Collecting Lab Quality Pipe Material Properties in the Field

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Abstract

In October 2019, the Pipeline and Hazardous Materials Safety Administration (PHMSA) adopted new regulations including §192.607 that require operators to collect material properties when existing records are not traceable, verifiable, and complete (TVC). Up until recently, destructive lab testing had been the default method to collect material properties. However, PHMSA now recognizes and allows nondestructive techniques to fulfil the TVC requirements. In order to successfully implement nondestructive techniques in the ditch, it is customary in the pipeline industry to develop training and certification programs that meet American Society for Nondestructive Testing (ASNT) requirements. Implementation of these programs ensures that data collected from different field users and inspectors is consistent, accurate, and reliable. ASNT requirements are currently not available for material verification. This paper presents an adaptation of SNT-TC-1A to formalize a user qualification and certification program used to train, certify, and audit proper implementation of in-situ nondestructive material verification via frictional sliding for mechanical tests and ancillary tests for chemistry and microstructure. The initial application of this technique was through expert users, limiting availability for routine inspection programs. Review of these early applications revealed that many procedural steps needed to be applied consistently across users including surface preparation and calibration verification. Over time, formalized field procedures, process automation, and a robust software interface reduced the level of expertise needed to execute the field process. For new users, the steps to certification includes a hands-on training curriculum and a rigorous field transfer competency program. Remote data quality control ensures that laboratory-level quality of data is obtained in the field. The application of this program to more than 50 third-party users has validated the effectiveness of the process and enables a growing number of users to collect material data nondestructively in the field. This training and certification program may become a new task listed in the Operator Qualifications (OQs) for individual technicians.

Introduction

For over a decade, regulators and operators have had ongoing discussions surrounding pipeline safety. These discussions culminated in October 2019, when the Pipeline and Hazardous Materials Safety Administration (PHMSA) published pipeline safety and assessment requirements for 49 CFR Parts 191 and 192 [1]. This rule, referred to as the Mega Rule, includes §192.607 which requires traceable, verifiable, and complete records of material properties and physical pipeline characteristics and attributes, including wall thickness, diameter, seam type, and pipe grade based on material strength. Material verification is required as part of opportunistic testing when material records are not TVC, and when referenced by other sections of Part 192.

Implementation of conventional testing methods to meet these requirements would require significant budgets and service interruptions for material cut-outs. However, PHMSA provides the opportunity for operators to utilize revolutionary nondestructive approaches to complete the testing, examinations, and assessments. As a result, the industry has supported the development of *in situ* nondestructive evaluation (NDE) methods which have been further improved through joint industry research programs and validated through third-party blind testing. One such validation study was performed in 2017 by Pipeline Research Council International (PRCI) evaluating multiple NDE methods on 50 blind samples of vintage pipe joints covering a range of pipe grades, geometries, vintages, and seam types.

In addition to development of NDE technologies, fully developed procedures, training programs, evaluation programs, and complete service requirements need to be implemented prior to completing *in situ* testing. A complete and detailed program following the framework established in SNT TC-1A and ASME B31Q ensures data collection is consistent, accurate, and reliable.

This paper presents an adaptation of SNT-TC-1A and ASME B31Q to formalize a qualification and certification program to train, evaluate, certify, and audit proper implementation and performance of *in-situ* nondestructive material verification via frictional sliding for mechanical tests and ancillary tests for chemistry and microstructure. The paper details the evolution of the training and implementation of the testing from a few expert users, to a widescale user base of varying experiences. This evolution includes improvements in procedures and testing methods, review of early applications, and modifications to the qualification framework. Over time, formalized field procedures, process automation, and a robust software interface reduced the level of expertise needed to execute the field process.

The current program includes classroom learning, a hands-on training curriculum, and a rigorous field transfer competency program. Additional elements to establishing NDE techniques include validation of the technology and development of a user-friendly tester and software. These elements work hand-in-hand to ensure that laboratory-level quality of data is obtained in the field. The application of this program to more than 50 third-party users has validated the effectiveness of the process and enables a growing number of users to collect material data nondestructively in the field. This training and certification program may become a new task listed in the Operator Qualifications (OQs) for individual technicians.

Summary of SNT TC-1A and ASME B31Q

Recommended Practice No. SNT-TC-1A Personnel Qualification and Certification in Nondestructive Testing (NDT) establishes guidelines for the qualification and certification of NDT personnel whose specific jobs require appropriate knowledge of the technical principles underlying the nondestructive tests they perform, witness, monitor, or evaluate [2]. These guidelines have been developed by the American Society for Nondestructive Testing, Inc. (ASNT) to aid employers in recognizing the essential factors to be considered in qualifying personnel engaged in NDT methods [2]. This document includes key definitions and terms to be utilized in qualification programs, defines standard levels of qualifications, and outlines the needs and basics of proper written practices, training programs, examinations, evaluations, and certifications.

