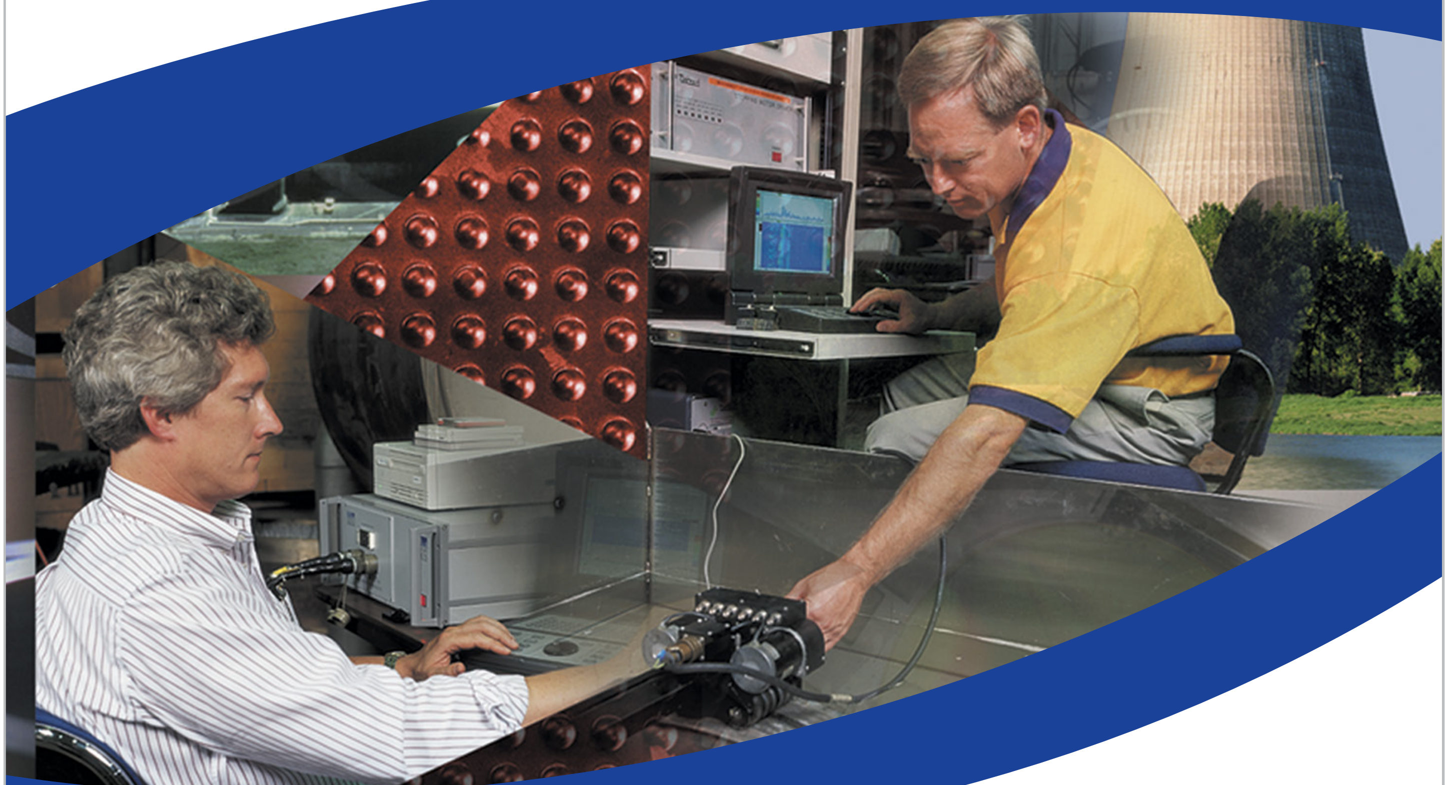
2021 TECHNICAL REPORT

Technical Basis for Nondestructive Examination Experience Requirements for ASME Section XI, Appendix VII



Technical Basis for Nondestructive Examination Experience Requirements for ASME Section XI, Appendix VII

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The Electric Power Research Institute (EPRI) prepared this report.

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ABSTRACT

Ultrasonic testing (UT) personnel working in commercial nuclear power plants in the United States and other countries that adhere to the American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code are certified based on the qualification requirements set by ASME Section XI, Appendix VII. In the United States, these requirements are further conditioned by the Nuclear Regulatory Commission through the Code of Federal Regulations (10 CFR 50.55a). The requirements in these codes and regulations specify the minimum number of hours of training and experience, and written examinations, for each level of UT personnel. The objective of this work was to develop and establish the technical basis specifically for the required experience for qualification of nuclear UT personnel. The technical basis in this document can be used to amend the currently prescribed criteria in ASME Section XI, Appendix VII.

Keywords

Appendix VII
Certification
CP-189
NDE
Nondestructive examination
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PRIMARY AUDIENCE: Individuals concerned with commercial nuclear power plant nondestructive evaluation (NDE) at utilities, inspection vendor organizations, and regulatory bodies.

SECONDARY AUDIENCE: NDE trainers and instructors, human factors specialists, and NDE researchers.

KEY RESEARCH QUESTION

There are three research questions being answered in this report: (1) "*How much nuclear NDE experience is needed to ensure that reliable ultrasonic testing (UT) is being performed?,*" (2) "*What proficiencies constitute meaningful experience*?," and (3) "*Where can meaningful NDE experience be obtained*?"

RESEARCH OVERVIEW

This research developed and established the technical basis for required experience for initial certification to UT Level II and III per the American Society of Mechanical Engineers (ASME) Section XI, Appendix VII. The technical basis was established through the review of prior literature, standards, and codes, as well as a detailed study of an industry-developed UT job-task-analysis with extensive discussions and input from an industry focus group of NDE subject matter experts (SME) to outline the specific areas of skills and knowledge needed to be an effective UT technician in the commercial nuclear power industry. A technical basis for the necessary experience hours for nuclear industry UT Levels II and III are presented and discussed.

KEY FINDINGS

- The current requirements as specified by ASME Section XI, Appendix VII are presented and described for UT Levels II and III.
- Based on prior industry studies and input from industry, it was determined that the prioritization of revisiting the criteria for UT experience hours, as currently prescribed in ASME Section XI, Appendix VII should be the focal point of this technical basis.
- A nuclear industry focus group was formed, and their UT SME input was used in conjunction with related works, codes, and standards to formulate the required experience.
- A representative set of skills and knowledge areas necessary to qualify an individual for ASME Section XI UT Levels II and III, along with the hours of experience needed to obtain proficiency in each area are supported with technical essays.
- The technical basis demonstrates that a certified nuclear UT Level I can become qualified for initial certification to Level II with 542 additional hours of experience performing Section XI or equivalent UT work, and that a nuclear UT Level II can become qualified for initial certification to Level III with 1,246 additional hours of experience performing Section XI or equivalent UT work.
- This report also addresses the fact that experience hours and proficiency areas that make up UT personnel experience can be effectively learned in various environments, and with a variety of mechanisms. Recommendations on learning environments, technology, and other considerations are discussed, and joined for a thorough and holistic analysis of UT experience.

WHY THIS MATTERS

This technical basis explores needed NDE experience, and knowledge, and what is realistically required to obtain it, for the purpose of optimizing the experience hour requirements in ASME Section XI, Appendix VII. This optimization can be used to enable utilities and inspection vendors to train and prepare their UT technicians with the skillsets and proficiencies needed to be highly effective and efficient in performing their job tasks without having to meet arbitrary experience hour requirements that are not technically defensible. Ultimately, this research contributes to the continual development of a strong and reliable NDE workforce for the nuclear fleet.

HOW TO APPLY RESULTS

The report is intended to serve as the technical basis to support future ASME Code action(s) to optimize the number of experience hours required by ASME Section XI, Appendix VII.

LEARNING AND ENGAGEMENT OPPORTUNITIES

The Electric Power Research Institute (EPRI) NDE staff routinely present materials such as this at EPRI conferences and workshops, and other industry meetings. Questions can be directed to the EPRI contacts shown below.

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PROGRAMS: Nuclear Power, P41; and Nondestructive Evaluation, P41.04.01

IMPLEMENTATION CATEGORY: Reference

LIST OF ACRONYMS

ACCP	American Society for Nondestructive Testing Central Certification Program
ANSI	American National Standards Institute
ASME	American Society of Mechanical Engineers
ASNT	American Society for Nondestructive Testing
BWRVIP	Boiling Water Reactor Vessels and Internal Projects
B&PV	Boiler and Pressure Vessel
CFR	Code of Federal Regulations
EPRI	Electric Power Research Institute
ET	Eddy Current Testing
ISI	In-service Inspection
MT	Magnetic Particle Testing
NDE	Nondestructive Examination
NDT	Nondestructive Testing
NRC	Nuclear Regulatory Commission
PDI	Performance Demonstration Initiative
PT	Penetrant Testing
RI-ISI	Risk-Informed In-service Inspection
RT	Radiographic Testing
SCC	Stress Corrosion Cracking
UT	Ultrasonic Testing
VT	Visual Testing

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1 INTRODUCTION

Ultrasonic testing (UT) personnel working in commercial nuclear power plants in the United States and other countries that adhere to the American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel (B&PV) Code are certified based on the qualification requirements set by the ASME Code Section XI, Appendix VII. In the United States, these requirements are further conditioned by the Nuclear Regulatory Commission (NRC) through the Code of Federal Regulations (10 CFR 50.55a) [1]. These codes and regulations specify the minimum number of hours of experience for each level of UT personnel. In the 1960s, when the amount of experience hours specified in the ASME Code for nuclear UT examiners was developed, the industry planned and conducted their outages differently than current day. For example, the Risk Informed In-service Inspections (RI-ISI) programs employed by nuclear power plants, presently, have drastically reduced the number of UT examinations performed during a typical refueling outage. Plant outages decades ago inherently provided UT examiners with the opportunity to scan more components and gain extensive amounts of field experience hours. However, in present day, it is more challenging for UT examiners to gain the magnitude of hours scanning components and to accumulate field experience in a nuclear plant.

Background

This section provides a brief and high-level overview regarding some of the history from the nuclear industry on UT personnel experience hours. This section helps frame the importance of a technical basis for UT Level II and III experience.

An important fact about experience hours applicable to developing UT technicians in accordance with Appendix VII was that hours spent working towards a UT Level I or II qualification could historically be credited simultaneously in multiple methods, as long as the examiner spent at least 25 percent of their time performing each method (see Table 6.2.1a in [2]). This will hereafter be referred to in this report as “the 25 percent rule.” The 25 percent rule was pertinent for gaining UT experience hours and is no longer applicable today which emphasizes the importance for a technical justification of UT experience hours. Fundamentally, the 25 percent rule allowed for an accelerated accreditation of experience.

An example case for using the 25 percent rule would be if an examiner spent a 12-hour day working at a plant and during that day they employed four different nondestructive evaluation (NDE) methods, spending three hours on each method, then the examiner could be accredited for a total of 48 hours of total NDE experience with 12 hours in each method. The 25 percent rule was eventually removed when ASME Section XI began requiring that CP-189 be used as the basis for certification written practices, in the 1992 Addendum [3]. The NRC endorsed the 1995 Edition with the 1996 Addenda of Section XI, in 1999 [4, 5], which was their first endorsement of a code year that didn’t enable use of the 25 percent rule. However, because utilities operate on a 10-year in-service inspection (ISI) program and don’t update their code years until they update to a new program, this change wouldn't have taken practical effect in the industry until at least the mid-to-late 2000s. In Appendix VII of the 2011 edition, ASME Code experience hours for UT personnel were modified for a reduction, but this reduction has not been endorsed by the NRC so currently it cannot be used by industry. A more detailed analysis of the ASME Code will be provided in Section 2.

A key takeaway from this fact is that the experience hours being mandated of NDE personnel could historically be accelerated by up to a factor of four, due to the 25 percent rule. With this rule no longer enabled for use by the industry, the legacy experience hour requirements in the Code have become even more onerous.

With a transitioning NDE workforce and the need for skilled and experienced UT examiners there is an opportunity to revisit Section XI, Appendix VII criteria. This opportunity will bring the industry's collective NDE experience and knowledge together to develop a technical basis which can be used to optimize UT personnel experience hour requirements in ASME Section XI.

Objective

The objective of this research is to develop and establish the technical basis for required nuclear UT experience for Level II and Level III personnel. The focus of this work is the experience criteria needed for UT examiners.

Approach and Scope

ASME Code Section XI, Appendix VII was analyzed to determine the requirements based on its current wording. This analysis allows for an interpretation of how experience is accredited, and what skills and knowledge are currently specified for UT personnel. Additionally, analyzing the current wording of ASME Code Section XI, Appendix VII allows for the identification of any points that might need revision based on the findings of this study. As such, this technical basis is intended to support future ASME Code action(s) to optimize the number of experience hours required by ASME Section XI, Appendix VII.

In addition to the analysis of ASME Code Section XI and its supporting documents, this report contains a review of existing NDE learning and human factors studies, and a review of proposed NRC rule changes relevant to the training and experience of nuclear industry UT personnel. The report then takes a systematic approach to determining the number of experience hours needed in a representative set of skills and knowledge that would qualify a nuclear UT examiner for initial certification to Levels II and III.

This systematic approach was accomplished by reviewing an industry job-task-analysis (JTA) on UT, relevant industry documents, and obtaining input from subject matter experts (SMEs) as well as an industry focus group. These inputs were used to develop a representative set of skills and knowledge that, if attained by an individual, would constitute legitimate qualification to Levels II and III in UT in the nuclear industry. After these UT skill and knowledge areas were determined, the hours needed to obtain proficiency in each individual area were explained and justified through a series of technical essays. These essays define the skill or knowledge area, describe the process of obtaining the required proficiency for each target level of qualification, and quantify the number of hours that can reasonably be considered sufficient to complete this process. The experience hour requirements from all the technical essays were then summed to establish the total number of experience hours that would be needed for the development of a well-qualified UT Level II and III examiner.

It's important to note that the skill and knowledge areas selected for this study are generic UT proficiencies that are gained by performing Section XI or equivalent UT work, under the direct supervision of qualified Level IIs and IIIs. There are additional specialized UT examinations that are performed in the nuclear power industry, which are not addressed in this study and that would require additional training. There also might be UT Level II or III roles, within an organizational structure, that might not require the same level of emphasis on certain generic skills outlined in this report. But developing an example list of skills and knowledge that would, itself, be sufficient to qualify an individual for certification to ASME Section XI, Appendix VII, conclusively demonstrates that the minimum experience hours currently specified in Appendix VII can be modified without undermining the intended purpose of the appendix.

This report also addresses the fact that experience hours and proficiency areas that make up UT personnel experience can be effectively learned in various environments and with a variety of mechanisms. Recommendations on learning environments, technology, and other considerations are discussed and joined for a thorough and holistic analysis of UT experience. Overall, this analysis provides a justification for the minimum amount of experience hours needed for the initial certification of UT Level II and III personnel in the nuclear power industry.

2
BACKGROUND

This section provides background information on the current requirements and standards, the specific criteria for UT Level II and III personnel, careful analysis of the applicable codes and standards, recent human factors and learning studies pertaining to NDE training and experience, and the challenges facing industry to implement these requirements.

Current Experience Requirements

In the United States and many other countries, UT personnel are certified based on the qualification requirements set by ASME Code Section XI, Appendix VII [6]. The current experience hours for UT Levels I through III, as shown in the 2010 addendum, are summarized below and can be found in Table VII-4110-1 [6] as follows:

- Level I – 250 hours
- Level II – 800 hours
- Level III – 4,200-8,400 hours and is dependent on education level

Starting in the 2011 addenda of Section XI, an alternative was included for Level II experience [7]. The alternative provided the replacement of the experience requirement with a minimum of 80 hours of field experience and a minimum of 320 hours of laboratory practice, provided the practice is dedicated to scanning specimens containing flaws in materials representative of those in actual power plants, and provided that the candidate also pass a Section XI Appendix VIII, Supplement 2 performance demonstration for flaw detection and length sizing [7]. However, the NRC disallowed the use of this alternative through the U.S. Code of Federal Regulations (10 CFR 50.55a) [1], by prohibiting the prerequisites for ultrasonic examination personnel certifications in Appendix VII, Table VII–4110–1 and Appendix VIII, sub article VIII–2200, beyond the 2010 edition. For the above reason, the ASME Section XI code years referenced in this report will be the 2010 Edition, specifically for the paragraphs of Appendix VII and VIII just mentioned, and the 2017 Edition for the balance of the Code.

A detailed analysis of Appendix VII of Section XI of the ASME Code (hereafter referred to as "the Code") will be provided for readers in the upcoming subsections. The purpose of this analysis is to provide an explanation and awareness of experience criteria for UT personnel as currently prescribed in the Code. Furthermore, an analysis is required to determine if amendments are required to the wording in the Code, and to also establish the rules that currently apply toward accrediting experience hours.

The current training requirements in the Code are not the primary focus of this analysis; however, they will be mentioned because a distinction between training and experience needs to be defined. Training is part of the initial qualification for UT personnel. It is clear from looking at the skills and knowledge requirements laid out by American National Standards Institute/American Society for Nondestructive Testing (ANSI/ASNT) CP-189 for UT Levels II and III (See Table 2-2) and comparing those to the required training course content for UT examiners specified in Appendix VII, Supplement 1 [6] that there is good correlation between what has been deemed necessary basic knowledge needed for nuclear UT personnel and what has been established as required minimum course content. Refer to Appendix B for this assessment. Because completion of the required training does not constitute nearly as extensive a time requirement as experience for UT personnel, it is not the primary focus of this report. For this reason, the analysis will not present findings for all subarticles and paragraphs because many of the subarticles and paragraphs are not applicable to the objectives of the technical basis.

Analysis of ASME Code Section XI, Appendix VII

Analysis of Appendix VII for Ultrasonic Personnel

The step-by-step analysis of Appendix VII is provided in this section and the analysis is systematically broken into categorical information for a consistent workflow. Readers are highly encouraged to follow along with this analysis in conjunction with a copy of the Code and a 2006 edition of CP-189 [8]. The 2006 edition of CP-189 is referenced here because it is the edition supported in the current editions of the Code that have been approved by reference in 10CFR50.55a.

The categorical information for the analysis is divided into the following groups and a description of each group is given as follows:

- ID #. An identification number for tracking each analysis item.
- Article(s). Identifies the article(s), subarticle(s), sub subarticle(s), paragraph(s), and/or subparagraph(s) of the Code being analyzed for a given ID #. The choice of the name "Article" for this group was selected for simplicity and alignment with Code terminology.
- Text. The verbatim text from a given article of the Code. The text that is displayed was selected because it is directly relevant to the research questions and objectives of this technical basis.
- Reference(s). This group will identify any reference documents or other portions of the Code that the reader is directed towards.
- Takeaway(s). This group highlights any key facts, points, or ideas based on the interpretation of the text for the given ID #. These takeaways will be used to determine where the wording establishes the rules relevant to the research questions and objectives of this technical basis.
- Action(s). In this group, follow-up or further investigation will be listed based on the findings from the Takeaway(s) group. For example, if the Code refers the reader to another document to seek out a piece of information or direction then the action would be to examine said document with a specific objective. Also, in certain instances "None" will be used for the action. In these instances, there is typically no action that needs to be performed because the Text has clearly stated the actions that need to be performed and minimal, to no, interpretation is required.

Table 2-1 provides the analysis of Appendix VII.

Table 2-1
Analysis of Appendix VII

ID#	Analysis
1	**Article**: VII-1000 (Introduction and Scope) **Text**: • This Appendix specifies requirements for the training and qualification of ultrasonic NDE personnel in preparation for Employer certification to perform NDE. Personnel shall be qualified in accordance with IWA-2300 as modified by this Appendix. **Reference(s)**: IWA-2300 (Qualifications of Nondestructive Examination Personnel). **Takeaway(s)**: • This appendix specifies requirements for training and qualification. • Personnel are qualified according to IWA-2300. • IWA-2300 will be used to define training and qualification requirements. **Action(s)**: • Review IWA-2300 to determine if the criteria for the training and qualification of a Level II and III will affect their experience requirements.
2	**Article**: VII-2000 (Qualification Level); VII-2100 (General Requirements). **Text**: • There shall be five qualification levels: Trainee, Level I, Level II, Level III, and NDE Instructor. The skills and responsibilities associated with each level shall be as defined in ANSI/ASNT CP-189. **Reference(s)**: CP-189. **Takeaway(s)**: • The code leaves the definition of *skills and responsibilities* to CP-189. It does not state experience in this article, only skills and responsibilities. • CP-189 should have information on the skills and responsibilities of UT personnel. **Action(s)**: • Use CP-189 to define skills and responsibilities for UT Level II and III personnel.
3	**Article**: VII-3000 (Written Practice); VII-3110 (Experience). **Text**: • The written practice shall specify the experience requirements for each qualification level in accordance with VII-4100 and additional experience that might be required for special NDE applications. **Reference(s)**: VII-4100 (Experience). **Takeaway(s)**: • The written practice shall specify the experience requirements. • Experience requirements are taken in accordance with VII-4100. • Refer to VII-4100 for experience requirements. **Action(s)**: • Determine experience requirements from VII-4100.

Table 2-1 (continued)
Analysis of Appendix VII

ID#	Analysis
4	**Article**: VII-3000 (Written Practice); VII-3120 (Training). **Text**: • The written practice shall specify the following: (a) classroom and laboratory training requirements for each qualification level in accordance with VII-4200. **Reference(s)**: VII-4200 (Training). **Takeaway(s)**: • The written practice will refer to VII-4200 for training requirements for each qualification level. **Action(s)**: • Refer to VII-4200 for training requirements.
5	**Article**: VII-3000 (Written Practice); VII-3200 (Responsibilities). **Text**: • The written practice shall specify the responsibilities, duties, and qualifications required for personnel who perform examinations or implement the personnel qualification program. **Reference(s)**: None. **Takeaway(s)**: • The written practice shall specify the responsibilities, duties, and qualifications. • As mentioned in ID #2, the responsibilities are referred to in CP-189. • The organization will develop their written practice in accordance with the details specified in Article VII-3000. **Action(s)**: • None.
6	**Article**: VII-4000 (Qualification Requirements); VII-4100 (Experience); VII-4110 (Initial Certification for Ultrasonic Examination). **Text**: • Table VII-4110-1 lists the required experience for initial certification for ultrasonic examination. As used in this Appendix, experience means performance of the skill activities described or referenced in Article VII-2000 for the applicable NDE level. • Note to reader: This portion of text is not verbatim but is a paraphrase of Table VII-4110-1. When referring to Table VII-4110-1 for a Level III, there are three criteria listed with the number being hours. The criteria are: 4200 (Option 1), 6300 (Option 2), 8400 (Option 3). When referring to Table VII-4110-1 for a Level II, 800 hours of experience are listed with general notes provided as well. General Note (a) states that Level I and Level II experience hours would need to be combined if someone is directly certified to Level II which would then be 1050 hours. **Reference(s)**: VII-2000. **Takeaway(s)**: • The definition of experience is given in this article, which is defined as: experience means the performance of the skill activities described or referenced in VII-2000; where upon review of VII-2000 it will refer the reader to CP-189. Thus, the Code defines experience as the performance of skill activities described or referenced in CP-189.

