Welding to AS/NZS 1554.1 of Boron Containing Steel

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Date: *2nd May 2016*
Ref.: *WEL1003*

Key Words
Structural steel, boron, welding, AS/NZS 1554

Introduction

Recent reports indicate that some imported steel may show elevated levels of boron; traditionally steel in Australia and New Zealand has been made without boron additions. The welding requirements of AS/NZS 1554 have been established without considering the effect of boron as an alloying element. This article discusses steps that should be undertaken by the fabricator to ensure the integrity of the steel fabrication work when welding structural steel with elevated boron levels.

Description of Boron

Boron is a metalloid chemical element with symbol B and atomic number 5. Boron does not occur in the elementary state, but always combined with oxygen. It is available in the form of boron-containing oxides such as Borax, Boracite, etc.

Boron is added as an alloying element to many materials such as structural steel, quenched and tempered, high-speed-cutting steels and high strength low alloy (HSLA). Typical quantities which have to be added in the steel to achieve desired effects range between 0.0003 to 0.005% B.

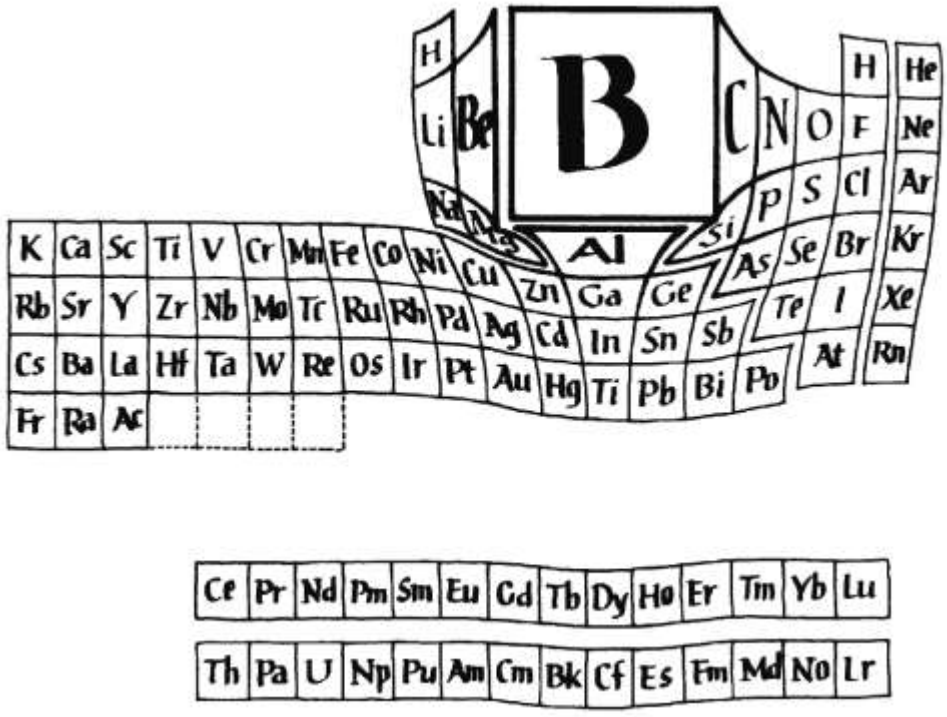

Figure 1: Bill's Periodic Table: Illustrated by Jean C. Evans

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While some steel standards leave boron alloying aspects to the discretion of the manufacturer or to agreement between the purchasers, standards such as AS 3597, EN 10025-6, etc. introduce a compositional limit for boron.

Only minor percentages of boron may be necessary to greatly increase the hardenability of steels. The boron content has also been found to significantly influence microstructure, notch sensitivity and impact properties of welded carbon steel.

Boron is supplied to steelmakers as ferroboron or as one of several proprietary alloys. Choice of addition depends on steelmaking practice. Historically, boron has not been intentionally added to structural steel manufactured in New Zealand or Australia to AS or AS/NZS standards. However some overseas steelmakers have added boron to structural steel (Bloomberg News, 2015) to take advantage of export subsidies or for other reasons, including improved impact energy.

Although the mechanical properties of the boron alloyed steels can be expected to comply with the steel standard e.g. AS/NZS 1163, this standard does not address weldability issues related to boron.

Treatment of Boron in Structural Steel Manufacturing Standards
Prior to the publishing of the 2016 revisions, the suite of AS/NZS structural steel manufacturing standards did not address the issue of the intentional adding of boron. The latest revisions address this issue in the following manner:

AS/NZS 3679.1 and AS/NZS 3678

- Boron shall not be intentionally added to the steel without the agreement of the purchaser
- The chemical composition of boron must be reported on test and inspection reports
- No limit on the boron content is given.

