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Welding Research Council

bulletin

FABRICATION AND REPAIR OF LOW ALLOY STEEL PRESSURE EQUIPMENT

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These Bulletins contain final Reports from projects sponsored by the Welding Research Council, important papers presented before engineering societies and other reports of current interest.

WELDING RESEARCH COUNCIL, INC.
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WRC - The Welding Research Council brings together science and engineering specialists in developing the solutions to problems in welding and pressure vessel technology. They exchange knowledge, share perspectives, and execute R and D activities. As needed, the Council organizes and manages cooperative programs.

MPC – A Council of the WRC, the Materials Properties Council is dedicated to providing industry with the best technology and the best data that can be obtained on the properties of materials to help meet today's most advanced concepts in design and service, life assessment, fitness-for-service, and reliability and safety.

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Martin Prager, Editor

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FOREWORD

In recent years there has been increasing need to acquire technology for the safe handling of hydrogen for petroleum and other energy related applications. The pace of research into metal/hydrogen interactions accelerated at the start of the space age due to the hydrogen's efficiency per unit weight as a rocket fuel. Practical applications called for hydrogen to be transported and used at high pressures thereby increasing its hazard potential. Exotic and expensive alloys could be used to put astronauts into space because cost was of little concern where safety was an issue. For most conventional applications steel is still the practical choice.

It has been long recognized that at ordinary and elevated temperatures hydrogen can be destructive to steels, not just to high-strength steels, but also to steels of ordinary strength levels. Hydrogen's capability to enter and then diffuse through the metallic lattice, accelerated by stress gradients and seeking out points of weakness where it can concentrate or react, renders it capable of destroying pressure retaining metals from the inside where damage defies detection and until it is too late and the pressure containment has failed or is no longer safe.

Considerable research aimed at understanding hydrogen-steel interactions has been conducted over the last half century. An important objective has been to permit the reliable use of steels of higher strength levels in aggressive hydrogen environments. Tied to this objective is the necessity of fabricating the higher strength steels without cold cracking due to hydrogen introduced during welding. The problems and solutions are complex because of the diverse microstructures and compositions that have been developed to achieve the performance goals set for steels.

This Welding Research Council (WRC) Bulletin is part of a series that captures the essential studies of the interaction of steel-hydrogen interactions in recent years. Topics include *Modern Vanadium Steels for High Temperature Petroleum Reactors (# 524), Fabrication and Repair of Low Alloy Steel Pressure Equipment (# 525), Performance of Steels in Hydrogen Charging Environments (# 526), Practical Aspects of Hydrogen Attack (# 527), Test Methods for Hydrogen Induced Cracking (# 530), Metallurgical Studies of Steels for Sour Service Environments (# 532), Studies of Cladding and Overlay for Pressure Vessel Service (# 534), and Toughness, Fracture and Fitness for Hydrogen Service (# 535).*

The papers included have been presented at international conferences sponsored by WRC's sister organization the Materials Properties Council Inc. (MPC). The technology reported in this series provides a comprehensive view of practical solutions to engineering problems and advances in the knowledge about hydrogen and steel interactions.

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HYDROGEN IN HEAVY WALL SAW-JOINTS OF 2¼Cr-1Mo STEEL AFTER DIFFERENT DEHYDROGENATION HEAT TREATMENTS

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1. Introduction

For many years, heavy wall pressure vessels of 2 ¼ Cr - 1 Mo steel have been used in the petroleum industry, and in ammonia or coal liquefaction plants. The specific advantages of this low alloy steel are:

- good resistance against high pressure hydrogen attack
- high tensile and creep properties at operating temperatures
- excellent toughness
- good weldability.

There are only a few other steels that have been so extensively investigated as this CrMo material. Steel making practice, chemical composition including trace elements, quenching and tempering parameters have been optimized during the last three decades in order to produce plates and forgings in wall thicknesses up to approximately 350 mm with low susceptibility to hydrogen embrittlement and long time operating temper embrittlement [Ref. 1, 2].

The preferred welding technique for the manufacture of heavy wall pressure vessels is the narrow gap submerged arc welding (SAW) process; shielded metal arc welding (SMAW) is used to string roots or for small nozzles and attachments. To prevent cold cracking the weld joint is not allowed to cool down to ambient temperature after completing the weld without sufficient outgassing of hydrogen. Therefore, before cooling down an intermediate heat treatment is normally done at temperatures not far above the interpass temperature.

While the temperature range and holding time for stress relieving or annealing is specified in material codes and customer specifications there are no common regulations for the soaking treatment - a name, very often used for the dehydrogenation heat treatment at elevated temperatures. Typically the temperature of soaking treatment ranges from 250 to 350°C, depending on fabricator or customer specification, usually for 1 to 4 hours [Ref. 1, 3, 4].

Some specifications require expensive intermediate PWHT at 620°C immediately after welding instead of soaking which must often be done in place.