PRESSURIZER MANWAY CLOSURE RE-ENGINEERING

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ABSTRACT

The primary heat transport system pressurizer vessels at Darlington NGS have required substantial maintenance of the gasketed joints. Two of these joints are the upper inspection port and the lower manway. In at least one instance there has been erosion damage to the carbon steel sealing faces from leakage of the high energy primary fluid. In the work described in the paper, each of the two closures was re-engineered to incorporate a seal welded diaphragm in place of the gasket. This approach for which patent protection is sought, required machining and weld build up of the nozzle gasket area to facilitate seal welding of a custom diaphragm plate. The closure covers were modified to support the diaphragm and were reinstalled using the original bolting arrangement.

The paper describes the re-engineering of these closures as well as the retrofit of the seal welded diaphragms in the field.

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INTRODUCTION

Darlington Generating Station Pressurizers are used as the primary control for pressure in the Primary Heat Transport System (PHTS). The 12 meter high vessels (one per unit) accommodate shrink and swell of the PHTS during normal operation by controlling the vessel water level. The Reactor Outlet Header pressure is maintained at the desired value by controlling the pressure of the vapour space in the pressurizer. This is achieved by heat addition via the heaters or by bleeding steam from the top of the vessel. The pressurizer heaters are also used to make up heat lost through the vessel walls. Internal spray nozzles are used to assist with cooling the vessel to perform maintenance.

Access to both the upper and lower portions of the pressurizer are via a 0.305m ID inspection port and a 0.457m manway respectively. Figure 1 shows the location of these two ports on the vessel. Figure 2 shows a typical double gasketed flange and cover, with a D_2O leakoff hole between the two annular gasket grooves. The leakoff allows for early detection and monitoring of a leak to a D_2O collection system while the outer gasket was designed to maintain the seal until such time that the inner gasket could be replaced during a normal outage.

The pressurizer vessels were designed and manufactured by Dominion Bridge Ltd.

STATEMENT OF THE PROBLEM

The gasketed joints of the lower manway and upper inspection port have required considerable maintenance over the past several years. Leakage to the D2O Collection system from the failure of inner gasket seals results in additional cost to upgrade the D2O to return it to the system. Larger leaks have resulted in minor erosion damage to the sealing faces, and in one instance a leak through both gaskets contributed to a forced outage.

A solution was required to reduce or eliminate the maintenance effort, the cost to upgrade the D2O resulting from leakage, and the risk of forced outages.

SOLUTIONS CONSIDERED

The first effort to address the leakage was to examine the existing joint geometry and the gasket material. As evident from past experience, increasing the bolt torque on the joint tended to result in greater leak rates from the inner gasket. By measuring 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 increased bolt force caused increased cover bowing so that the pressure on the inner gasket was relieved (see Figure 2.)

The gaskets already in use were deemed appropriate for this particular joint application.

Ontario Hydro (now Ontario Power Generation), reviewed solutions at Bruce GS "A" and "B" decided to implement the same solution i.e. seal weld a plate onto the openings.

Babcock and Wilcox was chosen by Ontario Hydro to design and install this solution on both the lower manway and upper inspection port. This solution involved modifications to the pressure boundary components with associated ASME code calculations and re-registration in Ontario with the Technical Standards and Safety Authority (TSSA).

THE WELDED DIAPHRAGM SOLUTION

Babcock and Wilcox Canada has designed and fabricated numerous diaphragmed inspection port and manway access ports, including some that have the capability to be gasketed after a diaphragm is initially opened. However, a retrofit diaphragm was a new challenge:

(a) The option to re-use the existing cover was desirable.
(b) Re-use of existing bolting was desirable.
(c) Avoidance of the typical 1100˚F minimum post weld heat treatment (PWHT) for P3 materials during installation, and an avoidance of any PWHT during possible re-installation of the diaphragm were desirable.
(d) The design must be readily and safely installable in the field with portable equipment.
(e) The diaphragm must be designed within the existing geometrical constraints and survive operation and transients without leaking.
(f) The design must satisfy jurisdictional requirements.
(g) The design and installation must be economically justifiable opposite the costs associated with the status quo.