Table 2-1 (continued)
Analysis of Appendix VII

ID#	Analysis
	• The keywords in this article are *experience means the performance of skill activities*. • It is imperative to determine how CP-189 defines the performance of skill activities because that definition bounds the accredited experience hours that are mandated in Table VII-4110-1 and it is directly relevant to the objectives of this technical basis. • The maximum number of experience hours needed for initial certification as a Level II and III is 800 hours and 8400 hours (Option 3), respectively. **Action(s)**: Refer to CP-189 to determine how *the performance of skill activities* is defined.
7	**Article**: VII-4000 (Qualification Requirements); VII-4100 (Experience); VII-4120 (Experience Options for Level III Personnel). **Text**: • The three experience options identified in Table VII-4110-1 for qualification as a Level III are as follows. • (VII-4121 Option 1) Graduate of a four-year accredited engineering or science college or university with a degree in engineering or science, plus two-years of experience in NDE in an assignment comparable to that of an NDE Level II in the ultrasonic examination method. • (VII-4122 Option 2) Completion with a passing grade of at least the equivalent of two full years of engineering or science study at a university, college, or technical school, plus three years of experience in NDE in an assignment comparable to that of an NDE Leve II in the ultrasonic examination method. • (VII-4123 Option 3) High school graduate, or equivalent, plus four years of experience in NDE in an assignment comparable to that of an NDE Leve II in the ultrasonic examination method. **Reference(s)**: VII-2000. **Takeaway(s)**: • Three experience options are given in VII-4100 for a Level III. The options differ based on the education level and years of experience in NDE in an assignment comparable to that of an NDE Level II in the ultrasonic method. • In VII-4110 the required experience for initial certification is said to be given in Table VII-4110-1, which lists the experience in the number of hours with the exception of a Level III where it lists both hours and the Options given in VII-4121 through VII-4123. • Because Table VII-4110-1 lists experience for Level IIIs in both hours and thus years (based on the options) it is not explicitly stating which criteria needs to be met for defining experience. For example, is it the number of hours or the number of years? **Action(s)**: • Clarify how experience is credited—either hours or years.

Table 2-1 (continued)
Analysis of Appendix VII

ID#	Analysis
8	**Article**: VII-4000 (Qualification Requirements); VII-4100 (Experience); VII-4130 (Experience Records). **Text**: • (a) The records maintained by the Employer to substantiate experience for initial certification to each level shall include the activity performed, the number of hours performing the method, and the level of certification. • (b) Documented experience with the current Employer might be used for certification in accordance with the Appendix, subject to acceptance by a Level III. **Reference(s)**: VII-2000. **Takeaway(s)**: • Records are maintained by the Employer to substantiate experience by three key aspects: activity performed, number of hours performing the method, and the level of certification. • Experience records need to be maintained describing the activity and number of hours spent performing the method. **Action(s)**: • None.
9	**Article**: VII-4000 (Qualification Requirements); VII-4200 (Training); VII-4210 (Program, Facilities, and Materials). **Text**: • (a) Personnel shall successfully complete the training program outlined in Supplement 1. **Reference(s)**: Mandatory Appendix VII - Supplement 1 (hereafter referred to as Supplement 1). **Takeaway(s)**: • Supplement 1 describes the mandatory training program. **Action(s)**: • Refer to Supplement 1 for a description of the training program.
10	**Article**: VII-4000 (Qualification Requirements); VII-4200 (Training); VII-4220 (Training Course Content and Duration). **Text**: • Training Course content shall be in accordance with Supplement 1. • The initial training hours shall be as specified in Table VII-4220-1. • Note to reader: This portion of text is not verbatim but is a paraphrase of Table VII-4220-1. When referring to Table VII-4220-1, for a Level III, 40 hours of classroom and 0 hours of laboratory are given. When referring to Table VII-4220-1 for a Level II, 40 hours of classroom and 40 hours of laboratory are given. **Reference(s)**: Supplement 1. **Takeaway(s)**: • Table VII-4220-1 assigns classroom and laboratory training for Level II and III certification. **Action(s)**: • None.

In Table 2-1, a list of actions are defined based on the text within ASME Code Section XI Appendix VII. Some of the actions direct the reader to other resources such as CP-189, IWA-2300, and Supplement 1. Reference documents are analyzed separately in the following subsections of this report, and they are analyzed based on the actions from Table 2-1. For example, actions from Table 2-1 that reference CP-189 will be analyzed in the CP-189 section.

Analysis of CP-189

In this section, a detailed analysis of CP-189 will be performed based on the actions defined in Table 2-1. The actions listed below were taken from Table 2-1 and specifically identify the needed outcomes from the analysis of CP-189:

1. Use CP-189 to define the skills and responsibilities for UT Level II and III personnel (refer to ID #2 in Table 2-1).
2. Refer to CP-189 to determine how the performance of skill activities is defined (refer to ID #6 in Table 2-1). Recall the keywords in this action are *skill activities*.

Action from ID# 2 in Table 2-1

The analysis of CP-189 will begin with the action from ID#2 in Table 2-1, which is to define the skills and responsibilities for a UT Level II and III. Upon review of CP-189, the exact wording of skills and responsibilities is not used. To proceed with the analysis, the use of each word will be analyzed separately to understand its intended meaning in CP-189 (that is the use of the word skills will be analyzed separately from responsibilities).

When searching for the word skills or skill in CP-189 the appearance of the word in context relative to this action is in 3.1 (Classification), which states:

> Six levels of qualification are defined in terms of the skills and knowledge required in a given method or methods to perform specified NDT activities.

As the reader can see, in this definition it does not refer to just skills, but instead states skills and knowledge. In 3.2 (nondestructive testing [NDT Level III]) and 3.3 (NDT Level II) of CP-189 it continues with a tailored description for Level II and III, as shown in Table 2-2.

Note: In various industries, NDE is also commonly referred to as nondestructive testing (NDT), and NDE. These variations can also be seen in the codes and standards applicable to this topic, which are referenced herein. For the purposes of this technical basis document, these terms are used interchangeably.

Table 2-2
CP-189 Level II and III Skills and Knowledge

Level	CP-189 Text	List of Skills and Knowledge
III	3.2 NDT Level III. An NDT Level III shall have the skills and knowledge to establish techniques; to interpret codes, standards, and specifications; designate the particular technique to be used; and to verify the adequacy of procedures. The individual shall also have general familiarity with the NDT methods covered in Appendix A of this standard. The NDT Level III shall be capable of conducting or directing the training and examining of NDT personnel in the methods for which the Level III is qualified.	1. Establish techniques. 2. Interpret codes, standards, and specifications. 3. Designate the particular technique to be used 4. Verify the adequacy of procedures. 5. Have general familiarity with the NDT methods covered in Appendix A of this standard. 6. Be capable of conducting or directing the training and examining of NDT personnel in the methods for which the Level III is qualified.
II	3.3 NDT Level II. An NDT Level II shall have the skills and knowledge to set up and calibrate equipment, to conduct tests, and to interpret, evaluate, and document results in accordance with procedures approved by an NDT Level III. The NDT Level II shall be thoroughly familiar with the scope and limitations of the method to which certified and should be capable of directing the work of trainees and NDT Level I personnel. The NDT Level II shall be able to organize and report nondestructive results.	1. Set up and calibrate equipment. 2. Conduct tests. 3. Interpret, evaluate, and document results in accordance with procedures approved by an NDT Level III. 4. Be thoroughly familiar with the scope and limitations of the method to which certified. 5. Be capable of directing the work of trainees and NDT Level I personnel. 6. Be able to organize and report NDT test results.

These descriptions of UT Level II and III skills and knowledge both provide six distinct skills and knowledge sets (refer to the right-most column in Table 2-2). When reviewing these lists, it becomes apparent these are the foundational skills and knowledge sets needed for a Level II and III. Although the lists are rather brief, they do provide the basis for assigning the skills and knowledge needed for proficient Level II and III personnel. Thus, a technical basis made on establishing the experience and training for Level II and III personnel will be guided by these lists, as identified in Section 3.2 and 3.3 of CP-189, which was originally referred to by sub article VII-2100 in the Code. In CP-189, there are no further uses of the word skills that would alter the above analysis.

The analysis will continue onto the responsibilities as defined in CP-189. The first appearance of the word responsibility or responsibilities in CP-189, with context to this action, is in 5.2 (Procedure Requirements). In 5.2 of CP-189, its states that the procedure shall include the personnel duties and responsibilities. An exact list of responsibilities for a Level III are not given in CP-189 outside of the administration and grading in 6.4.1 (Responsibilities).

The conclusions from conducting the action of ID# 2 from Table 2-1 are that CP-189 does not explicitly define the skills and responsibilities for UT Level II and III personnel; however, it does unarguably define, and list, the skills and knowledge for Level II and III personnel. Based on this conclusion, it is discernible that the current wording in the Code references the skills needed for a UT Level II and III and it is paramount that these skills guide and instruct any technical basis related to the experience and training of UT Level II and III personnel.

Action from ID# 6 in Table 2-1

The action for this section is to refer to CP-189 to determine how the performance of skill activities are defined in CP-189 because this will direct the required experience in VII-4110 of the Code. A point to realize before beginning this analysis is that CP-189 does provide a definition of experience and this definition is dependent on the edition of CP-189 being referenced. However, in VII-4100 of the Code does not refer to the definition of experience from CP-189; the Code states, "experience means the performance of the skill activities…" and for this reason there is no need to refer to the definition of experience given in CP-189. In fact, referring to the definition of experience in CP-189 would violate the direction of the Code. Even though the Code does not refer readers to the definition of experience in CP-189 its worthwhile to see how the definition of experience in CP-189 has evolved over the years. Table 2-3 shows the definition of experience from the 1995 and 2006 editions of CP-189.

Table 2-3
CP-189 Definition of Experience by Edition

Edition	Definition of Experience
1995	Actual performance or observation conducted during work time resulting in the acquisition of skill and knowledge. Classroom, or laboratory training time, or both shall not be considered as experience.
2006	Actual performance of an NDT method conducted in the work environment resulting in the acquisition of knowledge and skill. This does not include formal classroom training but might include laboratory and on-the-job training as defined by the employer's certification procedure.

As seen in Table 2-3 the definition of experience is different between the 1995 and 2006 editions. In the 1995 edition it explicitly stated that both classroom and laboratory training could not be considered as experience; however, in the 2006 edition laboratory and on-the-job training does apply as experience. This is an important observation because, in the 2006 edition, CP-189 recognizes the importance of laboratory and on-the-job activities as building the necessary skills and knowledge for personnel. Therefore, the definition of experience has been shown to evolve throughout time in CP-189 and it encourages a more diverse set of activities to account for experience.

When searching CP-189 there is no use of the wording skill activities within the text. Therefore, like in the analysis of action ID# 2 an analysis on the use of each word will be conducted separately.

In CP-189 the relevant use of the word activities appears in 3.1 (Classification) and this was discussed in the previous section of this report (refer to "Action From ID# 2 in Table 2-1"). Based on this analysis, the Code's definition of experience, as stated in subsection VII-4110, can be established. By joining the analyses of CP-189's use of the wording skills and activities, a concise and simplified definition for experience is given by the Code. Summarizing this implied definition of experience, specifically for Level II and III personnel, would be as follows:

Experience means the performance of skill activities. Skill activities for Level III personnel are as follows:

1. Establish techniques.
2. Interpret codes, standards, and specifications.
3. Designate the particular technique to be used.
4. Verify the adequacy of procedures.
5. Have general familiarity with the NDT methods covered in Appendix A of CP-189.
6. Be capable of conducting or directing the training and examining of NDT personnel in the methods for which the NDT Level II is qualified.

Experience means the performance of skill activities. Skill activities for Level II personnel are as follows:

1. Set up and calibrate equipment.
2. Conduct tests.
3. Interpret, evaluate, and document results in accordance with procedures approved by an NDT Level III.
4. Thoroughly familiar with the scope and limitations of the method to which certified.
5. Be capable of directing the work of trainees and NDT Level I personnel.
6. Be able to organize and report NDT test results.

Summary of CP-189 Analysis

If a reader were to follow the workflow presented here on Appendix VII, they should conclude a definition of experience based strictly on the current wording of the Code and CP-189. Now, it can be questioned if this definition of experience is the intention of the Code; however, that was not the objective of this analysis. This analysis has established clarity on the current rule given from the Code and through this definition of experience it now solidifies how experience hours can be accredited for the initial certification of UT Level II and III personnel. In conclusion, this definition of experience is descriptive and focuses on applying the foundational skills and knowledge needed for proficient UT Level II and III personnel.

Analysis of IWA-2300

In this section, an analysis of IWA-2300 will be performed based on the action defined in Table 2-1. The action listed below was taken from Table 2-1 and specifically identifies the needed outcomes from the analysis of IWA-2300:

1. Review IWA-2300 to determine if the criteria for the training and qualification of a Level II and III will affect their experience requirements (refer to ID# 1 in Table 2-1).

IWA-2300 is titled “Qualifications of Nondestructive Examination Personnel” and provides the requirements for the training and qualification of personnel in preparation for Employer certification to perform NDE. The analysis of IWA-2300 will be conducted similarly to the analysis performed on Appendix VII and again, categorial information is used for a systematic analysis and consistent workflow. The definition for each group in Table 2-4 is the same as the definition give for Table 2-1. Table 2-4 does not contain an “Action(s)” group because the Takeaway group is used to identify any relevant requirements or statements that need to be met for the training and qualification of UT NDE personnel and there is typically no follow-up that is needed. This analysis is specifically focused on identifying any text within IWA-2300 that would affect or have bearing on the experience requirements for the initial certification of UT personnel as defined in VII-4100.

Table 2-4 provides the analysis of IWA-2300.

Table 2-4
Analysis of IWA-2300

ID#	Analysis
1	**Article**: IWA-2310 (General); IWA-2311 (Written Practice); IWA-2312 (NDE Methods Listed in ANSI/ASNT CP-189). **Text**: • IWA-2310 - (a) Personnel performing nondestructive examinations (NDE) shall be qualified and certified using a written practice prepared in accordance with ANSI/ASNT CP-189, Standard for Qualification and Certification of Nondestructive Testing Personnel, and ANSI/ASNT CP-105, Standard for Topical Outlines for Qualification of Nondestructive Testing Personnel, as amended by the requirements of this Division. • IWA-2310 - (b) As an alternative to a personnel qualification program based on CP-189, the ASNT Central Certification Program (ACCP) might be used. The supplemental requirements of this Division shall apply to qualification of personnel in accordance with the American Society for Nondestructive Testing Central Certification Program (ACCP). • IWA-2311 - (a) The Employer shall prepare a written practice in accordance with ANSI/ASNT CP-189. • IWA-2311 - (b) The written practice shall specify the duties and responsibilities of the Principal Level III. • IWA-2312 - (b) Training, qualifications, and certification of ultrasonic examination personnel shall also comply with the requirements of Mandatory Appendix VII.

Table 2-4 (continued)
Analysis of IWA-2300

ID#	Analysis
	Reference(s): CP-189, CP-105, ACCP. **Takeaway(s)**: • NDE personnel are qualified and certified using a written practice prepared in accordance with CP-189. • ACCP might be used as an alternative to personnel qualification program. • The Employer shall prepare the written practice in accordance with CP-189. • Training, qualification, and certifications of UT examination personnel will comply with Appendix VII.
2	**Article**: IWA-2320 (Qualification Requirements); IWA-2323 (Level III Personnel) **Text**: • The qualifications of Level III NDE personnel shall be evaluated using written examinations and a Demonstration Examination. The written examinations shall cover the Basic, Method, Specific, and Practical areas of knowledge as defined in (a), (b), (c), and (d). The Demonstration Examination shall be in accordance with ANSI/ASNT CP-189, Level II Practical Examination rules. **Reference(s)**: CP-189. **Takeaway(s)**: • Level III personnel shall be evaluated using written examinations and a demonstration examination. • The demonstration examination shall be in accordance with CP-189, Level II practical examination rules. • IWA-2323 provides a detailed description of the number, types of questions, and content for the Basic, Method, Specific, and Practical examinations.
3	**Article**: IWA-2320 (Qualification Examinations); IWA-2340 (Level III Education). **Text**: • Level III candidates shall have high school or equivalent education. **Reference(s)**: None. **Takeaway(s)**: • Level III will have at least a high school education.
4	**Article**: IWA-2360 (Level I and Level II Training and Experience). **Text**: • (c) Experience is work time in an NDE method. Classroom and laboratory training time shall not be credited as experience. **Reference(s)**: None. **Takeaway(s)**: • A definition of experience for Level I and Level II personnel is given, which differs from the definition of experience in VII-4100. • The text also does not allow experience to be credited from classroom or laboratory training, which again differs from VII-4100.

Table 2-4 (continued)
Analysis of IWA-2300

ID#	Analysis
4	• The definition of experience in IWA-2360(c) might need to be revisited for a possible amendment.
5	**Article**: IWA-2370 (Level III Experience) **Text**: • Candidates for Level III certification shall meet one of the following criteria as follows: 1. Graduate of a four-year accredited engineering or science college or university with a degree in engineering or science, plus one year of experience in NDE in an assignment comparable to that of an NDE Level II in the examination method. 2. Completion with a passing grade of at least the equivalent of two full years of engineering or science study at a university, college, or technical school, plus two years of experience in an assignment comparable to that of an NDE Level II in the examination method. 3. Four years of experience in an assignment comparable to that of a Level II in the examination method. **Reference(s)**: None. **Takeaway(s)**: • Three options are provided for Level III personnel experience and are dependent on education level and years of experience. • A definition of experience for Level III experience is not provided in IWA-2370.

Summary of IWA-2300 Analysis

IWA-2300 provided the requirements for the qualification and certification of NDE personnel. In this analysis, pertinent requirements for UT Level II and III personnel were presented. IWA-2300 requires NDE personnel to be qualified and certified using a written practice and qualified by examination. IWA-2300 provides references to other documents such as CP-189, ACCP, and CP-105, which provide richer descriptions of the requirements. For a Level III, their qualifications are evaluated using written examinations and a demonstration examination. The written examination covers basic, method, specific, and practical areas of knowledge. The demonstration examination is in accordance with CP-189. In the written examination, several questions are asked, which are relevant to the skills and knowledge mentioned in "Analysis of CP-189" of this report. For example, it is required to ask questions on CP-189, materials, fabrication, product technology, interpreting codes, standards, and specifications. Basically, several of the questions directly pertain to the fundamental skills and knowledge sets needed for UT Level III's as referenced in VII-4100.

IWA-2300, in the 2017 edition of the Code, provides a definition of experience in IWA-2360(c), which does differ from the definition given in VII-4110. This discrepancy in the definition of experience, between IWA-2360(c) and VII-4110 might need to be amended based on review by ASME Code members. Clarification on terminology between laboratory training (for example, IWA-2360[c]) and laboratory practice (for example, VII-4110) will need to be performed. Nonetheless, one of the primary objectives of reviewing IWA-2300 was to determine if there are any requirements on the number of experience hours that would affect those proposed in Table VII-4110-1, and based on this analysis, none were identified. The most extensive requirements for UT personnel experience are defined in VII-4100.

Analysis of ACCP

As indicated in IWA-2310, ACCP can be used as an alternative to a personnel qualification program that is based on CP-189. In this section, an analysis of ACCP will be performed with the objectives of determining the qualification requirements regarding experience for UT Level II and III and how these requirements contrast against the Code and CP-189. The ACCP analysis in this section was performed using ASNT Document ACCP-CP-1 Revision 8 [9].

To begin, a few relevant definitions from ACCP were taken verbatim and are provided as follows:

> "**Experience**: The time period during which the candidate performs the specific NDT method or technique under general supervision, including personal application of the NDT method to materials, parts or structures.
>
> **NDT training**: The process of instruction in theory and practice in the NDT method in which certification is sought, which takes the form of training courses to an approved syllabus but shall not include the use of specimens used in practical examinations.
>
> **On-the-job training**: The practical application of an NDT test method in production or field conditions under the direct supervision of a Level II or Level III person in the applicable test method.
>
> **Practical training**: The instruction in which the personnel being trained are instructed in the hands-on set-up and use of equipment in the applicable test method."

ACCP provides a definition of experience, which is not restrictive to location such as the classroom, lab, or field. ACCP does provide three different definitions pertaining to training which are NDT, on-the-job, and practical.

ACCP Section 3.0 "Categories of Qualification" provides descriptive information about the job skills for Level II and III personnel. The following text was taken directly from ACCP Section 3.0:

> "The categories of qualification for the ACCP are defined as the job skills, necessary to adequately perform the NDT activities required within a given test method for the level of qualification indicated. Qualified personnel shall be cognizant in the subject material contained in the test method body of knowledge for the applicable test method and level of qualification.
>
> 3.2 Level II: An ACCP Level II shall have the skills and knowledge to set up and calibrate equipment, to conduct tests, and to interpret, evaluate, and document results in accordance with procedures approved by an ACCP Professional Level III or ASNT NDT Level III. An ACCP Level II shall be thoroughly familiar with the scope and limitations of the method to which certified and should be capable of directing the work of trainees and Level I personnel. An ACCP Level II shall be able to organize and report NDT results. An ACCP Level II shall be capable of developing an NDT instruction in conformance with a procedure. An ACCP Level II shall be knowledgeable in the NDT subject matter contained the NDT Body of Knowledge for Level II in the applicable test method(s).

3.3 Professional Level III: An ACCP Professional Level III shall have the skills and knowledge to establish techniques, to interpret codes, standards, and specifications, to designate the particular technique to be used, and to prepare or approve procedures and instructions. An ACCP Professional Level III shall also have general familiarity with other NDT methods. An ACCP Professional Level III shall be capable of conducting or directing the training and examination of NDT personnel in the methods for which the ACCP Professional Level III is qualified. An ACCP Professional Level III shall have knowledge of materials, fabrication, and product technology in order to establish techniques and to assist in establishing acceptance criteria when none are otherwise available. An ACCP Professional Level III shall be knowledgeable in the NDT subject matter contained the NDT Body of Knowledge for Level III in the applicable test method(s)."

The text just presented from ACCP Section 3.0 "Categories of Qualification" is similar in content and description to that of CP-189 (refer to Action from ID# 6 in Table 2-1). A key statement from ACCP about categories of qualification is that these are the job skills needed to adequately perform the NDT activities for a given method at that qualification level. ACCP then goes on to list these foundational skills, which again is like the skills and knowledge given in CP-189. With both CP-189 and ACCP being similar in their skills and knowledge for each NDE level, this further provides guidance and reassurance on which sets of skills and knowledge need to be deeply analyzed for the technical basis.

ACCP Section 9.0 "Eligibility for Certification" provides the experience requirements for Level II and III and this information is of particular interest for this technical basis. Table 2 of ACCP provides Level II experience requirements, and for UT a minimum of 800 hours performing ultrasonics and a total of 1,600 hours performing NDT is required. As noted in ACCP Table 2, the experience shall be based on the actual hours worked in the specific method and it also states that the hours spent performing NDT-related tasks can be counted. The 800 hours for UT Level II are the same for ACCP and in Table VII-4110-1 of Appendix VII.

