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Field Tool for the Examination of Tapered Weld Overlays with Complex Geometries

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ABSTRACT

This report provides a summary of technical information associated with the development of an examination tool (Excel workbook) that would aid the ultrasonic examiner when selecting search units required for tapered weld overlays. The purpose of this report is to provide a summary on the objectives and challenges encountered while trying to develop the tool. In addition, some recommendations are proposed.

Keywords
Complex Geometries
Performance Demonstrations
Tapered Weld Overlays

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1
INTRODUCTION

In the winter of 2010, EPRI released an examination aid in the form of an Excel spreadsheet (EPRI Product 1022288) that would calculate essential search unit parameters when scanning weld overlays. The implementation tool was developed to assist ultrasonic examiners when performing weld overlay examinations. The examiner would provide inputs pertaining to the field component. Based on the inputs, the tool would provide essential search unit parameters. These parameters included: size, frequency, angles, contouring and focal sound (FS) path. This tool was effective in performing calculations for flat weld overlays.

Over the last five years the nuclear fleet has seen an increase in the application of overlays. A large number of components containing dissimilar metal welds with complex outer geometries have been overlaid. To compensate for these complex geometries, weld overlays with one or more tapers have been applied. The existing examination tool is not directly applicable to tapered overlays.

This project, *Field Tool for the Examination of Tapered Weld Overlays with Complex Geometries*, would build on the existing spreadsheet by compensating for the taper angle associated with the overlay.

Objectives

This tool has two major objectives:

- First and foremost, to allow the user to verify if their existing conventional refracted longitudinal search units would fall within the search unit parameters required to obtain the coverage defined in PDI-UT-8.
- In respect to the first objective, the second goal was if the existing search units were outside of these tolerances, then which search unit(s) would be needed to comply with PDI-UT-8, Rev G; *PDI Generic Procedure for the Ultrasonic Examination of Weld Overlaid Similar and Dissimilar Metal Welds*.

Additional objectives included improving reliability and efficiency:

- Minimizing human error that is a common occurrence with math calculations done by hand.
- Reduction in man hours by eliminating the need for complex hand calculations or AutoCAD.

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RESEARCH AND DEVELOPMENT

The first task was to gather drawings of tapered weld overlays associated with complex geometries from the nuclear power fleet. Fortunately, EPRI had several of these configurations from performing prior coverage assessments for other applications (i.e., design of phased array probes, etc). In addition, the EPRI performance demonstration (PD) program had recently expanded their sample database to include several tapered weld overlaid configurations (Figure 2-1). These configurations, as well as those from the fleet, were used as a sample bases. Based on the data populated into AutoCAD, numerous drawings showing the complex configurations were generated.