AS/NZS 1163

- The chemical composition of boron must be reported on the test and inspection certificates
- No limit on boron content is given.

Standards related aspects
The problem associated with welding of boron containing steel is that the weldability concept of AS/NZS 1554 Part 1 and Part 5 is based on carbon equivalent (CE), which does not include effects of boron. There are a variety of formulas available addressing effects of boron on weldability of steels e.g. Pcm, CEN, CEw etc. The preheat temperature may be estimated using Method B, Appendix C of BS EN 1011-2. The method covers non-alloyed, fine grained and low alloy steels with boron content of 0.005% max.

The current argument is, however, that these methodologies have not been specifically evaluated for welding of Australian and Australian New Zealand structural steels welded to AS/NZS 1554.

Due to insufficient test data regarding an upper limit of boron that can be considered as safe for steel pipe, tube and plate products manufactured to Australian and New Zealand standards, Standards Australia Welding Committee WD-003 has recommended to limit it at 0.0008% in alignment with the steel classification standards ISO 4948-1 (Steels – Classification – Part 1: Classification of steels into unalloyed and alloy steels based on chemical composition) and EN 10020 (Definition and classification of grades of steel).

For procedural reasons, Standards Australia have removed boron-related provisions in AS/NZS 1554 Parts 1, 5 and 7 via a correction amendment published in September 2015. Specifically, this involves Clauses 2.1, 4.7.7.2 (for Parts 1 and 5 only) and 5.3.1 relating to the use of steel with boron content equal to or greater than 0.0008% by weight (eight parts per million).

The situation has changed again with the publication of the Technical Specification SA TS 102 *Structural steels—Limits on residual elements and Structural steel* and SA TS 103 *Structural steel*

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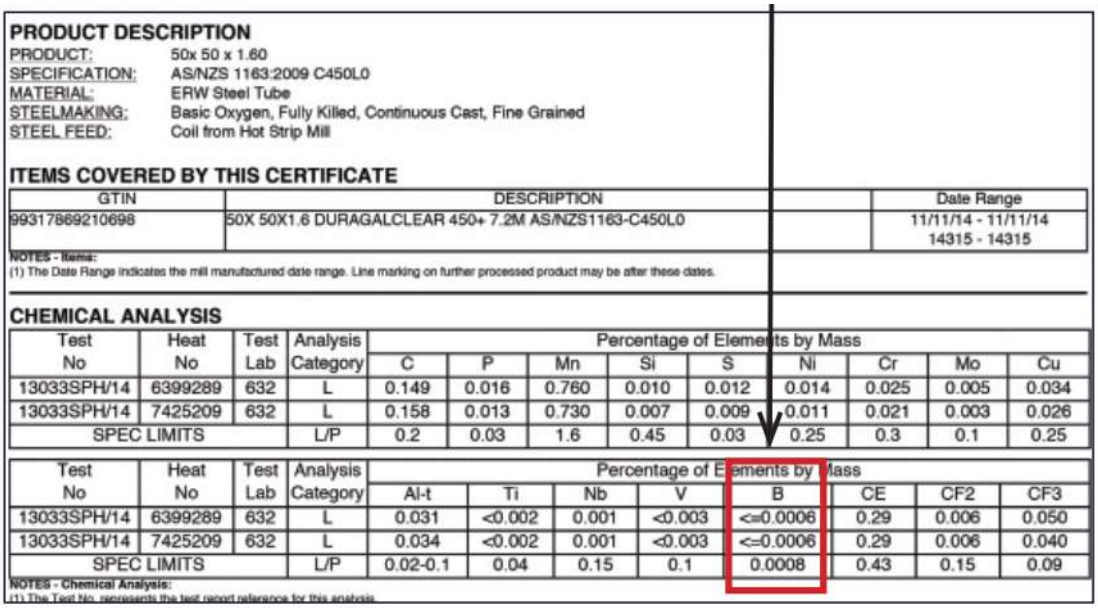
welding – Limits on boron in parent materials. Both documents have been published as Standards Australia documents in early 2016. They have not been adopted by Standards New Zealand and therefore have informative status only.

TS 102 sets maximum limits for residual elements to ensure products manufactured to these Standards are prequalified for welding to AS/NZS1554 Parts 1, 5 and 7. It does not allow for boron to be intentionally added to steel and limits the amount of residual boron to the level mentioned above.



