

Mistras implement two (2) round table “lessons learned” webinars to help increase the rate of knowledge transfer and to allow inspectors to share information about successful inspections and problem-solving strategies. The webinars occurred from May 17-23, 2018. The round table discussions focused on both successful and challenging projects. The problems or successes experienced during each project were discussed, as well as the factors that heavily influenced the outcome of the project. The round tables also discussed the decision-making process that helped lead to the overall outcome of the project.

6.7.1 Heath Lessons Learned

Presentations from the personnel in the Heath, OH lab were focused on the development of a mentoring relationship and how to use that relationship to better an inspector’s technical performance. The webinar’s goals were to offer encouragement to inspectors to have and develop a dynamic relationship where requesting for advice and offering help more frequently.

It should be noted that the mentor/mentee relationship was a newer concept for the Heath lab, compared to the Long Beach lab, where technicians tend to work more on pairs with different levels of experience.

After the presentations were complete, the inspectors (n=4) who received the presentations completed a Likert based survey to subjectively measure the extent to which they found the information presented by the mentorship pairs useful. Figure 11. Heath Lessons Learned Survey Results below details the results of the survey. In general, the inspectors found the information presented to them to be useful.

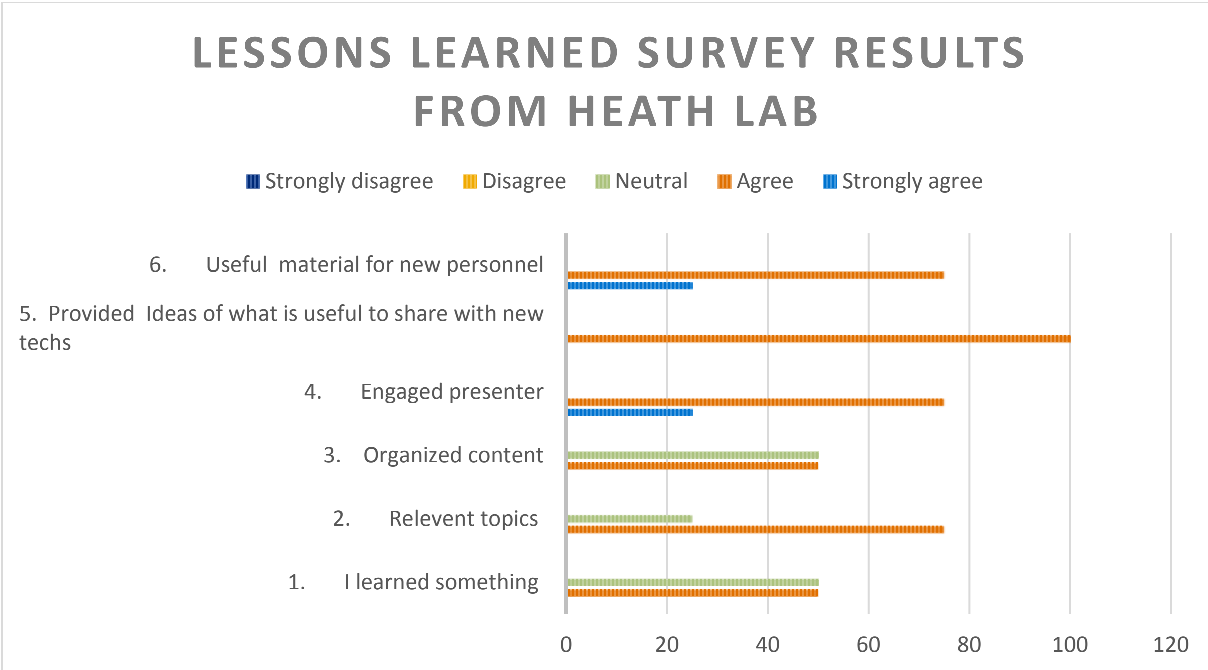


Figure 11. Heath Lessons Learned Survey Results

6.7.2 Long Beach Lessons Learned

The mentor/mentee pairs in Long Beach, CA focused on different aspects of an inspection that they identified as important to pay attention to while the inspection is prepared and deployed. Presentation topics included:

- A summary of several improvement procedures developed by one of the mentors in the program
- Review of safety procedures
- The importance of note taking and documentation while performing an inspection
- Verification of the documentation before leaving the site each day

After the presentations were complete, the inspectors (n=4) who received the presentations completed a Likert based survey to subjectively measure the extent to which they found the information presented by the mentorship pairs useful. The Figure 12 details the results of the survey. In general, the inspectors found the information presented to them to be useful.

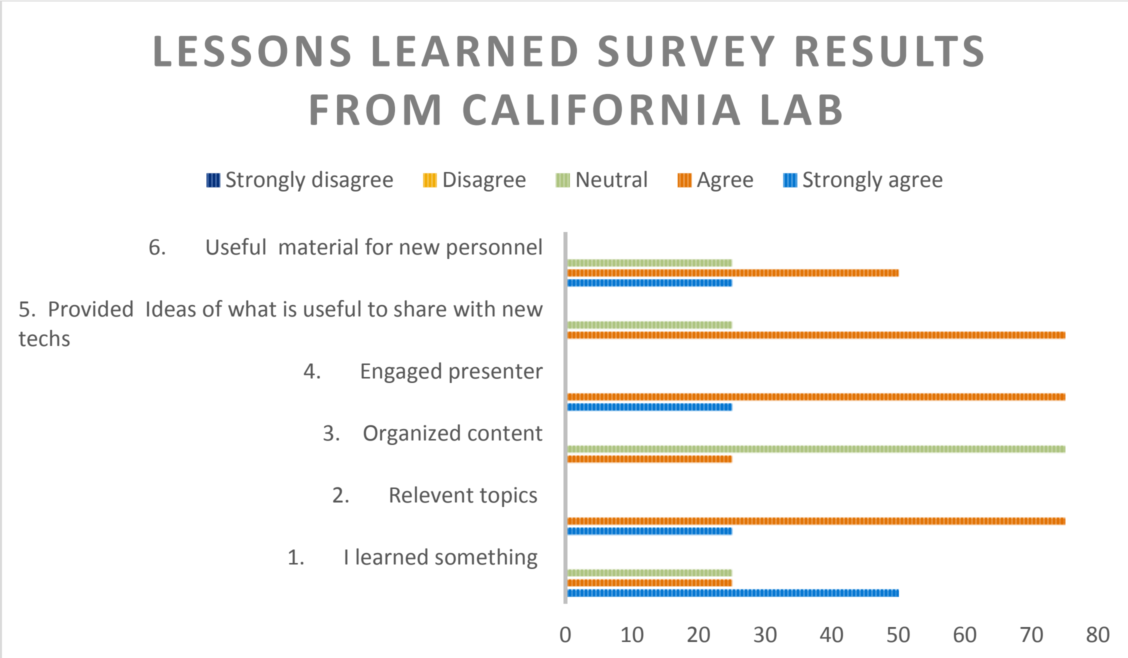


Figure 12. Long Beach Lessons Learned Survey Results

6.7.3 Conclusion

The effect of the lessons learned is not apparent on inspector performance. However, this intervention was highly linked to the mentoring program, as the seminars were implemented at the end of the program as a culmination of the mentor and mentee's time together.

