PRESSURIZER MANWAY AND INSPECTION PORT RE-ENGINEERING

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INTRODUCTION

The Pressurizer Vessels at Darlington Generation Station have had problems with leaks form the gasketed joints. The Pressurizer vessel is part of the Pressure and Inventory Control System, which produces and controls the coolant in the Heat Transport System, which facilitates the transfer of heat from the fission process to the steam generators. Figure 1 illustrates the location of the 18" ID manway and the 12" ID inspection Port. Figure 2 shows the typical double-gasketed bolted joint, which provides a double barrier against D2O leakage into containment. Leakage past the first gasket to the HT D2O Collection System via the inner gasket leak-off line is used to detect and monitor inner gasket seal failures. Over the last number of years, the gasketed joints have required significant maintenance. Occasionally, leakage to the D2O Collection System from failure of the inner gasket seals has resulted in additional cost to upgrade the D2O and return it to the PHT system. Larger leaks have resulted in minor erosion damage to the gasket sealing surfaces and in one instance, a leak through the outer gasket contributed to a forced outage.

This paper describes the seal-welded diaphragm modification to the Inspection Port and Manway closures to replace the original gasketed connections and eliminate leakage. The modification was designed, analytically qualified and field installed by Babcock and Wilcox Canada (BWC) at the Darlington Nuclear Power Station on all four units spanning five outages. The pressurizer vessels are ASME Section III Class 1 components and were designed and manufactured by Dominion Bridge Ltd.

DESIGN DEVELOPMENT

The first effort to address the gasket leakage was to examine the original joint geometry and gasket material selection. As evidenced from past experience, increasing the bolt torque on the joint tended to result in greater leak rates from the inner gasket. By measuring the deflection (rotation) of the flange and analyzing the bowing of the cover, it was evident that the inner gasket was being unloaded as the torque was increased. The gaskets in use were deemed appropriate for this particular joint application. Ontario Power Generation (OPG) reviewed previous seal welded diaphragm solutions at Bruce GS 'A' and 'B' and decided to implement a similar solution for Darlington.

The Bruce pressurizers are plain carbon steel (P-No. 1) which can be welded without subsequent Post-Weld-Heat-Treatment (PWHT), whereas the DNGS pressurizers are low alloy steel (P-No. 3) which would require PWHT (1100 F min for 30 minutes) if the identical modification were applied.

BWC has considerable experience in the design of small and large diameter seal welded closures for PWR applications. These closures have the capability of being sealed in the gasketed or seal welded configuration. The design modification developed for OPG DNGS by BWC is illustrated in Figure 3. The features of the design are itemized as follows:

1) The existing bolting and manway cover is re-used. Minor re-machining of the manway cover was performed on site to accommodate the diaphragm plate. The cover thickness is reduced slightly, however structural criteria are still met.

2) The diaphragm incorporates a centering feature to position it concentric with the nozzle flange and a centering boss to position the cover concentric with the diaphragm.
3) High alloy inconel material is used for the vessel overlay (F-No. 43), seal weld (F-No. 43) and diaphragm plate (P-No. 43) to maximize the fatigue resistance of the assembly. Figure 4 illustrates the improved fatigue resistance of inconel versus the low alloy pressurizer vessel steel. Enhanced fatigue resistance is particularly important for the seal weld to accommodate the relative cover; diaphragm and nozzle flange deflections during thermal transients experienced in large diameter openings. Smaller diameter openings (<6" ID) can utilize plain carbon steel diaphragms, overlay and seal welds, which is advantageous for weldability.
4) The F43/P43 assembly allows removal of the seal weld and diaphragm for access into the vessel and re-seal welding of the diaphragm without the need for preheat or PWHT.
5) Minimal amount of material is removed from the nozzle body/flange forging to preserve the structural strength of the flange.
6) A temper-bead technique is used to overlay the nozzle flange with F43 material to avoid the need for PWHT of the completed modification.