All of the above were accomplished with the B&W designed diaphragm and flange modification.

Design Description

Figure 3 shows the geometry of the typical modification of a flange, with diaphragm and cover. Babcock and Wilcox have pursued a patent for this design. The ASME-code mandated 1100˚F minimum PWHT for welding to P3 material was avoided with the use of a temper bead repair. An Inconel weld buildup was applied to the modified gasket groove region of the flange. The diaphragm was subsequently seal welded to this weld buildup.

Subsequent re-installation of the diaphragm (if necessary) would not trigger any thermal treatment for the diaphragm weld because it is not code mandated for Inconel. The Inconel buildup is sized to contain all of the weld heat affected zone during a diaphragm re-installation.

The diaphragm is of thin, fatigue resistant Alloy 690 material, with spigots and divets for centering on flange and with the cover. The diaphragms are attached to the flange with a fillet TIG weld.

The cover was re-designed and re-analyzed for a reduced thickness (compared to the original), so as to be re-usable if desired, and also to maintain close to original bolt lengths. Bolting and manway covers have been re-used on two units where the modification has been done, while new covers were manufactured for the inspection port modifications.

Design Analysis

Section III of the ASME code was invoked to govern the design, analysis, installation and inspection of the modifications. The vessel flange was re-analyzed using an ANSYS 5.0 finite element (FE) model (see Figure 4) according to the ASME code. The strength of the Inconel itself was not credited in the re-analysis of the flange. Functions of pressure and temperature versus time were applied to the FE model to conservatively envelope all transients specified for the pressurizer. These, together with original an/or recalculated inputs (material properties, heat transfer coefficients) were used to complete the level A and B analysis according to ASME code. Separate reports and registrations were performed for the modified inspection port and modified manway. Flange, cover and bolting were all included in the analysis.

The diaphragm and its weld to the Inconel buildup replaced the previous gasketing, and thus were not included in the certified stress reports that demonstrated compliance with the ASME code. This is consistent with Babcock and Wilcox's approach for all diaphragmed port designs and has been accepted by various customers and jurisdictions across North America.

Various calculations for the diaphragm and its weld have been performed. Further analysis (including fatigue analysis) can be performed at any time, and in fact have been successfully performed for other similar B&W diaphragm designs.

Field Installation

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

(a) Cover(s) are manufactured or re-machined to the new design.

(b) Diaphragms are manufactured.
(c) During the scheduled plant shutdown, the pressurizers are opened and brought into a safe condition for hot work. The egress of hydrogen from the pressurizer walls during shutdown creates the need for special steps including purging and the use of bungs.
(d) A portable flange-facing machine is mounted to the ID of the flange to cut the recess from the existing double gasket grooves. All of the vessel flange face inside the bolt circle is machined slightly, to at least the depth of "steam cuts",if present.
(e) PT is performed on all machined surfaces.
(f) The flange is preheated to 350˚F.
(g) Inconel is laid into the recess in a temper-bead process. That is, each subsequent layer tempers the previous layer. Grinding of the crowns of weld layers prior to laying subsequent weld is part of this qualified process. The leak off hole is plugged during this step.
(h) Machining of the final layer is done to achieve a flat surface.
(i) PT is performed on the final surface.
(j) Diaphragm is welded on, followed by PT of the diaphragm weld.
(k) New or re-machined cover is installed.

RESULTS

Analysis was successfully completed for both the inspection port and manway flanges, demonstrating that all jurisdictional and ASME code requirements are met for the modifications. Registration for the modifications was also obtained.

Execution of the modification was also successfully performed in September 1998 (Unit 1 pressurizer inspection port) and in January 1999 (Unit 3 pressurizer inspection port and manway).

