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Welding Research Council bulletin

THE EFFECT OF POST WELD HEAT TREATMENT AND NOTCH TOUGHNESS ON WELDED JOINTS AND ON NORMALIZED BASE-METAL PROPERTIES OF A516 STEEL

Part 1: The Effect of PWHT on Normalized Base-metal Properties of ASTM A516 Steel

Ken Orie
Charles R. Roper

Part 2: The Effect of Post-Weld Heat Treatment on Notch Toughness of Welded Joints in C-Mn Steels

Elmar Upitis

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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.

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Part 1
The Effect of PWHT on Normalized Base-Metal Properties of ASTM A516 Steel

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Abstract

This report details the investigations conducted by Bethlehem-Lukens Plate into the behavior of ASTM A516 Grade 70 steel plate subjected to post-weld heat treatment (PWHT). The results and conclusions described herein have been offered to the Pressure Vessel Research Council (PVRC) and specifically the Committee on Thermal and Mechanical Effects on Materials (TME) to complement the studies it has commissioned. Those studies, conducted under PVRC Project No. 98-TME-01, were initiated to characterize the effects of PWHT on hardness and notch toughness of welded joints. Inherent in the scope of these efforts was some work on the behavior of the base metal. However, the reports generated from those studies included little definitive discussion on the effects of PWHT on base metal properties. They further suggested that the amount of scatter in the limited amount of data made it difficult to establish trends, especially pertaining to any parametric analysis such as correlation with Larson-Miller Parameter (LMP).[1]

The results of earlier internal work by Lukens Steel demonstrated a well-defined correlation between base metal strength, toughness and time-temperature relationships.[2] Recently, additional investigations have been continued by Bethlehem-Lukens Plate in an attempt to improve normalized base metal toughness and improve internal guidelines for predicting properties of post-weld heat-treated material conforming to A516 Grade 70. These new data reinforce previous conclusions that PWHT has a detrimental and predictable effect on base metal properties that needs to be considered when evaluating the application of PWHT.

1.0 Introduction

Normalized ASTM A516/SA516 Grade 70 carbon steel is the most extensively used material for pressure vessels in the process vessel market. While post-weld heat-treatment (PWHT) is not required for all vessels or all conditions of use, ASME Boiler and Pressure Vessel Rules are such that many vessels constructed of carbon steel are for applications requiring PWHT. Following fabrication by welding, PWHT relieves internal stresses and provides lower hardnesses for weld deposits and heat-affected zones (HAZ). Improvements in HAZ toughness are also cited as a reason for PWHT. Customarily, the PWHT requirement for this grade is 1100°F minimum and typically 1125°F +/− 25°F for 1 hr./in. of wall thickness.

In recent years, fabricators have had to meet more stringent microhardness levels in the weld HAZ. These lower hardness requirements are especially prevalent in the case of vessels in "sour service" or are otherwise exposed to hydrogen in the aqueous phase. In those cases, there is concern over environmentally assisted cracking that can be exacerbated by a hard HAZ. Such guideline documents as NACE Standard MR0175[3] and NACE Recommended Practice RP0472[4] call for 22 Rc and 248 Hv respectively in weld and HAZ's. As a result, the trend has been to higher PWHT temperatures and longer hold times to achieve lower HAZ hardness. In addition to hardness issues, end-users often require that an "extra" PWHT cycle be held back for possible use in the field. This adds yet more time to the accumulated total for the conventionally required PWHT cycle. Today, requirements for 1175°F for up to 8 hours are not uncommon. Similar situations arise when P-1 materials are welded to, or must be PWHT'd with, P-3 or

*ISG Plate, Coatsville.

[1] Upitis, Elmar, The Effect of PWHT on Hardness and Notch Toughness of Welded Joints, PVRC Project No. 98-TME-01, Committee on Thermal and Mechanical Effects on Materials, January 2000.

[2] Bethlehem-Lukens Plate brochure. Retrieved 2002, from ***http://www.bethsteel.com/customers/tech_plate.shtml***

[3] NACE Standard MR0175 (latest revision), "Sulfide Stress Cracking Resistant Metallic Materials for Oilfield Equipment" (Houston, TX: NACE International).

[4] NACE Recommended Practice RP0472 (latest revision), "Methods and Controls to Prevent In-Service Environmental Cracking of Carbon Steel Weldments in Corrosive Petroleum Refining Environments" (Houston, TX: NACE International).