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Membrane Windows with Get-Lost Tubes for Use at Small Scattering Angles in Neutron Spectrometers

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Introduction

Many types of spectrometers require an evacuated incident beam path before and after the scattering sample to reduce the background due to scattering from air or gas otherwise present. When in the same instrument, detectors are located outside of the flight path vacuum and therefore thin windows must be used to reduce transmission losses and window-scattered background. Windows of membrane design are most efficient in this application. When in addition detectors are at small scattering angles close to the scattered beam, it is necessary to provide an opening in the window. This provides an extension of the flight path vacuum to some point distant from the detectors where it is easy to shield against the scattering at the exit window. We have found that the alternative, a beam stop within the vacuum, cannot provide the needed shielding of the window and at the same time avoid the scattered neutron background that it itself produces.

Our design and installation of "get-lost" tubes integral to large area membrane windows preserves the thinness of the window, yet provides strength for a safe extension of the vacuum path to a remote exit window. We have designed a window of this type for the HRMECS spectrometer at IPNS and have installed one in the GLAD diffractometer, which we describe. The window with get-lost tube reduced the background in GLAD by better than a factor of two below that accomplishable with our best-effort internal beam stop. The window size is 24.5 inches (62.23 cm) square. Window edges are clamped with a frame bolted at 2-inch intervals and o-ring sealed.

Analysis

The key tools used in the design and evaluation were the linear and non-linear analysis features of the NASTRAN finite element analysis code. Initial non-linear calculations based on available stress strain curves provided the shape and resulting maximum and residual stress levels of the deformed window, which were designed to be formed hydrostatically from 6061-T4 aluminum alloy, 0.063 inches (1.60 mm) thick (Figure 1). A fatigue analysis then determined the initial amount of the cumulative fatigue damage. A subsequent elastic stress analysis of the welded assembly assumed a final structure tempered to T-6 hardness after fabrication (Figure 2). Several support options for the extension tube were evaluated to determine the optimal design criteria. The tube structure was designed to be thinner in the area of the weld to the window to increase compliance and reduce stresses in the weld joint. A final fatigue analysis of maximum stressed areas including stress concentration, surface, reliability and safety factors was then performed to determine the expected life of 50 years based on a conservative estimate of subsequent 500 normal loading cycles per year. An analysis of the welded joint based upon the loading conditions was then performed to confirm the resulting stresses determined by the finite element analysis.