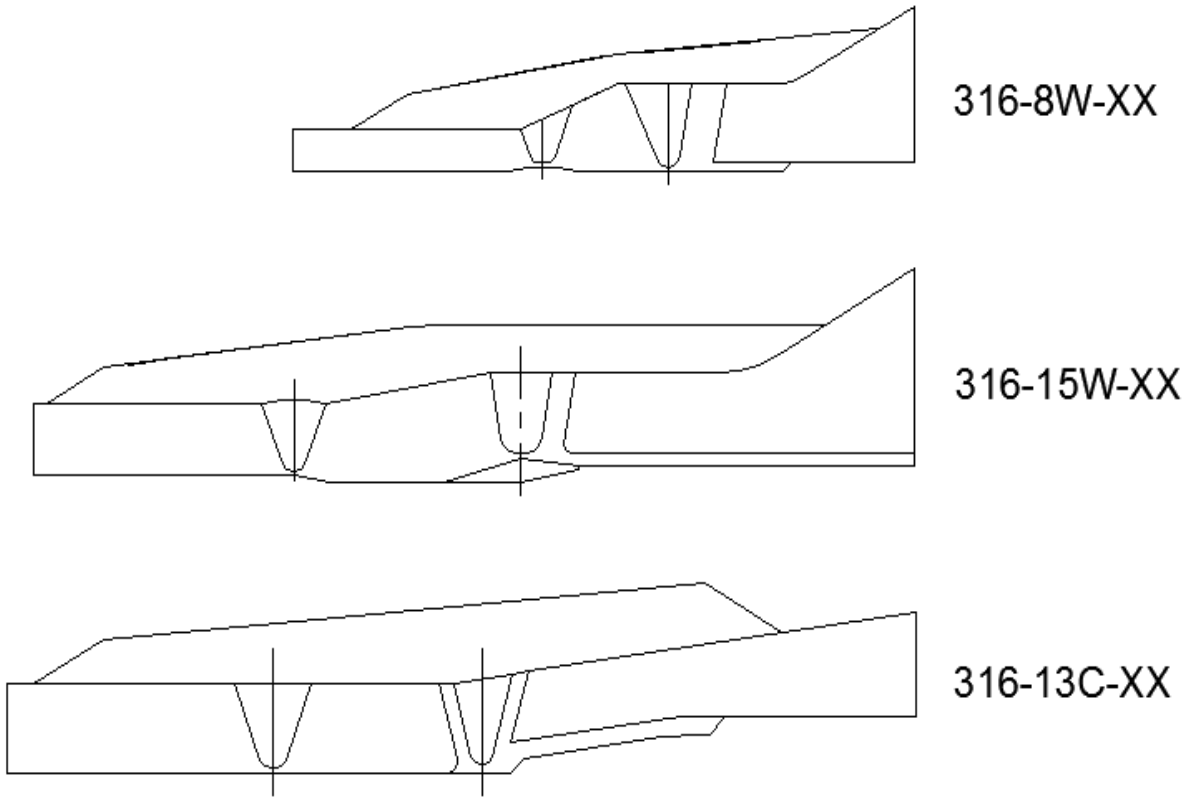


Figure 2-1
PD Program Tapered Weld Overlaid Configurations

Field Tool

The spreadsheet developed consists of two major areas; Configuration Details and Procedural Requirements (Figure 2-2). Cells highlighted in yellow are input fields, while white cells display calculated values based on the user inputs. The Procedural Requirements indicate which search unit angles, sizes, frequencies, and focal sound paths are required in order to be compliant with PDI-UT-8.

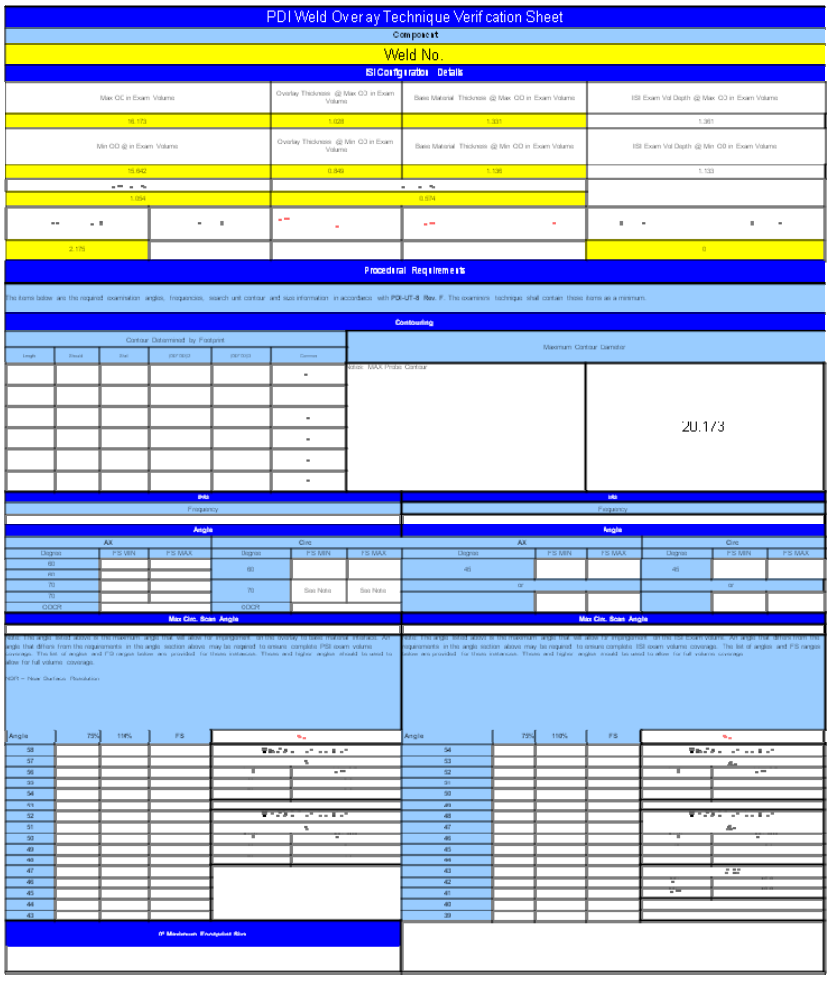
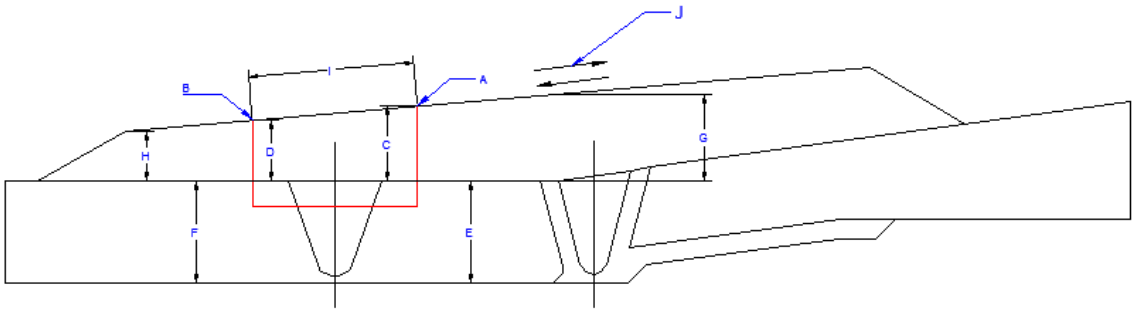