ACCP experience requirements for Level III personnel is specified in ACCP Section 6.2, where the following is provided:

"6.2 ACCP Level III candidates must satisfy one of the following sets of criteria to be eligible to examine as follows:

6.2.1 Have graduated from a minimum four-year* U.S. college or university curriculum with a baccalaureate degree in engineering or science, plus one (1) additional year of experience beyond the level II requirements in NDT in an assignment comparable to that of an NDT Level II in the applicable NDT method(s), or

6.2.2 Have completed with passing grades at least two years of engineering or science study at a university, college, or technical school, plus two (2) additional years of experience beyond the level II requirements in NDT in an assignment at least comparable to that of NDT Level II in the applicable NDT method(s), or

6.2.3 Have four (4) years of experience beyond the level II requirements in NDT in an assignment at least comparable to that of an NDT Level II in the applicable NDT method(s)."

ACCP Section 6.2 provides a time requirement in years of experience, not hours, for the promotion of Level III from a Level II but it is dependent on educational background. The relationship between years of experience and background education given in ACCP is similar, but not the same as what is in the Code. The Code applies an additional year of experience for two-year and four-year educational backgrounds in comparison to ACCP, but both require the same four years of experience for high school graduates. The Code also has a requirement on the experience hours that must be met for UT Level IIIs as described in Table VII-4110-1.

In summary, the key comparable requirements such as experience and job skills for UT Level II and III from ACCP were presented and compared against the Code and CP-189. ACCP clearly defined experience and indicated that it was dependent on performing the NDT method under supervision. This indicates that ACCP allows for experience to be gained in the field, laboratory, or elsewhere. ACCP lists the required skills and knowledge for Level II and III and those are commensurate with CP-189. Lastly, when compared to the Code, ACCP requires the same UT experience hours for a Level II. However, for a Level III it does reduce the years of experience for some educational backgrounds.

Literature and Proposed Rule Making for UT Personnel Experience

This section presents and discusses recent activities in the nuclear industry regarding UT experience, training, and learning. In 2020, Pacific Northwest National Laboratory (PNNL) published a technical report on human learning and memory with an emphasis on NDE [10]. This study provided an in-depth analysis of different principles of learning and gave recommendations for laboratory practice and field experience. A few relevant statements from Section 2.3 of the PNNL report, that relate to experience, are the following [10]:

> "The scientific literature on human learning suggests that more time on job-relevant training is better. Thus, the proposals to increase laboratory practice are commensurate with the guidance from literature."
>
> "There is latitude to reduce the overall number of experience hours with a corresponding increase in lab practice. However, the proposals should be evidence-based with a rationale for accumulating adequate experience to develop proficient examiners, rather than simply being able to pass a single demonstration test."

As shown in these statements, it is evident that more time spent performing job-relevant training, or as the Code states skill activities, is better for learning. This study also recognized that some learning can be moved from field time, or field experience, to laboratory practice while still gaining the skills and knowledge necessary to be an effective UT examiner. This is important to consider in this technical basis because it supports the notion that much of the learning can come from other activities outside of the field, given there is a rationale for such experience.

On March 26, 2021, the NRC published a proposed rule regarding the revision of 10CRF50.55a [11]. The proposed rule change will condition ASME Section XI, Appendix VII by adding options for reducing field experience requirements for UT Level I and II personnel. The proposed revision did not mention any changes to the current UT Level III experience as detailed in Appendix VII. The proposed regulation will offer options as follows [11]:

- Level I – 175 hours experience, 125 hours experience/50 hours lab practice.
- Level II – 720 hours experience, 400 hours experience/320 hours lab practice and successful completion of Appendix VIII, Supplement 2 detection and length sizing.

The proposed regulation has a couple of key takeaways in comparison to Table VII-4110-1 in the 2010 edition of the Code. First, there is an overall reduction of experience hours for Level I and Level II personnel. The reduction was 75 hours for Level I (that is from 250 hours to 175 hours) and 80 hours for Level II (that is from 800 hours to 720 hours). The second takeaway is the hour differentiation between experience and lab practice. For example, of the 720 hours specified for a UT Level II, 400 hours can be accredited from field experience and 320 hours from laboratory practice.

The proposed regulation agrees with the PNNL learning study [10], which indicates an offset of field experience with laboratory practice. Therefore, it is apparent that the industry supports the finding that acceptable skills and knowledge can be gained outside of field experience.

From 2017-2019, the Electric Power Research Institute (EPRI) conducted research regarding human factors associated with manual UT in the nuclear power industry [12, 13]. A key aspect of this study was to conduct one-on-one anonymous interviews with present day UT technicians, which are representative of UT technicians from the U.S. and China. These interviews provided firsthand testimony about the challenges and opportunities associated with performing a UT technician's job. Two open-ended questions were asked to interviewees during this study that are relevant to the PNNL UT learning study and the proposed rule change. The questions were (see Table 2-2 of [13]):

- What aspects of training for these tasks do you think could be improved, and how?
- What aspects of training for these tasks are unnecessary and why?

A notable trend emerged from both of these questions, and it was that UT technicians felt that the context of training material presently given was acceptable, but more feedback during the learning and training process is needed when scanning components (see Table 2-10 and Table 2-11 of [13]). This is an important statement from the UT technicians because it's informing the industry that the UT workforce desires more opportunities for feedback when they are gaining their training and experience hours. As the industry is aware, there are fortunately very few relevant indications in the field; therefore, UT personnel must gain feedback on relevant indications using other learning mechanisms outside of field experience. So, not only do learning studies [10], proposed rulemaking [14], and CP-189's evolved definition of experience (see Table 2-3) suggest lab practice as an acceptable resource for developing the skills and knowledge, the present-day UT technicians are requesting such solutions as well [13]. It should be noted that it is for these very same reasons that Note (d) of Appendix VII, Table VII-4110-1 (in the 2011 and later editions and addenda) contains the provision that laboratory practice is dedicated to scanning specimens containing flaws in materials representative of those in actual power plants.

A Poll of Nuclear UT Personnel Regarding Obtaining Experience Hours

This project conducted a poll of current nuclear utility UT Level IIIs in the United States, which asked the two questions as follows:

1. When you were hired by the utility, approximately how many UT experience hours did you have?
2. When you certified the first time for the utility, what level did you certify to for UT?

The point of this poll was to ascertain whether the U.S. utilities have traditionally created their own UT Level IIIs, by hiring new technicians as UT Trainees and bringing them up through the full training and experience processes from Trainee to Level III, or if they have traditionally hired individuals who had gained their training and experience elsewhere. From the 22 individuals that responded to the poll, overwhelmingly the answer was the latter. The majority of the respondents (that is, 16 of the 22 or 73 percent) were either certified directly as UT Level IIIs upon being hired by the utility (14 respondents) or already had the necessary experience hours to be eligible for Level III, but evidently were not needed in that capacity (two respondents). Four respondents (18 percent) were hired and immediately certified to UT Level II, already possessing at least 4,340 UT experience hours. Only two (9 percent) of the respondents said that they had very few, if any, UT hours and were brought in by a utility at the Trainee level. Both individuals were hired by the same utility, so that might be an outlier situation.

These poll results have shown that U.S. utilities have traditionally hired UT technicians that have obtained their experience hours elsewhere and oftentimes this experience has mostly been gained through inspection service vendors. As discussed in the previous section, laboratory time can offer many benefits for gaining quality UT experience. Thus, offering laboratory time as an alternative for experience hours will likely create new pathways for obtaining experience hours, which can challenge and leverage traditional approaches.

Summary

In Section 2 of this report, an analysis of Code requirements for the initial certification of UT Level II and III personnel have been presented. Based on this analysis, IWA-2300 provides an initial list of requirements for the certification of UT Level II and III personnel, as specified in VII-1000. IWA-2300 relies on other documents for specific requirements for tasks such as the written and practical demonstrations. Also, in IWA-2300 a minimum requirement is a high-school education for Level III personnel. The reader is encouraged to review IWA-2300 for specific details. In VII-4000, the experience and training requirements are specified. Experience requirements are provided in VII-4100. For a Level I to be certified as a Level II, it would require 800 hours of experience, but for direct certification to a Level II this would require 1,050 hours of experience. For high school educated NDE personnel, it would require 8,400 hours of experience as a UT Level II for initial UT Level III certification. Training is addressed in VII-4200 with the course content outlined in Mandatory Supplement 1. The time requirements for training are considerably less than those for experience. In summary, the challenging requirement for the initial certification of UT Level II and III personnel is the amount of experience hours, as currently specified in Table VII-4110-1.

Given that the most challenging or restrictive category of requirements for the initial certification of UT Level II and III personnel is experience hours, it was imperative that a clear understanding of experience be defined from the current Code requirement. In the analysis, the Appendix VII rules regarding experience were identified. Experience is currently defined as the performance of skill activities given in CP-189. CP-189 establishes a brief list of skill activities required for both Level II and III personnel, which build the foundation of guiding the skills and knowledge needed for proficient personnel (refer to section titled "Analysis of CP-189" in this report). It's also important to point out that Appendix VII's definition of experience does not restrict or mandate from which location or learning environment that experience can be gained—meaning that experience can be gained in other places, such as the laboratory, field, office, or relevant industry events and meetings. As shown earlier, editions of CP-189 since 2006 allow for laboratory and on-the-job activities to account for experience, per an organization's certification procedure. The importance of these statements is that it shows how the performance of skill activities is not constrained to the environment in which learning is being performed but instead that the content being learned directly supports the skills and knowledge needed to be a proficient Level II and III.

It was also shown in Section 2 that a recent NDE learning study [10] and proposed rulemaking [14] by the NRC are in support of reducing field experience hours in place of laboratory hours. As previously mentioned, this does not violate the Appendix VII definition of experience and, in actuality, it further supports that valuable experience can be gained through alternative means and environments.

With the challenges of the declining NDE workforce and decreases in numbers of examinations in the nuclear power industry, efficiency and effectiveness in the training and qualification processes of NDE personnel is becoming increasingly important. A goal is to improve NDE reliability while reducing costs through optimization of the quality and amount of NDE training and required experience. Although performance demonstration testing alone might screen out poorly performing systems, it does not automatically ensure reliable examinations. As concluded by a prior NDE Expert Panel [15], sufficient training and experience are the basis for performing reliable NDE. Therefore, an opportunity has presented itself, which is to reassess the experience hours for the initial certification of UT Level II and III personnel by means of a technical basis, which justifies the required time to obtain the needed skills and knowledge to develop proficient UT personnel.

3 BASIS FOR EXPERIENCE REQUIREMENTS

This section provides a technical basis for establishing appropriate experience hour requirements of ASME Section XI, Appendix VII for UT Levels II and III. The section begins with a summary of representative skills and knowledge that would qualify a technician to be considered for certification as a nuclear UT Level II and III, along with the associated number of experience hours needed to attain proficiency in each skill and knowledge area. The detailed discussions on how these experience hour values were derived are provided in the technical essays in Appendix A of this report.

In addition to the technical basis for experience hours, this section provides considerations for comparing the recommended experience levels with the historical requirements of this industry. A discussion is included on exceptions to the experience parameters selected for this technical basis, depending on an organization's structure and role in the industry, which should be addressed in their written practice for certification. Justification is provided for removing the educational background requirements for UT Level III personnel that currently resides in the Code. A technical basis is provided pertaining to minimum durations that should be spent at each certification level, to help ensure that effective knowledge retention is achieved. Finally, this section discusses alternative environments and technologies available for obtaining experience, and some important additional considerations involved in the decision to advance an individual's certification level. All the requirements and considerations presented in this section provide a holistic technical basis for UT Level II and III experience requirements.

Experience Hours

The amount of experience hours needed to become proficient at a representative set of skills and knowledge for UT Level II or III in the nuclear power industry were determined through a systematic and analytical approach. First, skills and knowledge areas were identified based on commonly occurring core job tasks for UT personnel. These were selected by reviewing a JTA on UT [16], NDE UT human factors reports [12, 13, 17, 18, 10], and other industry documents [19, 20, 21], and also by collecting input from a focus group of nuclear utility and inspection vendor Level III personnel as well as other industry UT SMEs. A technical essay discussing each selected skill and knowledge area and/or activity is then presented in Appendix A, which develops the number of experience hours needed to obtain proficiency in that area. These are derived, primarily, based on exploring the amount of time required to complete a task as well as the number of times that the task should be completed by a technician before they can reasonably be expected to be proficient.

An important factor to consider when reviewing job tasks for UT personnel is that it is unnecessary to identify all granular level and specialty tasks for UT personnel because job roles differ based on an organization's needs and other factors. As identified in the Code, it is the responsibility of the certifying organization to have a written practice that is consistent with the roles and responsibilities of their UT personnel, as well as any unique training and experience level requirements. There are certain UT examinations that occur in nuclear power plants, which are normally performed using personnel, equipment, or even techniques that are highly specialized for that examination. Some of these (for example, UT of steam turbine shafts or reactor head penetrations) are not covered in Appendix A, which is intended as a set of common skills and knowledge with which a nuclear UT technician will most likely need a minimum level of experience. Functionality in these more specialized examination methods would require additional training and experience than what is specified in Appendix A but will not be applicable for every nuclear NDE technician. Additionally, a technician with proficiency in the basic skills and knowledge areas identified in Appendix A should be sufficiently prepared to adapt to these other more specialized or advanced applications, with some additional training or experience. The Code identifies this in VII-3110 [22], where it states, “The written practice shall specify the experience requirements for each qualification level in accordance with VII-4100 and the additional experience that may be required for special NDE applications.” The portion of this section entitled, “Skill and Knowledge Requirements for UT Personnel Differ by Organizations and Roles” further discusses the fact that the skills and knowledge areas discussed in Appendix A do not serve as a required list that must be met by every nuclear UT technician, but instead provide representative skills and knowledge that would legitimately qualify an individual to the target UT certification levels specified in the Code.

Appendix A separates the skills and knowledge into two main categories: (1) Technical and (2) Administrative and General. For each category, a set of skills and/or knowledge is provided as well as an accompanying technical essay supporting the minimum number of hours for that proficiency. The summation of these hours provides justification for the minimum experience hour values that would be needed for a technician performing Section XI or equivalent UT work under the supervision of certified Level II and III personnel to legitimately obtain Appendix VII UT Level II and III qualifications. Furthermore, it is recognized that certain of these skills and knowledge can be gained in environments outside of the field and this is identified within certain essays, as well as later in this section.

The total hours accumulated for each area of proficiency provided in Appendix A, is as follows:

A UT Level I qualifying to Level II:

- The technical proficiency area hours add up to 453 hours.
- The administrative and general area hours add up to 89 hours.
- Therefore, the total experience hours needed for a certified UT Level I to become eligible for UT Level II certification using this valid prerequisite set of skills and knowledge is 453 hours + 89 hours = 542 hours.

Note: These 542 hours of experience would be in addition to the experience hours already required by Appendix VII for previous certification to UT Level I. An individual that was certified directly to UT Level II, without having previously been certified to UT Level I, would be required to meet the total experience hour requirements of both levels.

A UT Level II qualifying to Level III:

- The technical proficiency area hours add up to 565 hours.
- The administrative and general area hours add up to 681 hours.
- Therefore, the total experience hours needed for a certified UT Level II to become eligible for UT Level III certification using this valid prerequisite set of skills and knowledge is 565 hours + 681 hours = 1,246 hours.

Note: These 1,246 hours of experience are intended to be added to the experience hours required by Appendix VII for certification to UT Levels I and II.

An Important Consideration for the Reduction of Experience Hours

For the majority of the history of the nuclear power industry, the ASNT recommended practice SNT-TC-1a was specified in ASME Section XI (IWA-2310) for nuclear organizations to base their NDE certification procedures (written practices). SNT-TC-1a contained a 25 percent rule, which enabled an individual working on multiple NDE methods, during a set time period, to take 100 percent time credit for each of the methods so long as they spent at least 25 percent of the total time on that method. This means that it was technically possible, for example, for someone to gain the required 800 hours of on-the-job experience needed to become a UT Level II, by performing 800 hours doing a combination of four separate NDE methods, so long as they could say that at least 200 of those 800 hours were actually spent performing UT. This is an important point when considering the validity of the hours specified in this document for developing proficiency.

Note: An inquiry and response published by ASNT on the topic of the 25 percent rule (Inquiry 87-3 [23]) indicates that it was not the intent of ASNT that the 25 rule apply to qualifying for Level III certification, however they pointed out that the experience credited toward qualification for Level III "may be partially replaced by experience as a certified NDT Level II, or in assignments at least comparable to NDT Level II, in other methods … as defined in the employer's written practice." So, while the 25 percent rule might not have been directly applicable for qualification to Level III, there were allowances for an employer's written practice to enable the same sort of experience hour relief by crediting experience in other methods.

ASME Section XI editions and addenda, prior to the 1992 Addendum, Subarticle IWA-2310 specified that personnel performing NDE shall be qualified and certified using a written practice prepared in accordance with SNT-TC-1a, which contained the 25 percent rule [2]. The industry was not allowed to use editions and addenda of the code, beyond the 1989 Edition, until 10CFR50.55a incorporated by reference the 1995 Edition, up to and including the 1996 Addenda, in the Federal Register (64 FR 51370) dated September 22, 1999 [4, 5]. Taking into account that nuclear licensees do not update to the latest approved edition of the Code until they renew their 120-month (that is, 10 year) ISI program, it is likely that many U.S. licensees did not invoke a Section XI edition that required a written practice based on anything besides SNT-TC-1a until nearly 10 years after the NRC's endorsement.

Various editions/addenda of IWA-2310 were reviewed to identify when CP-189 was required as the basis of qualification and certification of NDE personnel, rather than requiring the use of SNT-TC-1a for that purpose and thus eliminating use of the 25 percent rule. EPRI carries a subscription to IHS Engineering Workbench [24], which contains a repository of all the published ASME Section XI editions and addenda and enabled this review process.

It was determined that the 1992 Edition, 1992 Addenda of Section XI was the first time that IWA-2310 referenced CP-189 for written practices. Following this discovery, the question became, "What year did the NRC incorporate by reference either the 1992 Edition with 1992 Addenda or a subsequent code year?" The dates of incorporation by reference of ASME Section XI editions and addenda can be tracked by reviewing Rulemaking Activities by Fiscal Year at the U.S. NRC's Agencywide Documents Access and Management System (ADAMS) [25]. Here summary documents, titled "Regulations and Amendments Put Into Effect," are provided of the rulemaking put into effect each year.

Beginning at 1992 and each subsequent year, the "Regulations and Amendments Put Into Effect" documents were reviewed. In Regulations and Amendments Put Into Effect—FY 1992, it was revealed that on August 6, 1992, in reference document 57 FR 34666, the NRC published an amendment to its regulations, effective September 8, 1992, that incorporated by reference the 1986 Edition through 1989 Addenda of Section XI [26]. Those years contained the reference to SNT-TC-1a, which included the 25 percent rule. The next document showing incorporation by reference of a Section XI edition or addenda was Regulations and Amendments Put Into Effect—FY 1999, which stated that on September 22, 1999, in reference document 64 FR 51370, the NRC published an amendment to its regulations that was effective November 22, 1999 [4]. This amendment incorporated by reference more recent editions and addenda of the ASME B&PV Code and the ASME Code for Operation and Maintenance (O&M) of Nuclear Power Plants for construction, in-service inspection, and in-service testing [4]. This summary document [4] did not state what code editions and addenda were incorporated in 64 FR 51370; thus, a review of 64 FR 51370 had to be performed and this review revealed that the NRC incorporated by reference the 1995 Edition with the 1996 Addenda of Section XI as part of that rulemaking [5]. Therefore, September of 1999 was the first time that the NRC endorsed a code year that referenced CP-189 as the required basis for certification written practices thus removing the option for the 25 percent rule.

Skill and Knowledge Requirements for UT Personnel Differ by Organizations and Roles

A consideration for the initial certification of UT personnel is the fact that the skills and knowledge provided in this technical basis, while generically applicable to Appendix VII attributes, are not appropriate to the same extent for each UT technician. An organization's written practice is required to specify the skills and knowledge needed for each position's roles and responsibilities. This is already a Code requirement spelled out in Appendix VII, Article VII-3200 (refer to Section 2, Table 2-1, ID#5).

It is not, therefore, the intent of this technical basis to indicate that the industry must ensure that all nuclear UT Level II and III personnel have completed each task to the exact minimum number of hours that are dictated in Appendix A. But in recognition of the fact that setting a minimum number of experience hours for UT certification is appropriate for the Code, compiling the skills and knowledge areas, and reviewing the experience needed to become proficient in each area, according to a corresponding certification level, was an important "thought experiment" in the development of this technical basis in that it establishes the fact that the current minimum Appendix VII experience hour requirements can be revised without undermining the basis of each level of qualification.

Appendix VII Level III Experience Requirements Based on Educational Background

Educational background currently influences the amount of experience hours required by the Code for the initial certification as a UT Level III (refer to in ID# 7 in Table 2-1). However, most educational systems, from high school through post-educational institutions such as technical colleges or universities, do not address the skills and knowledge areas listed in Appendix A. Therefore, many of the specific details for these proficiencies will need to be acquired through NDE specific activities and exercises, regardless of an individual's previous education.

An additional consideration on this topic emerged during the EPRI human factors study, which is relevant for the topic of educational background and can be found in Table 2-11 of [13]. During the one-on-one anonymous interviews, the interviewee (that is, an experienced UT examiner that at the time was actively practicing UT in the nuclear industry) was asked "What aspects of training for these tasks are unnecessary, and why?" and shown below is a quote from an interviewee, which is representative of the "need for more field applicable training" theme that emerged in response to this interview question [13]:

> "They press a lot of things you don't need in the field, like how to make a transducer, how to design an angle on a wedge, and so on; that's just not something your typical examiner will have any use to know. Would be better if they spent time on the codes we actually use, which is often left out of the training."

When looking at the response from this interviewee, there are takeaways that can be compared in relation to the background educational requirements currently specified in Appendix VII. As seen in this response, the interviewee is expressing the fact that low-level details on how to design transducers and wedges are not needed so they can adequately meet the roles and responsibilities of their job and a better use of their time would be to focus on the direct skills and knowledge needed to adequately perform their job. When applying this logic to the curriculum taught in most engineering and science educational settings, it will be observed that it is highly unlikely such curriculum directly supports the roles and responsibilities of UT Level III's as specified by Appendix VII.

Therefore, to prepare nuclear UT Level III personnel efficiently and properly, it is recommended to follow the foundational skills and knowledge specified by Appendix VII, and the qualification requirements specified in an employer's written practice, which will serve to optimally build and maintain industry UT personnel with the precise skillsets and knowledge needed for their roles. For these reasons, it is recommended to eliminate the experience hour requirement options based on educational background for initial certification to UT Level III that currently exist in VII-4000.

Repetitive Experience in Learning UT Skills and Knowledge

As mentioned in the PNNL study on human learning [10], it is beneficial for personnel to be exposed to learning opportunities over a period of time as opposed to dense and compact learning activities. The total experience hours calculated within this report to obtain the necessary skills and knowledge for Level II and III are 542 hours and 1,246 hours, respectively. Thus, it would be possible for someone to acquire the experience hours through a dense and compressed set of learning activities, while possibly not being exposed to enough on-the-job situations to develop operational proficiency.