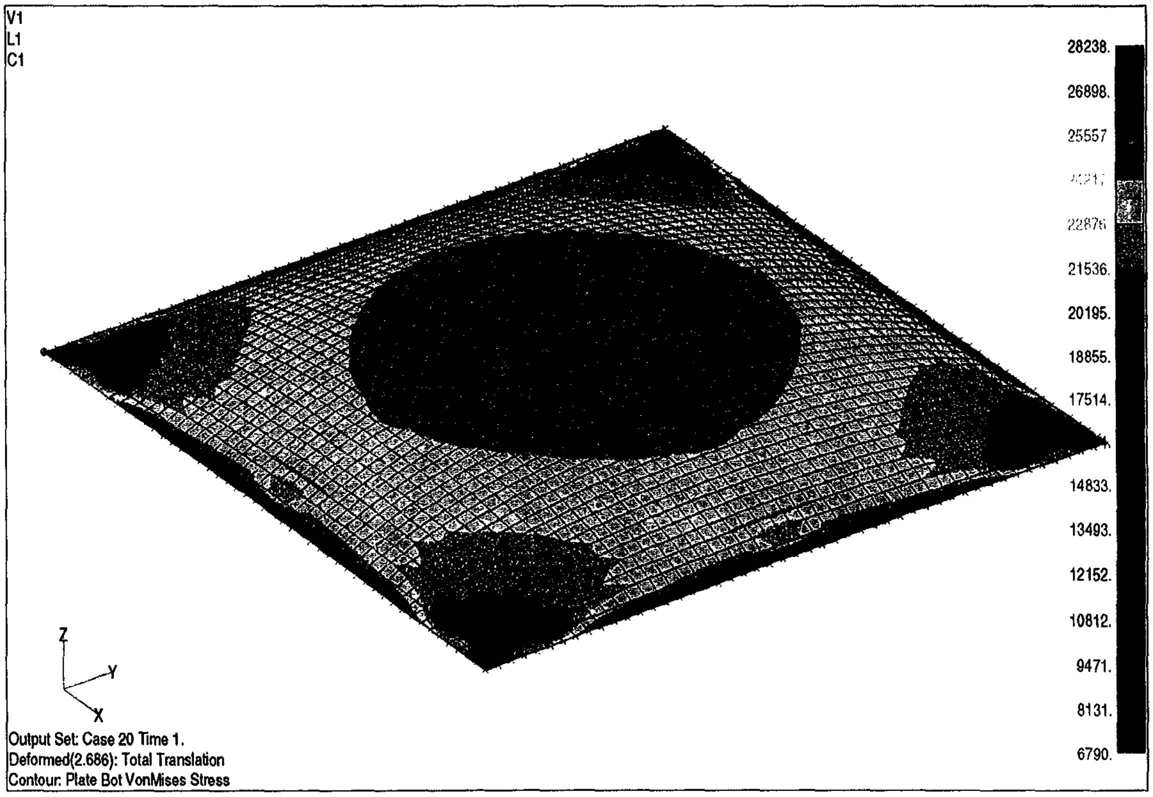

Figure 1 – Stress Distribution during hydrostatic plastic deformation forming process

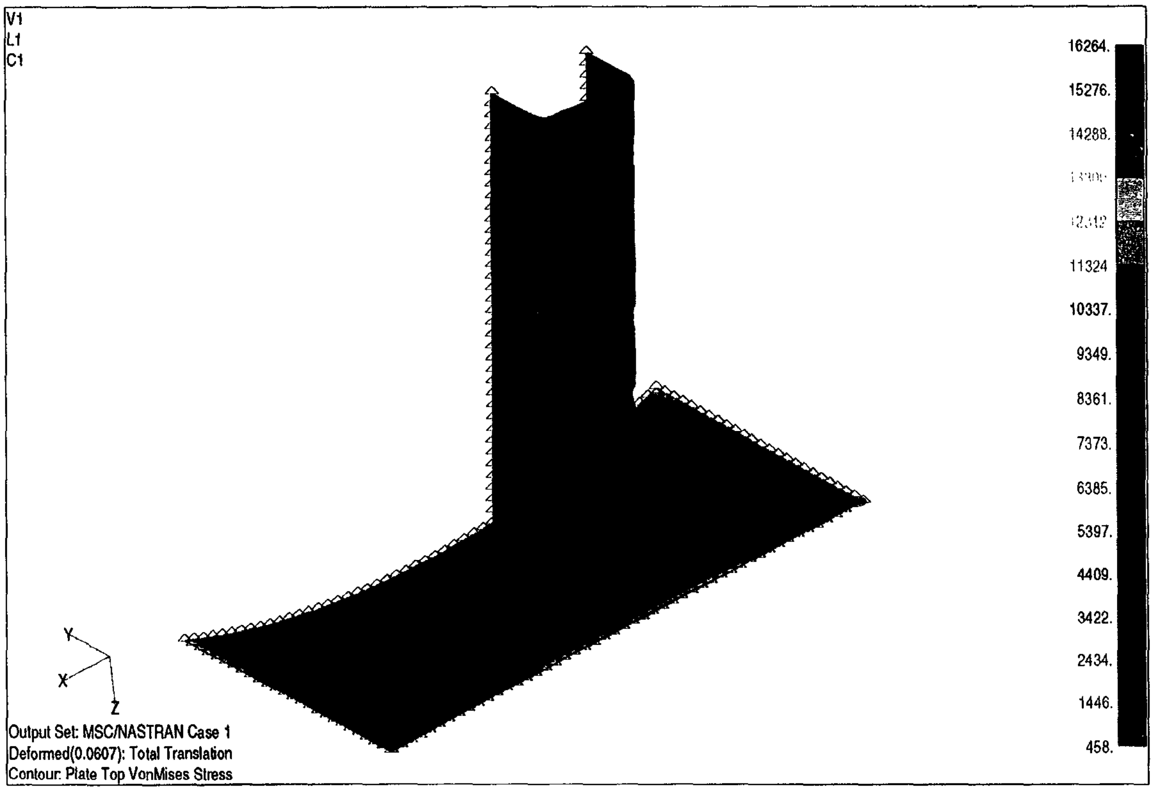

Figure 2 – Stress distribution of window during loading due to atmospheric pressure

Manufacture and Testing

The window structure consists of a rectangular welded tube section (the size of which is based upon the measured beam profile) shaped to match its intersection with the membrane, welded to the deformed membrane sheet after deformation, with supporting constraints which were found to reduce local stresses by substantial factors. Clamping forces from a heavy window frame support the membrane at the edges. Figure 3 shows the overall window/extension tube design. Modifications to the "membrane-forming fixture" were designed to test the welded assembly hydrostatically to 2 atmospheres of pressure after completion (Figure 4).