Figure 2-2
Field Tool

The figures (Figures 2-3 and 2-4) below show how the input values correlate to the component configuration's.

PDI Weld Overlay Technique Verification Sheet				
Component				
Weld No.				
ISI Configuration Details				
Max OD in Exam Volume		Overlay Thickness @ Max OD in Exam Volume	Base Material Thickness @ Max OD in Exam Volume	ISI Exam Vol Depth @ Max OD in Exam Volume
9.339		0.667	1.405	1.018
Min OD @ in Exam Volume		Overlay Thickness @ Min OD in Exam Volume	Base Material Thickness @ Min OD in Exam Volume	ISI Exam Vol Depth @ Min OD in Exam Volume
8.834		0.563	1.253	0.876
PSI Max Overlay Thickness		PSI Min Overlay Thickness		
1.200		0.400		
Exam Volume Width	Taper Angle	Maximium OD @ Probe Location	Maximium OD @ Probe Location	Looking Up Taper (0) or Looking Down Taper (180)
2.770	5.230	See Notes	See Notes	0

Figure 2-3
Workbook Input Parameters



A. Max OD in Exam Volume
B. Min OD @ in Exam Volume
C. Overlay Thickness @ Max OD in Exam Volume
D. Overlay Thickness @ Min OD in Exam Volume
E. Base Material Thickness @ Max OD in Exam Volume
F. Base Material Thickness @ Min OD in Exam Volume
G. PSI Max Overlay Thickness
H. PSI Min Overlay Thickness
I. Exam Volume Width
J. Looking Up Taper (0) or Looking Down Taper (180)

Figure 2-4
Configuration Dimensions Inputted into the Workbook

Challenges

There are several different types of Weld OverLay (WOL) configurations that will need to be accounted for in the design of this Microsoft Excel workbook. Most of these tapered WOL configurations are considerably different in taper angle, weld overlay thickness, and original pipe geometry.

A common ground approach was used in developing this workbook tool. The first step was to establish any shared parameters between the WOL configurations (if any). The second step was to normalize the shared parameters and to determine the extents of the outlying values. The third step was to bind the shared parameters to the requirements of the PDI-UT-8, Rev. G and to resolve the outliers using the same procedure.