ASME B31Q Pipeline Personnel Qualification establishes the requirements for developing and implementing an effective qualification program utilizing a combination of technically based data, accepted industry practices, and consensus-based decisions [3]. The standard primarily focuses on identifying covered tasks and establishing the requirements for the qualification and management of said qualifications for personnel to complete the identified covered tasks. Implementation of this standard is intended to minimize the impact of safety and integrity of the pipeline due to human error that may result from an individual's lack of knowledge, skills, or abilities during the performance of certain activities [3].

A complete field service training program can be developed by referencing the combination of these standards. While they mimic each other in many ways, they each provide fundamental requirements and guidance to ensure complete and successful development of a qualification program. The process discussed in this paper utilized both to develop a roadmap outlining requirements and milestones along the development process. This roadmap is detailed in Table 1 below and this paper will further discuss each step and examples of the iterative process.

Table 1: Industry requirements compared with implementation of qualification program for frictional sliding as a covered task.

Roadmap	ASME B31Q [3]	SNT-TC-1A [2]	MMT Implementation
Applicability	Establishes **requirements** for developing and implementing an effective pipeline personnel qualification program.	Establishes the general **framework** for a qualification and certification program.	Utilized ASME B31Q to establish requirements and referenced SNT-TC-1A for guidelines.
Step 1: Procedure Development	Covered Task: A task that can affect the safety or integrity of the pipeline	Method: Process that involves inspection, testing, or evaluation of materials or components Technique: A category within an NDT method	Established covered tasks and developed procedures over time as the testing method was implemented and refined by a few expert users.
Step 2: Abnormal Operating Conditions (AOCs)	Condition that may indicate a malfunction of a component or deviation from normal operations.	--	Establish AOCS which are outlined and covered during experience digs.

Step 3: Qualification Levels – Responsibilities	• Qualified: Individual has been evaluated and can perform covered tasks and recognize and react to AOCs
	• Subject Matter Experts (SME)
	• Identify responsibilities of qualified individuals
	• Trainers, Proctors, Evaluators
	• No breakdown for levels
		• Qualification: Demonstrated skill or knowledge, documented training, and experience required for personnel to properly perform duties of specific job
		• Trainee
		• NDT Level I
		• NDT Level II
		• NDT Level III
		• Limited
		• Sublevels
			Finalized Levels:
			• Trainee
			• Level I
			• Level I Sublevels
			  ○ Level IA
			  ○ Level IB
			  ○ Level IC
			• Level II Limited
			• Level II
			• Trainers, Proctors, Evaluators
			• SME

Step 4: Training Program	• Establish responsible parties • Instructor-Led Training • On-the-Job Training • Document training needs • Outline of training course and individual's successful completion of the training course • Can all be determined by SME	• Organized Training • Instructor-Led Training • Personalized Instruction • Virtual Instructor-Led Training • Computer-Based Training • Web-Based Training • Written practice for control and administration of NDT personnel training, examination, and certification – reviewed by NDT Level III • Describes training, experience, and examination requirements for each level of certification by method and technique	Launched complete program combining virtual instructor-led training, in-person instructor-led training, and on-the-job training. Developed by SME. Program consists of a Level I Training course, experience digs with performance evaluation requirement, and Level II Training course.
Step 5: Evaluations of Trained Individuals	• Determine individual's ability to perform covered tasks • Evaluation Criteria: specific knowledge and skill individual must possess • Establish passing criteria • Written Evaluations • Oral Interview Evaluations • Performance Evaluations	• Should include sufficient examinations • Generally adopts 80% passing grade • Written Exams • Practical Exams	Applied combination of written evaluations, oral interview evaluations, and performance evaluations for certifications. Performance evaluations further implemented in Level I sublevels. Passing criteria adopted 80% requirement which was further verified by testing proven Level I and Level II individuals.