When considering this issue, a survey of U.S. utilities and vendors was performed to estimate as follows: (1) the number of experience hours in the UT method that examiners typically acquire during an outage, and (2) the number of outages a UT examiner will typically work each year. From this survey, it was estimated that on average UT personnel will obtain 150 hours of experience in the method, per outage, and that UT personnel will typically work four outages per year. Using these estimates, one can calculate that a U.S. UT examiner will gain approximately 600 hours per year in the method. Using these estimates as a guideline, it is reasonable to assume that the 542 experience hours for a Level II can be gained in approximately one year by working outages; and that, for an individual to get the required experience to be eligible to certify to Level III would require approximately two years of outage work. Now, there will certainly be edge cases, or outlier circumstances, where personnel can obtain these hours in a shorter or longer time, but regardless, this does provide an estimate.

There is a concern with technicians gaining large amounts of experience hours in a short period of time, which would not constitute what is considered the more optimum condition of learning over a period of time and in varying circumstances. For example, if a Level II gained 600 UT experience hours in outages in their first year and also accumulated an extra 700 hours of experience by lab practice or other extracurricular activities, then this would total 1,300 hours of experience in their first year as a Level II. And while that would meet the total recommended number of hours of experience, specified in this technical basis to be considered eligible for UT Level III, it would not represent optimum learning conditions constituted by gaining experience over time. For this reason, it is recommended that, in addition to the minimum experience hours, a minimum time duration at a given UT certification level should also be satisfied before an individual can be considered eligible to certify to the next level.

Based on the considerations discussed in this section, it is recommended that a technician hold the following minimum time durations in their roles before being considered eligible for initial qualification to the next certification level as follows:

- A nuclear UT Level I would hold this position for a minimum of one calendar year, before being eligible for initial qualification as a Level II.
- A nuclear UT Level II would hold this position for a minimum of two calendar years, before being eligible for initial qualification as a Level III.

Lab Time for UT Experience

As identified in the technical essays throughout Appendix A, a significant amount of the technical skills needed by UT personnel can be gained in the laboratory environment. In Section 2 “Literature and Proposed Rule Making for UT Personnel Experience,” several observations were noted about the importance of providing feedback during learning as well as UT examiners expressing a desire for feedback for improved learning.

Aside from the obvious advantages that the laboratory provides (for example, reduced time pressure, less stress, and fewer environmental constraints such as heat and radiation) scanning a sample in a laboratory is arguably a superior experience because the truth is known or can be easily determined about the sizes, shapes, and locations of any flaws in the specimen, as well as any geometric reflectors or metallurgical conditions that might generate UT responses. Therefore, technicians can get meaningful feedback about their scanning techniques or signal evaluation skills after having examined a laboratory specimen, whereas no such feedback can be provided on a component in the field, except in the rare occasion that the component is subsequently removed and destructively tested.

Based on these learning advantages, it is recommended that some amount of the experience hours obtained in the pursuit of UT Levels II or III are permitted to come in the form of lab time. The quantity of hours spent in the lab does not necessarily need to represent a substantial amount of total experience but should be enough so that the technician has ample opportunity to receive the unique feedback afforded in that environment. Recent NRC proposed rulemaking [14] for initial certification UT Level II would allow 720 hours of experience, of which 320 of these hours can be obtained in the laboratory. That equates to approximately 45 percent of a technician’s Level II experience hours coming from laboratory practice. This percentage of laboratory time from the NRC proposed rulemaking was considered in this technical basis.

By adding up the technical skills category of experience hours that this document identifies as being obtainable in the laboratory, and then dividing that number by the total experience hours calculated to be needed for initial certification, it can be derived that approximately 77 percent of the UT Level II experience hours would be possible to obtain in the laboratory, and the number is approximately 43 percent for UT Level III. However, it is also recognized that some field experience in each of these skill areas is also important, because there are situations and issues that might be encountered in the field that are unlikely to be replicated in the lab. Therefore, a reasonable recommendation that is aligned with the proposed NRC rulemaking, is that up to 45 percent of experience hours for initial certification to UT Level II should be obtainable in the laboratory as well as up to 27 percent of UT Level III experience hours. It’s recommended that the laboratory time just discussed be dedicated to the examination of specimens containing flaws in materials representative of those in actual power plant components. This guarantees that a significant percentage of the experience gained in these key skill areas will be on field components, but also enables much of the experience in these areas to be practiced in conditions of low stress and where meaningful feedback and learning is available.

A New Technological Age for Gaining Experience

Technological improvements have been developed, and will continue to be developed, that offer previously unseen opportunities for acquiring NDE experience. In present day, manual UT simulators with a high-level of realism exist [27, 28], and this technology will likely only continue to be developed in the coming years. A unique aspect of simulators is the fact that all information on samples and data within the system are known, and the software can be developed to provide feedback to users for ample learning [13]. This type of technology is forward thinking and offers an innovative path for exposing UT personnel to an abundance of training and experience that was previously not easily, or efficiently, obtainable. Other forms of valuable technologies such as distance learning from computer-based training (CBT), videoconferences, or online courses will also likely continue to enhance and be incorporated into our modern world.

As shown in Appendix A, over half of a UT Level III's experience hours come from general and administrative skills and knowledge, vs. technical skills, which is logical considering this naturally supports their roles and responsibilities. When the general and administrative hours for a UT Level III are further analyzed, it shows that a significant percentage of their experience hours, can be obtained in non-field learning environments. This is an important reminder because this emphasizes that a considerable amount of critical experience for UT Level IIIs can be gained through activities that do not occur in the field.

For example, UT Level IIIs will undoubtably spend a portion of their time conducting tasks such as writing and reviewing procedures, reviewing NDE reports, discussing inspections with plant personnel, and attending regulatory, or codes and standards meetings. All these tasks are directly relevant for adequately performing their job. As pointed out, these types of skills and knowledge come from an ad hoc set of exercises, and it could be possible to develop a structured set of exercises to help consolidate and emphasize learning these activities while providing feedback on performance. For example, if a CBT was developed specifically for these types of UT Level III general and administrative skills and knowledge and it included worksheets or labs that a technician must complete and then compare with truth information, it is conceivable that such an activity could be applied toward experience hours. This content would need to be developed so it does not mix with training activities, but if the content was appropriately developed so that it supported the practical aspects of an individual's roles and responsibilities then it could be efficiently applied for gaining experience. In Section 2 of this report, an analysis of the Code's definition of experience was provided and it was found that the Code does not restrict experience to a certain environment, nor do any of the supporting standards. And the example just given for Level III experience showed that experience might currently be gained in various settings if the organization's written practice is supportive. Thus, additional means for gaining experience in various environments are likely to continue to be enabled as technology advances.

This example is part of the overarching takeaway that gaining experience for UT personnel is more encompassing than field and laboratory time. In fact, a mixture of different learning environments is available that can provide UT personnel with highly valuable, and needed, learning opportunities while simultaneously encouraging the industry to take advantage of new technologies for preparing and maintaining the UT workforce.

Additional Considerations for NDE Certification of Personnel

An organization must assess an individual's merit for promotion to the next UT certification level using more criteria than simply whether the individual has attained the minimum training and experience hours specified. We don't do an individual any favors when we advance them beyond their true capability level, and that is not simply a measure of training classes attended or the amount of time spent in a current role. Additionally, an organization will not always have the need to advance an individual in certification level, simply based on the fact that they have met the criteria to do so. The decision to advance an individual in certification level or organizational role should therefore be based on the needs of the organization as well as a careful assessment of the individual's personal readiness for the new role, based on their technical experience and knowledge, but also on other personal attributes needed to fulfill the roles and responsibilities of the position.

4 CONCLUSIONS

Appendix VII of the Code is used to ensure that UT personnel working in the nuclear industry are sufficiently qualified to effectively execute and oversee the examinations required during the construction and operation of a nuclear power plant. There is clearly an intended division of responsibilities specified for UT Levels II and III in the Code, dictated by the required skills and knowledge for those two certification levels specified in CP-189 [8]. Obtaining these skills and knowledge requires a combination of training and experience. The foundational skills and knowledge, as described in CP-189, for UT Level II and III personnel were derived and discussed in Section 2. These foundational skills and knowledge present the intention of Appendix VII for guiding the development of UT personnel.

This report has not focused on the training requirements contained in the Code, primarily because our assessment of those training requirements is that they appear more than adequate to accomplish the ends for which they are intended. Refer to Appendix B for a brief assessment of the adequacy of the Code training requirements.

An individual that has been identified as a candidate for initial certification to UT Level II or III should have obtained the proficiencies discussed in Appendix A of this report, as modified by their certifying organization's written practice. While it is recognized that perhaps not every UT technician in an organization will assist in specialty tasks such as procedure development, performing IWB-3500 flaw evaluations, or independently performing unique construction code-related examinations, this technical basis does provide a thorough list of the skills and knowledge gained through the performance of Section XI or equivalent UT work and that are needed for advancement in certification, along with rational arguments establishing the minimum experience levels needed for each. As such, it provides a systematic approach to determining the minimum experience hours to gain proficiency in a representative set of UT skills and knowledge areas for UT Level II and III. The result was 542 hours for Level II and 1,246 hours for Level III. The skills and knowledge shown in Appendix A align with the foundational skills and knowledge from CP-189, which were referenced in the Code's subarticle VII-2100 (refer to Section 2 of this report).

It is worth noting that, for much of the history of the nuclear power industry, NDE written practices were required by the Code to be based on the ASNT recommended practice SNT-TC-1a, which contained the 25 percent rule. This rule enabled NDE personnel to be given full experience credit for any NDE performance period during which at least 25 percent of their time was spent performing a method. The removal of this option coupled with the evolution of nuclear outage durations and the application of risk informed ISI rules has resulted in a practical hardship for nuclear UT technicians in meeting the experience rules currently contained in Appendix VII.

This report also considered the differing level of experience hours specified for UT Level III, in Appendix VII, based on an individual's educational background. It has been reasoned that the skills and knowledge required of a nuclear UT technician in CP-189 are unlikely to be part of most engineering or science curriculum taught at community colleges or universities. Therefore, it is recommended that the Level III experience hour requirement options provided in Appendix VII for different educational backgrounds be eliminated.

As discussed in Section 3, it is important for personnel to be exposed to frequent and not highly dense or compact learning events for the skills and knowledge commensurate with their role [10]. In Section 3, it was therefore recommended that, in addition to a minimum experience hour requirement, a minimum time period of working at a given UT certification level should also be required before a person becomes eligible to qualify for the next certification level. The recommendation was that a UT Level I should hold that position for at least one year and that a UT Level II should hold that position for at least two years. This additional requirement is intended to help ensure that UT personnel encounter sufficient on-the-job learning opportunities, over a period of time, rather than rapidly gaining experience over a short period of time and potentially not retaining the skills and knowledge as effectively.

A review of ASME Section XI Appendix VII was conducted to determine the current rules for accrediting UT experience hours. This analysis determined that the Code provides a clear definition of experience and that, as currently written, the definition of experience allows for skills and knowledge to be gained through a variety of mechanisms. This finding suggests that the current wording of the Code appears acceptable for accrediting experience hours to activities outside of the field and through valuable exercises and tasks conducted in a laboratory or various vocational environments.

An argument was then made that UT scanning and signal evaluation experience gained in the laboratory can in some ways be more valuable than equivalent experience gained in the field. Recently, the NRC and PNNL have indicated that experience can and should be gained through laboratory exercises [10, 14]. Providing UT personnel with ample opportunity to see a variety of UT samples and with the added benefit of a learning feedback loop that is almost exclusively obtained in a laboratory environment was the predominate response obtained from UT examiners both domestically and internationally during a recent EPRI human factors study [13]. If an examiner fails to locate a defect in a laboratory specimen and receives constructive feedback, they can then easily go repeat the examination by applying better techniques while learning from their mistakes. It is usually not possible to repeat an examination in a power plant, even if you could receive meaningful feedback.

Based on these findings and the technical justifications provided, it appears that the nuclear industry has an opportunity to continue to maintain qualified UT examiners even with a reduction of UT experience hours and while simultaneously allowing for some of those hours to be obtained through experiences outside of the plant environment. The technical justifications provided for experience throughout this report would be in alignment with this viewpoint. When considering the list of skills needed for a Level II or III, easily two-thirds are nearly or completely replicated in the laboratory. It was therefore recommended that UT technicians be allowed to gain a maximum of 45 percent of the experience hours needed to qualify for Level II and a maximum of 27 percent of the experience hours needed to qualify for Level III through laboratory exercises. This recommendation helps ensure that valuable lab experience can be accredited, but also that UT personnel are exposed to an adequate variety of field situations and conditions that might not be encountered in the lab.

Additional discussion on different environments and the use of technologies for learning are given in this technical basis. As technologies continue to develop and are more widely used in our world, they will also become more available for use in the nuclear industry. It was recognized that a mixture of environments such as the field, lab, classroom, and vocational will increasingly be used to prepare and maintain our workforce. The Code, and other applicable standards, do not restrict or mandate specific environments aside from the laboratory for gaining experience for skills and knowledge. Therefore, its recommended that these environments and technology be applicably used if they meet the written practice of the certifying organization.

This report has been dedicated to exploring the experience hours needed to obtain the necessary proficiency in a representative set of UT Level II and III skills and knowledge. However, as discussed in Section 3, it is incumbent on an organization who certifies UT personnel to determine an examiner’s merit to be elevated to any level of certification. While the industry might set a certain minimum threshold for experience hours, reaching that milestone should never be the only consideration in judging an individual’s readiness for advancement. The written practice developed by the certifying organization needs to be aligned with the roles and responsibilities expected of their UT personnel.

The content within this document can be used as the technical basis for amending ASME B&PV Code Section XI, Appendix VII, with regards to the minimum experience requirements for the initial certification of UT Level II and III personnel. The experience requirements for UT Level II and III personnel were developed and prescribed in this technical basis by using prior literature, standards and codes, a UT JTA, human factors studies, and discussion and input from industry SMEs. The experience requirements in this technical basis are an example of applicable and tailored skills and knowledge needed for the initial certification of UT Level II and III personnel in the nuclear industry. Detailed discussions for each specified skillset and knowledge area are provided. The requirements recommended in this technical basis differ from the Code requirements that have largely been in place from the 1970s, but the pressing need to maintain an effective and knowledgeable workforce, in an era of shorter outages and reduced examination scopes, brought forth an opportunity to closely examine UT Level II and III certification requirements. The recommendations given in this technical basis have been provided to guide the commercial nuclear industry into using a justified set of criteria for raising, and maintaining, a strong and reliable NDE workforce.

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A
APPENDIX A

The following technical essays are provided for the minimum hours needed to become proficient in skill and knowledge areas gained through the performance of Section XI and equivalent UT work under the supervision of qualified Level II and III personnel. As discussed in Section 3, these skills and knowledge areas were selected based on a review of a recently developed industry job task analysis (JTA) of nuclear UT [16], as well as from discussions with the project's focus group of subject matter experts and active nuclear utility and inspection vendor UT personnel. The project team and focus group agreed that a technician who acquired proficiencies in all these areas would be legitimately qualified to operate as an ASME Section XI UT examiner. Therefore, by working through the definitions of each activity, a calculation of the average time spent completing them, and the number of evolutions of each activity that it would take to reasonably expect a technician to be considered proficient, we were able to establish a legitimate minimum number of experience hours needed to produce capable and knowledgeable ASME Section XI, UT Level II and Level III examiners.

Basis for Experience Hours Specified for Technical Proficiency Areas

Inspecting UT equipment for wear/damage/operation (3 hours for Level II; 2 hours for Level III) – The typical UT equipment needed to perform a piping or vessel weld examination includes an instrument, two to three transducers, two to three wedges, two to three coaxial cables, a container of couplant, and a reference standard. Each of these items needs to be visually inspected to make sure that they are intact and not worn or damaged to an extent that might affect their usability during the examination. Aside from a basic visual inspection, each item to be used in the field will be part of the UT system and, as such, will be part of the pre-examination calibration, which serves as the second form of investigation as to the operation and proper usability of the equipment. A technician must become proficient at visually identifying issues of wear and damage to each component of the UT system, as well as being proficient at system calibration.

Visual inspection of all aspects of a UT system will normally take less than one quarter of an hour to complete and investigations into issues related to UT system function, during calibration, will only be necessary when there appears to be an unexpected anomaly. Therefore, each time a UT technician performs an examination, they will log around one quarter of an hour of equipment inspection. This is not an intellectually challenging endeavor, nor a perishable skill, and there are a limited number of problems that can occur with the assortment of equipment. A UT technician can reasonably be considered proficient at the entire process after performing it 12 times as a Level I and an additional eight times as a Level II. Thus, it is estimated that three hours is sufficient experience to qualify for Level II and two additional hours is sufficient experience to qualify for Level III. This is a skill that can be developed in the lab as well as in the field.

Performing instrument linearity checks (2 hours for Level II; 4 hours for Level III) – The process of performing screen height and amplitude control linearity checks of a UT instrument involves a little hand-eye coordination, a basic knowledge about the manipulation of the instrument being tested, and a working knowledge of the purpose of the test and the expected results. The procedures to accomplish these checks might vary slightly from company to company, but because the processes are designed to meet ASME Code or an equivalent industry standard, the tasks are basically a recipe of steps that must be performed with a prescribed outcome. Considering that there are several different instrument types and brand names that might be encountered over the course of a career in UT, each with varying menus and controls, a technician should go through the process several times to master it.

Fully exercising the typical linearity procedure on one instrument can take as much as a half hour. Considering the level of difficulty of this task and the fact that the required skills are not perishable, a technician should be proficient in performing these types of checks on a variety of instruments after going through the process about 10 to 12 times. This works out to be six hours of experience being required to gain sufficient proficiency in this skill area. When a UT Level I is approaching the level of experience needed to become a Level II, they might be given the responsibility to perform linearities, under the supervision of a Level II. So, at least two of the six hours of experience is likely to be gained as a Level I, with the additional four hours being gained as a Level II. This skillset can be developed in the lab as well as in the field.

Use of common calibration standards (15 hours for Level II; 15 hours for Level III) – The most basic aspects of calibrating any UT system for depth or metal path, as well as to establish the index point and examination angle, requires the use of one of several types of basic calibration standards. There are common standards used throughout the industrial world, such as IIW blocks, DSC blocks, Rompas blocks, and step wedges. There are also standards that are unique to the nuclear industry, such as the Performance Demonstration Initiative (PDI) Alternative Calibration Block. Some are contoured to accommodate contoured UT wedge calibration. And each type of standard will have different numbers and types of reflectors (radiused edges, notches, and holes) as well as markings to indicated where to line up the transducer/wedge combination to establish the index point or measured examination angle.

Each instance of calibrating a transducer/wedge combination for an examination, or of establishing the linearity of a UT scope, will involve the use of a calibration standard. Mastering the use of one particular type of calibration standard can be accomplished in just one or two applications and would not be considered a perishable skill. The process of calibrating a UT system for a typical weld examination takes approximately one hour. Therefore, reasonable proficiency with several of the more common standards can be expected to be achieved rather quickly – say within around 10 hours of practice. However, given the fact that there are many different varieties of standards, as well as the issue of mastering calibration on some of the more challenging types, such those made for wedges contoured for the circumferential scan direction, it is estimated that 30 hours of experience on a variety of standards is likely needed to obtain the necessary level of knowledge and proficiency at this skillset.

A Level I will gain some of the requisite experience needed to become proficient in the use of calibration standards, although it will likely be limited to the more common, straightforward designs and will not cover all the eventual calibration circumstances. It is therefore expected that a technician that has certified to Level II will need to gain additional proficiency in use of some of the more complex calibration standards on their way to becoming a Level III. Therefore, the 30 hours of experience, specified above, is roughly evenly split between qualification levels (that is, 15 hours as a Level I looking to qualify as a Level II, and an additional 15 hours as a Level II looking to qualify as a Level III). This skillset can be developed in the lab as well as in the field.

Application of common UT mathematics (25 hours for Level II; 15 hours for Level III) – A Level II UT technician should be proficient in the use of several mathematical equations that are used in the planning and performance of UT examinations and the plotting of UT indications. These include equations for calculating refraction, near field, half-angle beam spread, beam path (metal path), surface distance, and skip or target depth. A UT Level III with field examination responsibilities should additionally be capable of designing UT techniques for specific applications, which requires knowledge of the application of additional equations, such as those to calculate wavelength, acoustic impedance, reflectivity (reflective coefficient), longitudinal and shear wave velocities, and dB gain or loss. An internet search for "ultrasonic testing formulas", returns various websites on which lists of UT formulas can be found. These range from as low as 12 [29] commonly used formulas to as high as 16 [30]. The EPRI Nuclear Sector NDE Program offers training courses for UT Levels I, II, and III in which a handout is provided that includes 22 formulas [31]. But only 12 of those formulas are emphasized during the training courses, which are those that are regularly used as part of nuclear UT examinations.

Learning the trigonometric formulas and algebraic equations commonly used in UT is a matter of some formula memorization, obtaining an understanding of the basic mathematical principles involved, and a working knowledge of the ultrasonic theories that are used to obtain individual variables that feed the equations. Some of these processes are recognized as perishable skills, which need to be practiced to maintain proficiency. But it is also recognized that notes, calculators, and spreadsheets can all be employed in lieu of rote memorization and routine practice. Understanding the interactive relationships of transducer element sizes and frequencies and their effects on beam spread, incident, refracted, and reflected angles and how all of that relates to materials with different velocities requires knowledge that starts out with proper training and is reinforced with hands-on experience.

It is difficult to formulate a specific number of hours needed to master all the aspects of UT mathematics discussed above, partially because it is difficult to specify how much time is actually spent on the mathematical theory and practical application each time it is used. But it is asserted that at least 10 instances of working through each type of common UT-related mathematical formula is needed to obtain a sufficient level of proficiency, each taking no more than 15 minutes to complete, and that there are a maximum of 16 different formulas that the Level III needs to master. It is then reasonable to say that, in addition to formal training, a candidate for Level III certification will need to have 40 hours of experience to be considered proficient in the application of common UT mathematics. A Level I preparing to advance to Level II, as discussed previously, will be required to master a subset of these mathematical formulas, which are those used in the planning and performance of common straight beam and angle beam examinations. There is a maximum of 10 different formulas involved in these processes, which in addition to formal training equates to 25 hours of minimum experience in their use. As such, the breakdown of experience is that a candidate for UT Level II should have a minimum of 25 hours of experience with common UT mathematics, and a candidate for UT Level III with field examination responsibilities should have an additional 15 hours of experience. This is one of the skillsets that can be developed in the lab as well as in the field.

Calibration and examination using conventional shear wave transducers (40 hours for Level II; 40 hours for Level III) – Angle beam examinations using the shear wave mode of transmission is one of the more common UT techniques employed in the nuclear power industry. There are many unique situations and circumstances that can be encountered in using this technique, which need to be experienced to be understood. This is also an area of proficiency with a relatively large number of perishable skills, necessitating regular practice to be maintained. There is a wide variation of examinations performed with conventional shear waves, each involving their own unique intellectual challenges and physical skillsets. All these factors culminate in the recognition that technicians need to acquire a large amount of experience in this technique to be considered proficient. Fortunately, because this is such a common examination performed in nuclear power plant settings, it is not difficult to obtain higher levels of experience.