Initially the tapered examination aid workbook was developed by using the existing MS Excel platform associated with the flat overlays. Utilizing the existing logic, where applicable, would save a substantial amount of development time and reduce costs. Modifications were made and several new cells were added for data input corresponding to the taper parameters.

AutoCAD Verification

Autodesk's AutoCAD was used to verify the probe specification that the workbook tool produced. A cross section of the WOL configuration along with its preservice inspection (PSI) and inservice inspection (ISI) examination volumes was drawn in AutoCAD. Multiple rays simulating the sound beam were drawn to the probe specification that the workbook tool produced (probe angle and focal sound path). The rays were plotted along the tapered WOL Outer Diameter (OD) surface. With the correct focal sound path, the furthest extent of all rays will remain in the examination volume. Figure 2-5 is an example of a 316-8W-XX sample with the PSI 60-125% calculated metal path focal range (magenta box) and rays with the incorrect focusing. Rays 5, 6, 7 and 8 are all outside of the maximum (125%) focal sound path allowed by the procedure.

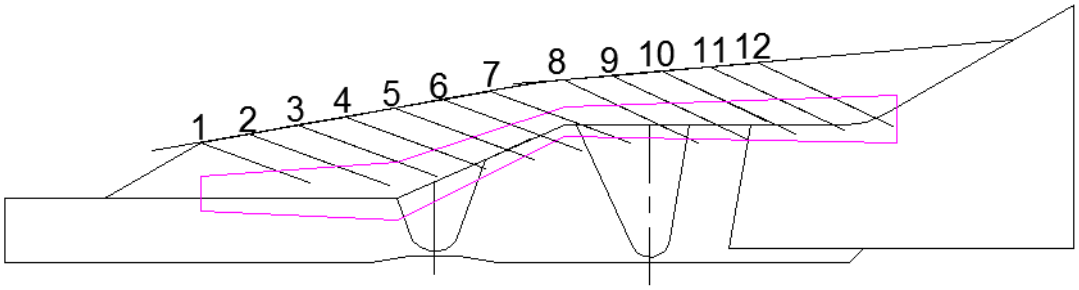


Figure 2-5
Focusing of Rays Outside of the PSI Focal Range of 60%–125%

Figure 2-6 is an example of a 316-8W-XX sample with the correct focusing; all rays are inside of the minimum and maximum focal sound path of the procedure.

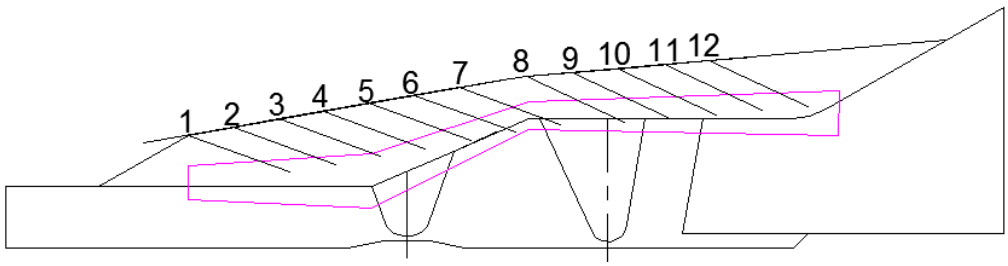


Figure 2-6
Focusing of Rays Within the PSI Focal Range of 60%–125%

AutoCAD verifications were also used for the circumferential scan validations, examples are shown in Figure 2-7. These examples are of a 316-8W-XX sample with circumferential inservice inspection (ISI) calculated metal path focal range (magenta). The minimum (43°), maximum (58°) angles and min/max focusing from the workbook tool are shown as rays (red lines). All rays are within the upper and lower limits (magenta lines).