Modifications for the remaining ports on Units 1, 2 and 4 are planned.

CONCLUSIONS

The Darlington pressurizer upper inspection port and lower manway port have been successfully and safely modified. All applicable jurisdictional requirements were met and objectives for the re-use of components and ease of diaphragm re-installation, were met within the existing geometrical constraints.

Re-engineering and site modification of chronically leaky joints in CANDU plants is possible, safe, and economically feasible.

Figure 1: Darlington Pressurizer

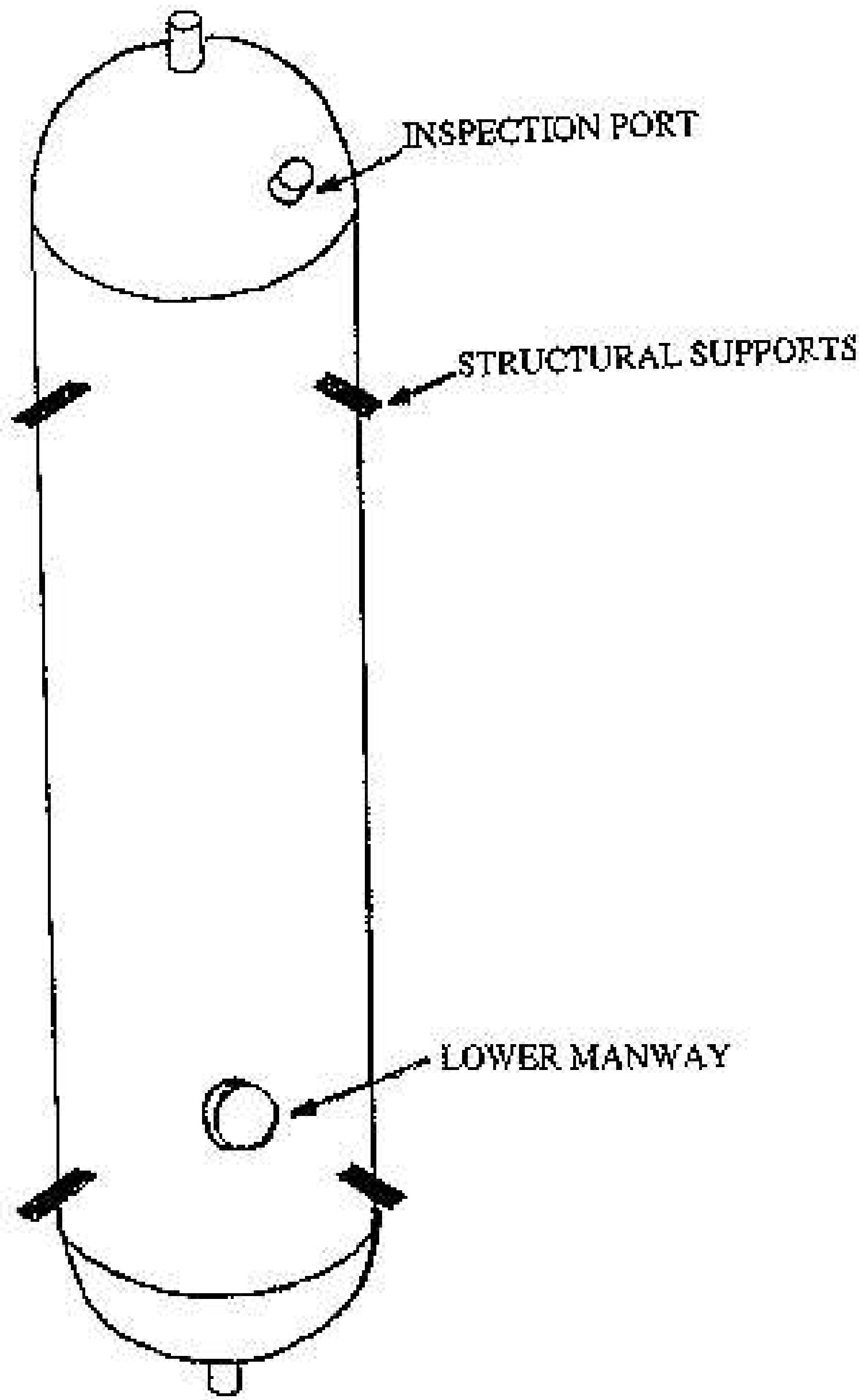

Figure 2: Darlington Pressurizer Manway and Inspection Port Original Double Gasketed Joint

