THE PRACTICAL USE OF UT IN LIEU OF RT IN THE POWER INDUSTRY

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ABSTRACT

In recent years there has been a steady rise in request for alternatives to weld acceptance examinations in lieu of traditional radiography in both fossil and nuclear generating plants. In response, ASME Code Sections I and VIII have addressed this desire with revisions to the respective codes to allow ultrasonic examination to be substituted for radiography. For Section I and VIII the rules for using UT in Lieu of RT are detailed in Code Case 2235 (now in Revision 9) and for the 2010 edition of the referenced codes, the requirements are set forth in the body. The power piping code, ASME / ANSI B31.1, also specifies the UT requirements for volumetric examination in the body of its code requirements. They too have approved measures that reflects the requirements of 2235 concerning fracture mechanics acceptance criteria.

Additional sections of the code have also developed code cases to address alternatives to radiography. Code cases N-659 for ASME Section III and N-713 for ASME XI apply to nuclear components.

This paper will discuss the differences in requirements, applications, and acceptance criteria between ASME Section I and VIII and ANSI B31.1 code requirements, various ultrasonic techniques and the advantages and disadvantages of using ultrasonic examination in lieu of traditional radiography.

BACKGROUND

For many years industrial radiography has been the standard NDE method used for weld acceptance for the construction of pressure retaining components and piping. This method is usually carried out using either a radioactive isotope such as Iridium 192 or Cobalt 60 sources which produce gamma rays or in more permanent facilities through the use of x-ray machines. Simply put a radiograph is a photographic record produced by the passage of x-rays or gamma rays through the object of interest onto a film. Because an actual picture is produced, this allows for easy interpretation of the flaws detected within the weldments. However, determining the exact position of a flaw within the weld is sometimes difficult to determine with radiography.

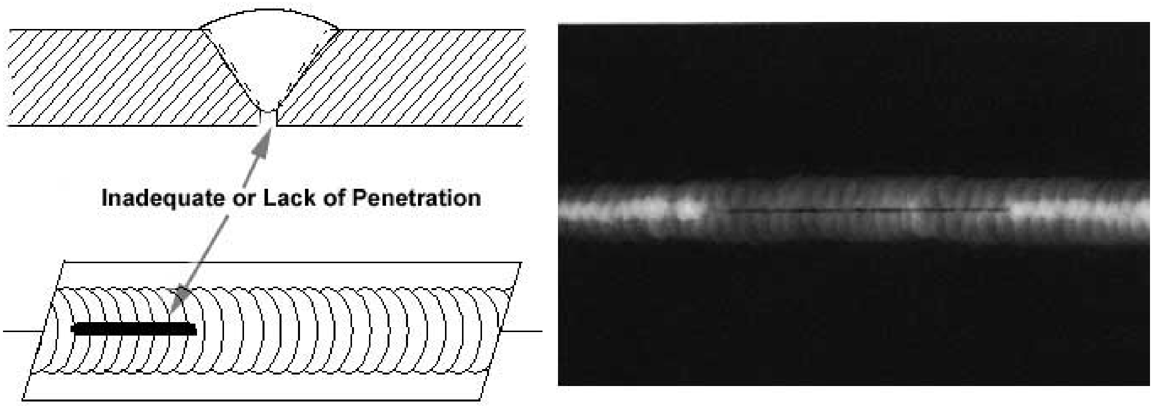

Figure 1. Incomplete penetration

In recent years awareness has risen concerning radiography for safety, convenience, loss of production due to exclusion zones required to conduct radiography and personnel exposure to radiation.

Ultrasonic Examination

Ultrasonic examination is the use of high frequency sound waves to penetrate materials to detect internal flaws or to characterize materials. Listed below are some of the advantages of ultrasonic examination.

1. High penetrating power, which allows the detection of flaws deep within the part.
2. High sensitivity, permitting the detection of extremely small flaws.
3. Only one surface need be accessible.
4. Greater accuracy than other nondestructive methods in determining the depth of internal flaws and the thickness of parts with parallel surfaces.
5. Some capability of estimating the size, orientation, shape and nature of defects.
6. Nonhazardous to operations or to nearby personnel and has no effect on equipment, materials or in progress work in the vicinity.
7. Capable of portable or highly automated operation.

Item 6 above is a very important attribute to ultrasonic examination. Ultrasonic inspection does not produce harmful radiation therefore eliminating the need for an exclusion zone while tests are being conducted. This attribute will be discussed later.