Experience for technicians in the performance of conventional shear wave UT normally starts when the individual is a Trainee and is added to substantially as a Level I. And even though personnel at these lower levels of certification are usually not allowed to be responsible for the final outcome of examinations, they will take part in most aspects of the work, including selection and calibration of equipment, scanning, evaluation of signals/data, and documentation of results. So, by the time a UT technician has been certified to Level II they will normally have logged a substantial amount of their total experience hours, performing shear wave examinations. Even so, after being certified to Level II, there will be different emphasis on the knowledge and skillsets required because the individual is now held responsible for procedural compliance and the overall outcome of the examination.

In the interest of limiting exposure to radiation, typical manual piping weld examinations in nuclear power plant settings are completed on average in one hour and 40 minutes (time on the component). The source of information for this time estimate was supplied to EPRI from a U.S. utility that will remain anonymous. This average was derived by the actual duration of time spent during manual UT piping weld examinations performed at one U.S. plant, from 2007 until 2021, and includes stainless steel, carbon steel, and dissimilar metal weld examinations. Vessel weld examinations can take longer. Even so, when you include calibration time, the entire process of a typical weld examination using conventional shear waves will take approximately three hours. Extracting out signal interpretation, profiling of the weld, and other activities that are covered separately in this report, there will still be at least an hour of experience that is specific to the use of this mode of propagation in each examination experience. In the interest of ensuring that a candidate for Level II has been exposed to the full variety of scenarios and challenges encompassed in the realm of shear wave examinations, they should experience this entire process a minimum of 40 times (40 hours). And because the perspectives, considerations, and responsibilities are different between a Level I and a Level II UT examiners when performing an examination, which results in different areas of focus and learning, an additional 40 hours of shear wave examination experience is recommended for a Level II who wishes to be considered as a candidate for UT Level III that will have field examination and oversight responsibilities. This skillset can be developed in the lab as well as in the field. In fact, experience gained in the lab where feedback on performance can be provided, might prove more valuable.

Calibration and examination using conventional longitudinal straight beam transducers (10 hours for Level II; 8 hours for Level III) – Calibration and examination using conventional longitudinal waves is a straightforward proposition. While there are intricacies to learn about, around the function and advantages of different transducer frequencies, dual “pitchcatch" configurations versus single element pulse echo set ups, and the uses of accessories like standoffs, the principles of examination with a conventional UT straight beam are not difficult to comprehend. Most uses and expected results of a straight beam technique are readily understandable, if well explained or experienced. In nuclear power plant NDE, straight beam UT is used in a variety of applications, and a few of them should be experienced, firsthand, to solidify a technician's understanding of the application. During a one-hour UT examination of a piping weld, about 10 minutes will normally be spent obtaining thickness information across the weld joint to facilitate profiling of indications and determining examination coverage. A few experiences in this process should be sufficient to obtain proficiency. Use of straight beam UT to examine a component for wall thinning or pitting is also a matter of seeing a few examples of each degraded condition, to master the technique.

Because conventional straight beam UT is so widely used in examinations of nuclear power plants, experience is likely going to be easier to accumulate, versus other UT techniques. However, once a technician has a few hours of experience, even if they have not performed a particular type of exam with a "zero degree" transducer, a simple explanation of it will usually suffice to prepare them to complete it, independently. Therefore, it is estimated that 10 hours of experience using conventional longitudinal straight beam UT is sufficient to obtain the proficiency to be a functional Level II UT technician. An additional eight hours of experience as a UT Level II, with the added responsibility and resulting perspectives of that role, should be sufficient to ensure exposure to the variety of situations and challenges that should be experienced to obtain the needed mastery of the technique to be considered qualified to be a UT Level III. This is one of the skillsets that can be developed in the lab as well as in the field.

Calibration and examination using conventional longitudinal wave angle beam transducers (40 hours for Level II; 40 hours for Level III) – UT examination with conventional longitudinal wave (L-wave) angle beams is somewhat more challenging than with conventional shear wave angle beams. Because most L-wave transducers are dual element, focused configurations, with cork or some other type of damping material separating the transmit and receive wedges, they require a more liberal use of couplant to maintain healthy sound transmission. This presents some physical differences in how these transducers are manipulated, during scanning. The generation of typical longitudinal wave examination angles also necessarily produces shear waves at approximately half the longitudinal wave angle value (that is, a 60° longitudinal wave transducer will simultaneously produce a 28° shear wave in a stainless-steel calibration block or component). As a result of producing more than one angle in the part, there will be multiple sound waves returning to the transducer with multiple resulting signals appearing on the instrument display. Additionally, when a longitudinal angle beam wave strikes a reflector, the sound wave will not simply reflect a longitudinal wave back to the transducer at the same angle but will also create one or more mode converted sound waves in the part, all of which will return to the transducer at different times. All the added physics and the resulting signal responses should be understood by the technician, for them to be able to perform meaningful UT examinations with conventional longitudinal wave angle beams.

While much of the understanding of the physics involved in the deployment of L-wave angle beams is obtained via classroom training, it is also necessary to perform many examinations with the technique in field or laboratory settings to get used to the unique aspects of the technology and to learn to perform the examinations effectively. In a nuclear power plant setting, conventional L-waves are typically used for examination of components fabricated with stainless-steel and nickel alloys, which are mainly found in piping welds. A typical stainless-steel piping weld will take a minimum of four hours to plan, complete the UT system calibration, complete the examination on the part, and then to perform the post examination data evaluation and reporting. Of that time, only about 30 minutes might involve calibration and scanning with a conventional longitudinal wave angle beam transducer and that is only if the component is at least partially limited to a single side access and is at least 0.5 inches (13 mm) in wall thickness. Examination of dissimilar metal welds will also normally take about roughly the same amount of time to examine, but in that case around three hours of that time will be spent on calibration and scanning using longitudinal wave angle beam transducers, because L-wave is the primary mode of propagation for that type of examination. Much of what the technician will need to learn and understand with L-waves is also applicable to shear wave angle beam examination, so there will be some synergy in learning both techniques. But even so, there will need to be some focused time spent on the use of L-waves.

With the above factors in mind, a technician will need to perform in the neighborhood 20 examinations with conventional refracted longitudinal wave angle beam transducers, at least half of which are on dissimilar metal welds, to obtain a high level of proficiency with the technique. This equates to 35 hours of experience. And because some of the required skills are perishable, they will also need to perform examinations with L-waves during a portion of their annual eight-hour hands-on practice to maintain proficiency. So, if a Level I UT technician is gaining experience in conventional shear wave angle beam examination while they are learning about conventional L-wave angle beam examination, 40 hours of focused L-wave experience should prove sufficient to obtain the necessary proficiency with the technology. And as discussed in the section on examination using shear waves, because the areas of focus and learning will be different when performing an examination as a Level II, who is responsible for the outcome of the examination, an additional 40 hours of experience is recommended for a Level II preparing to advance to a UT Level III role that will have field examination and oversight responsibilities. This is one of the skillsets that can be developed in the lab as well as in the field, and for which experience gained in the lab where feedback on performance can be provided, might prove more valuable.

Application of radiological protection for UT equipment (2 hours for Level II) – Properly bagging or wrapping UT equipment in plastic and taping it up, prior to taking it into a radioactive contamination zone, is a necessary skillset for a technician in the nuclear power industry. The equipment must be protected in such a way that, 1) it will be unlikely to become contaminated in a way that requires more than a minimal wipe down after completion of the examination; 2) the protection will not interfere with the operation and function of the UT equipment, during the examination; and 3) removal of the protective materials, after the examination, will not damage the equipment (that is, coaxial cables will not be cut or damaged and the connectors will not be over-stressed). For most common UT examinations, applying these types of protections will take approximately 10 minutes, prior to entry into the contamination area, and removing the materials will take five minutes, after the job.

Once this process has been completed six or eight times, there is a good understanding of what needs to be done and some reasonable skills will have been developed. It is expected that these skills will be obtained by a technician when they are at the Trainee and Level I stage of their career. Therefore, two hours should be a sufficient amount of experience for a Level I wishing to be certified to Level II to be considered proficient in this skill area.

Reviewing historical UT data for a component (5 hours for Level II; 10 hours for Level III) – There are different schools of thought on the importance of reviewing historical UT data and when that evolution should take place. Some technicians prefer to review previous data, if available, prior to examining any component. Other technicians would prefer to approach a component without any biases from the information previously recorded on the component. Even in the latter case, sometimes a technician will need to go back and review previous data after the examination has been performed to determine if a recorded indication, 1) was previously recorded as a fabrication-related defect and was successfully dispositioned as acceptable via the construction code; 2) was recorded during previous ISI examinations and does not appear to be growing or changing, indicating that it is likely benign; or 3) has either not been recorded previously or has significantly changed in size, indicating the possibility that the indication represents a service-induced flaw.

Reviewing historical UT data will necessitate the consideration of basic information about the procedures, equipment, and even the inspection code used during previous exams. Knowledge of these things will help determine what differences might exist in examination sensitivities, coverages obtained of the required volume, and the recording criteria required at the time. For manual UT examinations, meaningful historical data will be limited to calibration sheets, indication data sheets, and indication plots. For components previously examined in an encoded fashion, there will likely be at least printouts of the top, end, and side views of the volume examined and there might even be electronic data that can be reviewed, if the software for reading those scans is available and the means exists to read the electronic media on which the data was stored.

Historical data will vary in both volume and value, from component to component, so it is useful to gain multiple experiences in performing these reviews. The review of a component can take as little as five minutes and will rarely take more than an hour to complete. So, because the vast majority of presently available historical UT data is from manual examinations, several hours will equate to many different experiences in performing the process. Like other skillsets discussed in this document, experience of reviewing previous UT data that is gained when working in the role of a Level I, while valuable, will differ in perspective from experiences performing the same activity as a Level II. Therefore, this is another activity for which experience should be gained both as a Level I and then again as a Level II. As such, Level I's should have at least five hours of experience in previous UT data review to be considered proficient enough to move to Level II, and Level II's should have an additional 10 hours of experience to be considered proficient enough to qualify as a UT Level III that will be in a role involving field examinations or oversight thereof.

Reading plant isometric and fabrication drawings (6 hours for Level II) – Isometric drawings simplistically illustrate the configuration of a single system within a power plant. They are useful for locating specific locations along a piping system, because they provide dimensional information (length, width, and depth) in a single view while also providing elevation information and component identification numbers. Although the information on an isometric drawing is provided in a straightforward manner, some experience with following them through the plant is helpful to solidify the meaning of the symbology and the skill to go through the necessary mental process of superimposing the layout of a piping system into the physical layout of all the other aspects of the plant. Even so, only a couple of hours of experience with isometric drawings should be sufficient for a technician to become proficient in their use.

Along with isometric drawings, plant fabrication drawings are usually available to assist an NDE technician with locating features or components within a system and for verifying details about the item to be inspected. Fabrication drawings are sketches that provide a little more detail about the relative size and shape of items in a system, including information about the parts and materials used. Critical information about the fabrication will be identified with leader lines to balloons which include the item reference number linking to the parts list. Understanding how to read fabrication drawings is helpful for a UT technician, not only for understanding the layout of the system, but also for verifying the size, thickness, and material makeup of the component, all of which is needed to properly plan a UT examination.

Becoming proficient at reading and understanding the details of fabrication drawings takes practice and exposure to different drawing types. Normally, each instance of reading a series of fabrication drawings associated with a single examination evolution will take no more than 10 minutes. But this needs to be repeated many times, in different situations, to solidify the skillset. Therefore, four hours should be accumulated in the review of fabrication drawings, to become proficient. When coupled with the two hours specified for isometric drawings, six hours of experience is specified for this skill area. Optimally, this experience should be acquired prior to being considered qualified to be a UT Level II, because this skillset is necessary to be functional in the Level II role.

Location and positive identification of field components (6 hours for Level II) – Developing the knowledge of power plant layouts and the skills associated with following plant drawings to locate field components is a skillset that can be obtained in a couple of hours of practice. Much of this skill is associated with understanding isometric and fabrication drawings, which is covered in the section above. This is also not a skill or knowledge base that is exclusive to performance of UT, so it is expected to be acquired as part of all NDE experience.

The more difficult aspect of this skill to acquire is being able identify exactly where a particular weld or portion of a component is located, where it starts and ends, and consequently what the scan area should be for a required examination. Power plant components and some of their associated piping systems are normally fabricated in a shop and then transported out to the plant to be attached to the larger system, via field welds. And while the field welds are usually readily identifiable, shop welds are often prepared in such a way that they are smooth and appear congruent with the component and associated piping. Some UT examinations are not associated with welds, but with areas of a component or piping run. In any case, an important knowledge area for a technician is understanding the configuration of various nuclear plant piping systems and component types and learning to identify shop and field welds.

Like many things, mastering this skillset simply requires the learning gained through experience. A technician needs to see different plant configurations and to learn to compare isometric and fabrication drawings with reality, as well as to learn how to reason their way through different plant layouts to successfully identify shop weld locations. Helpful tricks, like looking for weld identification stamps, will be picked up along the way. But there is no substitute for experience in the plant, for gaining these skills. For any field examination, only a few (a maximum of ten) minutes will normally be spent on aspects of locating a weld or component location to be examined. And the difficulty associated with positive identification of the examination area will vary greatly, from component to component. Because of this, it is reasoned that at least six hours should be logged in identifying components and specific areas for examination, which equates to at least 35-40 separate instances of performance. And this is another skill that should be acquired during a technician's time spent as a UT Trainee or Level I, because this skill is required to be functional as a UT Level II.

Assessing accessibility and condition of a component for UT examination (2 hours for Level II; 2 hours for Level III) – Assessing a component as to its readiness for UT examination boils down to answering a few straightforward questions. First, are there any scan obstructions? The technician must be able to assess whether there are any physical obstructions in the area of the component that would limit the examiner's ability to gain full code required examination coverage. If so, can these obstructions be temporarily or permanently removed? Secondly, is the surface of the component clean enough to perform a UT exam? The surface must be assessed to ensure that it is free of weld spatter or any roughness that would interfere with the free movement of the search units. The surface also must be free of dirt, loose scale, machining or grinding particles, or other loose foreign material or any coatings which might interfere with the transmission of ultrasonic waves.

Some experience is helpful in answering these questions and successfully making these accessibility and surface condition assessments in an efficient manner. The entire time required to make this type of assessment for one examination location is generally inside of 5 minutes, but experience will be gained with repetition and with encountering different types of scan obstructions and surface conditions. Errors in judgement can also play a role in gaining this experience, because a less experienced technician might begin an examination only to discover that there is a limitation or surface condition that went unnoticed and won't allow the examination to proceed. Because these assessments are completed in a short amount of time, normally, a good deal of experience in this process will not add up to many hours. If a technician has assessed 40 or 50 examination locations, they will likely only have logged around three to four hours of time performing the activity, but they will have had an opportunity to see many different issues with examination readiness. Prior to becoming a UT Level II, it will be necessary for a technician to be exposed to this scan assessment process so that they are prepared to be responsible for this aspect of the examination-readiness decision making. However, this is a process that a UT Level II will continue to learn about, through repetition and encountering different types of surface conditions and obstructions. Therefore, two of the four experience hours prescribed for performing these assessments should be obtained by a UT Trainee or Level I, to gain an understanding of the basic concepts involved in making these assessments. The additional experience that will be gained as a working UT Level II will round out the level of expertise in this process that is needed to be a candidate for a UT Level III role that has responsibilities for field examinations and oversight.

Review of UT procedures and preparation for examinations (20 hours for Level II; 30 hours for Level III) – Whether it is the first exposure to a given procedure, or the technician has worked to it many times, it is always a good idea to review a UT procedure prior to using it to perform an examination. This provides the technician with an opportunity to familiarize themselves with important details that might vary from procedure to procedure, such as transducer size, angle, and frequency parameters, instrument settings, the recording criterion for geometric reflectors and flaws, and required documentation. It also provides an opportunity for the technician to mentally "walk" through the examination process, to make sure that they have all the equipment that they might need and that they don't forget any important or unusual steps.

Once the procedure has been reviewed, the technician will need to select the UT equipment for the examination at hand. Initial equipment selection decisions will be based on the component size, shape, and material makeup. Then the procedure will dictate transducer sizes, frequencies, and modes of propagation, based on the component constituencies. The technician will also need to take into account procedural considerations such as angles needed to achieve examination coverage, additional angles that might be needed for indication investigation, and the cable types and lengths required. If the procedure is qualified to ASME Section XI, Appendix VIII, then all the equipment combinations selected must be verified as having been qualified for use together for the examination type to be performed.

Aside from the aspects above, preparing for an examination involves familiarization with the component location in the plant and any special considerations about the area, making sure the UT equipment is in good physical condition and works properly, ensuring that all the additional tools, materials, and paperwork are gathered up, calibrating the instrument and probe combinations, and protecting the equipment for the environment in which the examination will take place.

The amount of time spent reviewing a procedure and preparing for an examination can vary greatly, depending on a lot of factors. And some of the aspects that make up the overall examination preparation process are separately covered in this report. However, in addition to skills covered elsewhere, one can expect to spend an average of one hour on this process, for each examination or series of similar examinations. And because these processes can change drastically, based on the component, the location in the plant, and the type of examination and procedure being used, the process will need to complete many times and in many situations, to achieve the level of proficiency needed. A technician that has 50 hours of experience in the exam preparation process could reasonably be expected to have the proper level of proficiency. A working nuclear UT Trainee and Level I will naturally gain some useful experience with examination preparation, but because the perspective of the Level II will be different given the added responsibility for the examination, at least 60 percent (30 hours) of the prescribed experience should be gained by an individual after they are certified as a UT Level II. These are among the skills that can be developed in the lab as well as in the field.

Examination of ferritic piping welds (16 hours for Level II; 16 hours for Level III) – In the list of common UT examinations performed in the traditional nuclear power plant, carbon steel piping weld examinations is one of the most common. It is also arguably the most straight forward because many of the challenges associated with examination of many of the other common materials and configurations are non-existent or less pronounced in carbon steel piping welds. Sound passes through carbon steel weldments with relatively little resistance and attenuation. As a result, indications observed in this material tend to be very predictable. UT also tends to be more sensitive to smaller reflectors, such as porosity, small slag inclusions, and even less pronounced weld root and other geometric reflectors, due to the lack of beam attenuation. So, the signal (data) analysis of carbon steel piping welds is relatively easy to master with a little experience and is mostly made up of identifying and discriminating the source of UT signals based on their position relevant to the weld or component profile.

Because the preparation for weld exams, equipment calibration, and the post-examination analysis and documentation are discussed in other areas of this document, this section is focused simply on the component examination itself. A typical carbon steel piping weld examination can be completed in 94 minutes (time spent at the component), on average, and 10 separate examinations (approximately 16 hours) should be sufficient to expose an examiner to enough conditions and configurations to gain the needed level of proficiency. The source of information for this time estimate was supplied to EPRI from a U.S. utility that will remain anonymous. This average was derived from taking the actual duration of time spent during manual UT carbon steel piping weld examinations performed at one US plant, from 2007 until 2021. Like other skill areas, what is gained taking part in these examinations as a UT Level I will be different than that gained in performing an examination as a UT Level II. So, it is reasonable to say that 16 experience hours should be gained both in preparation to become a Level II and then again as part of becoming a candidate for Level III, especially if the Level III position will involve field examinations and oversight. Examination of carbon steel piping welds is among the skillsets that can be developed in the lab as well as in the field and for which experience gained in the lab, where feedback on performance can be provided, might prove more valuable.

Examination of austenitic piping welds (50 hours for Level II; 50 hours for Level III) – Compared to examination of carbon steel, stainless steel can be more challenging from a UT perspective. The process used to form a stainless-steel component will have a big effect on how it reacts to the transmission of ultrasonic waves. For instance, most forms of wrought stainless-steel pipe will have small and very congruent grains, allowing sound waves to pass through very easily and with a minimum of attenuation or other disturbances. However, the addition of a weld produces grain structure changes that can adversely affect sound beams. There are also forms of wrought stainless-steel, such as 316L, that have a larger grain structure and can have adverse effects on the transmission of ultrasound or can affect the sound differently when examining in different scan directions.

There are various effects that stainless-steel grain structure can have on sound transmission, especially for shear waves. The dendritic grain structure that is created around a piping weld, as a result of the welding process, can actually cause sound to follow the grain boundaries and effectively redirect the sound beam toward the inside surface of the pipe and away from the weldment itself. These grain boundaries can also cause some of the sound to bounce back toward the transducer, creating signals that could be misinterpreted as representing a flaw or other reflector type. Because the effect of grain structure can be dependent upon the direction of the grains and the angle and direction of the sound transmission, the angle of a shear wave sound beam can be altered after it skips off a surface or has been redirected by geometry or some other type of reflector. All of this must be understood and taken into account by the UT technician. Additionally, if a stainless weld has limited or no scan access from one side, then the UT procedure will require the use of refracted longitudinal (RL) transducers to supplement the shear wave examination, because RL sound beams are less susceptible to redirection and reflection when passing through the weld material with all the associated grain structure issues.

Because the preparation for weld exams, equipment calibration, and the post-examination analysis and documentation are discussed in other areas of this document, this section is focused simply on the component examination itself. A typical stainless-steel piping weld examination can be completed in 99 minutes (time spent on the component), on average. The source of information for this time estimate was supplied to EPRI from a U.S. utility that will remain anonymous. This average was derived from taking the actual duration of time spent during manual UT stainless steel piping weld examinations performed at one US plant, from 2007 until 2021. Because there are several different situations and challenges with examination of this material type that must be mastered, to be considered a proficient UT Level II, at least

30 separate examinations are needed to ensure that a Level I has encountered all these challenges. Therefore, 50 hours of experience on austenitic (stainless) steel piping weld examinations is a reasonable expectation for a candidate for UT Level II. However, like other skill areas discussed in this report, what is normally learned by performing these examinations as a UT Level I will be different than what is learned performing these types of examinations as a UT Level II. So, it is reasonable to say that 50 experience hours should be gained by a Level I in preparation to become a Level II and then 50 additional experience hours should be gained by a Level II as part of becoming a candidate for Level III. As with many of the skills discussed in this report, experience level expectations might vary depending on an individual's role in an organization. But for a field examiner or someone performing oversight for field examinations, the proposed amount of experience described here can be reasonably expected to ensure that the necessary proficiencies are achieved at each level of responsibility. Examination of austenitic piping welds is among the skillsets that can be developed in the lab as well as in the field and for which experience gained in the lab, where feedback on performance can be provided, might prove more valuable.