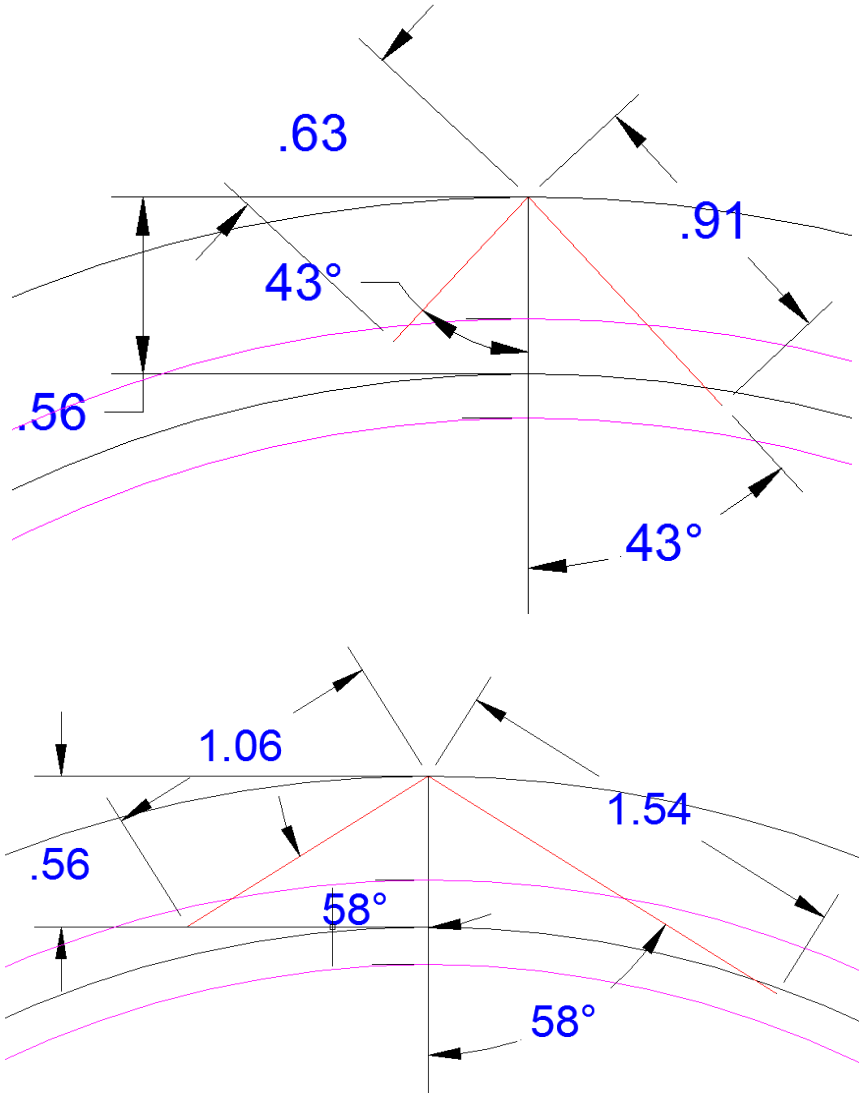


Figure 2-7
Focusing of Rays Within the ISI Calculated Focal Range

Quality Testing

The initial beta tests showed promising results. However, it was discovered when flat overlay parameters were entered, erroneous results were produced. Essentially, the spreadsheet was looking for inputs, though calculations from other cells, where there were none since the overlay was flat. Several solutions were made to correct the error. Additional testing proved none of the solutions to be ideal however they did improve an understanding of the complexity of the issue. Accordingly, it was felt the best approach would be to limit the spreadsheet to tapered overlays. The existing examination tool (1022288) developed in 2010 could be used for flat overlays.

The tool was redesigned to only address tapered overlays. Through continued development, it was determined some additional input parameters were required for extreme changes in the thickness of the weld overlay. The examination aid was resubmitted for testing.

Excel spreadsheets, classified under EPRI's QA program as "Emedia", that are developed within the performance demonstration (PD) program require verification and validation. This rigorous quality process is performed in accordance with the requirements of PDI's QPI-309*, Implementation Tools – Functional Verification and Control*. This quality performance instruction (QPI) requires extensive testing for each Excel spreadsheet cell value generated from a calculation. These calculations must be performed manually (pencil and paper) to ensure that the Excel calculated value is the same as the hand calculation. While performing validations and verifications, it was determined that the results produced by the tapered examination tool were too limiting for practical applications of the tool.