The primary success of the lessons learned was to provide a forum for the technicians to show their work and approach to others. This intervention also led to the development of new materials that can be used by inspectors. These materials take the form of narrated presentations that can be given to newer or less experienced technicians.

The deployment of the lessons learned intervention encountered significant resistance from lab-managers and technicians because of the time and effort required form the mentor-mentee pairs to prepare the presentation. Additionally, mentor-mentee pairs did not necessarily work together in the field for every inspection. However, the content within the lessons learned webinars was generally well-received. The evaluation of a broader implementation of this intervention could better determine the overall effect that lessons-learned webinars have on inspector performance.

6.8 Employee Recognition Programs

Mistras currently utilizes a *Technician Evaluation Form* to gain customer feedback on inspector performance after the completion of a given job. This form provides information used to recognize and reward inspector teams for high quality work. Mistras proposed to take a more personal approach in requesting customer feedback and following up with an email to the customer that would contain a link to the *Technician Evaluation Form.* Mistras intended to use the information from the *Technician Evaluation Form* to provide personal recognition to inspectors and to identify successful inspection teams to use as positive examples for the rest of the lab.

However, due to lack of customer follow up by Mistras project management, this intervention was proposed but never fully implemented during phase 2. Mistras was unable to implement a successful process change for requesting customer feedback. These findings indicate that some human-based interventions need to account for corporate bureaucracy and properly identify all stakeholders prior to implementation. Future considerations should include all potential stakeholders during the design phase of the intervention.

7 Technology-Based Interventions

7.1 Inverse Wave Extrapolation (IWEX)

This section summarizes Applus' IWEX technology modifications and operational results designed to reduce the negative impact of human performance shaping factors on the speed and accuracy of an inspection. The content contains excerpts from the Applus RTD draft report. A complete description of Applus RTD phase 3 work will be in their final report, *Human Centric Approach to Improve Pipeline NDE Performance and Reliability, Phase III*.

The updates applied to the IWEX tool during phase 3 comprise improved automated calibration to facilitate data acquisition and image production, inclusion of a decision tree for the inspection procedure, and improved processor software to facilitate detection, classification and sizing of field scan image data.

Table 7 lists the improvements of the IWEX technology modifications and links each improvement to PSFs identified in phase 1 of this program.

Table 7. Performance shaping factors addressed by IWEX technology-based interventions.

Description	Performance Shaping Factor(s) Addressed
1. Improved Automated Calibration	PSF3f PSF2b
2. Decision Tree for IWEX Inspection Procedure	PSF2a, b PSF5b, c
3. Automated Detection, Sizing, and Classification of Field Scan Image data	PSF2a PSF3e, f, i PSF5a, b

7.1.1 Improved Automated Calibration

Calibration of IWEX imaging parameters is time consuming and potentially error-prone because optimizing image quality requires manually measuring and/or adjusting a wide variety of parameters simultaneously (e.g. wedge angle, wall thickness, probe center separation/offset). This is a non-trivial exercise and requires experienced operators to perform correctly.

Applus proposed and implemented an approach to automate calibration algorithms to facilitate data acquisition and image production. Complete descriptions of the calibration algorithms developed, and the test results reported, are found in the Applus final report noted above. A summary of activities and results is provided in this section.

Applus developed a calibration tool to facilitate:

- calibration of wedges;
- calibration of wall thickness below the wedge on a single position; and,
- calibration of probe center separation/offset.

The tool was developed assuming a cylindrical pipe with some limited variability. The existing wedge calibration routine was improved in terms of robustness and – through the implementation of a graphical user interface to provide visual feedback – simplicity of use.

The calibration of the wedges consists of three different parameters to be determined consecutively:

- System latency – the delay in the measurement change between sending and receiving the ultrasonic signal.
- Wedge velocity – the longitudinal sound velocity in the wedge influences the travel time from the array to the outer pipe surface.
- Wedge indices – describes the distance from the array center to the outer pipe surface, measured perpendicular to the pipe surface.

All above parameters are now determined from ultrasonic measurements, such that the input of manually determined values, for example using mechanical measurements, is avoided; thereby reducing potential measurement and/or entry errors. As a result, the system latency can now be calibrated without removing the probes from the wedges, the calibration of the wedge velocity and indices uses a higher number of measurements to increase robustness and accuracy, and all parameters are determined for both wedges independently.

7.1.2 Decision Tree for IWEX Inspection Procedure

A decision tree was developed and added to the IWEX inspection procedure with the goal of improving repeatability between operators.

Applus conducted an analysis of the human-machine environment with the goal of defining the optimal conditions to generate consistent inspection results with minimal variability among operators. Inspectors were given pipe samples with electrical discharge machining (EDM) ID/OD notches and asked to scan the samples using IWEX and phased array inspection techniques. This comparison of technology/techniques was performed with the same data set to assess the thought processes used during analysis for decision tree development. A questionnaire was given to generate inspector subjective feedback.

Figure 1313 shows the decision tree as an output of the human-machine environment analysis.