The provisions of ASME Section III Div 1 NB-4622.11 for temper bead weld repair to dissimilar metal welds or buttering were used to preclude the need for subsequent PWHT of the nozzle flange after the F-43 overlay welding. Whenever PWHT is impractical or impossible, these provisions allow limited weld repairs to dissimilar metal welds of P-No. 3 and F-No. 43 to be made without PWHT. The requirements of NB-4622.11 were incorporated into the design of the modification and field work-packages.

Figure 5 illustrates the steps to modify the nozzle flange and cover. As illustrated in the figure, the manway cover is re-machined to accommodate the diaphragm. The nozzle flange is prepared by machining the overlay pocket and the inter-gasket leak-off port is plugged. The weld pocket is filled with F-43 weld overlay using the temper-bead technique and the flange face is machined flush. The diaphragm plate is positioned and seal welded to the F-43 overlay. No preheat nor PWHT is required to perform this weld.

DESIGN ANALYSIS AND DESIGN QUALIFICATION

The Inspection Port and Manway are ASME Section III Class 1 components and thus the design modification must be demonstrated to satisfy all acceptance criteria for Design, Test, Level A&B, Level C and Level D Service Conditions, including assessment for non-ductile failure. The loads and service conditions given in the original Design Specification for the pressurizer were used for this analysis, which was documented in formal stress reports submitted to OPG. The design modification was registered with the TSSA.

Classical hand calculation methods were used to determine primary stresses in the modified cover, flange (neglecting the structural effect of the F-43 vessel overlay) and bolting for comparison to the primary stress criteria (Design, Test, Level C, D).

For the analysis of Level A&B Service Conditions, it is necessary to predict the actual stresses in the assembly for comparison to the linearized stress range limit and to perform the fatigue analysis. The axisymmetric finite element model illustrated in Figure 6 was developed to perform this analysis. The model incorporates the interaction between the flange, cover and bolting and temperature dependant material properties are included to facilitate transient thermal analysis and subsequent stress analysis. The bolting is modeled as equivalent stiffness axisymmetric rings. The model incorporates compressive contact elements between the diaphragm and nozzle flange to assess diaphragm seating.

The transient thermal response of the assembly was determined using a temperature transient that conservatively bounds the Design Specification temperature transients. The worst case temperature distributions (upper and lower end of the range), including internal pressure, were input to the model to determine stresses and resulting stress range and alternating total stresses for comparison to the stress range and fatigue acceptance criteria. While the seal weld is not an ASME structural weld, it simply performs the sealing function, detailed analysis were performed to verify the structural adequacy of the weld. The rotations of the diaphragm were monitored to ensure that it remains seated on the nozzle flange and thus does not lift-off and impose a severe rotational bending moment on the weld. In addition, a detailed fatigue analysis of the seal weld was performed to demonstrate that the cumulative fatigue usage factor was less than 1.0.

Calculations to assess the non-ductile failure susceptibility of the assembly, in accordance with ASME Section III Div 1 Appendix G were also completed.

FIELD MODIFICATION

Modification of the flange ports in the field can be understood in the following sequence of steps:

During a scheduled plant shutdown, the pressurizer is opened and brought into a safe condition for hot work. The egress of hydrogen from the pressurizer walls during shutdown creates the need for vessel purging with constant gas monitoring and the implementation of specialized sealing and vented bungs.

A portable flange-facing machine is mounted to the ID of the nozzle as illustrated by Figure 7. A weld pocket is machined inside the bolt circle of the flange face. Steam cuts are removed if present.

After the flange-facing machine is removed and machined surfaces have passed required NDE, the flange is preheated to 350F.

The leak off hole is plugged and a thin buttering layer of inconel is laid into the weld pocket, after which the weld bead crowns are ground off to facilitate better heat penetration of subsequent temper bead layers of weld. The flange face is brought to 450F for a four hour 'heat soak'.

The final layer is machined to achieve a flat surface and the flange–facing machine is removed. After a forty-eight hour waiting period, NDE is performed and the diaphragm is welded on, followed by NDE of the diaphragm fillet weld as illustrated in Figure 8.