The preservice (PSI) and inservice inspection (ISI) volume could vary significantly based on the original pipe OD. In order to compensate for the minimum and maximum extremes that could be associated with a tapered overlay, the focal sound (FS) path range had to be drastically reduced. These restrictions ensured that the probe, within the calculated parameters, could be used across the entire overlay while obtaining the required volume coverage. Figure 2-8 shows an example of a relatively uniform (thickness) weld overlay. The image shows the workbook's ISI calculated focal sound path (magenta box) versus the 60%-125% focal sound path range (red box) allowed by PDI-UT-8, Rev G (paragraph 6.7.2). It is important to note that the magenta box calculated by the spreadsheet does fall within the red box allowed by the procedure. However, it is also important to point out that search units focused outside the Excel calculated FS parameters may be allowed. The conservatism produced by the spreadsheet may not be necessary for all complex weld overlaid configurations. In summary, the spreadsheet is compensating for the worst case scenario (i.e., 316-8W-XX) since it needs to be applicable to all of the overlays in the fleet. Components with a uniform overlay thickness would be evaluated by the same criteria programmed into the Excel spreadsheet.

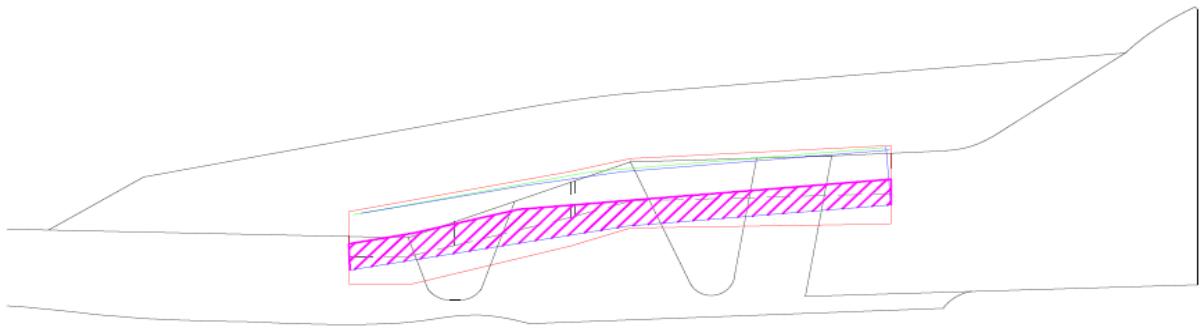


Figure 2-8
AutoCAD Image of Calculated FS Versus Allowed FS

3
LESSONS LEARNED

Quality Assurance Results

Based on the quality assurance validation and verification, it was determined that the tool did not meet the first project objective: To allow the user to verify if their existing conventional refracted longitudinal search units would fall within the search unit parameters required to obtain the procedure defined coverage. In fact, the spreadsheet may imply a search unit is outside acceptable parameters when actually it is well within the procedure requirements. Use of the tool could potentially lead to confusion by restricting the extent of the focal sound path allowed by the procedure. Based on this assessment and in accordance with QPI-309, a nonconformance was written.

A solution to the error is that additional input parameters will be needed to obtain focal sound path parameters more in line with those allowed by the procedure. Additional data points, when there is any transition along the original pipe component, will have to be acquired. Depending on the number of additional data points the complexity of the calculations may eliminate Excel as the calculation platform and an alternative programming platform more suited for these complex geometry calculations may be necessary.

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SUMMARY AND RECOMMENDATIONS

Going Forward

Through the research, development and quality testing of the examination tool for tapered overlays, it was determined that the tool was too restrictive when programmed to compensate for extremes in overlay thicknesses. As a result, it was determined that additional work is necessary. Several options for the field tool still exist:

- Determine if Excel can support additional parameters and the associated complex calculations thus providing results aligned with the procedure, while maintaining a user friendly interface.
- Determine if other platforms or programs would be more appropriate and capable of performing iterative calculations.
- EPRI provide support for the use of the tool in its current state, where EPRI enters the data and accounts for the restrictive output.

The results of this work will be discussed with the NDE Program technical advisors to determine the feasibility of the options noted above or provide any additional options.

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