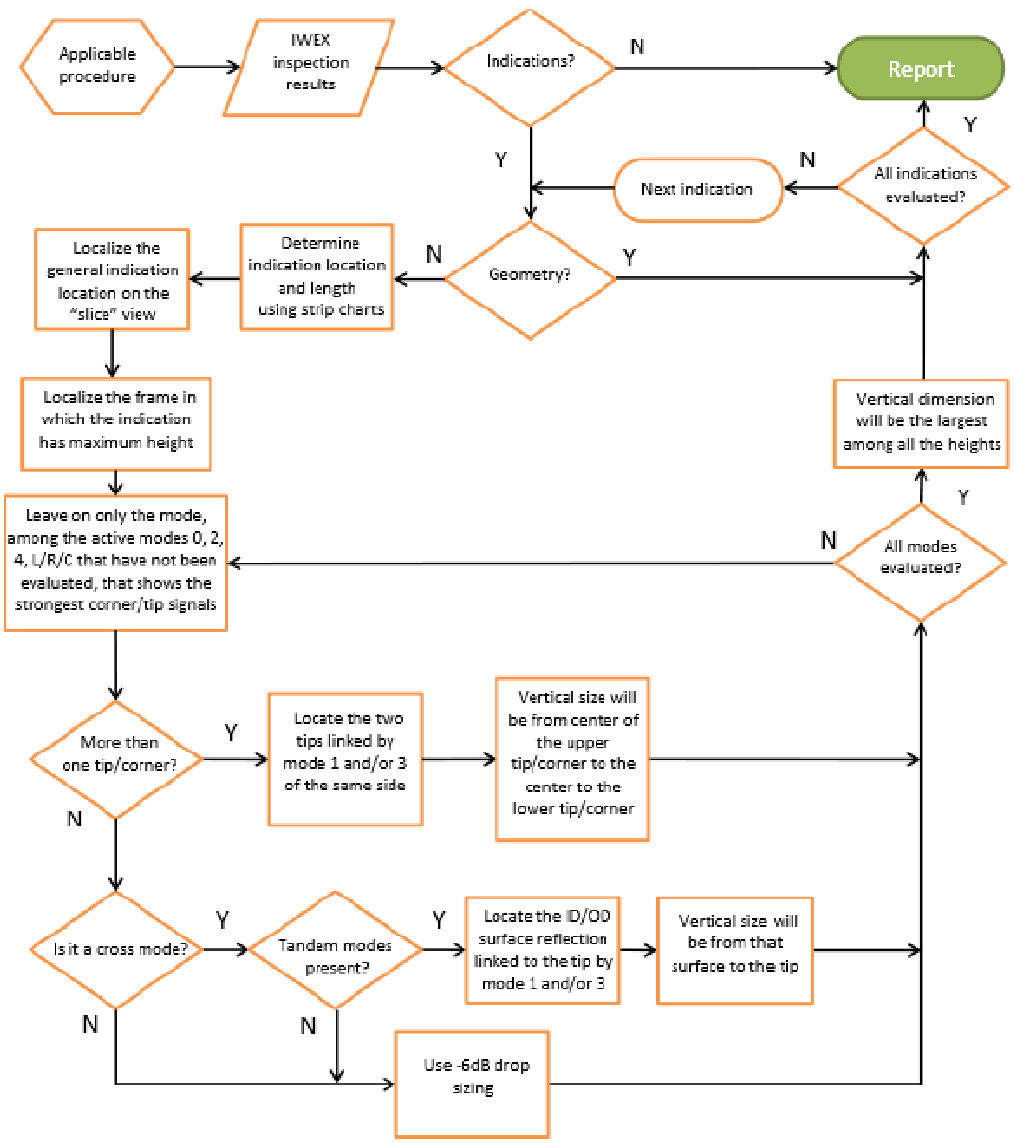


Figure 13. Decision tree for Applus IWEX inspection procedure.

7.1.3 Automated Detection, Classification, and Sizing of Field Scan Image Data

IWEX processor software was modified to facilitate detection, classification and sizing of image data once obtained from field scans.

Applus modified the IWEX processor software to provide 3D and 2D graphical displays of the IWEX data to the operator. The modified processor was designed to render and merge multiple IWEX scan data files in an efficient manner. The modified processor also allows detection and analysis of features within the data.

Applus developed a structured query language (SQL) database to store the feature data of IWEX project files. The SQL database was designed so that data could be exported to allow other inspectors to use existing data for comparison purposes.

Applus also developed a module that merges 1-inch wide scans into a continuous data set. The merging of data was recognized as a need because the inspection width for IWEX is ~1-inch, but the width of an integrity anomaly may be wider than 1-inch. This is expected to make the process of detecting, sizing, and classifying for SCC colonies more accurate and efficient.

To facilitate classification and reporting, inspectors can now automatically or manually classify the features and calculate the severity of a given anomaly. Once all features are sized and classified, the IWEX software also allows for on-site reporting. The reporting process starts with choosing the sections to include in the report. The automated reporting module allows for the generation of the report in different formats (i.e. simple field report vs final report). Testing of the automated sizing has shown consistency in identifying features. The threshold level of the algorithms can be tuned to catch low image amplitude signals and interaction rules (e.g. axial distance, circular distance, and depth distance) between indications to combine small indications in one feature. Early results indicate automated sizing can reduce sizing time up to 80%.

The new IWEX processor is a tool to evaluate the IWEX data files and was developed to reduce errors during analysis and reporting. Detection, sizing, and characterization of the indications can be done with the assistance of automatic detection algorithms that can improve the accuracy of evaluation and reduce the reporting time by up to 80% (i.e. days rather than weeks for large data sets and hours rather than days for smaller data sets).

7.1.4 Modified IWEX Scanner Results

Efficiency Improvements

Applus conducted a series of inspection tests with three employee technicians prior to any modifications being made to the IWEX scanner. The first test was intended to determine how long it takes set up and conduct an inspection with the legacy IWEX system. Table 8 identifies how long it takes each technician to take the equipment out of the box, put it together, calibrate, collect data, interpret data, and draft a report. Each technician was issued the same equipment for this test and the test pieces are in the same condition and prepared before they begin. The same tools are supplied as part of the basic kit that is sent into the field.

Table 8. Efficiency Data (Before IWEX Improvements)

Operator/Technician	Time to set up	Time to calibrate	Time to collect data/avg per sample	Time to analyze data	Time to report
Technician 1	40min	55min	3min	6hr	1day
Technician 2	1hr	1hr	3min	2hr	1day
Technician 3	2hr	2hr	3min	8hr	1day

The first column (time to set up) measured the physical and mechanical dexterity of the technicians. The technicians were not aware that they are being timed and could be influenced by interruptions in the shop with other people and relaxed time restraints. This is not typical of "in the field" inspection setup. Even in controlled conditions, the probe holder is difficult to set up and mount on the scanner. The scanner itself is too heavy and not safe for a single person to manipulate.

The next field (time to calibrate) is a significant part of the inspection process. This can be a stressful step for the technician in the field. During this step they often have the site supervisor (client representative) watching and wanting to get the job done as quickly as possible. An hour of sitting still is unacceptable for some clients and two hours is going to be viewed as unacceptable regardless of inspection quality. This was a factor that was identified for immediate improvement.

The third column (time to collect data) represents the shortest part of the inspection process. No improvements were identified in the scan speed. This is as fast as or faster than other technologies available. Each scan was about 1-meter long.