CONCLUSIONS

The Darlington GS pressurizer inspection port and manway have been successfully modified to incorporate a seal welded assembly and eliminate the troublesome gasketed joints. All applicable jurisdictional requirements were satisfied for the design qualification, material supply and field modification. The modification re-used the existing components to the maximum extent possible and provides for ease of diaphragm removal and re-installation, within the existing geometric constraints.

This successful modification demonstrates that re-engineering and site modification of chronically leaking closures in operating CANDU plants is feasible, safe and economically justifiable.

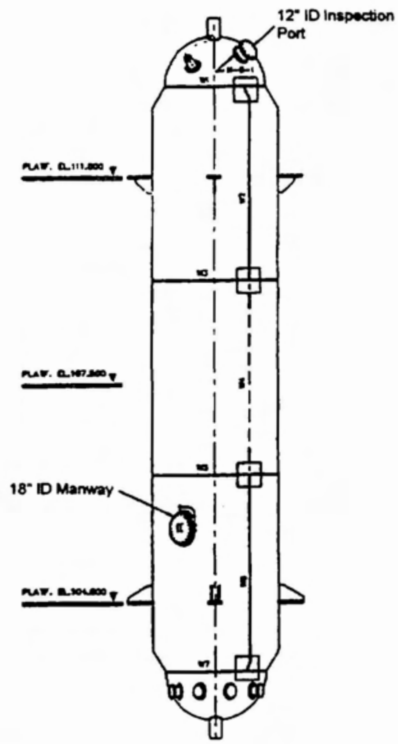

Figure 1 – DNGS Pressurizer Arrangement

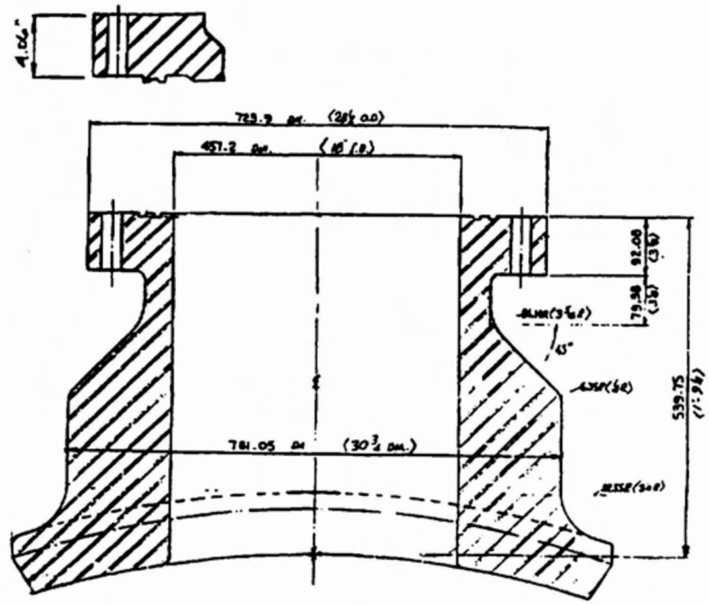

Figure 2 – Original Pressurizer 18" ID Manway Double Gasketed Configuration
(Typical for both Manway & Inspection Port)
(SA-508 Cl. 3, P. No. 3)