Roadmap	ASME B31Q [3]	SNT-TC-1A [2]	MMT Implementation
Step 6: Preliminary Implementation	--	--	Implementation of preliminary program to small set of early adopters. Preliminary training program consisted of Level I Training course, experience hours, and Level II Training course.
Step 7: Program Effectiveness and Assessment	Process to appraise the effectiveness of the qualification program including whether it is implemented as documented and whether or not it is effective as implemented	--	By assessing the issues from the original implementation, the qualification program was reviewed for effectiveness. During this review, specific components in the training program were identified as contributors to the issues.
Step 8: Program Changes	Program shall have processes or procedures for implementing changes including methods for communicating the changes	Written practice shall be maintained	The training program was updated to include Level I sublevels, performance evaluations during the experience digs, and a Level II Limited certification. MMT worked with existing qualified individuals to incorporate changes and provided best approaches for remedial actions.
Step 9: Final Implementation	--	--	Larger roll out for a final implementation of the program to a larger group of individuals. This program has proven successful with zero human error issues and over 300 successful digs.
Documentation Requirements	Should be maintained consistent with the knowledge and skills needed to perform covered tasks	Written practice shall be maintained on file	Completed set of documents including: o Qualification Program o Training Program o Evaluations o Evaluation Criteria o Examinations o Certifications
Step 10: Continuous Improvement	All programs should be maintained, and proper change processes and procedures shall be followed.	--	With a successful program, MMT aims to further improve the program by: o Submitting Operator Qualifications o Developing online learning management systems o Developing a train the trainer program o Establishing qualification intervals o Determining span of control metrics

Step 1: Identification of Covered Tasks and Procedure Development

The initial challenge to successfully collect lab quality data in a field setting is to identify the necessary covered tasks and configure traditional lab procedures for application in a field setting. ASME B31Q defines a covered task as a task that can affect the safety or integrity of a pipeline, however, for the purposes of the process detailed in this paper, a covered task is any task or technique part of the NDE needed to complete material verification of the pipeline asset. The original task list included:

- Documentation
- Safety
- Surface Preparation
- Nondestructive Testing
    - Calibration testing
    - Pipe Testing
- Data Review and Organization

However, as the process was implemented and validated, the need for additional tasks emerged to further improve accuracy and meet regulatory requirements. As a result, in addition to the tasks listed above, the updated covered tasks list includes:

- Ultrasonic Thickness Measurements
- Metallographic Grain Structure
- Chemistry Collection
- Seam Weld Classification and Testing

For any testing on pipeline assets, complete documentation and safety measures are required prior to any work being done on the asset. As a result, documentation requirements and safety procedures were the first to be established. These required the development of documents to be filled out and completed, as well as procedures outlining the requirements. Experiments and research and development (R&D) efforts had to be applied to all tasks to ensure that every procedure was focused on safety and consistent execution. One example of this approach is with the surface preparation procedure. The original surface preparation procedure and practice used traditional belt sanders and orbitals to incrementally buff the pipe surface from a coarse 50-grit finish to a 1200-grit finish. During the R&D efforts for this process, the surface preparation procedure was evaluated for material removal and consistency. Through these efforts, it was concluded that the process resulted in inconsistent material removal, difficulty getting a uniform finish across pipes of varying grades, and introduction of foreign particulates being imbedded in the surface as shown in Figure 1. As a result, new tools were researched and experimented with and the procedure was revised. Part of these revisions included material removal experiments, which established ultrasonic thickness reading requirements throughout the procedure to ensure material removal is being monitored and maintained at a safe threshold. Today, the procedure utilizes a PTX tool which ensures uniform material removal and consistent buffing from a 40-grit belt to a 2000-grit mirror like finish as shown in Figure 2.

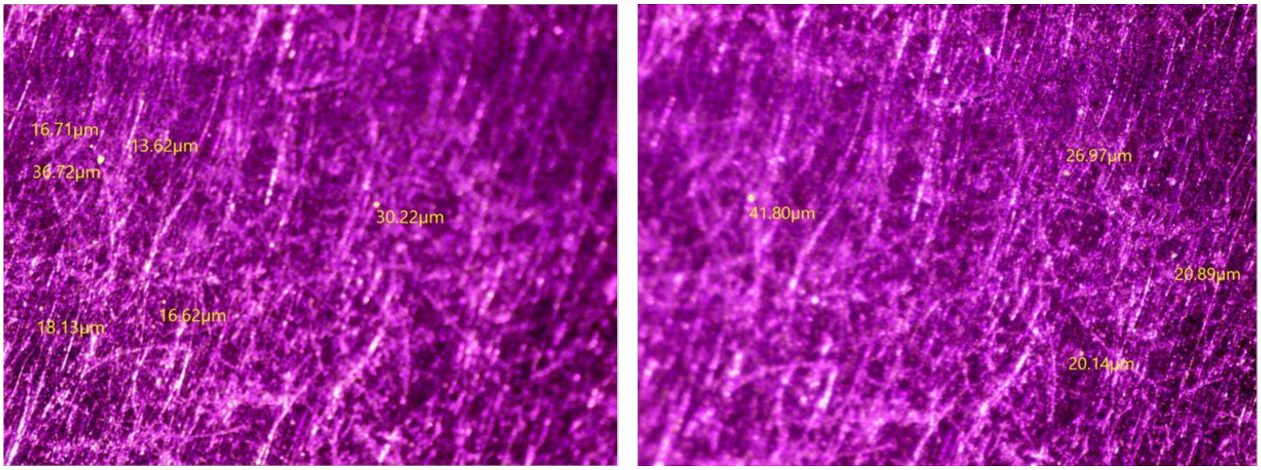

Figure 1: Surface preparation study performed in 2017 examining introduction of embedded particles into prepped surface from grinding belts.