The "time to analyze data" column shows a large variation between technicians. This variation could be explained by technician experience. Each of the technicians received the same training for IWEX. Out of the four samples specific locations have been identified on one and another sample only contains EDM notches. These two samples take the technician's only minutes to identify and interpret. The other two samples are left to the technician to interpret with no acceptance criteria or direction. This is typical in the field. Identify and report everything. Technician 2 has the shortest time. While all of the technicians all have about the same amount of experience in the field using IWEX in the field Technician 2 has years of additional experience in the field using other technologies to inspect long seam anomalies. This experience helped Technician 2 to better understand the images and the flaws he was identifying.

The last column (time to report) in the table shows the same for all three technicians.

Based on this exercise Applus identified improvements that needed to be made to the probe holder, the weight and/or setup of the equipment to make it more user friendly. Applus's goal was to improve setup times, calibration times, and analysis time.

To test the improvements to the IWEX scanner, another technician was trained and given the same instruction as the previous three technicians. Table 9 highlights the results of Technician 4 using the updated system.

Table 9. Efficiency Data (Initial Modifications)

Operator/Technician	Time to set up	Time to calibrate	Time to collect data/avg per sample	Time to analyze data	Time to report
Technician 4	25min	15min	3min	2hr	45min

Technician 4 displayed significant time improvements using the modified scanner when compared to the previous three technicians. These results are consistent with what Applus is currently observing in the field. Since these improvements have been available, field production has improved for each technician. For example, one technician was on a project where he was scanning full joints and only completing about 60 feet of scanning per day. With the updated scanner, the same technician is now averaging 110 feet of scanning per day.

Applus continued to make improvements to the scanner, GUI, and software throughout the project. After all scanner improvements were complete, Applus conducted the same timed test with the technicians that were initially tested on the legacy system. The table below highlights the efficiency improvements compared to the legacy IWEX scanner.

Table 10. Efficiency Data (Final Modifications)

Operator/Technician	Time to set up		Time to calibrate		Time to collect data/avg per sample		Time to analyze data		Time to report	
	Before	After	Before	After	Before	After	Before	After	Before	After
Technician 1	40min	20min	55min	15min	3min	3min	6hr	45min	1day	2min
Technician 2	1hr	25min	1hr	20min	3min	3min	2hr	30min	1day	2min
Technician 3	2hr	25min	2hr	18min	3min	3min	8hr	45min	1day	2min

Before modifications were made to the IWEX scanner, the average time to set up and calibrate across all three inspectors was 2hrs and 31min. After modifications were made to the scanner, that average improved to approximately 41min. Exactly how much credit can be given to the improved scanner for the observed time savings is somewhat difficult to judge as the technicians were aware that they were being timed during the second scan. However, Technician 4 (from the previous test) showed similar improvements in the "time to set up" category and he was not aware that he was being timed. These gained efficiencies can allow the technician more time to accurately classify any anomalies found in a specimen as well as help minimize the amount of time a pipeline is out of service.

Of all the efficiencies gained with the modified scanner, the "time to report" displayed the most improvement. This is a direct result of the new IWEX processor being able to generate an automatic report. The new processor can export all indications with profiles and screen shots. Substantial improvements to the analysis portion is also apparent across all technicians due to the automatic detection and length sizing capability of the new IWEX processor. This leaves only the depth and height to be verified and corrected if needed, and classification.

Accuracy Improvements

To evaluate the ability of technicians to correctly locate and classify indications while using the legacy IWEX system, technicians scanned two Battelle provided samples and reported their findings. Each technician was only given the location of the indications on each pipe sample and was instructed to provide the classification, height, and depth of each indication. The project lead, Jeff Vinyard's height, depth, and classification of each indication were used as the control.

Table 1111 shows the results of the scan results of the two Battelle provided samples. Scan 1 was based on the technician's manual interpretation (i.e. before modifications were made to the IWEX scanner). Scan 2 was based on the technician's use of the improved IWEX system that contained new processor software that better facilitates detection, classification and sizing of image data once obtained from field scans. The table below shows the improved technician results from Scan 1 to Scan 2. During Scan 2, a new technician was trained during this project was been added to this data set.

Table 11. Sample 16-33-C-D Accuracy Data

Technician	Sample	Indication #	Scan 1 Depth .in	Scan 2 Depth .in	Scan 1 Height .in	Scan 2 Height .in	Scan 1 (Legacy System)	Scan 2 (Improved System)
Jeff Vinyard (Control)	**16-33 C-D**	**1**	**0.000**		**0.047**		**Cold Weld**	
Technician 1		1	0.019	0.010	0.055	0.049	Cold Weld	Cold Weld
Technician 2		1	0.020	0.000	0.044	0.050	Cold Weld	Cold Weld
Technician 3		1	-0.016	0.000	0.060	0.050	Cold Weld	Cold Weld
Technician 4		1	N/A	0.000	N/A	0.052	N/A	Cold Weld
Jeff Vinyard (Control)		**2**	**0.177**		**0.055**		**Upturned Fiber**	
Technician 1		2	0.122	0.178	0.067	0.067	Upturned Fiber	Upturned Fiber
Technician 2		2	0.178	0.178	0.044	0.044	Hook Crack	Upturned Fiber
Technician 3		2	0.169	0.176	0.066	0.066	Hook Crack	Upturned Fiber
Technician 4		2	N/A	0.178	N/A	0.044	N/A	Upturned Fiber
Jeff Vinyard (Control)		**3**	**0.169**		**0.039**		**Upturned Fiber**	
Technician 1		3	0.175	0.168	0.044	0.044	Upturned Fiber	Upturned Fiber
Technician 2		3	0.167	0.167	0.056	0.056	Cold Weld	Upturned Fiber
Technician 3		3	0.166	0.166	0.067	0.067	Upturned Fiber	Upturned Fiber
Technician 4		3	N/A	0.168	N/A	0.044	N/A	Upturned Fiber