Examination of dissimilar metal welds (46 hours for Level II; 46 hours for Level III) – Dissimilar metal (DM) welds are created whenever it is necessary to connect a carbon steel vessel, component, or piping system to a stainless steel or high-nickel alloy component or piping system. These welds are typically but not always made by buttering the carbon steel weld bevel with an Inconel weld material, which is then also beveled and connected to the beveled stainless-steel component with a different grade of Inconel weld material. These welded connections normally must be included in a nuclear plant's in-service inspection program because of their higher susceptibility to cracking, which is a result of the combination of multiple heat inputs required to make the weldment and the higher susceptibility to corrosion-related cracking of some traditionally used alloys of Inconel. Therefore, it is important for a UT technician with field examination responsibilities to be knowledgeable and proficient in their examination.

The challenges associated with examination of stainless-steel welds are also present in DM welds, but with DM welds there are additional challenges and considerations associated with the transition between materials of different velocities and the fact that more than one austenitic material is normally involved. These layered materials can create compounding instances of sound refraction as the sound beam passes between them. Additionally, the buttering material is usually applied with a different welding process and direction than the final weld, which creates multiple grain directions and boundaries that can also affect the sound beam. Finally, whereas stainless-steel welds will normally be examined primarily with shear waves, especially if dual-sided examination access is available, DM welds are primarily examined with RL waves, to minimize the effects of the grain structure changes and the resulting beam refraction. It is recognized that performing examinations with RLs requires a different set of skills and knowledge.

The typical manual DM weld examination will take 91 minutes (time spent on the component). The source of information for this time estimate was supplied to EPRI from a U.S. utility that will remain anonymous. This average was derived from taking the actual duration of time spent during manual UT dissimilar metal piping weld examinations performed at one US plant, from 2007 until 2021. And just like with stainless-steel weld examinations, it is necessary to examine around 30 DM welds to ensure that all the varieties of challenges have been experienced. Therefore, it is reasonable to assume that a minimum of 46 hours of experience is needed to adequately prepare a technician to be a candidate for UT Level II. Based on the nature of challenges that are unique to the DM weld configuration, important experience and learning will continue to be gained after a technician is working as a UT Level II and has responsibility for all aspects of the examination. Therefore, an additional 46 hours of experience as a UT Level II will be beneficial to preparing them to be a candidate for a UT Level III role with field examination and oversight responsibilities. Examination of DM welds is among the skillsets that can be developed in the lab as well as in the field and for which experience gained in the lab, where feedback on performance can be provided, might prove more valuable.

Examination of cast austenitic piping welds (45 hours for Level II; 45 hours for Level III) – The examination of cast austenitic stainless-steel (CASS) piping welds with UT can be extremely challenging. A CASS component can have a comparatively large grain structure, or even multiple grain structures that are layered through its thickness, as a result of the casting process, all of which might have detrimental effects on the transmission of sound waves. And because the only way to know the precise grain structure in a component is to destructively analyze it, examiners must assume the worst-case scenario in terms of grain structure when preparing to examine a CASS component.

Research in recent years on the examination of CASS has revealed that it is often necessary to use ultrasonic frequencies lower than 1Mhz and to employ nominal examination angles below 45° to successfully detect discontinuities indicative of service-related cracking [32]. Because these are uncommon frequencies and angles, the examiner must adapt to the sound beam behavior and signal characteristics that will be encountered during these examinations. There are also specific requirements that must be followed for examination of CASS, in many codes and standards, that are unique to that material type such as Appendix III, Supplement 2 of [7].

The typical UT examination of a CASS piping weld will normally take at least 90 minutes (time spent on the component). Because of the uniqueness of the techniques and equipment involved in the examination of these welds, it will be necessary to gain a substantial amount of experience to obtain the necessary knowledge and proficiency needed. Therefore, a candidate for a UT Level II position should perform at least 30 CASS piping weld examinations, amounting to at least 45 hours of experience, to reasonably be expected to have the necessary level of proficiency in this skill/knowledge area. And like other similar examination types, a Level II will have additional learning opportunities, based on the nature of their role. So, it is reasonable to expect that a Level II will benefit from an additional 45 hours of experience in preparation for advancing to a UT Level III role with field examination and oversight responsibilities. Examination of CASS piping welds is among the skillsets that can be developed in the lab as well as in the field and for which experience gained in the lab, where feedback on performance can be provided, might prove more valuable.

Examination of carbon steel vessels (20 hours for Level II; 60 hours for Level III) – Pressure vessels vary greatly in size, thickness, and material, but this section will only discuss larger carbon steel vessels, such as reactor vessels and steam generators, because smaller vessels in nuclear plant settings are generally examined with piping procedures. But even with that limitation applied to this discussion, the use of several different examination techniques must be understood to perform or oversee these examinations. Vessels vary greatly in wall thickness from two inches (51mm) up to greater than 12 inches (305mm) and the required examinations include the shell welds, nozzle-to-shell welds, and the nozzle inner radius examinations. The vessel shell material is also a consideration, which in many cases will include austenitic cladding on the inside surface.

Examination of a vessel shell weld that does not include cladding on the inside surface is relatively straight forward and much like examining a carbon steel piping weld, with the main difference being the thickness consideration and acceptance standards. The greater thickness of a vessel requires more care when determining the location and size of a flaw. Vessels with inside surface cladding are more challenging to examine due to the irregular interface between the cladding and the carbon steel. This irregular interface creates a varying ultrasonic signal response which might be high amplitude and can be misinterpreted to be a flaw. Vessel shell welds in nuclear plants are predominantly examined using encoded equipment from either the inside or outside surface. Non-encoded examinations are also performed but generally on areas where the encoded equipment is restricted due to a physical obstruction.

The examination of nozzle-to-shell welds differs from a vessel shell weld with respect to the location and orientation to the circumference of the vessel wall. Examination of a nozzle-to-shell weld might be performed from the inside or outside surface as dependent on access and restrictions. Nozzle-to-shell welds examined from the inside surface might also require an augmented examination to be performed from the nozzle bore.

Nozzle inner radius examinations are not like any other vessel or piping examination due to the variety and complexity of configurations. The nozzle inner radius might be examined from the inside or outside surface. An inner radius examination conducted from the outside surface is very complex due to the geometry of a nozzle, the thickness changes, and the scanning surface, which might include the vessel shell, the nozzle blend, or the nozzle boss. The examination is so complex that a qualified modeling technique to determine where the sound is contacting the inside radius surface and the impingement angle at a specific location is required.

Because the preparation for weld exams, equipment calibration, and the post-examination analysis and documentation are discussed in other areas of this document, this section is focused simply on the component examination itself. Because there are several different situations and challenges with vessel examinations that must be mastered to be proficient, a candidate for UT Level III who is intended to have responsibilities for performance or oversight of vessel examinations should experience a variety of vessel examination types. Preferably, a technician would perform at least 10 feet of vessel shell weld examination, at least three nozzle-to-shell weld examinations, and at least three nozzle inner radius examinations to help ensure that they have encountered and learned to compensate for all these challenges. This would add up to a minimum combined 80 hours of experience. Of these 80 hours, at least 20 hours of this experience should be gained performing some type of reactor vessel UT examinations as a UT Level I, to be prepared to function in the Level II role and to understand the basics of properly identifying items such as the examination location, reference points, scan areas/sizes, basic equipment, and calibration information. The remaining 60 hours of experience would therefore be gained in the Level II role. These are among the skillsets that can be developed in the lab as well as in the field and for which experience gained in the lab, where feedback on performance can be provided, might prove more valuable.

Examination of bolts and studs (4 hours for Level II; 4 hours for Level III) – UT examination of bolts and studs in a nuclear power plant is generally accomplished via a 0°, looking down the length of the shank from the end of the stud or the bolt head. However, for certain configurations, the examination can be accomplished via an angle beam bore probe, looking outwards from the bore hole extending down the center of the stud (for example, some reactor closure stud designs can be examined via the bore hole). Each of these examination techniques is looking for cracking in the threaded areas or at the head-to-shank transition and other geometric transitions. These components are made from a single, homogeneous material and have a relatively simple geometry.

The set up and careful mechanical movements involved in performing these examinations are more complicated and challenging than the evaluation of the data. Therefore, the bulk of the knowledge and experience needed to perform these examinations revolves around learning to use the equipment. Once an examiner has performed one or two of these examinations, the evaluation of signals is self-explanatory.

Typically, bolts and stud examinations are done in batches, because there are generally several identical bolts or studs being used on any given piece of equipment. Therefore, the preparation, calibration, examination, and reporting involved in one of these evolutions will typically take a minimum of four hours. Because a Level I and a Level II will have different responsibilities, perspectives, and opportunities for learning while performing bolting examinations, it is recommended that a technician experience at least one evolution of bolting examinations (4 hours) at each level of certification, if the goal of the individual is to eventually take on a UT Level III role with responsibilities in field examinations and oversight. Examination of bolts and studs is among the skillsets that can be developed in the lab as well as in the field and for which experience gained in the lab, where feedback on performance can be provided, might prove more valuable.

Performance of erosion/corrosion examination of service-water and other Code Class "C" or non-Code Class piping & components (10 hours for Level II; 10 hours for Level III) – UT examination of service-water piping and other class "C" or non-Code Class piping and components, looking for erosion or corrosion degradation, amounts to either scanning or taking point measurements on the component with a 0° longitudinal wave transducer, looking for wall thinning or pitting.

Most purely UT-related knowledge and skillsets needed to perform these examinations are covered in other sections of this report. But because there are many varieties of configurations and many examination issues and challenges in this category that will not be encountered in Code Class 1 and 2 piping and components, performing several of these examinations can provide important UT experiences and knowledge. A typical examination of this type will take between one and two hours to complete, and it is reasonable to expect that 20 hours of experience in performing these types of examinations is needed for a UT technician to be considered a candidate for a UT Level III position with responsibilities in field examinations and oversight. The learning involved in these examinations is fairly straightforward, so useful experience can be gained either as a Level I or a Level II or split between the two functional levels.

Performance of UT examination in difficult field conditions and environments (6 hours for Level II; 6 hours for Level III) – One aspect of performing UT in power plant environments is that the conditions are rarely ideal and can sometimes be stressful and even hazardous. Through plant experience, a technician learns how to persevere through or to overcome difficult situations and to perform high quality examinations despite the environment.

Each exposure to field conditions in a nuclear power plant will likely introduce at least one, and sometimes several "difficult" conditions. The technician might need to scan overhead or while reaching around a component. They might need to contort their body in an uncomfortable position to complete the required scanning. They might have to work from scaffolding or while in a confined space. It might be dark, loud, or hot. The radiation levels might be high, or there might be other work going on in the area that is distracting or potentially hazardous. In any case, these types of field experiences enhance a technician's skills and their ability to apply perseverance.

To establish proficiency in this area, a technician simply needs to experience performing UT in the field and getting the job done correctly, regardless of the challenges. Field examinations normally take at least 90 minutes, of which at least 10 percent of the time is spent determining how to overcome or "deal with" field-related exam performance challenges. If a Level I has taken part in at least 40 examinations, they will have at least six hours of experience particularly focused on performing UT in difficult environments and will understand the importance of and many of the tricks for completing the examination correctly, despite the challenges. This will qualify them to operate in the role of UT Level II. An additional six hours of experience gained as a Level II, where the individual is now responsible for the examination outcome and will likely pay attention to different aspects of the challenges, will enhance a technician's understanding of these principles and techniques and will help quality them to be a candidate for UT Level III who has a role in field examinations and oversight.

Taking thickness and contour information of a component, including identification of component W and L zero locations (5 hours for Level II; 5 hours for Level III) – Two key aspects of any standard UT examination of a weld will be 1) the recording of thickness and contour information, and 2) the identification of width (W) and length (L) zero locations.

Using a pin gauge or other profilometry device to record the outside diameter profile of a component and then taking UT thickness measurements at several points along that profile enables a technician to create a two-dimensional cross-sectional view of the component. This then enables the performance of examination coverage calculations as well as plotting of recorded indications, to determine their exact location in the component, which will help identify whether they can be attributed to geometrical features or flaws. Experience with this process will entail seeing different types of inside surface geometries, such as tapered lands, concave, or convex weld roots, and counterbore, and learning to equate those features to the UT signals observed during the angle beam examination.

Identifying the W zero and L zero positions of a component is necessary to establish the starting point of the examination and the reference points for all subsequent width and length measurements that will be used for recording indications, obstructions, and scan limitations. The UT procedure will usually dictate the preferred zero reference points for a UT examination and how those are to be determined for each different component type.

The performance of the processes discussed above will normally be completed in approximately 15 minutes, during a typical UT weld examination. Performing these steps at least 20 times, should be sufficient to establish a basic understanding of the processes and to get a chance to see a good variety of component configurations and inside surface geometries. Therefore, a UT technician with a minimum of five hours of taking thicknesses and contours and identifying W and L zero locations, during their time as a Trainee and Level I, could reasonably be considered proficient enough to be eligible for UT Level II certification. And with regards to the precision required when recording weld profile information so that plotting of indication locations are optimally effective for assisting with data analysis, additional learning will likely be gained in this area while exercising these skills as a Level II. Therefore, an additional five hours of experience in these processes, as a Level II, should be adequate to position an individual to fulfill a UT Level III role overseeing weld examinations in the field. These are among the skillsets that can be developed in the lab as well as in the field and for which experience gained in the lab, where feedback on performance can be provided, might prove more valuable.

Recording and Plotting of UT indications (25 hours for Level II; 25 hours for Level III) – Precise recording of UT indication information, while examining a component, and then transferring that information to a profile drawing of the examination area is key to determining the location and shape, and therefore the most likely sources of a reflector. These are crucial skills to master to enable proper analysis of manual UT examination results.

Assuming that the technician properly measured the beam angle, during the calibration process, and has collected accurate thickness and profile data of the component being examined, the next crucial step comes in the recording of indication data. This step involves documenting the precise transducer index point location in relationship to the W and L zero reference points of the component, and accurately recording the corresponding UT signal locations on the A-Scan presentation of the instrument that were observed at these W and L locations. These data collection processes and measurements require care and precision, as well as some physical skills related to hand-eye coordination.

Once the technician has returned from the field, the final step of the process involves converting this field data into two-dimensional component profile sketches, with the UT indications superimposed on them based on triangulation of 1) the recorded transducer location, 2) the metal path or depth reading from the instrument, and 3) the measured angle of the sound beam. To do this properly, the geometric principles of angle beam UT examination must be thoroughly understood by the technician. But if done correctly, the information provided by these cross-sectional plots will identify the location, shape, and size of the indication, which enables identification of the most likely source of the reflector.

Developing proficiency in recording and plotting UT indications is a matter of exercising these skills numerous times and gaining the knowledge of all the scenarios that can present themselves and what the penalties can be with making incorrect field measurements. All the steps that must be completed to successfully plot and profile UT indications will normally take a minimum of an hour, during each weld examination. As a Trainee or Level I, a UT technician should be exposed to the entire process a minimum of 25 times to reasonably expect that the necessary understanding and skills to enable them to function at the next level have been solidified. This equates to 25 hours of experience. And then, with the change in level of responsibility and perspective in performing these processes, accompanying the role of Level II, there will be different opportunities for learning. Therefore, a Level II working toward a UT Level III position with field examination and oversight responsibilities would benefit from an additional 25 hours of experience in these processes. These are among the skillsets that can be developed in the lab as well as in the field and for which experience gained in the lab, where feedback on performance can be provided, might prove more valuable.

Reporting examination results (40 hours for Level II; 40 hours for Level III) – Reporting the results for typical examinations is a process that includes filling out calibration and indication data sheets, creating component profile drawings with indication plots, and providing information on examination coverage and coverage limitations (if any). In the case of a detected flaw, a flaw evaluation might also be involved. In the case of generating a report for a straight beam examination, looking for erosion damage or pitting, the report might include individual thickness values at referenced locations or a topographical map of the component, created by the collection of measurements. In any case, NDE results in a nuclear power plant setting are considered quality records, which must be legible and accurate, and must contain all the information that the plant needs to satisfy the applicable codes, standards, and regulations, as well as to make the appropriate operability and asset management decisions.

For an average UT examination in a nuclear power plant, at least one hour will be spent documenting the results in a standard nuclear UT report. By the time a Trainee or Level I has been involved in the development of 30 or 40 such reports, they can reasonably be expected to have had the opportunity to experience various types of report formats and will have likely achieved the necessary level of understanding about the information that needs to be documented, as well as the expectations around legibility and accuracy. Therefore, it is prudent for a UT Level II candidate to have at least 40 hours of examination reporting experience. And as with many other aspects of performing UT in the nuclear industry, the change in perspectives and responsibility associated with reporting NDE results in the Level II role will provide additional learning opportunities that are important in the technician's growth toward becoming a Level III. Therefore, a UT Level II should gain an additional 40 hours of experience in this area, to be considered proficient enough to operate in the role of a UT Level III with field examination and oversight responsibilities. This is one of the skillsets for which at least a portion of the experience can be developed in the lab as well as in the field and for which experience gained in the lab, where feedback on performance can be provided, might prove more valuable.

Reporting examination coverage limitations and performing calculations of coverage (10 hours for Level II; 20 hours for Level III) – It is not uncommon to encounter a scan limitation when performing UT in a nuclear power plant. Limitations can result from many different conditions, such as the intrados of a small diameter piping elbow causing probe liftoff, the existence of component identification plates or RT plugs in the required scan path, or the proximity of adjacent equipment obstructing physical access, just to name a few. In any case, these scan limitations must be carefully measured and recorded. Then, the recorded information must be translated into examination coverage calculations, which are documented as part of the final NDE report.

Measuring and documenting the physical scan limitations in the field requires a knowledge of the coverage calculation process, because the technician needs to ensure that all the necessary measurements are recorded and, if the examination involves multiple transducers and scan directions, the measurements will have to be repeated for each aspect of the examination that is limited. The technician must also understand the examination procedure well enough to determine if there are alternative ways to pick up the required coverage, such as using other qualified examination angles or adding RL scans from the available side of a single-side access austenitic weld.

The process of documenting examination coverage in the final NDE report often requires the technician to develop plan drawings of the examination area, clearly delineating the areas of scan limitation and rendering them into geometrical configurations that make area calculations straightforward and easy to understand. Additionally, the technician will often need to provide cross-sectional profiles of the limited areas, indicating the extent to which effective examination angles were able to be successfully transmitted through the required volume, such that the limited surface area can be combined with the achievable volume to produce an overall coverage calculation.

Examination coverage documentation and calculations will not be necessary on all UT examinations but, when necessary, will likely add two hours to the overall examination and reporting process for a single exam. Each situation will require knowledge and skills for accurate measurement and recording and will require additional knowledge and skills to depict the limitation area and perform the mathematical calculations. Because all of this takes practice and because there are many variables that can come into play, it is necessary to perform these activities 10 or 15 times in order attain the experience and proficiency needed to master them. Therefore, 30 hours of experience in the documentation and calculation of examination coverage would be a reasonable expectation of a technician being considered for a UT Level III role in which examination coverage calculations and oversight is part of the job. Of the 10 to 15 experiences discussed above, probably at least five (10 hours) should be experienced prior to a technician certifying to UT Level II, so that they will have enough of a basic understanding of the considerations and measurement techniques used in the field and some exposure to the depiction and calculation processes. The remainder would be advantageous to experience in the role of Level II, as the increased level of responsibility will provide different opportunities for learning. These are among the skillsets that can be developed in the lab as well as in the field and for which experience gained in the lab, where feedback on performance can be provided, might prove more valuable.

Comparison of RT film to ultrasonic data (2 hours for Level III) – For many existing nuclear power plants, the radiographic testing (RT) method was almost exclusively used to accept welds fabricated during the plant construction phase or as part of component repairs or replacements. If the weld was rejected during these initial inspections and had to be repaired, additional radiographs were made until the weld could be accepted. All these radiographs are normally stored, on site, as part of the construction records. So, if a UT indication is recorded in one of these welds as part of a pre-service or in-service inspection examination and the technician suspects that it might be flaw-related, the plant will often pull the fabrication radiographs to help the technician determine if there is evidence that the reflector was there since construction and was accepted at that time.

Because RT is not employed as often in nuclear plants during operation, there might not always be a qualified RT technician around to assist in interpreting film that has been pulled to help sort out a suspect UT indication. Therefore, a useful skill for any UT Level II or III, with field examination or oversight responsibilities, is to be able to read RT film at least to a level of proficiency to be able to identify common geometric weld features. The technician should also have a working understanding of RT “reader sheets”, which can help identify if there were repairs performed on the weld in question and, if so, how many and where they occurred. By reviewing the repair history of the weld, if there is insufficient evidence of a pre-existing geometrical reflector that could have created the UT signal, the technician might also determine if the area that the indication was recorded in was the site of one or more previous repairs. A repair could contribute to that location having an increased likelihood for service-related flaws to occur.

Reviewing construction RT film to support UT examinations is not a very time-consuming activity. Even with reviewing any associated reader sheets for evidence of previous repairs, the entire process will normally take less than 15 minutes to complete. Eight separate evolutions of this activity should be plenty of experience to gain a working understanding and proficiency in the process. This will amount to around two hours of experience and, because comparison between UT signals and geometric features on RT film requires a well-developed understanding of UT signal interpretation, this experience will all likely occur exclusively after a technician is operating as a UT Level II.

Application of advanced flaw detection techniques (40 hours for Level III) – Certain known flaw mechanisms in commercial nuclear power plants, such as stress corrosion cracking (SCC), can be challenging to detect with UT and might require the use of advanced detection techniques. These challenges might be related to the materials that are susceptible to the flaw type, to the locations in which these flaws are likely to occur, to the morphology of the flaw mechanisms themselves, or to a combination of these factors. Often, a technician will be required to go through special training and testing to be considered qualified to perform some of these examinations. But any Level II or III UT technician with field examination or oversight responsibilities might encounter situations requiring advanced flaw detection techniques and should have a minimum level of knowledge and experience in their use.

There is a broad diversity of techniques that can be considered to fall under the umbrella of “advanced flaw detection”. These include everything from the use of detailed “if-then” logic found in the evaluation section of SCC detection procedures to the use of special equipment such as inside-diameter or outside-diameter creeping waves, Time-of-Flight-Diffraction or phased array transducers, and encoded scanning mechanisms. The advanced techniques needed will vary from situation to situation. That is why it is good for a UT Level III with field examination and oversight responsibilities to have a broad set of experiences, as it affords them the ability to work out what techniques might be the most advantageous to bring to bear on a particular problem.

In addition to the normal UT skills involved in any examination, each encounter with a UT challenge that requires the use of some form of advanced flaw detection technique will expose a technician to at least two hours of experience that is unique to that advanced technique. A well-rounded candidate for a Level III role that will have field examination and oversight responsibilities should have at least 15 to 20 such experiences from which they can draw. Therefore, it is a reasonable expectation that such a candidate needs to have 40 hours of experience related to advanced flaw detection techniques. Advanced flaw detection techniques are among the skillsets that can be developed in the lab as well as in the field and for which experience gained in the lab, where feedback on performance can be provided, might prove more valuable.

Application of through-wall sizing techniques (30 hours for Level III) – Through-wall flaw sizing, especially with manual (non-encoded) UT is a completely unique skillset. Specialized transducers are often used, specialized calibration methods are often required, and unique scanning and evaluation techniques are involved. The skills practiced for flaw detection are not much help in gaining what is needed to be proficient in flaw sizing.

