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Guidelines for Strain Gaging of Pressure Vessels Subjected to External Pressure Loading in the PVHO-1 Standard

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GUIDELINES FOR STRAIN GAGING OF PRESSURE VESSELS SUBJECTED TO EXTERNAL PRESSURE LOADING IN THE PVHO-1 STANDARD

Lawrence J. Goland

Southwest Research Institute

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Two Park Avenue, New York, NY 10016-5990

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FOREWORD

Strain gaging of pressure vessels (also known as pressure hulls) subjected to the external hydrostatic test pressure loading serves to monitor the structural behavior and response of the pressure vessel under external pressure load conditions. Monitoring the gages during the hydrostatic test can allow the hydrostatic test to be halted prior to causing significant damage and/or collapse of the hull. Therefore the use of strain gaging is recommended to help observe any deviation from the predicted strains (stresses) vs. external pressure in order to avoid unexpected deformation of the hull and possible collapse during the hydrostatic test.

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ABSTRACT

This document provides information and guidance regarding the use of strain gaging of pressure hulls subjected to external hydrostatic test pressure loading. The document presents two examples of strain gaging a pressure vessel subjected to external pressure loading. The first example shows a basic strain gaging plan useful for validating strain and stress analyses, which requires a minimal number of strain gages located at general positions on the hull, and the second example shows a strain gage layout plan which is useful for not only validating strain and stress analyses, but also for monitoring the behavior of the hull during the hydrostatic test, which requires the most number of strain gages since gages are placed at both general locations and regions of concern due to hull as-built geometries that might initiate collapse. These two strain gaging examples are provided as illustrative examples only. These examples in no way establish actual strain gaging requirements per any code, design rules, or jurisdictional body. They do not establish required placement gage locations, gage types to be used, or number of gages. For each hull, the actual strain gaging plan implemented is a function of many factors, such as the chamber's configuration, number and size of openings, attachments, actual as-built geometry, weld details, and whether just validating an analysis and/or monitoring hull behavior to preclude collapse.

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1 PURPOSES OF STRAIN GAGING PRESSURE HULL

1.1 General

The strain gaging of pressure vessels (also known as pressure hulls) subjected to the external hydrostatic test pressure loading serves two purposes. First and foremost, the gaging is to monitor the structural behavior and response of the pressure vessel under external pressure load conditions. The resulting strains and stresses can then be compared to those obtained from the design analyses performed.

Secondly, proper strain gaging can indicate the onset of collapse of the pressure hull under the external hydrostatic pressure test. Theoretically, using the design rules of the latest ASME PVHO-1 "Safety Standard for Pressure Vessels for Human Occupancy," standard, the pressure hull will not collapse during the external hydrostatic pressure test and serves as the proof test. However, given an unknown circumstance such as an undetected out-of-tolerance fabrication issue, onset of the collapse of the pressure hull can be detected by monitoring the strain gages.

Deviation from the predicted strains (stresses) vs. external pressure is an indicator that the hull is behaving unexpectedly, deforming more than expected, and possibly be near collapse. Monitoring the gages during the hydrostatic test can allow the test to be halted prior to causing significant damage and/or collapse of the hull.

Two examples of strain gaging a pressure vessel subjected to external pressure loading are presented herein. The first example, presented in Section 5.0, shows a basic strain gaging plan useful for validating strain and stress analyses. This level of gaging requires a minimal number of strain gages located at general positions on the hull. The second example, presented in Section 6.0, shows a strain gage layout plan which is useful for not only validating strain and stress analyses, but also for monitoring the behavior of the hull during the hydrostatic test. This level of strain gaging requires the most number of strain gages since gages are placed at both general locations and regions of concern due to hull as-built geometries that might initiate collapse.

These two strain gaging examples are provided as illustrative examples only. These examples in no way establish actual strain gaging requirements per any code, design rules, or jurisdictional body. They do not establish required placement gage locations, gage types to be used, or number of gages. For each hull, the actual strain gaging plan implemented is a function of many factors, such as the chamber's configuration, number and size of openings, attachments, actual as-built geometry, weld details, and whether just validating an analysis and/or monitoring hull behavior to preclude collapse. Other factors not mentioned here might also dictate the placement of strain gages.

1.2 Monitoring For Behavior

The primary purpose of strain gaging a pressure hull subjected to external pressure loading is to monitor its structural behavior under load. Monitoring the behavior consists of measuring the resulting strains, and then typically calculating the corresponding stresses. Traditionally, the desired type of strains and stresses are the maximum and minimum principal strains and stresses. Given these principal stresses, the von Mises stress (also known as the equivalent stress) and stress intensity can then calculated if desired. Given these strains and stresses, they then can be compared to the predicted strains and stresses calculated by classical formulations and/or finite element analysis, thereby validating the analyses performed. The key to obtaining the correct principal strains at a particular location is knowing the principal strain directions on the structure at the location in question. Whether or not these principal strain directions are known is a deciding factor in choosing the proper type of strain gage or strain gage rosette to use. (A strain gage rosette consists of two or