Technician	Sample	Indication #	Scan 1 Depth .in	Scan 2 Depth .in	Scan 1 Height .in	Scan 2 Height .in	Scan 1 (Legacy System)	Scan 2 (Improved System)
Jeff Vinyard (Control)		4	0.079		0.008		Lamination	
Technician 1		4	0.080	0.080	0.050	0.050	Upturned Fiber	Lamination
Technician 2		4	0.089	0.080	0.034	0.034	Lamination	Lamination
Technician 3		4	0.070	0.081	0.046	0.046	Lamination	Lamination
Technician 4		4	N/A	0.081	N/A	0.046	N/A	Lamination
Jeff Vinyard (Control)		5	0.106		0.028		Upturned Fiber	
Technician 1		5	0.100	0.104	0.032	0.022	Lamination	Upturned Fiber
Technician 2		5	0.112	0.102	0.054	0.034	Upturned Fiber	Upturned Fiber
Technician 3		5	0.098	0.102	0.055	0.035	Upturned Fiber	Upturned Fiber
Technician 4		5	N/A	0.102	N/A	0.034	N/A	Upturned Fiber
Jeff Vinyard (Control)		6	0.106		0.035		Upturned Fiber	
Technician 1		6	0.100	0.100	0.042	0.032	Upturned Fiber	Upturned Fiber
Technician 2		6	0.100	0.100	0.038	0.038	Upturned Fiber	Upturned Fiber
Technician 3		6	0.102	0.102	0.044	0.034	Upturned Fiber	Upturned Fiber
Technician 4		6	N/A	0.104	N/A	0.030	N/A	Upturned Fiber
Jeff Vinyard (Control)		7	0.000		0.031		Hook Crack	
Technician 1		7	0.057	0.000	0.034	0.044	Upturned Fiber	Hook Crack
Technician 2		7	0.023	0.001	0.045	0.045	Upturned Fiber	Hook Crack
Technician 3		7	0.022	0.000	0.060	0.040	Upturned Fiber	Hook Crack
Technician 4		7	N/A	0.001	N/A	0.042	N/A	Hook Crack

Technician	Sample	Indication #	Scan 1 Depth .in	Scan 2 Depth .in	Scan 1 Height .in	Scan 2 Height .in	Scan 1 (Legacy System)	Scan 2 (Improved System)
Jeff Vinyard (Control)		**8**	**0.154**		**0.031**		**Upturned Fiber**	
Technician 1		8	0.122	0.154	0.045	0.035	Lamination	Upturned Fiber
Technician 2		8	0.134	0.144	0.044	0.042	Upturned Fiber	Upturned Fiber
Technician 3		8	0.150	0.150	0.033	0.033	Upturned Fiber	Upturned Fiber
Technician 4		8	N/A	0.153	N/A	0.040	N/A	Upturned Fiber
Jeff Vinyard (Control)		**9**	**0.000**		**0.031**		**Hook Crack**	
Technician 1		9	0.000	0.000	0.056	0.031	Hook Crack	Hook Crack
Technician 2		9	0.019	0.010	0.034	0.034	Upturned Fiber	Hook Crack
Technician 3		9	0.019	0.008	0.055	0.035	Upturned Fiber	Hook Crack
Technician 4		9	N/A	0.000	N/A	0.032	N/A	Hook Crack
Jeff Vinyard (Control)		**10**	**0.000**		**0.039**		**Hook Crack**	
Technician 1		10	0.000	0.000	0.056	0.056	Hook Crack	Hook Crack
Technician 2		10	0.020	0.010	0.072	0.062	Upturned Fiber	Hook Crack
Technician 3		10	0.019	0.019	0.067	0.060	Upturned Fiber	Hook Crack
Technician 4		10	N/A	0.000	N/A	0.059	N/A	Hook Crack
Jeff Vinyard (Control)		**11**	**0.019**		**0.217**		**Cold Weld**	
Technician 1		11	0.000	0.000	0.198	0.200	Hook Crack	Cold Weld
Technician 2		11	0.018	0.018	0.154	0.208	Upturned Fiber	Cold Weld
Technician 3		11	0.029	0.019	0.167	0.202	Upturned Fiber	Cold Weld
Technician 4		11	N/A	0.000	N/A	0.200	N/A	Cold Weld

Table 12. Sample 16in. EDM Accuracy Data

Technician	Sample	Indication #	Scan 1 Depth .in	Scan 2 Depth .in	Scan 1 Height .in	Scan 2 Height .in	Scan 1 (Legacy System)	Scan 2 (Improved System)
Jeff Vinyard (Control)	**16in EDM**	**1**	**0.252**		**0.098**		**ID Notch**	
Technician 1		1	0.232	0.252	0.100	0.100	ID Notch	ID Notch
Technician 2		1	0.234	0.252	0.990	0.090	ID Notch	ID Notch
Technician 3		1	0.233	0.252	0.120	0.090	ID Notch	ID Notch
Technician 4		1	N/A	0.252	N/A	0.100	N/A	ID Notch
Jeff Vinyard (Control)	**16in EDM**	**2**	**0.252**		**0.059**		**ID Notch**	
Technician 1		2	0.228	0.252	0.046	0.055	ID Notch	ID Notch
Technician 2		2	0.247	0.252	0.041	0.060	ID Notch	ID Notch
Technician 3		2	0.234	0.252	0.048	0.050	ID Notch	ID Notch
Technician 4		2	N/A	0.252	N/A	0.051	N/A	ID Notch
Jeff Vinyard (Control)	**16in EDM**	**3**	**0**		**0.120**		**OD Notch**	
Technician 1		3	0	0	0.100	0.117	OD Notch	OD Notch
Technician 2		3	0	0	0.098	0.115	OD Notch	OD Notch
Technician 3		3	0	0	0.119	0.119	OD Notch	OD Notch
Technician 4		3	N/A	0	N/A	0.110	N/A	OD Notch
Jeff Vinyard (Control)	**16in EDM**	**4**	**0**		**0.049**		**OD Notch**	
Technician 1		4	0	0	0.056	0.059	OD Notch	OD Notch

Technician	Sample	Indication #	Scan 1 Depth .in	Scan 2 Depth .in	Scan 1 Height .in	Scan 2 Height .in	Scan 1 (Legacy System)	Scan 2 (Improved System)
Technician 2		4	0	0	0.050	0.056	OD Notch	OD Notch
Technician 3		4	0	0	0.067	0.057	OD Notch	OD Notch
Technician 4		4	N/A	0	N/A	0.056	N/A	OD Notch

The primary improvement that can be observed from Scan 1 to Scan 2 is a higher accuracy in depth measurements. In Scan 1 several depth fields contained negative values. This is not possible as it would mean that the indications begin outside of the material that is being scanned. The processor automatically places the OD image at zero. This removes the potential of reporting a depth in negative space. The table below shows the percentage error difference in depth and height accuracy of all technicians from Scan 1 to Scan 2 when compared to the control measurements on specimen 16-33-C-D. Technicians were more accurate (i.e. less percentage of error from the control) on 18 of a potential 22 measurements.