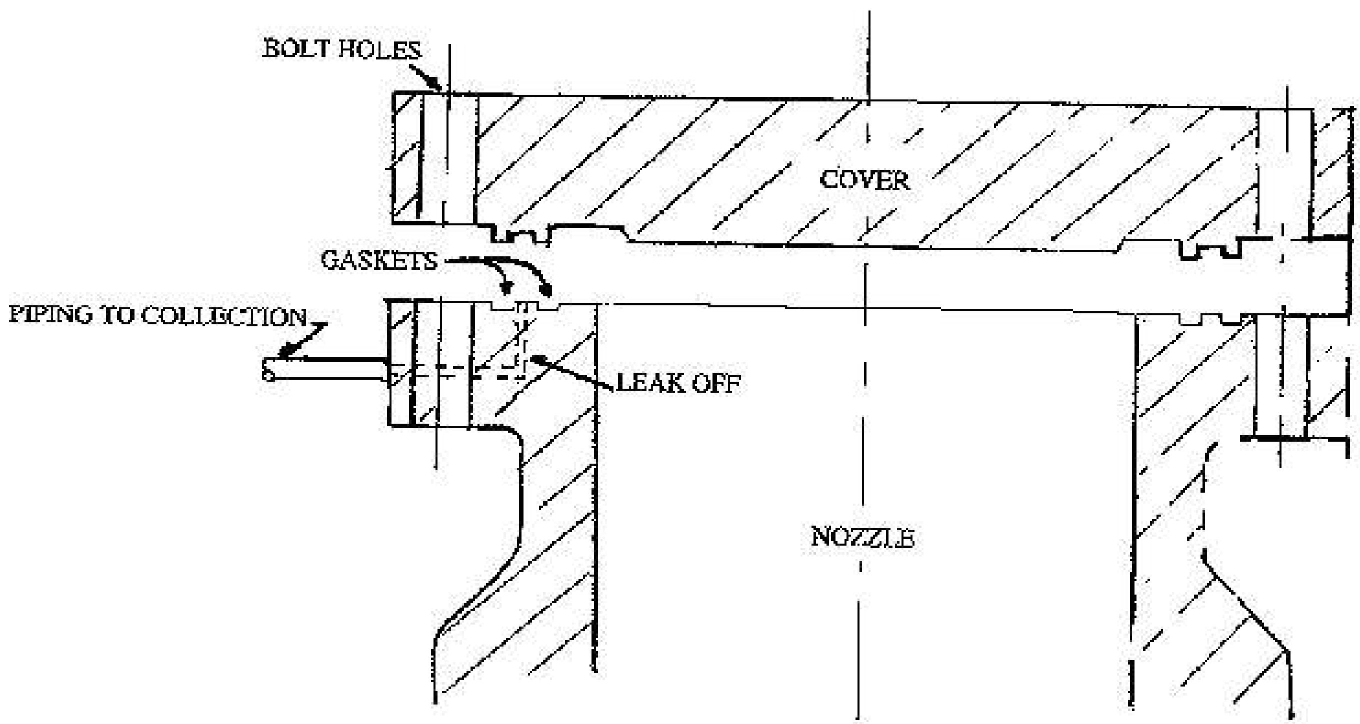

Figure 3: Modified Inspection Port Flange