UT flaw sizing requires specific and specialized training to be mastered. The techniques for sizing have names like absolute arrival-time technique, relative arrival-time technique, and satellite pulse observation technique, all of which must be diagramed and carefully explained to be understood. The training also provides the technician with information on how to calibrate for such techniques and how to discern flaw tip signals from normal material noise or other reflections. And once a technician has been trained in the techniques, experience employing them in the field is extremely valuable.

Because everything from the equipment selection to the calibration, to employing sizing techniques in the field is unique, all the time spent in the process should be counted as valuable experience. A typical evolution of this type will take an average of five hours to complete, and it is helpful to perform such evolutions at least five or six times, to gain the necessary understanding and proficiency. Therefore, a candidate for a UT Level III role that will have flaw sizing and oversight responsibilities should have at least 30 hours of experience employing through-wall sizing techniques. Flaw sizing techniques are among the skillsets that can be developed in the lab as well as in the field and for which experience gained in the lab, where feedback on performance can be provided, might prove more valuable.

Basis for Experience Hours Specified for Administrative and General Areas

Knowledge of the advantages and uses of other commonly used NDE techniques in nuclear power plants, including magnetic particle testing (MT), penetrant testing (PT), eddy current testing (ET), visual testing (VT), and radiographic testing (RT) (100 hour for Level III) – Among the important responsibilities of any NDE Level III involved in field examination and oversight is to determine if a particular NDE method is appropriate for a particular purpose. To be able to make that determination, the individual must have a working general knowledge about all commonly used NDE methods, their capabilities, and their advantages and disadvantages.

Much of the general knowledge needed in this area might be gained through training. It is not necessary, for instance, for a technician certified in one method to obtain the required qualifications in all other methods to be a functional Level III. However, field experience is advantageous, especially for situations in which two NDE methods could be technically used for a purpose and would both be allowed by the governing codes and standards. In such a case, the more the Level III understands about the opposing methods, the better equipped they will be to determine the best overall approach for the situation.

The experience needed in this area is normally gained via working outages, seeing different situations transpire, and by paying attention to industry operating experience (OE). And it is recognized that much of this time will run concurrent with experiences being accumulated in the method for which a technician is certified. But in the spirit of trying to attach a measurable amount of time that should be spent in each area of specific knowledge, it is reasonable to assume that a minimum of 20 hours of separate experience should be gained in each other commonly used NDE method, to understand its strengths and weaknesses and to be able to determine if it is more or less appropriate for a given examination. Therefore, it is reasonable to assume that 100 hours of accumulated experience in the various NDE methods used in the nuclear industry would establish the desired level of proficiency in this area, for an individual who is working toward a UT Level III position with responsibilities in field examination and oversight.

Knowledge of welding and fabrication (20 hours for Level II; 50 hours for Level III) – To be an effective Level II UT technician, it is important to understand the components that you are examining, how they are fabricated and welded to other components, and what defects can be inherent in those processes. It is also helpful to have some understanding of the types and locations of stresses that are present in the material, based on the location and configuration of the component. All this information can help the technician examine the component thoroughly and to understand indication information that might present itself.

Knowledge of welding and fabrication is also critically important to a UT Level III with field examination responsibilities, not only with respect to deciding what UT techniques and procedures should be employed on a component, but also with regards to their role in overseeing the investigation of suspected flaw indications. Different configurations can create challenges for certain modes of sound propagation or examination techniques and knowledge of this can help a Level III steer away from those pitfalls. Likewise, establishing the likely source of a UT reflector that has been recorded during an examination is largely dependent on a solid understanding of component or weld design, the various potential geometrical reflectors that could exist within the area, as well as the potential fabrication and service-related flaws that could exist and what their likely orientation and morphology would be.

Much of the knowledge base that an individual will need on this subject will be obtained through classroom training. But sufficient field experience is also invaluable, to allow an examiner to observe how UT interacts with real life examples of plant configurations, experiencing the relevant and non-relevant responses that are inherent in each one.

Preparing for the examination of a component, which requires an examiner to think about the examination process and the types of UT responses that are likely to be encountered, and then the actual performance of the examination will include at least an hour of experience, each time, specifically related to the component configuration involved. A Level I technician with at least 20 such experiences (20 hours) can be reasonably expected to have enough practice in thinking about these things to be functional in the role of a UT Level II.

A working Level II will continue to gain experience considering the components and how they have been manufactured in order determine how best to examine them, as well as having the added experience of working through the disposition of observed UT reflectors each time they perform an examination. It is useful for a candidate for UT Level III, in addition to the formal training they will receive on this subject, to have been exposed to many manufacturing and fabrication-related challenges in the field, to understand how to think about and solve those problems. Therefore, an additional 50 hours of this type of experience is a reasonable amount for someone working toward a UT Level III role with field examination responsibilities to have established the necessary level of knowledge in this area.

Knowledge of metallurgy (15 hours for Level II; 25 hours for Level III) – A UT Level III needs a basic knowledge of materials chemistry, mechanical properties, behavior of metals, processing techniques, foundry practices, welding characteristics, and the expected defects in various product forms to be effective in their job. Different productions of steels, such as the casting, forging, or drawing of a product can have a profound effect on how it will ultimately interact with ultrasound during examination. The manufacturing method will also determine the types, orientations, and morphologies of both fabrication-related and service-related flaws that can be present in a component, and this knowledge can help a Level III in selecting the examination approach that will be most effective and in understanding and interpreting the signals that they see during an examination.

Most of the understanding of metallurgy that a UT technician requires will be obtained via formal training. However, interacting with materials in the field or laboratory and seeing the various issues associated with their inspection and with the geometrical and flaw responses associated with them, depending on how they were made, greatly helps to solidify the principles that are learned in the classroom. A UT technician will often have opportunities to work through the investigation of the findings of their inspections with engineers and material experts in the plant, which is also a valuable experience that enhances what is gained in the classroom.

While performing UT on various component types and material makeups, a technician can gain valuable metallurgical experience. Much of that experience is credited toward the examination of the material and is adequately described in other places in this report. But a portion of any examination will specifically be spent considering the material aspects of the component. Perhaps a total of 30 minutes of the time spent preparing for an exam, calibrating, examining the part in the field, and then evaluating and reporting the results will directly contribute to the technician's learnings specifically around metallurgical principles. After a Level I technician has been exposed to 30 separate examinations (equating to about 15 hours), of various materials, it is expected that they will have had the opportunity to develop an adequate level of understanding of metallurgical principles to be able to be functional in the role of UT Level II. A Level II technician will continue to be exposed to various materials and material combinations, but with the added responsibility level and resulting perspective, it is reasonable to assume that there will be additional learnings associated with these experiences. It is therefore expected that a Level II will benefit from an additional 50 individual experiences (25 hours) to enhance their level of understanding of metallurgical principles to the point that they are ready to take on most UT Level III roles.

Training/mentoring of lower-level UT personnel (40 hours for Level III) – Part of a Level II or III's responsibility is to answer questions, provide guidance and training, and to otherwise generally mentor lower-level UT technicians for the purpose of helping them achieve the next certification level. This responsibility is unique, in that it is incumbent upon each Level II or Level III to take on this role, regardless of job titles and organizational structure. In other words, even if a UT Level III's supervisor was trying to become certified in UT for the first time, it would be the UT Level III's job to mentor their boss in that capacity.

The training/mentoring role is one of being a teacher and a coach. In this context, the Level II or III might formally train personnel on specific topics, such as on the use of a particular code or standard, or on technical topics, such as how to set up and perform an angle-beam examination on a particular component. The trainer role can also often be less formal, simply involving the lower-level technician in learning opportunities, such as allowing them to “tag along” on an examination for which the lower-level individual has little or no prior experience. It can also simply involve being a “life-line” for the mentee, to assist or answer questions whenever the lower-level technician comes up against something that they are unclear or less confident on.

Training and mentoring UT personnel can and will take many forms, each requiring different skills and techniques and requiring different time commitments. Preparing for and teaching a UT class can easily take more than 40 hours, whereas simply answering a UT-related question and explaining the background information can take under 30 minutes. But each aspect is important in ensuring that lower-level UT technicians get the information and learning that they need to progress efficiently and effectively. As such, it is important that a UT Level II gain at least 40 hours of experience in mentoring lower-level technicians as part of becoming a candidate for UT Level III.

UT procedure preparation (16 hours for Level III) – Developing a UT procedure that meets all appropriate industry standards and all internal company and customer needs is a common and very important job for a UT Level III. Doing so, correctly, requires a solid understanding of the component(s) and material(s) to be examined, the UT examination technique(s) to be performed, the customer or internal company-specific needs, and a firm grasp of any industry standards, regulations, or industry guidelines that exist pertaining to the subject matter.

Obtaining the requisite experience and knowledge in all the subjects addressed in this section of the report will be important to a Level III’s ability to properly prepare examination procedures. But in addition to a deep understanding of the materials involved and how to perform the examination, the individual will have to gain some technical writing skills to be able to lay out the procedure in an effective way. They must be able to describe the entire examination process clearly and concisely, including equipment selection, calibration, data collection, signal interpretation, and reporting. There must be a level of organization, as the procedure is being developed, to systematically address the code and regulatory requirements and industry guidelines, ensuring that everything is captured and can be followed. They must also understand and employ the correct auxiliary verbiage (for example, shall, should, might) to indicate mandatory steps versus recommendations or suggestions.

Preparing procedures requires a combination of knowledge and practice. And the practice can only be gained through reviewing and revising procedures or developing them “from scratch”. Developing a draft procedure and then resolving comments from technical reviewers will normally take 30 to 40 man-hours to complete and this process needs to be performed several times, to fully solidify the skillset. Unfortunately, Level II personnel do not normally engage in this process, except on occasions when the currently prescribed procedure for an examination must be altered to account for a component or field condition. Therefore, much of the experience needed to make an individual fully proficient in this process is expected to be gained only after a technician has assumed a UT Level III position. But a Level II should have at least cursory experience with the modification or development of procedures which meet the governing codes and standards applicable. Therefore, it is reasonable to expect that at least 16 hours of experience should be obtained by a Level II, assisting in aspects of the process of procedure development, in order for them to be prepared to perform these tasks in the role of a UT Level III.

Identification of component inspection requirements (24 hours for Level III) – The capability to identify inspection requirements for a nuclear power plant component requires the ability to correctly assess a component's purpose, function, material makeup, and as-built configuration, as well as a fundamental understanding of any applicable inspection program attributes and any codes, standards, and industry guidelines applicable to it. Inspection requirements for code class components, for example, are generally dictated by the code category and the inspection requirements specified for that category. However, these requirements might also be augmented by the applicable regulatory body, via a published regulatory rule or an inspection order, or by an industry Issue Program's guidance based on emergently identified degradation mechanisms. When these industry rules and guidance exist, the Level III must know how to obtain and interpret them.

At times, a component might be identified for examination for which there are no applicable industry or code requirements. In such a case, the Level III will have to obtain material and configuration information, to identify the best inspection methods and techniques, as well as any available engineering data on the postulated flaw mechanisms for the component, the likely locations and orientations of those flaws, and the acceptance criteria that is to be applied. With all this information, a Level III should be able to specify a technique or techniques which will be effective for the intent of the examination.

Regardless of whether the examination requirements for a given component are captured in existing codes, standards, regulations, and industry guidance, or if no such industry requirements are available and the technician must determine them on their own, identifying the proper examination requirements for a nuclear power plant component will typically take one to two hours to complete. A Level II might gain experience for this by taking part in the creation of ISI examination packages for outage inspection campaigns, or by spending time performing UT on balance-of-plant components for which the examination rules are often not as well established by the industry. In any case, a technician with their sights set on moving into a UT Level III role with field examination responsibilities should have at least 24 hours of experience in deriving examination component inspection requirements in preparation to be effective in that role.

Review of UT examination reports (40 hours for Level III) – To be proficient at reviewing UT examination reports, an individual needs to have plenty of experience with performing examinations, including all aspects of the reporting process. These reviews include checking to see that all the required examinations were performed per the procedure, that all the calibrations were completed correctly, and that the results of the examination are credible. If there were exam limitations, the reviewer must be able to determine if the limitation is valid, if any additional examinations should have been performed to mitigate the limitations, and if the coverage calculations were done correctly. If recordable indications were identified, the reviewer must be able to ascertain whether the indications are the result of defects or geometry and, if they are defect-related, whether they exceed the acceptance criteria for the procedure and the applicable examination program.

Most of the experience a technician needs to be proficient at reviewing NDE reports will be gained from performing examinations themselves, which involves skills and knowledge that are detailed in other parts of this report. The process of calibrating, performing examinations, generating reports, laying out and reporting exam limitations, performing coverage calculations, and performing numerous indication plots and profiles will all help prepare someone to be knowledgeable about what to look for when reviewing another technician's report. Additionally, Level IIs will often review reports developed by a Level I or another Level II, during the course of a normal outage.

Reviewing other technician's reports requires becoming familiar with various ways that data can be communicated and being able to stay focused on ensuring that all the required documentation is present and understandable. This is a skillset that is bolstered by experience. Performing a review of the typical nuclear power plant UT report will take an hour or more, depending on the complexity of the exam. One needs to review a variety of reports, written by a variety of technicians, before the necessary proficiency is solidified. As such, a reasonable recommendation is that a Level II complete the review of 30 to 40 reports (equating to a minimum of 40 experience hours), to be considered eligible to take on the role of a UT Level III with field examination and oversight responsibilities.

Application of ASME B&PV Code – Section III or equivalent construction code (40 hours for Level III) – For nuclear plants constructed to the requirements of ASME B&PV Code, ASME Section III governs the rules for construction of nuclear components, including the associated NDE requirements. A nuclear UT Level III working within certain countries, or that is involved with certain plant designs, will have to be familiar with the examination requirements of the Subsections of ASME Section III, Division 1.

Some of the knowledge needed to work in ASME Section III can be obtained in a classroom, such as the layout and purpose of Section III, how to apply the different subsections, and example applications. However, experience in how to interpret UT signals to determine the precise locations and sources of the reflectors, how to ascertain defect types from a combination of physical location and signal characteristics, and some practical application of comparing NDE results to the acceptance criteria is also critical in being able to proficiently apply this section of the code. It is also crucial to understand how UT measurements are made and what effects UT physics (for example, refraction and beam spread) can have on how those measurements should be interpreted and applied. Much of this experience will be gained prior to becoming a Level III, through the performance of calibrations, beam spread measurements, and the exercise of interpreting, plotting, and recording UT data during lab and field examinations.

While much of the experience-related knowledge discussed in this section will be gained performing processes that have already been discussed in this report, some of the unique UT applications dictated by this section, along with the process of comparing UT defect data that you have recorded, in the lab or field, specifically to construction-code acceptance criteria are unique processes that won't all be learned from other UT examination experiences. For instance, each time new construction-related UT examination results identify the existence of a defect, in addition to the profiling, plotting, and reporting of the collected data, the interpreted defect type and dimensions will have to be directly compared to the acceptance criteria in Section III, based on the applicable component and defect types. This differs from the flaw evaluation processes in ASME Section XI.

Each instance of measuring and evaluating construction-related defects and comparing them to construction code acceptance criteria takes some time, probably on the order of four hours per event. And because there are various types of defects that might be encountered during this type of examination, it is reasonable to expect that an individual needs to experience this process at least four to five times to begin to be proficient. Likewise, many examinations dictated by the construction code are unique and will require a review of the applicable requirements. Each instance of this will take a couple of hours of unique preparation and four or five such experiences would equate to a reasonable level of knowledge and understanding. Therefore, it is estimated that 40 hours of experience is needed, specifically around reviewing Section III, and preparing for examinations and around recording of construction-related defects and comparing those to ASME Section III, or an equivalent construction code, to achieve the level of proficiency required to be considered a candidate for a UT Level III role that will have responsibilities that include construction code examinations.

Application of ASME B&PV Code - Section V or equivalent NDE code (40 hours for Level III) – In ASME Code space, Section V contains Code requirements for NDE to the extent they are specifically referenced and required by other Code Sections. So, while there is a great deal of UT-related information in Section V, not all of it is referenced by ASME Sections III or XI. A nuclear UT Level III will, therefore, need a familiarity with the layout and contents of ASME Section V, but will only have to be particularly knowledgeable about a certain subset of those contents. For example, a UT Level III that works at operating nuclear plants will primarily only need to be intimately familiar with the specific portions of Articles 4, 5, and 23, referenced in Section XI. However, that Level III will still also need knowledge of the general layout and contents of Section V, to be capable of finding and reviewing the numerous Section V references contained in Section III when dealing with installation of new components or certain repair/replacement-related activities. Likewise, the need will occasionally arise to reference Section V for UT-related requirements that might be invoked for turbine examinations or other balance of plant activities.

As with other codes and standards, much of the initial knowledge needed to work in ASME Section V will be obtained in the classroom. However, a technician will also benefit from a level of practical application in becoming proficient in this area. Completion of Section V-related UT examinations, including the time spent preparing and the time spent developing the report(s) will take 10 to 12 total hours, of which approximately 4 hours of the process could be considered beneficial for learning to applying aspects that are unique to Section V. It is estimated that completion of 10 different examinations or series of Section V-related examinations, which would equate to approximately 40 hours of experience specific to that code book, is needed to become comfortable and proficient enough with Section V and its related examination rules to be qualified for a UT Level III role involving performance or oversight of field examinations.

Application of ASME B&PV Code - Section XI or equivalent in-service inspection code (100 hours for Level III) – By far the most in-depth NDE-related code requirements that a nuclear UT Level III working at an ASME-governed plant will need to learn to work with are contained in ASME Section XI, which are the rules for in-service inspection (ISI) of nuclear power plant components. For much of the nuclear industry, this section contains everything inspection-related, including what examinations might be used, how to qualify NDE personnel, what an inspection program must contain, how to evaluate detected flaws, how to repair or replace plant equipment, and what documentation is required for all activities. This section categorizes plant components and prescribes examination types and frequencies, extent of examination area/volume, and any other special rules that might be applicable to each category. UT is the primary volumetric examination technique prescribed within this section of the code and there are relatively few references to other code books, related to UT, as the nuclear industry has taken it upon themselves to specify the majority of the rules around how this examination method is to be employed for nuclear ISI. As such, there are general requirements for UT examination and UT personnel qualification, provided in the main text, along with several distinct mandatory appendices covering aspects and applications of this method. A functional UT Level III in the nuclear industry must be well-versed in all these requirements.

Much of the knowledge about this and other codes can be gained in the classroom, including the history and development of this section, the general purpose and layout, the use of code cases and interpretations, and information about how different editions and addenda are invoked and conditioned through regulations. However, due to the volume and complexity of information that needs to be understood and closely adhered to in Section XI, a significant amount of experience working to these rules is also a necessary component to becoming technically proficient. Much of this experience will be gained exercising the skills and knowledge discussed elsewhere in this report, because nearly all nuclear UT procedures will be written to these rules. But there will be times when this code section will have to be directly referenced by a technician, such as when an existing UT procedure cannot be executed, exactly as written, due to unexpected component or plant conditions and needs to be changed to compensate for real world conditions. In such a case, the procedure changes must find a way to meet the actual conditions and still adhere to the code, and this will require the technician to read and correctly interpret it. Another example is when a flaw has been detected. Level II personnel will usually be involved to some extent in the flaw evaluation process, requiring them to become more familiar with the actual code language and processes.

So, in addition to thorough classroom training on ASME Section XI, a technician's experience should include sufficient time spent understanding and applying the various applicable aspects of this section. It is harder to put direct time-correlations to the various activities that will lend to the technician's experience but obtaining 100 hours of direct exposure to the various UT-related applications of Section XI would be a good target for developing the necessary knowledge and proficiency to be a candidate for UT Level III certification.

ASME B&PV code case or equivalent usage, via relief requests and regulations (8 hours for Level III) – A general understanding of the existence and usage associated with code cases is a necessary subset of code knowledge that is needed for a nuclear UT Level III candidate. Much of this will go along with, and is covered by, the previous essay on Section XI. However, there are enough unique components associated with the use of code cases that it can be considered an independent area of proficiency.

Code cases are used to modify existing code requirements and are sometimes used in lieu of a code change, to allow the use of the alternative sooner than the code itself can be revised and approved for use. Plants will obtain relief or relaxation from regulations, so that they can use a code case regarding UT examination. Additionally, there are times when a regulatory body will require implementation of a code case, involving UT, because they are anxious to get what they have determined is a better technique into wide usage in the industry. In either case, a UT technician will be exposed to these alternatives to the published code and will have to employ them correctly.

The typical evolution of familiarization with a code case, how it differs from what is published in the plant's code of reference, and the act of employing it to perform an examination will require a couple of hours of time spent specifically in regard to understanding how and why it has been selected for use, what it specifically says, and then ensuring adherence to the requirements. A technician should experience at least three to four such evolutions, so that they fully grasp the process and will be capable of correctly employing code cases as a Level III. As such, eight hours of experience in the usage of code cases is a reasonable recommended prerequisite for someone qualifying to become a UT Level III capable of taking on field examination and oversight responsibilities.

Knowledge of In-service Inspection (ISI) Programs (4 hours for Level II; 4 hours for Level III) – One way that a nuclear power plant adheres to codes and regulations is through the use of an ISI program, which is their plan and schedule for performing examinations and tests. These programs have a heavy emphasis on NDE, so working nuclear NDE technicians will have a great deal of involvement in the technical execution of a plant's ISI program, and field UT Level IIIs will likely have some involvement in their oversight.

It is necessary for UT Level I and II technicians to gain some understanding of what constitutes an ISI program. A UT technician who is an employee of a nuclear licensee utility will benefit from a detailed understanding of their facilities ISI program and will likely share in the responsibility of its execution. But even an individual working for an inspection vendor will have some level of exposure to a power plant's ISI program, because that is where the components selected for examination are listed, as well as the procedures and calibration standards to be used. Often, when Level I and II technicians are reviewing UT procedures that will be employed during an outage, the Edition and Addenda of ASME Code to which the plant is currently committed will be an important consideration, as certain examination rules will be different with different code years. There might also be, from time-to-time, exposure to other ISI program considerations such as the necessary expansion of ISI scope due to the detection of a flaw, the need to walk down and select an alternative component of a certain code category due to access issues with the original selection or understanding the critical timing of an examination as it relates the where the plant is in their inspection interval. For many Level I and II UT personnel, these exposures to the ISI program will be somewhat scattered and indirect, never accounting for much time in the overall examination process. But those exposures will gradually add up to a basic understanding that power plants perform their UT examinations to an ISI program and that these programs must adhere to the governing codes and regulations.

Similar to other code and regulatory information, much of what is required to be learned about an ISI program will be obtained through classroom training. The experiences gained from working in the industry will also help round out the technician's practical view of how these programs are implemented. Therefore, by virtue of having worked in the nuclear industry for a time, UT Level I and II personnel are expected to have many small exposures to the workings of an ISI program and should have a minimum of four hours of experience directly associated with that topic as a Level I and a minimum of four additional hours as a Level II to be considered reasonably knowledgeable and eligible for advancement to the next level of certification.