ASME Section I, VIII and Code Case 2235

In 1996 the ASME code adopted code case 2235 for Section I and Section VIII Div I and II. This code case addressed the requirements for use of ultrasonic testing in lieu of traditional radiography for code required examinations. The code case acceptance criteria are based on fracture mechanics rather than traditional workmanship criteria. Additionally there are specific requirements in the code case for implementing the UT examinations.

1. The examination shall be performed using a device employing automatic computer based data acquisition.
2. Data is recorded in unprocessed form.
3. The procedure must be demonstrated on a flawed specimen containing a minimum of 3 flaws. Two surface flaws and one subsurface flaw.
4. Personnel performing the examinations shall be trained and participate in the demonstration.
5. Both Amplitude based techniques and non distance amplitude based techniques can be used.
6. A scan plan showing transducer placement and component coverage shall be developed. See Figure 2 below.

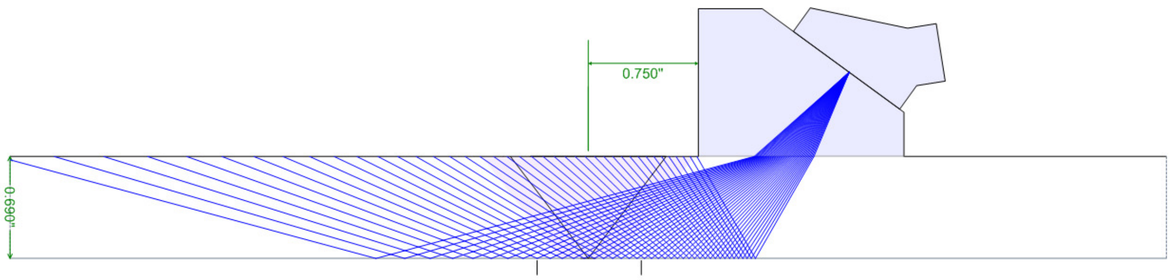

Figure 2. A typical beam coverage plot found in a scan plan for a Sectorial Phased Array scan

ASME ANSI B31.1

ASME B31.1 for power piping has written and adopted requirements in the body of the Code to allow for the use of either UT or RT for volumetric examinations. The acceptance criteria contained in B31.1 is based on workmanship criteria. Again there are specific requirements for applying the ultrasonic method which have varied somewhat since the first integration. The requirements contained in the 2004 version of the Code are as follows:

1. The equipment used to perform the examination shall be capable of recording the UT data including the scanning positions.
2. The nominal thickness of the material being examined shall be greater than ½".
3. Personnel collecting and analyzing UT data shall have demonstrated their ability to perform an acceptable examination using written procedures.
4. The procedures shall have been demonstrated to yield acceptable results when applied to a calibration block fabricated in accordance with ASME Section V, Article 4, T-542.2.

Item 4 has been revised in recent years to read on a "test block approved by the Owner".

This requirement is still very vague in what is actually required when compared to code case 2235.

ASME Section V

When ASME Section VIII incorporated the use of ultrasonics identified in Code Case 2235 into the Division 2 rules, the portions of the Code Case that dealt with the nondestructive examination requirements were incorporated into ASME Code Section V. To that, the 2010 edition of ASME Section V, Article 4 includes mandatory appendices which outline the requirements for implementing phased array technologies for code compliant examinations. Specifically, Article 4 mandatory appendix IV and V specify the requirements for performing manual and encoded phased array examinations. Additionally Appendix VI and VII address the requirements for Workmanship Based Acceptance Criteria and Fracture Mechanics Acceptance Criteria respectively. The acceptance criteria presented in Code Case 2235 are based on fracture mechanics. The workmanship based ultrasonic acceptance criteria are only applicable, per the construction codes, when examining certain weld types (e.g. Electroslag welds) and when radiography is not practicable because of an inability to obtain the necessary image sharpness.

When using the fracture mechanics driven Appendix VII acceptance criteria, an additional requirement is imposed in Appendix VIII which covers flawed demonstration blocks etc.

While it is commendable that ASME Code has addressed these requirements, at times they do seem a bit onerous and expensive just to get prepared for conducting an ultrasonic examination. For example why is a scanner block required in addition to the calibration block?

Yet, ASME Code Section V, Article 1, T-150, paragraph (b) allows for special processes which can be used that differ from the requirements as long as the procedure can be demonstrated to be capable of detecting discontinuities comparable to the general methods. This paragraph opens the possibilities of altering the requirements as set forth in the mandatory appendices of Section V, Article 4.