Table 13. Error Percentage Data

16-33-C-D Error Percentage				
Indication	**Scan 1 Depth**	**Scan 2 Depth**	**Scan 1 Height**	**Scan 2 Height**
1	12%	0%	17%	7%
2	12%	1%	21%	21%
3	2%	1%	42%	42%
4	8%	2%	442%	442%
5	7%	4%	68%	22%
6	5%	5%	18%	9%
7	34%	1%	49%	38%
8	12%	3%	31%	21%
9	13%	5%	56%	7%
10	7%	5%	67%	52%
11	53%	51%	20%	6%

Another significant improvement from Scan 1 to Scan 2 is that all the flaws were classified the same across all technicians. In Scan 1, eight (8) indications were classified incorrectly by one or more technicians. This improvement is a result of the addition of the decision tree and the updated processor software. The updated processor automatically tries to identify the indications. As a result, when the technician goes back to make the height measurement, he/she can more easily make the correct decision regarding the classification of the indication (based on the location and proximity to the bond line).

The improved accuracy in the integrity data means that better engineering decisions can be made with respect to pipeline and thus better supporting the technicians overall job accomplishment (as identified in phase 1). It is expected that improved engineering decisions will result in pipelines being down for shorter periods of time.

7.2 Modified Scanner and Inspection Procedure Using Eddy Current

This section summarizes JENTEK's technology modifications and operational results designed to reduce the negative impact of human performance shaping factors on the speed and accuracy of an inspection. The content contains excerpts from JENTEK's final report. A complete description of JENTEK's phase 3 work is in their final report, *JENTEK SCC Technology Intervention, Human Centric Approach to Improve Pipeline Non-Destructive Evaluation (NDE) Performance and Reliability* (F-055 Revision 3), dated December 22, 2017.

The updates applied to the SCC tool during phase 3 comprise a more automated scanning system to facilitate the physical inspection process, as well as modified software to improve the user interface and increase data processing speed, and modified calibration and operating procedures to reduce use errors.

Table 1414 lists the improvements of the new automated scanner and links each improvement to PSFs identified in phase 1 of this program.

Table 14. Performance shaping factors addressed by Eddy Current technology-based interventions.

Description	Performance Shaping Factor(s) Addressed
1. The automated scanner only requires an initial setup (i.e. no additional positioning is required for each scan pass), which eliminates scan-to-scan variation. Whereas the manual scanner must be placed by hand for each scan pass, with the potential for positioning errors the can exceed ±0.1 inches.	PSF2a PSF3b, c, e, h, i
2. The inspector does not have to mark the pipe.	PSF3c, d, f PSF5b, e
3. Better spatial registration when generating scan images that are constructed from multiple scans. Registration errors with the manual system can cause cracks that span multiple scans to appear as two or more cracks in the scan images.	PSF4b PSF5b, c
4. Communication and positioning errors often seen with the manual system (e.g. losing count of which scan is being performed, performing scans out of order by scanning one area more than once or skipping an area) are eliminated.	PSF2a PSF3e, f, i PSF5a

5. Automated scanning results are much more reproducible.	PSF3e PSF5b
6. It is easier (i.e. less work) to inspect the bottom of a pipe.	PSF5e, f PSF7h
7. Appropriate scanning speed can be maintained with operators of any experience level and across all areas of the pipe – including the bottom where operator fatigue often plays a part in inconsistent scan rates.	PSF2a PSF3c, e, f, h, i PSF5e, f PSF7h

In addition to the table above, the system shipping containers were redesigned to accommodate the entire scanner assembly (i.e. the axial rail and circumferential motors) leading to a reduction of up to 20 minutes of setup and assembly time.

7.2.1 Physical System Modifications

JENTEK Sensors proposed and implemented modifications to the scanner, software, and procedures associated with their stress corrosion cracking (SCC) mapping and crack depth analysis tool to address the PSFs listed in Table 44. The baseline design for this program is a manual scanning system as shown in Figure 14.

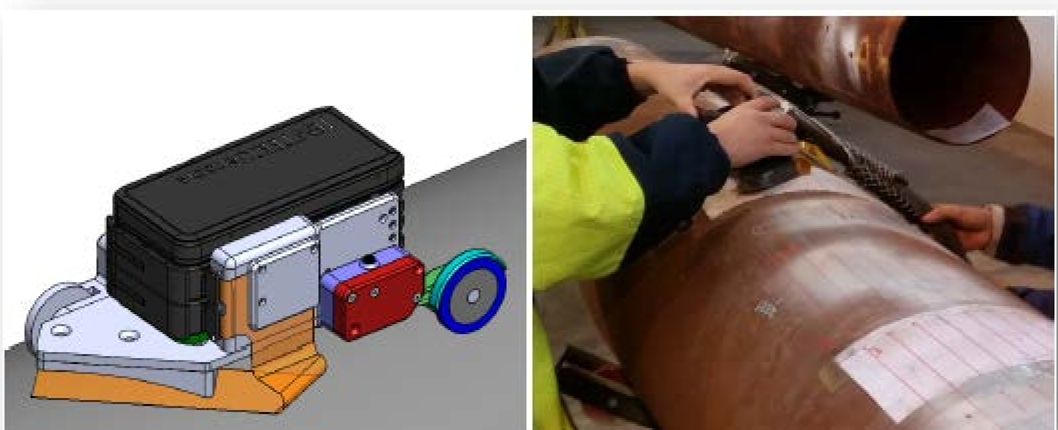


Figure 14. The JENTEK SCC manual scanning system.

The left image in the figure shows a rendering of the scanner design, including the probe electronics unit (black), the sensor (orange), and the encoder (red with blue/grey wheel). The right image in the figure is a photograph of an operator using the manual scanner. The scanner is used my manually moving it axially down the pipe, then performing repeat scans at 30mm circumferential increments. The starting point and the circumferential increments are usually marked on the pipe with either a paint marker or permanent marker (shown as the red lines on the pipe image in Figure 14).

Figure 15 shows the automated scanner with its major components labeled.