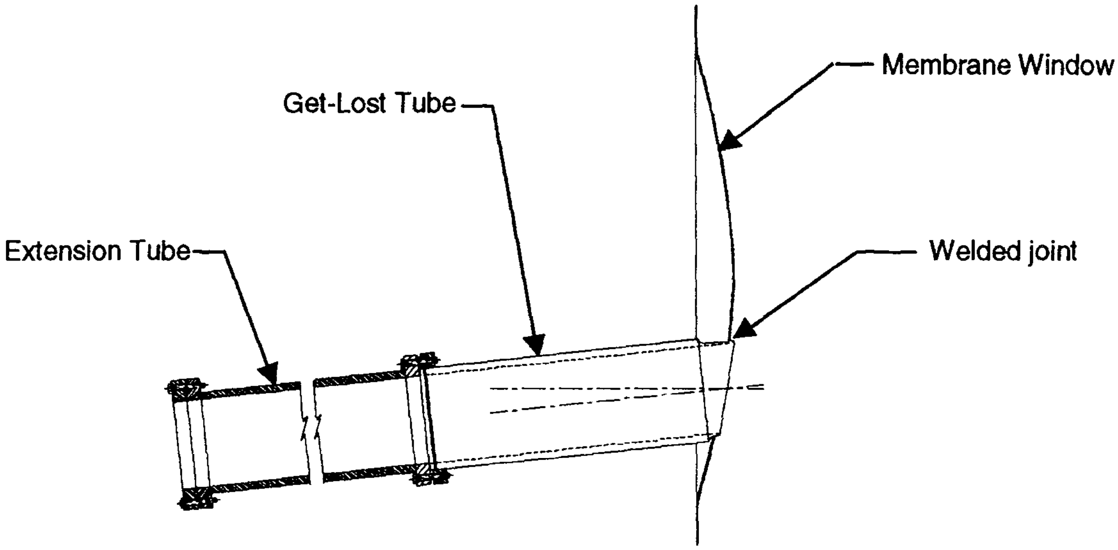

Figure 3 – Assembly of Get-Lost Tube to window (Instrument not shown for clarity)