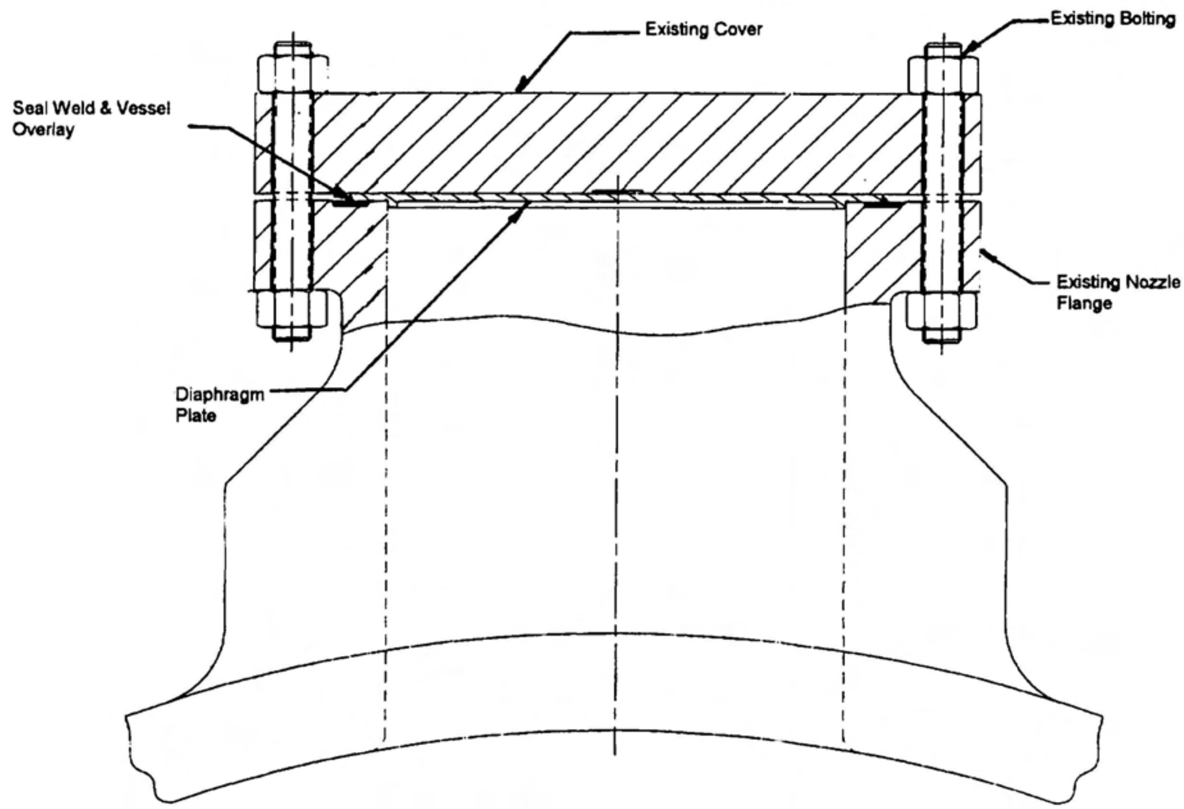

Figure 3 – Manway and Inspection Port Design Modification

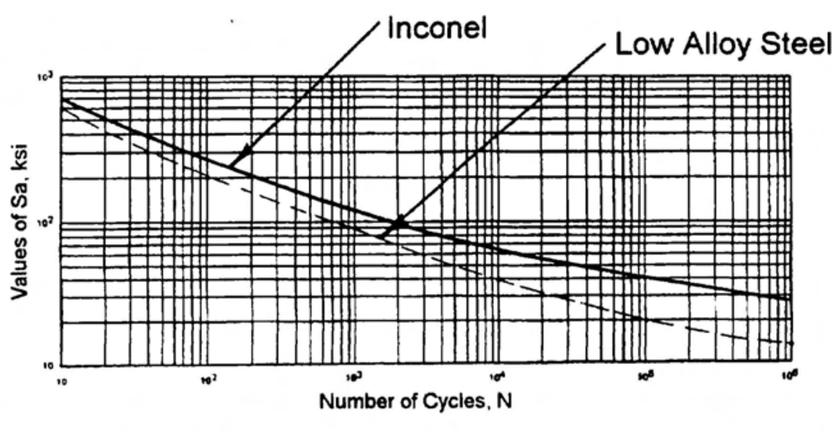

Figure 4 – ASME Fatigue Design