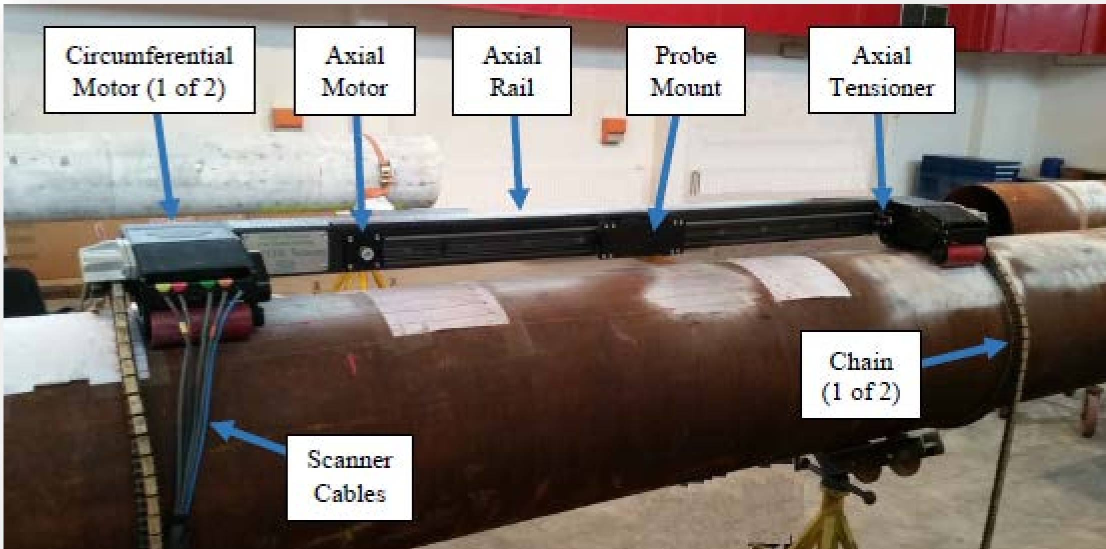


Figure 15. The JENTEK SCC automated scanning system.

Significant features of the automated scanner include:

- being secured to the pipe using rubber-top chains to provide a rigid connection without the use of magnets that can interfere with magnetic sensors;
- a circumferential motor assembly to allow scanning of the full circumference of the pipe;
- a chain tensioner as part of the circumferential motor assembly;
- an axial motor to provide axial motion for the probe mount where the sensor and probe electronics unit are mounted during an inspection; and,
- a carbon fiber axial rail.

Table 1515 compares the general specifications for both the manual and automated systems.

Table 15. General specifications for the manual and automated scanning systems.

	Manual Scanner	Automated Scanner
Pipe Diameter	4" and larger	8" and larger
Scan Length	Limited only by cable lengths 2 meters is typical	1 meter
Circumferential Scan Extent	90° (larger extents are possible but not practical, especially the bottom of the pipe)	360° (including the bottom of the pipe)
Area Coverage	1.5 sq. ft./min	3.0 sq. ft./min

	Manual Scanner	Automated Scanner
Environmental	Dry locations only	IP64 (scanner) IP61 (system)
Calibration	Air-Shunt	Air with data checks
Data Processing	Manual input	Automated input
Data Quality	Manual	Automated
Reporting	Manual	Automated

7.2.2 Procedural and Software Updates

The system calibration procedure was revised to streamline the process and reduce the opportunity for use error. The baseline calibration procedure is of the air-shunt type, in which measurements are first taken in air with the sensor and then the sensor is removed and a shunt – identical to the sensor but with the sense elements shunted – is inserted. This is a robust calibration method, but it requires multiple remove and replace actions that are a source of damage and wear on the system itself, and it provides opportunity for task error (i.e. not replacing sensor with shunt) that can result in an invalid calibration. The new procedure relies on a known, saved calibration loading upon startup, against which the system is recalibrated in air (i.e. no shunt is required) and, therefore, does not require the sensor to be removed. This new procedure is compliant with ASTM EW2884[5] and has the advantage of saving inspector's time, reducing the opportunity for use error, and increasing the availability of the technology for inspections by reducing the opportunity for damage to the sensor.

Improvements were made to the crack depth algorithm with the goal of improving the user interface and increasing the data processing speed. The baseline version used a generic analysis module to process the measurement data to provide crack depth estimates. While this analysis module was convenient since it used the standard grid measurement methods within the existing JENTEK GridStation software environment, it was not very user-friendly, and it was computationally inefficient, which significantly increased the data processing time. Under this program, options were investigated for a more user-friendly analysis module that reduced the number of configuration parameters through which the operator is required to review and enter; providing a more streamlined interface with reduced potential for use error. In addition, the data processing time was decreased without slowing down measurements during the inspection; providing a near real-time inspection and characterization capability.

An automated reporting function was developed to generate a shell that includes most of the major text and images that should be in an inspection report. Images and text from the operator are added to the shell template. This does not generate a complete report. However, the provision of content for the template will reduce the reporting burden.

[5] ASTM E2884-17 Standard Guide for Eddy Current Testing of Electrically Conducting Materials Using Conformable Sensor Arrays, West Conshohocken, PA, 2017, https://doi.org/10.1520/E2884-17

7.2.3 Scanner Demonstration and Results

JENTEK performed testing of the automated scanner alongside an equivalent test of the manual scanner at a customer location in November 2017. The customer provided access to an SCC sample, as well as technicians familiar with the use of the manual system. These technicians also had familiarity with the automated scanner, but not all the procedural upgrades.

Table 16 summarizes the test results for some of the major steps for setup, calibration, and scanning that were investigated.

Table 16. Summary of time to complete various steps in the setup, calibration, and scanning process.

	Manual Scanner (minutes:seconds)	Automated Scanner (minutes:seconds)
Calibration Time	3:15	1:25
Cycles on the sensor connection	2 count	0 count
Scanner Setup	5:00	9:00
Pipe setup/marking	30:00	None
Calibration Verification	No	Yes
Scan Time	6:00	5:30
Example Crack Depth Data Processing Time	2:22	0:02
In-process Crack Depth Processing	Not possible due to data processing time	Yes
Reporting	Not automated/not performed	1:30 Automated

Note that both the automated and manual scans were performed at chest height under laboratory conditions. It is anticipated that under field conditions manual scanning would be much more difficult to execute if the area to inspect includes the bottom of the pipe. It is expected that the manual scanning time would increase significantly over automated scanning time for the same section of pipe.

Likewise, it is worth noting that timing individual steps (i.e. part task trials) using operators that have some experience with the system may not fully capture the time advantage gained by use of the automated system. One JENTEK customer provided time estimates based on experience using both systems to perform scans on a set of SCC colonies under laboratory conditions. Using the manual scanner required approximately 15 hours and, using the automated scanner, the same inspection took approximately 4 hours to complete.

8 Conclusions

Human intervention results were mixed, with the implementation and effectiveness of interventions such as mentoring, training and employee wellness programs varying among test locations. This is not unexpected given the duration of the pilot program effort and inherent human variability. Training, mentoring and other human resource-focused programs often require extended development timelines and evaluation over several implementation cycles to show consistent and generalizable results.