Figure 2: Current end result of surface preparation procedure displaying mirror-like 2000-grit finish.

In addition to safety challenges, the procedure development required adapting lab practices for implementation in a field setting. Many lab testing procedures require the use of large machines and access to chemicals and products that cannot be realistically introduced into a field setting. As a result, significant R&D efforts were pushed behind finding portable, easily accessible, and consistently achievable solutions to collect lab quality data in the field. One such example is with the metallographic grain structure procedure. In a lab setting, grain structure is viewed and imaged using a destructive cut out, which is: 1) machined; 2) polished using a wet polish wheel in combination with a variety of diamond pastes; 3) submerged in an etchant solution; and 4) imaged under a lab microscope. These steps can be broken down to tackle each challenge individually. Using the established surface preparation procedure, the need for additional polish was identified. Multiple approaches including using wet solvents with buffing discs and oil-based diamond pastes with buffing bobs were experimented with until an approach using small buffing bobs, a Dremel, and a two-step diamond paste approach was verified. From there, experimenting with different etching solutions was conducted. Traditionally, Nital etchant is used, which was applicable to a field setting as well, so the main efforts were behind determining a suitable concentration resulting in implementation of a Nital 2%. The most challenging adaptation for grain structure imaging, was capturing the grain structure for analysis. A widescale practice known as surface replicas was initially introduced. However, this practice was not reliable and limited the ability for instant QA/QC of grain structure. As a result, a portable microscope with a magnetic base and imaging software were introduced. In the end, the grain structure images captured resemble the same quality as images captured in a lab setting as shown in Figure 3.

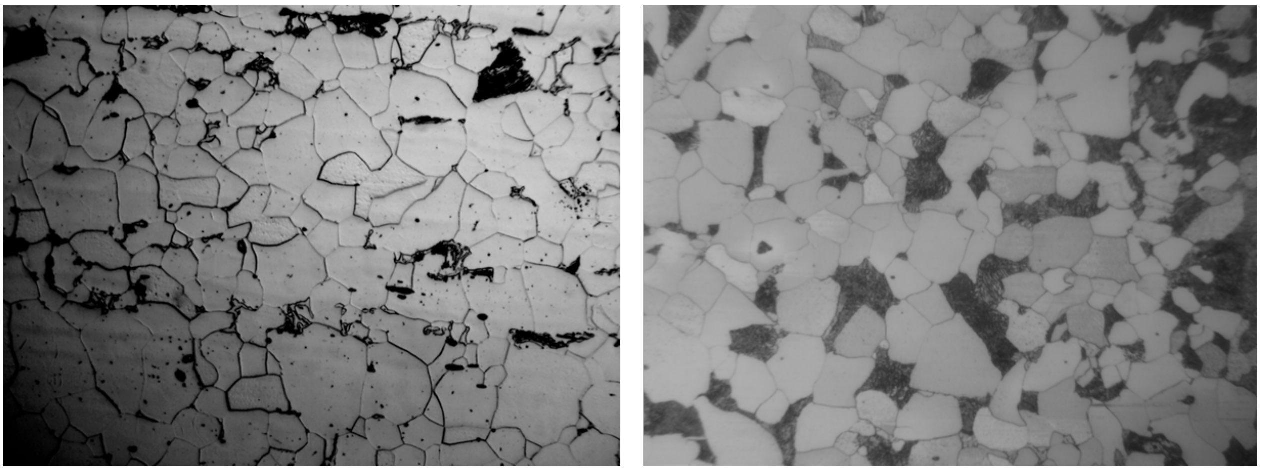

Figure 3: Comparison of grain structure captured through traditional lab procedures (left) and grain structure captures through field procedure (right).

The final challenge to procedure and process development is the concept of scalability. Traditional labs may have one to many expensive machines for testing. However, for widescale field applications, cheaper, less specialized processes are required. This can be further explained through the development of the *in situ* chemical composition testing procedure. There are many reliable technologies out there for chemical composition testing, such as Spark OES and LIBS testing. However, these devices can be expensive and introduce an additional technology to the field-testing process which must be calibrated and potentially diagnosed for troubleshooting. As a result, for chemical composition testing, the procedure utilizes a standard deburring tool found at any hardware store and deburring tips for metal shavings collection which can be sent to a lab for testing. This allows for efficient scalability, increased accuracy, and consistent results.