Ultrasonic Techniques

Conventional Pulse echo

Until recently, one of the drawbacks of ultrasonic examination has been the need for personnel to be highly skilled in interpreting the signals produced during the examination. Conventional ultrasonics are also limited to performing one angle beam examination at a time which can be time consuming. Also since conventional ultrasonics utilize a single fixed angle, the transducer must be manipulated in and away from the weld to provide for 100% coverage.

Phased Array Technologies

Through the advancement of electronics and computing power the ultrasonic technologies today are far superior to those of even a decade ago in industrial applications.

Phased array ultrasonic examinations have revolutionized the method and are rapidly becoming the method of choice for ultrasonic examinations. Originally developed in the medical industry, phased array ultrasonic technology has become very common for industrial applications and is one of the most efficient ways to implement- code compliant UT examinations.

With linear phased array technology a single transducer is cut into a series of smaller crystals that can be electronically programmed to control the angle anywhere within a 0-90 degree spectrum (Figure 3). Furthermore the system is also programmed to pulse the transducer at different focal depths angles from the same position. This is referred to as beam steering, which results in an image of the entire sector scan (Figure 4).

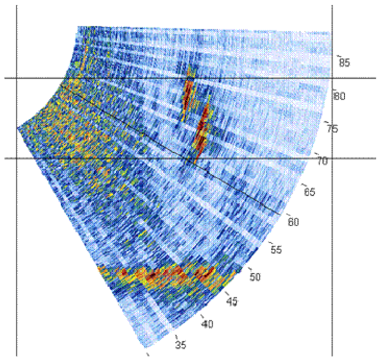

Figure 3. Example of a Sector Scan

Additionally "Escans" or linear scans can be used which are fixed angle exams (i.e. 45, 60, 70 degree) where the beam is electronically raster scanned.

Time of Flight Diffraction (TOFD)

Another technique that can be used for code compliant UT is time of flight diffraction or TOFD as it is commonly referred to. TOFD relies on diffracted sound emanating from the flaw tips for detection and sizing. Sizing flaws with the TOFD method is very accurate, however access from both sides of the weld are required. A typical TOFD image is found in Figure 4.

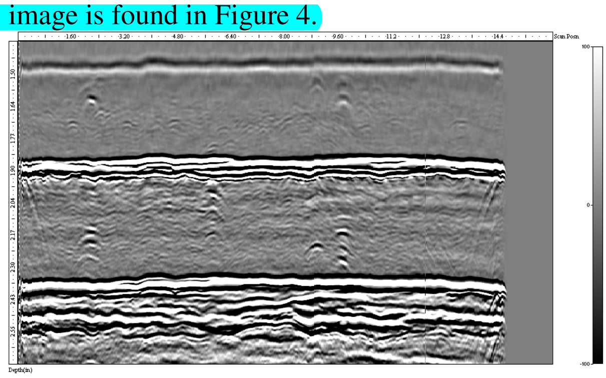

Figure 4. Example of a TOFD Image of a flawed specimen

Advantages / Disadvantages

There are many potential benefits of utilizing an ultrasonic examination for code acceptance. Below are a few of the most obvious:

• No radiation hazard associated with UT therefore there is no loss of production of other crafts working within close proximity to the examination area.

– UT examinations can be performed within close proximity to welding/fabricating personnel as well as other personnel and processes with no side-effects or loss in work progress.

– This alone can be a significant factor at nuclear power plants where plant outage time is critical.

– Can potentially shorten outage time.

- Highly portable with no transport restrictions. UT equipment is small, portable, and usually handled by a small team of technicians and has minimal impact on surrounding work activities.
- Can be faster than RT depending on configuration. On average, UT examinations take half the time or less than that of RT.
- UT allows for through wall depth sizing along with positioning information. This information is easily provided for detected rejectable conditions.
- Today's systems provide imaging capabilities which make interpretation and sizing more precise.
- Encoded Phased Array examinations allow for a permanent record of electronic UT data to be captured and archived for future reference.
- UT testing results are essentially immediate and available for peer review.

Along with the advantages there are some disadvantages as well. Some of the obvious ones are listed below:

- Can be costly upfront to meet code requirements
  – System cost
  – Qualification Block
  – Calibration Block
  – Scanner Block
  – Personnel training and qualification
- Configuration of components can be a challenge
  – Pipe to fitting welds require additional considerations for 100% coverage
- Certain flaw types may be easier to detect using RT such as
  – Porosity
  – Excess root penetration
- Weld cap/surface preparation may be required to provide a smooth surface for scanning

Case Study

A client at a nuclear facility had a planned replacement of a portion of their feed water piping. This project involved installing new welds for the sections of replacement piping being installed. The plant's recent experience with performing RT onsite was very costly and onerous on surrounding plant activities. As many as 40 people had to be involved from approving for a source to be onsite and attending to the required exclusion zone. This is not to mention the lost productivity of other craft personnel during the actual radiation exposure time required to make the shots.