Curve for Inconel and Low Alloy Steel

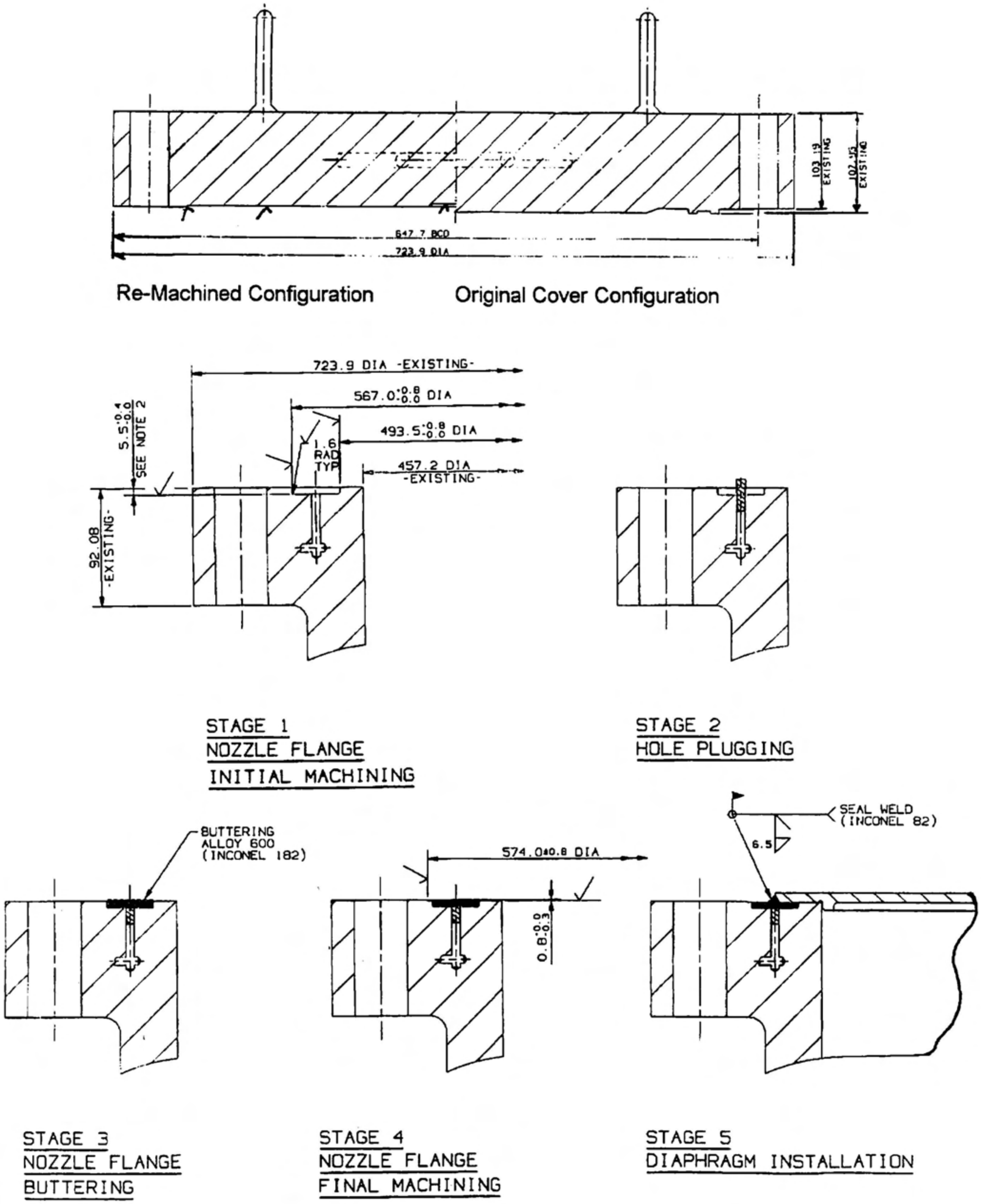

Figure 5 – Field Design Modification of Pressurizer Manway and Inspection Port