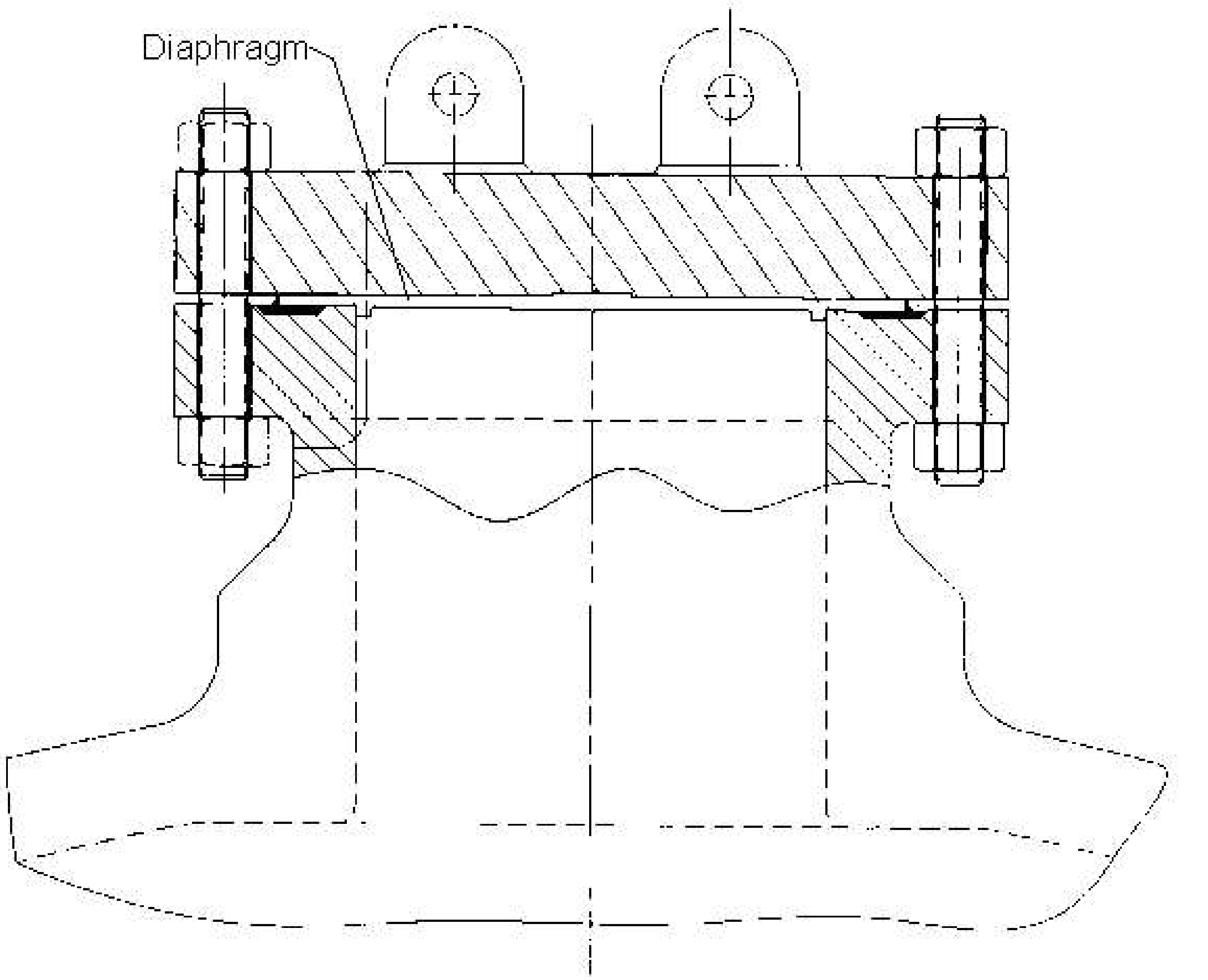

Figure 4: Finite Element Model of Manway Flange