Based on this experience, the client was looking for alternatives to performing radiography. Our recommendation was to perform a code compliant ultrasonic examination utilizing phased array technology. The examinations were to be conducted in accordance with the requirements of ASME / ANSI B31.1 2007 edition.

In order to satisfy the client's requirements and those of the Code, a procedure demonstration had to be performed on a flawed specimen that was of similar size and weld configuration to that of the production welds. Based on the requirements of B31.1 the procedure, personnel, and equipment used to collect and analyze UT data were required to be demonstrated on a test block approved by the owner. This demonstration was conducted to prove that the procedure, personnel, and equipment have the ability to perform an acceptable examination to the satisfaction of the client. During the demonstration it became immediately apparent to the client that phased array UT technology has full capabilities in detecting and accurately sizing fabrication defects such as weld root and toe cracks, slag inclusions, and side wall and interbead lack of fusion.

In addition to the procedure, a component specific scan plan was required to be developed in order to show how full volumetric coverage of the weld and the adjacent HAZ would be achieved (Figure 5). The scan plan is required to be prepared prior to the examination in order to document the required transducer positioning with respect to weld centerline, which will ensure 100% full volume coverage is being obtained. The scan plan also provides the system operator with the proper scanning parameters necessary and identifies the scan coordinates necessary to bound the examination area.

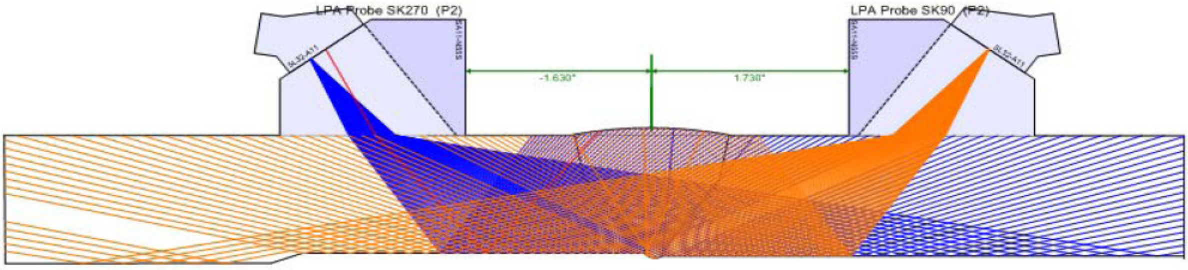

Figure 5. Example of Beam plot coverage for weld to be examined
showing two probe placements to achieve 100% coverage

Also as part of the examination procedure, a technique sheet is prepared to identify various parameters associated with the exam. These parameters include required exam volume coverage information including probe selection, probe setback position, sectorial range, focusing type and the essential parameters associated with the instrument and equipment chosen for the examination.

The calibration portion of the examination procedure includes steps for focal law verification, angle beam verification, time base and probe delay calibration, and reference level sensitivity using vertical plane projection focusing. Figure 6 is an example image of the vertical plane projection focusing calibration.