Many of the procedures used in this process have undergone many revisions and will continue to be revised as implementation of the process increases. The original revisions were based on initial R&D efforts. When introduced in a field setting by expert users, the procedures had to be revised to be more suitable for field applications, and new procedures were introduced to increase accuracy. Another revision cycle followed the publication of the Mega Rule to ensure regulatory compliance. Finally, as execution of the procedures has transitioned from expert users to wide scale users, the procedures have been revised for scalability, ease of training, and to ensure consistent and successful job completions.

Step 2: Abnormal Operating Conditions (AOCs)

An abnormal operating condition (AOC) is a condition that may indicate a malfunction or a deviation from normal operations [3]. For the purposes of the process described in this paper, AOCs are any conditions that require deviation from normal procedures or indicate malfunctions with the equipment. It is an essential step to identify potential AOCs prior to developing a training program. AOCs are the difference between an individual performing a procedure after reading it versus after **understanding** it. Some of the AOCs identified for the process described in this paper include:

- Pipe Fittings (Elbows, Tee Joints, etc.): Require the user to deviate from normal test locations
- Limited Length of Exposed Pipe: Requires the user to deviate from minimum spatial requirements between testing locations

- Condensation on Pipe Surface: Dilutes nital etchant upon contact, requiring deviation from normal grain structure procedure
- Pipe Vibrations: Complicates focusing of portable microscope requiring deviation from normal grain structure procedure

A qualified individual is trained to recognize and react to all the AOCS listed above and all others identified in the complete training program.

Step 3: Levels of Qualification Determination

Qualification indicates that an individual has been trained and evaluated to perform assigned covered tasks and recognize and react to AOCs [3]. For each covered task, a magnitude of qualification levels may be applicable. However, by referencing the recommended practices in SNT-TC-1A, there are three basic levels of qualification. Further, these levels can be subdivided or limited when necessary. These levels include:

- Trainee: An individual in the process of being initially trained, qualified, and certified [2].
- NDT Level I: Individual who has sufficient technical knowledge and skills to be qualified to properly perform specific calibrations, specific NDT, and specific evaluations for acceptance or rejection determinations according to written instructions and to record results, should receive necessary instruction from a NDT Level II or higher [2].
- NDT Level II: Individual who has sufficient technical knowledge and skills to set up and calibrate equipment, and evaluate results with respect to applicable codes, standards and specifications [2]. The Level II may also exercise the assigned responsibility of on-the-job training and guidance of trainees and NDT Level I personnel.
- NDT Level III: Individual who has sufficient technical knowledge and skills to be capable of developing, qualifying, and approving procedures, establishing and approving techniques, interpreting codes, standards, specifications, and procedures; and designating particular NDT methods, techniques, and procedures to be used [2].

When compared to ASME B31Q, as opposed to an NDT Level III, the standard introduces a subject matter expert (SME) who possesses knowledge and experience in the process/discipline they represent [3].

Using this framework, the process discussed in this paper uses the qualification levels detailed in Table 2 below.

Table 2: Established qualification levels and requirements [4].

Qualification Level	Description	Minimum Requirements
Trainee	Procedural orientation by qualified individual. Cannot independently conduct any task or reporting of results.	High school diploma or equivalent GED certificate
Level I	An individual qualified to setup and calibrate equipment, perform covered tasks, and record results under the supervision and instruction of a qualified Level II individual.	Completion of Level I Training including online and in-person instruction, written exam, and practical exam
Level IA	A qualified Level I individual that has demonstrated competency in field service fundamentals necessary to prepare samples for testing & record results.	Received at least 3 endorsements for Level IA skills and competencies
Level IB	A qualified Level I individual that has demonstrated competency in data collection and evaluation, and calibration of the NDE technology.	Received at least 3 endorsements for Level IB skills and competencies
Level IC	A qualified Level I individual that has demonstrated competency to independently lead all covered tasks and lead operation of the NDE technology.	Received at least 5 endorsements for Level IC skills and competencies

Qualification Level	Description	Minimum Requirements
Level II Limited	An individual qualified to independently setup and calibrate equipment, interpret and evaluate results, and exercise assigned responsibility for on-the-job guidance of qualified Level I individuals. The limited certification indicates that the individual has less experience and is required to obtain approval from designated reviewers prior to leaving the job site and reporting results. If contact with the designated reviewer is not possible through mobile or satellite internet at the job site, another location with suitable connectivity must be found as soon as possible.	Completion of Level II Training, including On-site Technical Performance Evaluation (TPE), online and in-person instruction, written evaluation, oral interview evaluation, and performance evaluation.
Level II	An individual qualified to independently setup and calibrate equipment, interpret, evaluate, and report results, and exercise assigned responsibility for on-the-job guidance of qualified Level I individuals.	Received at least 10 endorsements for Remote TPEs
SME	SME designated based on overall process knowledge gained through process development and experience. SME is capable of developing, qualifying, and approving procedures, establishing and approving techniques, interpreting codes, standards, specifications and procedures; and designating the particular methods, techniques and procedures to be used. The SME has sufficient practical background in applicable materials, fabrication and product technology to establish techniques and to assist in establishing acceptance criteria when none are otherwise available.	