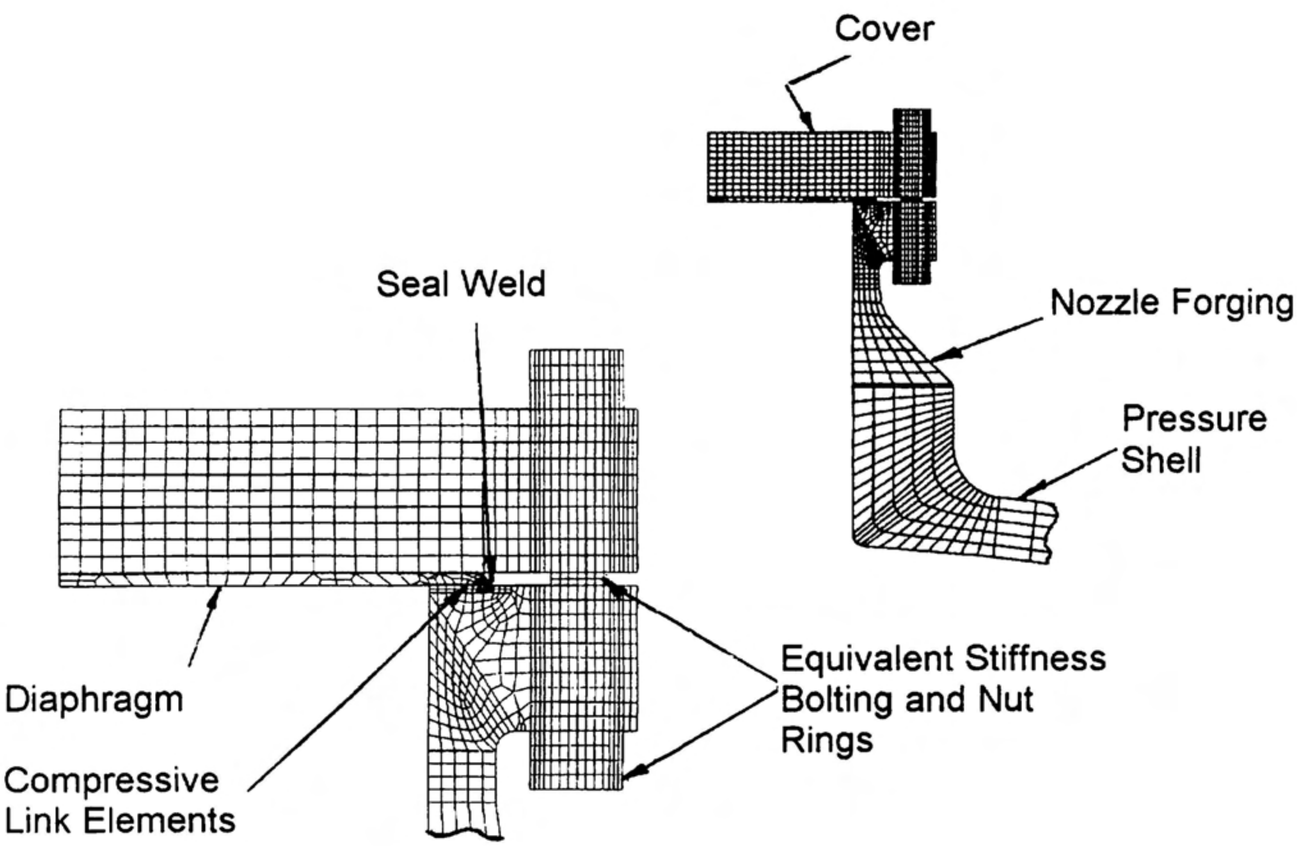

Figure 6 - Axisymmetric FE Model for Stress Range and Fatigue Analysis

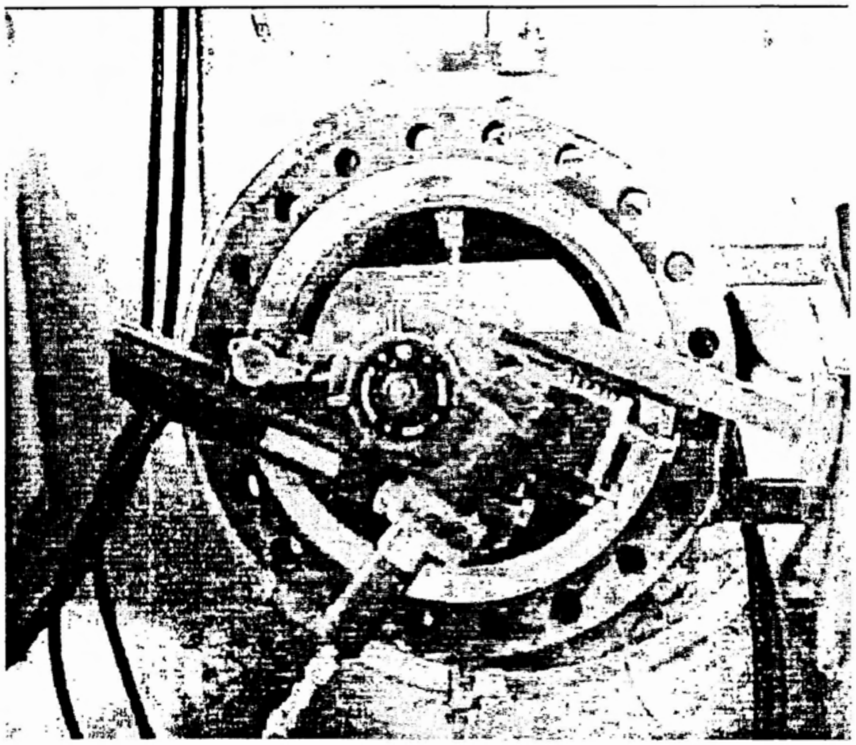

Figure 7 – Portable flange-facing