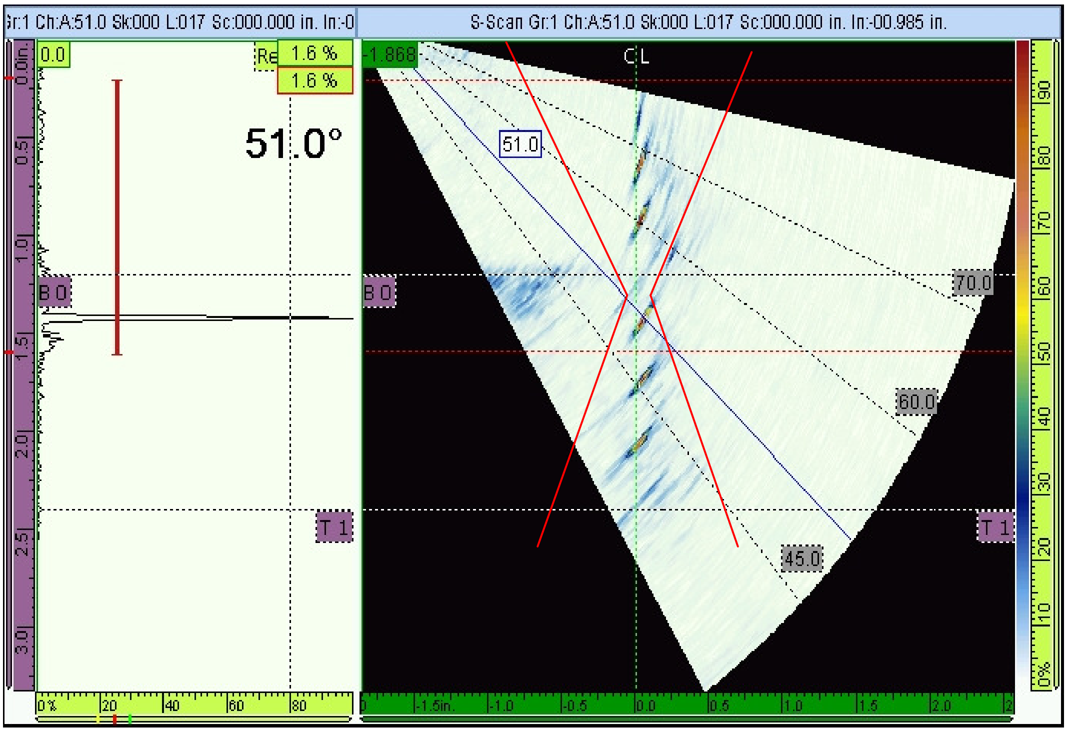

Figure 6. Example of calibration image
showing 1/4T 1/2T 3/4T 5/4T 6/4T and 7/4T side drilled holes

One of the added advantages of UT is that the examination of the weld root can be conducted fairly easily prior to full weld out. Prior to the final weld examination, many clients prefer to assure that the root area of the weld is acceptable prior to completing the remaining full volume weld out. This added examination, for information only, is usually completed manually and helps to avoid a costly repair at the root once the weld has been completed.

For the final weld acceptance examination, a fully encoded scan is performed per the scan plan and examination technique sheet. A minimum of two line scans are performed at two different index points from the center of the weld using probes set on both sides of the weld. Once the data has been collected, the analysis is then performed using a computer based software program. The software has the capabilities of displaying many different views simultaneously such as the "A", "B", "C", and Sector scan (Figure 11). The capability of displaying multiple views of the electronic UT data aids the analyst in the characterization of various indications detected within the completed weld.

All examinations conducted on the feed water replacement piping welds were conducted on time and at a significant time and cost savings to the client. The utility and welding contractor were very much impressed with the fact that UT examinations could be carried out in parallel to in process welding and machining efforts occurring within the same general area. Total savings are hard to estimate, however with consideration given to shutting down all work in the vicinity of the welds productivity cost could add up rather quickly.

SUMMARY

Phased Array Ultrasonic Examination is a viable alternative to radiography for a code compliant examination. However, it is very important that the examination be carried out by competent technicians. Also it is essential that the weld material, weld geometry and configuration, and thickness of the material be known upfront so that the proper focal laws can be developed and the proper transducers with the appropriate aperture be utilized for the examination. All of this information should be contained in the technique sheet and scan plan.

To summarize the following points should be noted

- Performing a code compliant UT examination in lieu of traditional RT is a viable alternative
  - Significant cost and time savings can be expected especially at nuclear plants that are sensitive to bringing RT sources onsite
- Utilizing paragraph T-150 of Section V under General requirements allows for special procedures that if properly demonstrated can be utilized in lieu of the referencing requirements
  - Some of the requirements outlined in the latest edition of Section V limit the technology and capabilities of phased array.
- In the future consideration should be given to component designs that will aid in providing adequate clearance for a quality UT examination
- As technology advances the choice to use UT in Lieu of RT becomes an easy decision to make
  - 3D modeling provides for visualization of the UT data in the component
- Upfront cost can be significant
  - Equipment investment
  - Procedure and personnel qualifications
  - Demonstration Blocks Calibration Blocks and Scanner blocks
  - Once the procedure is qualified and has been demonstrated these cost become insignificant
- A permanent record is established in a modern electronic format for archival purposes which is available for future reference and comparison to of in-service examination data

REFERENCES

1. American Society of Mechanical Engineers, Boiler and Pressure Vessel Code Section I, VIII Code Case 2235 Rev.9
2. American Society of Mechanical Engineers, Boiler and Pressure Vessel Code B31.1 2004 and 2007
3. American Society of Mechanical Engineers, Boiler and Pressure Vessel Code Section V Appendix

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