Step 4: Training Program

Once the qualifications are determined, the next step is to outline what the training requirements to achieve said qualifications are. The training program is the written description, processes, procedures, training, materials, and training tests that establish and document training [3]. This includes determining the need for training, identifying all training materials, and assuring documented completion of the training [3].

The training program for the process outlined in this paper includes a combination of virtual instructor-led training, in-person instructor-led training, on-the-job training, and experience requirements with performance evaluations. This process has undergone many iterations, and, through implementation and assessment of the program effectiveness, it has been improved over time. The general framework of the program follows traditional practices to ensure candidates for certification in NDT have sufficient education, training, and experience [2].

The initial program consisted of rigorous instruction and constant exposure to the methods and procedures for a few expert users. This program lacked proper documentation and consistent structure, heavily relying on individual case-by-case success and being adapted for each user. When developing a more wide-scale qualification program, this approach had to be reconfigured. The preliminary iteration of the program consisted of a 2-day Level I Training course, combining instructor-led training and hands-on demonstration and practice. This was still limited to an early set of adopters for a pilot program. Following the Level I Training, two options were available to reach Level II, either a weeklong combination of instructor-led training and simulated experience, or 10 real experience digs followed by another 2-day Level II Training course.

Developing a structured program requires several key documents and materials. The first is a complete curriculum to ensure consistent and thorough training independent of trainer or trainee. Additionally, videos and content had to be developed for adequate training and understanding on all procedures which also had to be rewritten for a wider audience. Finally, documentation of successful completion of the training had to be generated including evaluation criteria.

Step 5: Evaluations

Evaluations are required in order to effectively measure an individual's ability to perform the covered tasks. Proper evaluations are designed to ensure that an individual possesses the complete knowledge, skills, and abilities to perform the covered task under evaluation [3]. Evaluations can be in the form of written evaluations, oral interview evaluations, and/or performance evaluations. The type of evaluation selected is a critical decision and one that has been revisited multiple times.

For the process detailed in this paper, Level I evaluations include a written evaluation in the form of a multiple-choice exam and a performance evaluation where individuals are judged on a pass/fail criterion for execution of each procedure. Establishing the passing criteria for all evaluations requires additional discussion and an effective exercise utilized for the process detailed in this paper was to grade active Level I users with the least amount of experience but who had proven to be effective Level I's during testing. Based on their performance, passing criteria was determined. Additionally, for a performance evaluation, detailed criteria must be established to ensure consistent evaluator judgement for satisfactory completion.

Level II evaluations follow a similar model, however, introduce multiple oral interview evaluations as well. The oral interview evaluations include guidelines and questions that must be answered during performance of certain tasks. Whereas a normal performance evaluation guarantees that an individual knows how to complete a covered task, an oral interview evaluation takes it one step further and ensures that an individual understands a covered task and has the required knowledge to react to AOC's and troubleshoot equipment when needed. Therefore, it is an effective method to evaluate Level II's.

An ongoing challenge for the evaluation portion of the program is proper passing requirements. While a current metric is established by benchmarking against the performance of trusted Level I and Level II individuals, the question remains whether certain exam questions or procedures should hold a higher weight than others. For example, performing ultrasonic thickness measurements during surface preparation correctly has a greater safety impact than performing the extended polishing procedure for grain structure imaging. However, proper execution of the polishing procedure is more complicated and has a greater impact on the data being submitted. This is where ongoing discussions and the current challenge exists, on how to effectively judge these different procedures on a fair and even scale. Ultimately, the evaluations are focused on ensuring safety and proper completion of covered tasks.

Step 6: Preliminary Implementation

The preliminary iteration of the training program was implemented in 2019 for an early adopter pilot program. The training for this preliminary launch consisted of the 2-day Level I Training course which comprised of an instructor-led training session and hands-on training. The program was implemented to four individuals, two of which continued to the next requirement. The next requirement was to complete 10 experience digs. These 10 digs were completed with limited issues, indicating some need for improvement in the Level I Training course, but a general acceptance of its effectiveness.