PRODUCT DESCRIPTION

PRODUCT: 50x 50 x 1.60
SPECIFICATION: AS/NZS 1163:2009 C450L0
MATERIAL: ERW Steel Tube
STEELMAKING: Basic Oxygen, Fully Killed, Continuous Cast, Fine Grained
STEEL FEED: Coil from Hot Strip Mill

ITEMS COVERED BY THIS CERTIFICATE

GTIN	DESCRIPTION	Date Range
99317869210698	50X 50X1.6 DURAGALCLEAR 450+ 7.2M AS/NZS1163-C450L0	11/11/14 - 11/11/14 14315 - 14315

NOTES - Items:
(1) The Date Range indicates the mill manufactured date range. Line marking on further processed product may be after these dates.

CHEMICAL ANALYSIS

Test No	Heat No	Test Lab	Analysis Category	Percentage of Elements by Mass								
				C	P	Mn	Si	S	Ni	Cr	Mo	Cu
13033SPH/14	6399289	632	L	0.149	0.016	0.760	0.010	0.012	0.014	0.025	0.005	0.034
13033SPH/14	7425209	632	L	0.158	0.013	0.730	0.007	0.009	0.011	0.021	0.003	0.026
SPEC LIMITS			L/P	0.2	0.03	1.6	0.45	0.03	0.25	0.3	0.1	0.25

Test No	Heat No	Test Lab	Analysis Category	Percentage of Elements by Mass							
				Al-t	Ti	Nb	V	B	CE	CF2	CF3
13033SPH/14	6399289	632	L	0.031	<0.002	0.001	<0.003	<=0.0006	0.29	0.006	0.050
13033SPH/14	7425209	632	L	0.034	<0.002	0.001	<0.003	<=0.0006	0.29	0.006	0.040
SPEC LIMITS			L/P	0.02-0.1	0.04	0.15	0.1	0.0008	0.43	0.15	0.09

NOTES - Chemical Analysis:
(1) The Test No. represents the test report reference for this analysis

Figure 2: Example of a Mill Certificate including Boron (www.Onesteelmetalcentre.com , 2015)

Welding of Boron Containing Steels

TS 103 defines requirements for welding procedure qualification tests for steel containing boron. Parent material containing total boron equal to or exceeding 0.0008% should be treated as non-prequalified. When qualifying these steels, weld heat affected zone (HAZ) Charpy testing shall be performed in lieu of the parent plate Charpy test (only applicable to Part 1 and 5).

Qualification test will involve welding of a butt-weld test piece following a welding procedure including preheat requirements that will be used on the job.

The test should be carried out on three test pieces taken out of the welded joint. The notch of the Charpy test specimen should be placed in the heat affected zone (HAZ) adjacent to the fusion line of the weld. Position of the notch relative to the fusion line should be verified by light polishing and etching of the face of the specimen before testing. The test should be performed in accordance with the testing requirements of the applicable materials standard and AS 2205.3.1. The test temperature and minimum absorbed energy acceptance criteria are given in the materials standard as a function of the steel grade.

Additional qualification tests involve macro, tensile and bend as per Table 4.7.1, AS/NZS 1554 part 1 or part 5 following the route of not prequalified consumables and materials.

If in doubt, advice should be sought from the parent material manufacturer regarding welding and preheating requirements.

Compliance with Limits for Boron

Compliance to the limit on boron shall be demonstrated by either of the following:

(a) Reporting boron levels on test reports (mill certificates) compliant with the Australian Standard/New Zealand for that parent material.

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(b) Tests results of the boron levels performed by an accredited laboratory.

Although the use of Technical Specifications above is optional, following engineering best practice fabricators should require their steel supplier to declare the boron content of the material.

Some of the steel suppliers have already announced changes to their test certificates by adding Boron to the list. If the boron exceeds the limits described above, additional butt weld testing should be considered by the fabricator.

Measurement of Boron in Delivered Steel

Quantitative analysis of boron content in the delivered steel in the workshop situation is not straightforward as boron is a light element with low energy peaks. The detection limits and measurement uncertainties of readily available analysis techniques such as X-ray fluorescence spectrometry (XRF) also known as "handheld analyser" and Optical Emission Spectroscopy (OES) may not be adequate in dealing with the lower levels of boron as mentioned above. Reliable results can be obtained by using Atomic Emission Spectroscopy (ICP) or energy dispersive X-ray spectroscopy (EDX) in the scanning electron microscope (SEM), which is typically available at universities and some advanced labs.

Summary

The addition of a relatively small amount of boron to steels may result in an increase in the hardenability and this is a consideration for welding. The fabricator should advise their steel supplier to declare the boron content. Additional butt weld testing to verify properties of the heat affected zone is required to qualify welding procedures for steel containing total boron equal to or exceeding 0.0008%.

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