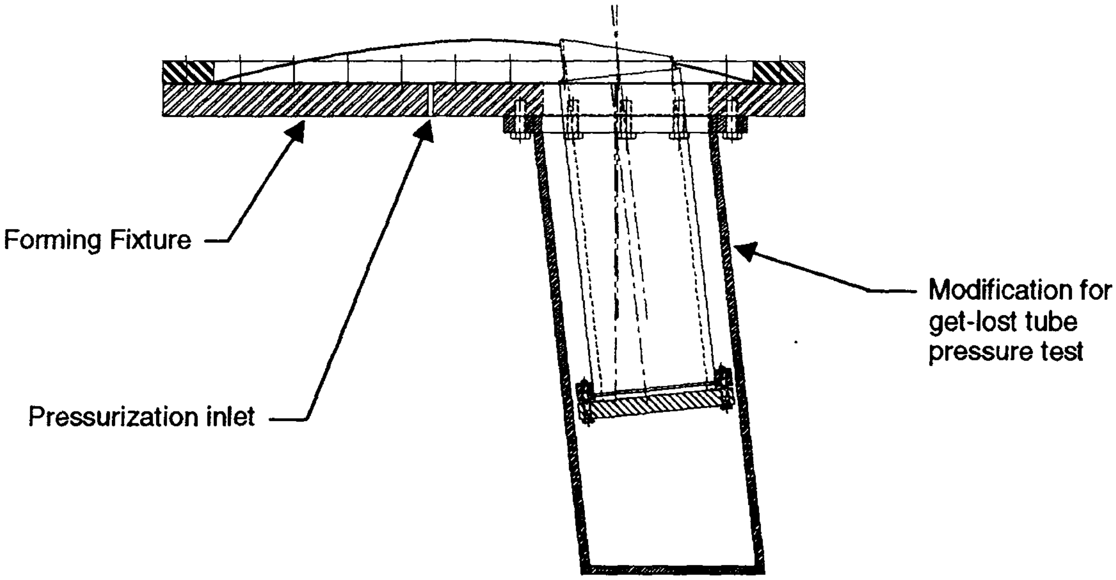

Figure 4 – Modification to membrane forming fixture for hydrostatic test

Detector Array Modifications

The supports for the vacuum flight path extension were designed into the detector array structure as shown in Figure 5. The detector array was modified to include horizontal as well as vertical linear position sensitive detectors that surround the vacuum extension tube. The calibration bars for the linear position sensitive detector array were modified using several gear driven mechanisms to provide calibration capabilities to both horizontal and vertical detectors.

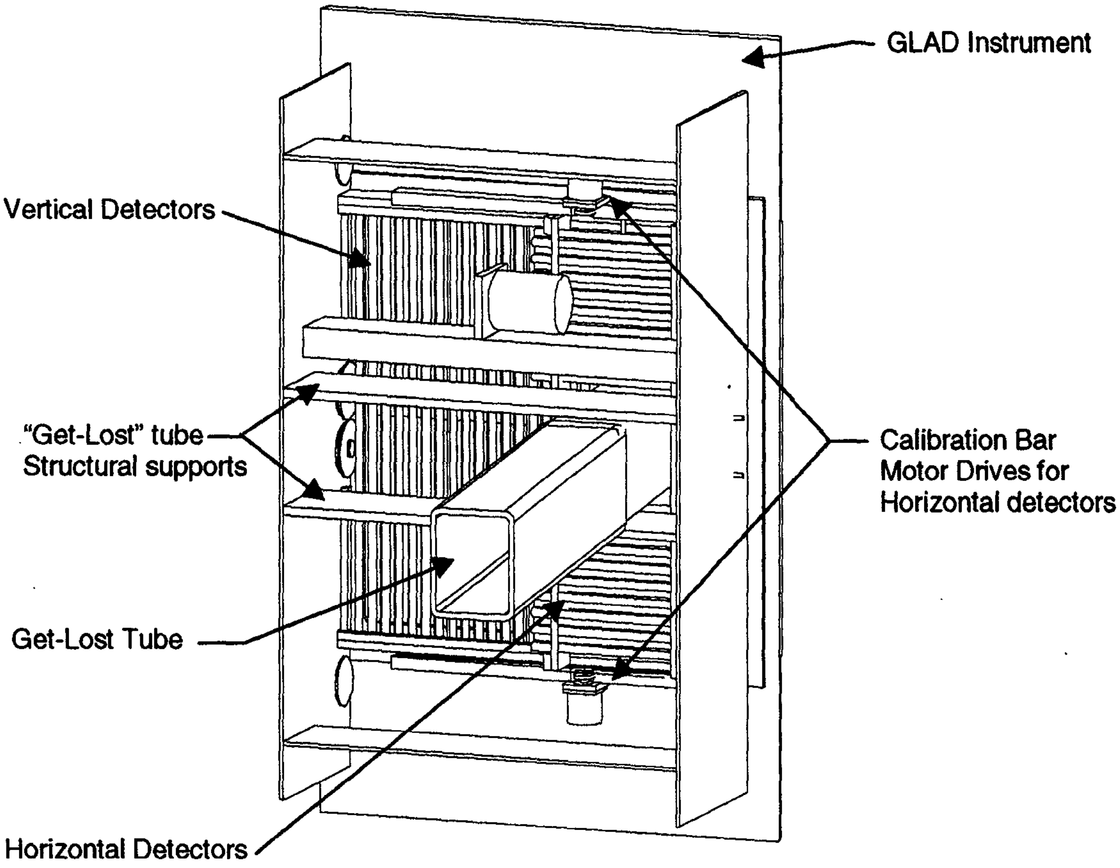

Figure 5 – Modified LPSD array (covers and electronics removed for clarity)

Conclusion

The GLAD window has been in place since August 1997 and the background is at least a factor of two lower than the level accomplished using the best internal beam stop arrangement.

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