Upon completion of the 10 experience digs, the individuals returned for the Level II Training course. The Level II Training course was still largely under development but comprised of multiple days filled with instructor-led training, hands-on training, and multiple oral interview evaluations. During the training, it became evident that the 10 experience digs were not satisfactory for preparing the individuals for the Level II course. The intention of the Level II Training course was to focus on specific covered tasks related to the NDE technology, however, the individuals were not as well versed in the other covered tasks as the program had intended. As a result, the Level II training was extended to ensure the individuals would be fully qualified as Level IIs on all tasks.

The pilot Level IIs were then ready for independent testing and performing covered tasks independently. During this segment, many issues arose, largely due to the unsuccessful implementation of the knowledge gained during the trainings. Simply put, the individuals were not prepared properly to complete the covered tasks to the expectations of a Level II. These issues were compounded with difficulties with the NDT equipment, complex data uploading requirements, and inefficient technical support.

Step 7: Program Effectiveness and Assessment

All qualification programs should have a process to appraise the effectiveness of the program as detailed in ASME B31Q [3]. An effective program minimizes human errors caused by an individual's lack of knowledge, skills, and abilities to perform the covered tasks to the expectations [3]. The preliminary implementation of the training program for the process detailed here-in was assessed for its effectiveness following a similar model to that detailed in ASME B31Q which comprises of two parts:

1. Whether the program is being implemented as documented
2. Whether the program is effective as implemented

The lack of structured framework for the Level II Training course already flagged room for improvement in the program implementation. However, a larger evaluation was conducted on the effectiveness of the implemented program.

From a review of the preliminary implementation in the pilot program, it became evident that the program was not effective in its current implementation. Specifically, individuals were not qualified on all covered tasks largely due to a lack of experience. This had its greatest impact on proper use of the nondestructive testing instrument and review of data. As a result, the program was revisited to better optimize the experience digs in a manner that would ensure an individual's readiness for the training.

Step 8: Program Changes and Communication of Changes

Part of revisiting the program requires methods for making changes. It is not simple to make changes to a qualification program and there were many challenges to effectively do so. This required defining program responsibilities, so all parties were aware of their role in the process and establishing a communication process. This process includes describing the changes, assessing the impact of the change on the qualified individuals, and ensuring communication of these changes.

The changes to the program included introducing sublevels to the Level I qualification. These sublevels required specific task performance evaluations during the experience digs. This approach would then ensure that an individual is qualified on all the expected tasks prior to returning for Level II Training. The resulting training program was significantly more rigorous and detailed, to guarantee consistency across all individuals and an acceptable readiness level. In addition to these sublevels, the Level I Training course was extended to a 2.5-day training, consisting of an initial virtual instructor-led training, in-person instructor-led training, hands-on training, and a combination of written and performance evaluations. This further optimized the in-person training time and allowed for detailed training on the fundamentals of all covered tasks. The Level II Training was improved to follow a similar curriculum and have a robust framework, including oral interview evaluations to ensure individuals understand all covered tasks, in addition to being able to simply perform them. Upon completion of the Level II Training course, a limited qualification of Level II Limited was introduced. This limited qualification requires an individual who is qualified to perform all covered tasks to be audited for initial independent digs to ensure immediate QA/QC. This program follows careful documentation and consistent evaluations to qualify individuals to the acceptance standards.

The greatest challenge to making these changes was to accommodate for the early adopters in the pilot program. This required customized programs to be implemented for each user to reach comparable training, experience, and qualification levels.

Step 9: Final Implementation

The new program was implemented on a larger scale roll-out, now with the confidence from the lessons learned during the preliminary implementation. The larger scale roll-out comprised of four individuals being sent through the updated qualification program and three individuals receiving customized programs of similar structure. Ultimately, all seven individuals reached the same qualification level.

Appraisal of this new program indicates a large success on its effectiveness and implementation. Issues from human error are virtually non-existent and the auditing portion for the Level II Limited individuals is completed to satisfactory levels. All qualified individuals continue to meet requirements and the program has been expanded to an additional 5 individuals with many more completing their Level I sublevel. To date, the program has been successful on over 300 digs with over 12 qualified Level II individuals and 4 different NDE companies. With this level of success, areas for improvement are centred around documentation of sublevel completions and scalability of the program to a larger audience.

Documentation Requirements

An effective qualification program requires thorough documentation. This documentation must be maintained, and processes must be established for making changes and communicating changes as discussed earlier in this paper. Initially, the program was implemented with only a training program and certifications. The training program is the written description, processes, procedures, training materials, and training tests that establish and document training [3]. This includes a detailed curriculum, exams, and completion documents. A certification on the other hand is a written testimony of qualification [2]. For the preliminary program, the certifications were simple certificates.