machine mounted to the ID of the lower manway flange

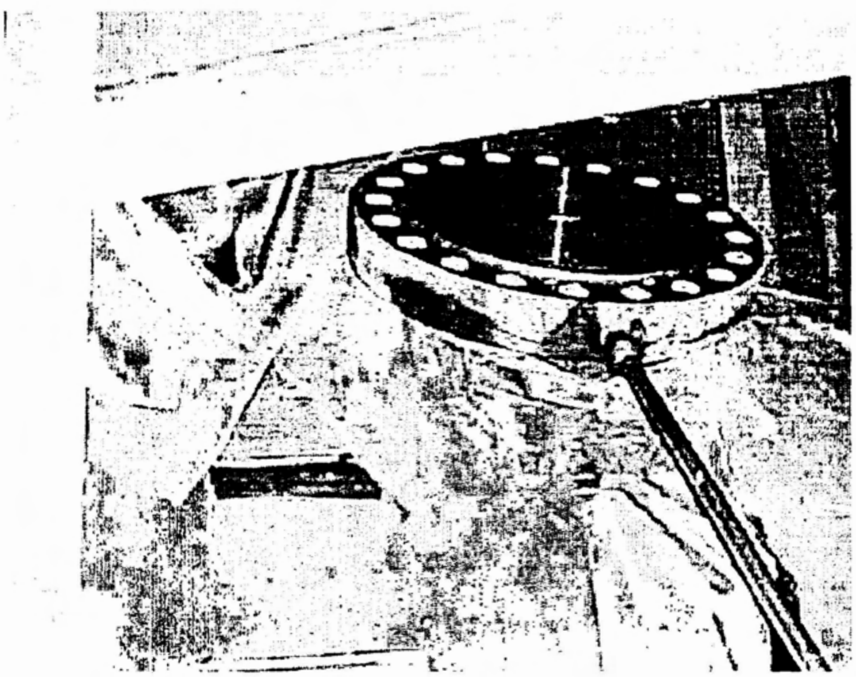

Figure 8 – Welded diaphragm on the upper inspection port after passing final NDE