Knowledge of Risk-Informed ISI (4 hours for Level II; 4 hours for Level III) – Risk-Informed ISI parallels a traditional ISI program in some basic ways and so, for a UT technician, an understanding of one type of program will transfer easily to the other type. The fundamental difference with regards to how UT is performed for RI-ISI components is that the examination volumes are often different than they would be for components governed by a traditional ISI program and, as a result, a different scan area will sometimes need to be applied. For example, RI-ISI takes into account the fact that, in certain pipe configurations, the presence of a counterbore can increase the risk of thermal fatigue cracking. In such cases, the program will call for affected piping weld examination volumes to increase from the normal weld, plus ½ inch (13mm) of base material adjacent to either side of the weld, to expand to include ½ inch (13mm) beyond the end of the counterbore. A UT Level III with field examination and oversight responsibilities will need to understand this aspect of a plant's RI-ISI program and to be knowledgeable about which welds in the inspection scope are affected by this change, to make sure that these examinations are flagged. Examiners will need to be briefed on this change in examination volume, and the purpose for it, prior to examining the component. Then the Level I and II field examiners that perform the examination will have to be cognizant of the fact that they will have to complete the thickness and contour measurements of the weld, up front, so that the proper scan area can be determined and implemented during the weld examination.

Because a growing number of nuclear plants, worldwide, have adopted or are in the process of adopting RI-ISI programs, it will not be difficult for most UT Level Is and IIs to obtain practical experience with the unique UT applications associated with these programs. Because of the increased examination area requirements that a UT Level II must be aware of on certain RI-ISI welds, it is recommended that a candidate for Level II have a minimum of four hours of experience with RI-ISI program implementation. And with the increased level of responsibility and, consequently, additional opportunities for perspective and learning as an operating Level II, a candidate for UT Level III should have a minimum of an additional four hour exposure to RI-ISI, to be reasonably expected to have a workable understanding of the subtle differences those programs present with regards to the performance of UT.

Knowledge of Augmented ISI (4 hours for Level II; 4 hours for Level III) – Augmented ISI consists of in-service inspections that are added to a plant's Section XI (or equivalent) ISI program, via regulatory requirements (for example, Code of Federal Regulations, generic letters, NUREGs, and Regulatory Guides), usually due to the emergent identification of a degradation mechanism. These examinations differ from code examinations in that they might carry special qualification or examination requirements. Level I and II examiners preparing to perform an augmented ISI examination will need a good understanding of the special examination and reporting requirements for the component, so that they can implement the exam properly. And it will be important for them to understand when they are dealing with an augmented ISI item and, as such, might have different examination and qualification requirements than other similar components in the plant.

Like other Code or ISI program-related knowledge, much of the knowledge a UT technician needs regarding augmented ISI will be obtained in the classroom. But four hours of exposure to augmented ISI while operating as a UT Level I, with that level of responsibility and perspective, and an additional four hours of experience with augmented ISI as a Level II is reasonably expected to be sufficient to round out an individual's understanding, so that they can functionally implement augmented ISI requirements at the next level of qualification.

Performance of repair/replacement ISI and NDE (16 hours for Level III) – NDE associated with repair/replacement activities are governed by a combination of construction code requirements and ISI code requirements. As such, a repair/replacement plan must be developed to dictate the examinations that need to occur and the examination and qualification requirements that are applicable. There are normally more than one set of examination requirements applicable to a repaired or replaced component, because part of the purpose is to accept the workmanship and the other purpose is to establish a pre-service baseline for future ISI examinations. This is important to understand, so that the examination approach selected can accomplish all the requirements, practically and efficiently.

Some aspects of repair/replacement NDE will be learned about in the classroom environment. However, due to its uniqueness, some experience with the repair/replacement process is also helpful to becoming knowledgeable and proficient in that area of the applicable codes. Therefore, an individual qualifying for a UT Level III position that will have responsibility in field examination and oversight should be exposed to at least two repair/replacement activities as part of their learning development. Interacting with the engineering and craft personnel, preparing for, and performing the examinations involved, and completing the paperwork for a typical repair/replacement activity will a take minimum of eight hours, per occasion. Therefore, it is estimated that a UT Level III candidate should have 16 hours of experience with repair/replacement ISI and NDE to be considered reasonably knowledgeable in that area.

Performance of balance-of-plant (BOP), non-code UT examinations (40 hours for Level II; 80 hours for Level III) – In a nuclear power plant, there are a variety of NDE application that occur in the turbine building, the machine shop, and other places outside of the "power block", which are not governed by the normal ISI codes and might or might not even be governed by any industry standards. In such cases, it is critically important for an examiner to understand all the important elements driving the need for NDE, including the purpose or use of the component, the materials and configuration involved, any known or likely degradation mechanisms, and the locations that those damage mechanisms might occur in the part.

A significant number of the UT topics covered in the classroom, such as are dictated in Section XI, Appendix VII – Supplement 1, become more valuable and applicable when approaching non-code UT examinations. This is because Code driven examinations, which make up the bulk of the UT examinations performed in nuclear plants, are being performed on safety-critical components for which the degradation mechanisms are well understood and, therefore, the procedures governing them tend to be much more prescriptive. Knowledge of the code and of the procedure are the primary concerns in those cases. Whereas the concern often shifts to knowledge of the component configuration, general manufacturing/processing, materials issues, and the strengths and weaknesses of different UT techniques when preparing for and performing balance-of-plant examinations.

There are a wide variety of UT examination situations and challenges that are encountered when working on balance-of-plant components, therefore it is important that UT technicians gain a good amount of experience on that side of the plant. This starts with the Level I, who has their sights set on becoming a Level II. It is important for the Level I to gain experience in the examination of components for which less procedural guidance is provided and, therefore, the examiners must bring to bear more of their knowledge of materials, manufacturing/processing, and welding. Then, once in the role of UT Level II, technicians should gain additional experience in performing these types of examinations from the standpoint of being responsible for the outcome of the examination, because this perspective will exercise the technician's knowledge base in a different way. As such, it is reasonable to recommend that a candidate for UT Level II should have a minimum of 40 hours of experience working on balance-of-plant, non-code UT examinations and that an individual qualifying for certification to UT Level III and that plans to be capable of being responsible for field examinations and oversight should have an additional 80 hours of experience in this area.

Planning of outage UT activities (16 hours for Level III) – Planned outage UT examinations are largely made up of those required by the plant's ISI program. The examination techniques employed in these cases are usually established by the applicable codes and might be supplemented by industry issue program guidelines, such as those published by the Material Reliability Program (MRP) and the Boiling Water Reactor Vessel Internals Program (BWRVIP). The early planning of these examinations involves several important activities. These might include ensuring code cases that are to be employed are understood, identifying any applicable relief requests or regulatory commitments involved, ensuring any required modeling of complex components is completed, understanding the examination requirements for augmented inspection program components, and ensuring that there is a plan in place to have the right qualified personnel and equipment on hand to complete the examinations. Closer to an outage, the examination packages need to be assembled. These packages generally include items such as an area map of the component location, isometric drawings and other sketches, component design information, previous examination data (if available), and might even include the examination procedure to be used.

Most of the experience needed to equip someone to perform the outage UT preparations outlined above will be gained through the normal UT Level II job activities. However, understanding where to obtain the required code cases, relief requests, and other industry guidance information and how to understand things like whether you have the correct version, whether and how much of it is applicable, and how to interpret it for use are skills that are best learned through performance. Therefore, some experience of going through outage UT examination preparation is needed for an individual working toward their UT Level III. Working with a Level III to assemble examination packages and helping them work out what all is needed for each package is a good way to obtain this experience. The assembly of UT examination packages for a typical outage scope can usually be completed in about 16 hours. Coupled with all the other experience obtained in the normal examination practices of a Level II, 16 hours of experience specific to outage preparation activities is a reasonable amount to obtain the requisite level of knowledge in that area to be qualified to function as a UT Level III with field examination responsibilities.

Oversight of outage UT activities (40 hours for Level III) – Oversight of outage UT activities is really a multifaceted set of responsibilities that evolves as the outage scope progresses. Prior to the work getting started, there is the task of orienting the workforce. They should be oriented to the plant and the plant support personnel, to the scope of work, to the procedures that will be used, and to the expectations that you have about conducting work and reporting results. During completion of the scope of work, there will be many concurrent responsibilities including conducting pre- and post-job briefs, problem-solving with regards to component access and preparation, and responding to procedural questions and issues. A major touchpoint between leadership and the workforce during the completion of the UT work scope is always with regard to paperwork reviews, which is where procedure adherence and the fact that volumetric coverage requirements are being met are monitored, and that UT indications are being dispositioned appropriately. On occasion, there will be the need to help with the disposition of suspected flaw indications, up to and including going in the field to observe or assist with a “re-look”. As the scope of work begins to be wrapped up, a Level III must double-check that the ISI program goals for the outage have all been completed, or that any deferrals have been squared with the ISI program.

Many normal UT Level II work activities are good experience for the preparation of providing oversight during outage activities. Having lots of experience performing work in the plant is invaluable for understanding what information will be the most helpful for technicians that are new to a plant. Likewise, no one is better prepared to take someone through the use of a procedure or to answer questions about it, than someone well versed in using it themselves. A Level II performing examinations with a Trainee, Level I, or even another Level II will have many opportunities to review examination reports that have been generated by the other person on the team, as well as having many experiences of having their own paperwork reviewed, all of which is good preparation for the job of reviewing and approving examination reports as a Level III. Still, it is a good idea for a prospective Level III to spend some time in more senior positions, during one or more outages, performing these types of jobs as a leader rather than as a peer, because it requires slightly different people skills to do so effectively. It is therefore reasonable to suggest that 40 hours of experience, specifically in an oversight role, should be obtained by a UT Level II who is working toward qualification to Level III and wishes to have field examination and oversight responsibilities.

Performance of ASME Section XI or equivalent flaw evaluations (24 hours for Level III) – Flaws discovered in the course of in-service inspections are required to be evaluated to determine what type of flaw they are as well as their location, size, and shape. In ASME Section XI space, the process for evaluating volumetric flaws is covered in IWA-3000. Once fully evaluated, the flaw(s) are compared against the applicable acceptance criteria found in the 3500 sub-articles, based on the code class of the component.

The process laid out by the Code to evaluate a flaw can be complicated, especially for individuals that are new to the process. But even a seasoned technician can make mistakes, which is why this process is normally performed by one person and then independently checked by at least one other qualified peer. A Level III is usually responsible to sign off on the completion of these evaluations and, as such, needs to have a thorough understanding of how they are to be performed and what the pitfalls might be that lead to incorrect evaluations. For individuals in this role, sufficient experience with the process is critical.

When a UT Level II discovers a service-induced flaw, they will be responsible for collecting all the positional and dimensional data needed to evaluate it. Often, they will also be responsible to perform the initial evaluation of the flaw, which requires performing the mathematical calculations called for in the Code and comparing the results to the applicable 3500 tables. Each instance of evaluating a flaw, this way, will normally take at least four hours and a technician should go through this process at least five to six times to gain a good working understanding and proficiency with it. Therefore, a reasonable recommendation is that a candidate for a UT Level III position involving oversight of ASME Code examinations should have a minimum of 24 hours of experience with ASME Section XI, or equivalent, flaw evaluations.

Knowledge of 10CFR50.55a or equivalent regulations (8 hours for Level III) – It is critical for a nuclear UT Level III to understand the relationship between the codes and standards governing NDE and any regulatory rules conditioning the use of those codes and standards. The NRC incorporates editions and addenda of ASME Code by reference in Title 10 of the Code of Federal Regulations, Part 50.55a (10CFR50.55a), and this is also where they place conditions on the use of that code. Knowing how this works and having an ability to find and reference this regulation allows a Level III in the US to have a complete understanding of the rules by which NDE is to be performed in nuclear plants.

Much of the information needed for using 10CFR50.55a, or an equivalent regulation, will come from the classroom. However, some experience in locating the material and being able to read and interpret the information in it is also needed. A candidate for UT Level III should learn to review a regulation such as this, whenever a new version is published. They should also learn to reference parts of it whenever a question about the regulation and its relation to the code comes up. By doing this a few times, they will become comfortable and proficient with working with this regulation and others of its type.

The process of carefully reviewing a document like 10CFR50.55a, for UT regulations, for the first time can easily take three to four hours. There is lots of information specific to UT in the document. After having been through it once, it starts to become easier to navigate. Then, going back through it, such as when a new revision comes out, can usually be accomplished in an hour or less. Therefore, it is reasonable to assert that a candidate for UT Level III should have a minimum of eight hours experience with reading and interpreting10CFR50.55a, or an equivalent regulation.

Knowledge of ANSI/ASNT CP-189 and SNT-TC-1A or equivalent qualification standards (2 hours for Level II; 2 hours for Level III) – Part of the responsibilities of being a Level III is being capable of conducting or directing the training and examination of other NDE personnel. This requires knowledge of the standards that govern those processes. In ASME Code, the standards that are referenced for qualification and certification of UT personnel are CP-189 (Section XI) and SNT-TC-1a (Section III). Because this is not a Level II responsibility, many Level IIs will only be exposed to this and other such qualification standards in the normal process of tracking their own progress through the certification process. However, even with this level of exposure, by the time an individual is ready to certify to Level III, they will be aware of these qualification standards and will have some knowledge of their content. In fact, it is common to have UT Level II certification test questions about the content and purpose of these standards.

Much of the knowledge of these standards will be obtained in the classroom. This learning, coupled with a couple of hours of exposure to these standards, at each level of certification, that is naturally gained through the course of studying for certification tests or determining what is needed to continue to move up, will adequately prepare an individual for the UT Level III responsibilities associated these documents.

B
APPENDIX B

Table B-1 is a side-by-side assessment of the required skills and knowledge listed in ANSI/ASNT CP-189 for UT Levels II and III and the corresponding training course content specified in ASME Section XI, Appendix VII – Supplement 1. The purpose of this comparison is to determine if the required training material appears adequate to prepare UT personnel with the initial knowledge needed to perform the duties for which they will be held responsible as UT Levels II and III.

Table B-1
Assessment of Required UT Level II and III Skills and Knowledge Versus Training

Assessment of Required UT Level III Skills and Knowledge Versus Training	
Required Skills and Knowledge in CP-189 (Section 3.2)	**Corresponding Training Course Content in Appendix VII, Supplement 1**
Establish techniques	4.0 ULTRASONIC TESTING TECHNIQUES 4.1 Contact testing (a) Straight beam (b) Angle beam (c) Surface wave (d) Lamb wave (e) Through transmission 4.2 Immersion testing (a) Straight beam (b) Angle beam (c) Through transmission 4.3 Modified immersion testing (a) Tests employing special devices 4.4 Resonance testing 4.5 Geometric indications, flaw indications, and methods of discrimination 4.6 Flaw sizing 5.0 ULTRASONIC TESTING EQUIPMENT 5.1 Description of basic pulse-echo instrument (a) Time-base (synchronizer) circuit (b) Pulser circuit (c) A-scan display circuit

Table B-1 (continued)
Assessment of Required UT Level II and III Skills and Knowledge Versus Training

Assessment of Required UT Level III Skills and Knowledge Versus Training	
Required Skills and Knowledge in CP-189 (Section 3.2)	**Corresponding Training Course Content in Appendix VII, Supplement 1**
Establish techniques (continued)	5.2 Special instruments (a) B-scan display (b) C-scan display (c) Monitors and recording devices 5.3 Scanning equipment (a) Manipulators (b) Bridges (c) Special scanning devices 7.0 SPECIFIC TESTING PROCEDURES 7.1 Selection of test parameters (a) Frequency (b) Search unit size and type (c) Water distance (immersed test) (d) Scanning speed and index 7.2 Test standardization (a) Ultrasonic reference blocks (b) Adjustment of test sensitivity 7.3 Interpretation of results (a) Acceptance standards (b) Comparison between responses from discontinuities to those from ultrasonic reference standards (c) Estimated length of discontinuities (d) Location of discontinuities (e) Zoning 7.4 Test records (a) Data sheets (b) Maps (c) Identification stamps and certification 7.5 Equipment performance variations

Table B-1 (continued)
Assessment of Required UT Level II and III Skills and Knowledge Versus Training

Assessment of Required UT Level III Skills and Knowledge Versus Training	
Required Skills and Knowledge in CP-189 (Section 3.2)	**Corresponding Training Course Content in Appendix VII, Supplement 1**
Establish techniques (continued)	8.0 VARIABLES AFFECTING TEST RESULTS 8.1 Instrument performance variations 8.2 Search unit performance variations 8.3 Inspected parts variations (a) Entry surface condition (b) Part size and geometry (c) Metallurgical structure 8.4 Discontinuity variations (a) Size and geometry (b) Distance from entry point (c) Orientation to entry surface (d) Discontinuity types and reflecting characteristics 9.0 ADDITIONAL TRAINING FOR LEVEL III CANDIDATES 9.1 Nuclear power plant design, function, and system operation 9.2 Materials, metal processing, fabrication technology, failure mechanisms, and fracture mechanics techniques 9.3 Review of NDE methods commonly used during ISI 9.4 Administration of NDE personnel qualification and certification practices and instructional techniques 9.5 Code, standard, and regulatory requirements 9.6 Procedure preparation
Interpret codes, standards, and specifications	9.5 Code, standard, and regulatory requirements

Table B-1 (continued)
Assessment of Required UT Level II and III Skills and Knowledge Versus Training

Assessment of Required UT Level III Skills and Knowledge Versus Training	
Required Skills and Knowledge in CP-189 (Section 3.2)	**Corresponding Training Course Content in Appendix VII, Supplement 1**
Designate the particular technique to be used	4.0 ULTRASONIC TESTING TECHNIQUES 4.1 Contact testing (a) Straight beam (b) Angle beam (c) Surface wave (d) Lamb wave (e) Through transmission 4.2 Immersion testing (a) Straight beam (b) Angle beam (c) Through transmission 4.3 Modified immersion testing (a) Tests employing special devices 4.4 Resonance testing 4.5 Geometric indications, flaw indications, and methods of discrimination 4.6 Flaw sizing
Verify the adequacy of procedures	7.0 SPECIFIC TESTING PROCEDURES 7.1 Selection of test parameters (a) Frequency (b) Search unit size and type (c) Water distance (immersed test) (d) Scanning speed and index 7.2 Test standardization (a) Ultrasonic reference blocks (b) Adjustment of test sensitivity 7.3 Interpretation of results (a) Acceptance standards (b) Comparison between responses from discontinuities to those from ultrasonic reference standards (c) Estimated length of discontinuities (d) Location of discontinuities (e) Zoning 7.4 Test records (a) Data sheets (b) Maps

Table B-1 (continued)
Assessment of Required UT Level II and III Skills and Knowledge Versus Training

Assessment of Required UT Level III Skills and Knowledge Versus Training	
Required Skills and Knowledge in CP-189 (Section 3.2)	**Corresponding Training Course Content in Appendix VII, Supplement 1**
Have general familiarity with the NDT methods covered in Appendix A of this standard	9.3 Review of NDE methods commonly used during ISI
Be capable of conducting or directing the training and examining of NDT personnel in the methods for which the Level III is qualified	No training material appears to correspond with this skillset.
Assessment of Required UT Level II Skills and Knowledge Versus Training	
Required Skills and Knowledge in CP-189 (Section 3.3)	**Corresponding Training Course Content in Appendix VII, Supplement 1**
Set up and calibrate equipment	5.0 ULTRASONIC TESTING EQUIPMENT 5.1 Description of basic pulse-echo instrument (a) Time-base (synchronizer) circuit (b) Pulser circuit (c) A-scan display circuit 5.2 Special instruments (a) B-scan display (b) C-scan display (c) Monitors and recording devices 5.3 Scanning equipment (a) Manipulators (b) Bridges (c) Special scanning devices 6.0 OPERATION OF SPECIFIC EQUIPMENT 6.1 General operating characteristics 6.2 Functional block diagram of circuits 6.3 Purpose and adjustment of external controls 6.4 Care of equipment and calibration blocks
Conduct tests	7.0 SPECIFIC TESTING PROCEDURES 7.1 Selection of test parameters (a) Frequency (b) Search unit size and type (c) Water distance (immersed test) (d) Scanning speed and index 7.2 Test standardization (a) Ultrasonic reference blocks (b) Adjustment of test sensitivity

Table B-1 (continued)
Assessment of Required UT Level II and III Skills and Knowledge Versus Training

Assessment of Required UT Level II Skills and Knowledge Versus Training	
Required Skills and Knowledge in CP-189 (Section 3.3)	**Corresponding Training Course Content in Appendix VII, Supplement 1**
Interpret, evaluate, and document results in accordance with procedures approved by an NDT Level III	7.3 Interpretation of results (a) Acceptance standards (b) Comparison between responses from discontinuities to those from ultrasonic reference standards (c) Estimated length of discontinuities (d) Location of discontinuities (e) Zoning 7.4 Test Records (a) Data sheets (b) Maps
Be thoroughly familiar with the scope and limitations of the method to which certified	1.0 FUNDAMENTAL PROPERTIES OF SOUND 1.1 Frequency, velocity, and wavelength 1.2 Definition of ultrasonic vibrations 1.3 General application of ultrasonic vibrations 2.0 PRINCIPLES OF WAVE PROPAGATION 2.1 Modes of vibration 2.2 Acoustic impedance 2.3 Reflection 2.4 Refraction and mode conversion 2.5 Diffraction, dispersion, and attenuation 2.6 Fresnel and Fraunhofer effects 3.0 GENERATION OF ULTRASONIC WAVES 3.1 Piezoelectricity and types of crystals 3.2 Construction of ultrasonic search units 3.3 Characteristics of search units (a) Frequency-crystal thickness relationships (b) Conversion efficiencies of various crystals (c) Damping and resolution (d) Beam intensity characteristics (e) Divergence 3.4 Care of search units

Table B-1 (continued)
Assessment of Required UT Level II and III Skills and Knowledge Versus Training

Assessment of Required UT Level II Skills and Knowledge Versus Training	
Required Skills and Knowledge in CP-189 (Section 3.3)	**Corresponding Training Course Content in Appendix VII, Supplement 1**
	4.0 ULTRASONIC TESTING TECHNIQUES 4.1 Contact testing (a) Straight beam (b) Angle beam (c) Surface wave (d) Lamb wave (e) Through transmission 4.4 Resonance testing 4.5 Geometric indications, flaw indications, and methods of discrimination 4.6 Flaw sizing
Be capable of directing the work of trainees and NDE Level I personnel	No training material appears to correspond with this skillset.
Be able to organize and report NDE test results	7.3 Interpretation of results (a) Acceptance standards (b) Comparison between responses from discontinuities to those from ultrasonic reference standards (c) Estimated length of discontinuities (d) Location of discontinuities (e) Zoning 7.4 Test Records (a) Data sheets (b) Maps

There were two skills and knowledge line items in the table above, one for each level of UT certification, that did not seem to have corresponding training course content in Appendix VII, Supplement 1. The Level II skill was the capability of directing work of trainees and Level I personnel. The Level III skill was the capability of conducting or directing the training and examining of NDT personnel in the methods for which the Level III is qualified. Both items are related more to the experience and personal attributes of an individual, than to their initial knowledge base. The remaining skills and knowledge appear to be adequately covered by the training material. Therefore, no modifications are recommended for the training criteria provided in the Code.

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