After the initial appraisal of the preliminary implementation of the program, additional documents were required and introduced to the program. Many of the issues could have been avoided if the qualification program document was created first. The qualification document outlines the entire qualification program, including qualification levels, covered tasks, requirements, responsibilities, training programs, and evaluations. This document established the framework for all other required documents. These other documents include a more detailed training completion and certification form that includes task list completion and evaluation scores. The updated documents require both trainer and trainee signatures guaranteeing proper implementation of the program and understanding of all covered tasks. With the introduction of the Level I sublevels, on-the-job performance evaluation documentation had to be generated to track and monitor individual success. Along with updated performance evaluation documentation, complete written evaluations and oral interview evaluations had to be generated for review and scoring.

All documentation continues to be revised as program effectiveness appraisals are conducted and the demand for updates continues to grow. However, having a strong framework established in the qualification program document is fundamental for success.

Other Contributing Factors

An effective qualification program for a new methodology such as the process discussed in this paper relies on additional factors in order to be successful. The initial expert users were thoroughly trained on a complex technology and process that has been improved over time to enable scalability and expansion.

Product Development: In order to expand to a wide audience of users, the testing instrument itself had to be upgraded to be a more commercial unit that is more user independent and automated. Significant design efforts were pushed behind reducing the need for troubleshooting the tester and reducing the steps needed to run tests. Now, all testing steps are fully automated, requiring the user to only secure the testing instrument to the testing specimen. In addition to improvements on the product, auxiliary equipment has been optimized to limit needed supplies and maximize reliability and consistency.

Software Updates: Significant strides were accomplished on the software side of the NDE methodology as well. The original expert users manually organized data and had to interpret results. However, software updates now fully automate the process, provide step-by-step guidance to ensure all data is collected uniformly across all users, and process data instantly to analyse and give users immediate feedback to ensure data QA/QC.

Technical Support: With these improvements comes a full technical support network for all qualified individuals to access. The technical support performs audits for individuals with limited qualifications and provides instant guidance and support on all issues and AOCs.

The combination of these developments allows for an improves qualification program that can minimize human error and increase consistency. As the product reliability and data assistance continues to evolve and become more automated, the qualification requirements become less complex and easier for a larger user base to achieve.

Step 10: Next Steps and Conclusion

This paper details an adaptation of SNT-TC-1A and ASME B31Q to develop a qualification program for a novel nondestructive field testing process. By referencing standards that already exist, a complete program was developed and modified for optimal implementation. Many obstacles could have been evaded by outlining a qualification program prior to developing a training program, however the lessons learned led to significant developments in the qualification program discussed in this paper. One such lesson was how essential it was to understand the qualification levels and required training material needed to achieve each qualification level. This document discussed the challenges with a flawed preliminary implementation of the program, appraisal of the program, and changes made for a final program.

The final program combines classroom learning, instructor-led training, hands-on training, and on-the-job performance evaluations. This program is completed and has been successfully implemented in over 300 digs across 12 active, qualified Level II users. Despite this success, the program will continue to evolve as the demand for scalability grows and the user base expands.

In addition to changes to the program based on reviews and assessment of the program effectiveness, next steps for continuous improvement include:

- **Operator Qualification (OQ):** Part of the PHMSA Mega Rule details an OQ requirement for all performed tasks for material verification. This process requires updating the qualification program to include additional sections and submitting for approval to become a covered task.
- **Online Learning Management Systems (LMS):** An LMS is a web-based platform that allows for creating, importing, assigning, tracking, and reporting trainings. Implementation of an LMS will enable larger expansion of the qualification and allow users to monitor individual completions and certifications. Additionally, it will optimize Level I sublevel performance evaluation tracking and allow for greater transparency and reports. Along with the OQ process, the LMS can output qualified individual reports for submission to a larger OQ database.
- **Train the Trainer:** Currently, evaluators, trainers, and proctors are selected and qualified at the discretion of the SME. With the expansion of the qualification program, the need to develop training material and evaluations to qualify trainers will grow. This will require updated qualification levels and a program specific for qualifying trainers.
- **Qualification Intervals:** The current program is missing detailed qualification intervals. The qualification interval establishes the minimum period before subsequent qualifications are required to maintain a qualification. Failure to complete subsequent qualifications can lead to suspension or revocation of a qualification. An effective exercise to determine qualification intervals is a difficulty, importance, and frequency (DIF) analysis for all covered tasks in a specific qualification.
- **Span of Control:** Establishes the maximum number of nonqualified individuals that a qualified individual can direct and observe. The program needs to establish this number and define which covered tasks are permitted for nonqualified individuals to perform under the supervision of qualified individuals.

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