Findings also indicate that some human interventions (i.e. the Employee Wellness Program and Employee Recognition Program) need to account for corporate bureaucracy and properly identify all stakeholders prior to implementation. Future considerations should include all potential stakeholders during the design phase of the intervention. Additional investigation into the design and effectiveness of prospective human interventions is still needed.

Technology intervention results to-date indicate that scanner, software, and procedure updates to identification, mapping and crack depth analysis tools have helped in

- producing better spatial registration for scan images to support accurate crack identification,
- generating more reliably reproducible results to confirm data acceptability decisions
- reducing communication and scanner positioning errors that can result in skipping pipe areas, and
- reducing the physical burden of scanner positioning in hard to reach areas.

The results of the technology intervention pilots suggest higher reliability standards can be achieved through enhancements that support data visualization, interpretation and decision making. However, human inspectors, and therefore human performance shaping factors such as training, motivation, and attitude will still play an important role throughout the inspection process.

9 Reference Documents

9.1 Phase 1 Final Report

- Human Centric Approach to Improve Pipeline Non-Destructive Evaluation (NDE) Performance and Reliability: Phase 1 Final Report (dated September 30, 2016)

9.2 Phase 2 and 3 Partner Reports

- Applus RTD: “Human Centric Approach to Improve Pipeline NDE Performance and Reliability Phase 3” (dated June 28, 2018)
- Jentek Sensors: “JENTEK SCC Technology Intervention: Human Centric Approach to Improve Pipeline Non-Destructive Evaluation (NDE) Performance and Reliability” (dated December 17, 2018)
- Mistras Inc: “Human Centric Approach to Improve Pipeline NDE Performance and Reliability” (dated July 20, 2018)

9.3 Literature Resources

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Appendix A: Mistras Technician Score Card

TECHNICIAN SCORE CARD

Project Number:	Customer:
Technician Assessed:	Inspection Date:
Number of People involved:	Assessment Performed by:

Please rate the following items on a scale of 1 – 10, with 10 being the best possible score.

Completed Pre-Inspection tasks completely:	1	2	3	4	5	6	7	8	9	10
Completed Pre-Inspection tasks in a timely manner:	1	2	3	4	5	6	7	8	9	10
Followed all applicable safety protocols prior to arrival on site:	1	2	3	4	5	6	7	8	9	10
Arrived on site with all appropriate PPE:	1	2	3	4	5	6	7	8	9	10
Arrived on-site with all necessary equipment:	1	2	3	4	5	6	7	8	9	10
Showed technical competency while setting up test:	1	2	3	4	5	6	7	8	9	10
Showed technical competency during test:	1	2	3	4	5	6	7	8	9	10
Communicated any issues to supervisor in a clear manner:	1	2	3	4	5	6	7	8	9	10
Communicated any issues to supervisor in a timely manner:	1	2	3	4	5	6	7	8	9	10
Followed all applicable safety protocols while performing test:	1	2	3	4	5	6	7	8	9	10
Properly retrieved all equipment post-test:	1	2	3	4	5	6	7	8	9	10
Cleanliness of test area following tear-down:	1	2	3	4	5	6	7	8	9	10

Please enter a value for the following:

Time spent (hours) preparing for test prior to on-site:

Time spent (hours) preparing for test on-site:

Time spent (hours) on data acquisition:

Number of test points:

Number of points needing rework:

Time spent (hours) on tear-down:

Appendix B: Mistras Wellness Program Initial Assessment Survey

Survey #1: Initial Assessment Survey

	None of the time	A little of the time	Some of the time	Most of the time	All of the time
In the past four weeks, about how often did you feel tired for no good reason?					
In the past four weeks, about how often did you feel nervous?					
In the past four weeks, about how often did you feel so nervous that nothing could calm you down?					
In the past four weeks, about how often did you feel hopeless?					
In the past four weeks, about how often did you feel restless or fidgety?					
In the past four weeks, about how often did you feel so restless you could not sit still?					
In the past four weeks, about how often did you feel depressed?					
In the past four weeks, about how often did you feel that everything was an effort?					
In the past four weeks, about how often did you feel so sad that nothing could cheer you up?					

In the past four weeks, about how often did you feel worthless?					

Appendix C: Mistras Wellness Program Needs Assessment Survey

1. **Which of the following would you most like included in Mistras' workplace health and wellbeing program? Please tick all that apply. Note that it will not be possible to implement all chosen activities but your response will help identify areas of interest.**

   - ❑ Bicycle or walk to work activities
   - ❑ Easily accessible stairwells
   - ❑ Employee Assistance Program
   - ❑ Exercise/physical activity sessions
   - ❑ Fatigue management information sessions
   - ❑ Financial planning support
   - ❑ Flu vaccinations
   - ❑ Health assessments – 'face-to-face'
   - ❑ Health assessments – 'online'
   - ❑ Health coaching to address physical activity or nutrition issues
   - ❑ Healthy food options available (e.g. fruit bowls, vending machines, canteens)
   - ❑ Information seminars/workshops
   - ❑ Injury prevention/rehabilitation services
   - ❑ Lunch/break room
   - ❑ Activities that promote good mental health
   - ❑ Organization sport team(s)
   - ❑ Pedometer event or walking challenge
   - ❑ Personal development opportunities for life skills
   - ❑ Shower and change facilities
   - ❑ Smoking cessation programs (e.g. Quit smoking program)
   - ❑ Sports/activity days
   - ❑ Stress management programs and strategies
   - ❑ Stretching sessions
   - ❑ Storage areas (e.g. bike storage, lockers)
   - ❑ Subsidised membership to off-site facilities/programs
   - ❑ 'Walk and talk' or active meetings
   - ❑ Website with health and wellbeing information
   - ❑ Workplace massage

1. **When would you prefer these activities to occur?**

- ❑ Before work
- ❑ During lunch time
- ❑ After work
- ❑ At weekends

2. **How often would you attend a workplace health and wellbeing activity (if offered this frequently)?**

- ❑ Every day
- ❑ A few times a week
- ❑ Once a week
- ❑ A few times a month
- ❑ Once a month
- ❑ Less than once a month

3. **What factors would *stop* you from participating in workplace health and wellbeing activities?**

- ❑ Not enough time
- ❑ Not motivated
- ❑ Too expensive
- ❑ Not interested
- ❑ Out on the road/away from the worksite or office most of the time
- ❑ Other (please specify) ____

4. **What other health and wellbeing initiatives would you like to see implemented at Mistras?**

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BATTELLE

It can be done