Carpenter Technology Corporation



ENGINEERED FOR A CHANGING WORLD

Micro-Melt® DuoSorb™ and NeutroSorb® Alloys

L W Lherbier
Director – Technical Market Development

NRC Neutron Absorbing Materials Meeting
March 14, 2013
Rockville, MD

Disclaimer

Applications suggested for material described herein are made solely for the purpose of illustration to enable the reader to make his/her own evaluation and are not intended as warranties, either express or implied, of fitness for these or other purposes.

Alloy performance data presented are typical or average values and are not a guarantee of maximum or minimum values.

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Agenda:

- Why Use Borated Stainless Steel?
- Why Use Powder Metallurgy(PM) Technology?
- NeutroSorb Stainless Steel Alloys & Products
  - Processing Steps
  - Mechanical Properties
  - Microstructure
  - Inspection
- DuoSorb Stainless Steel Alloys & Products (Patent Pending)
  - Objectives
  - Concept
  - Boron Equivalency
  - Mechanical Properties
  - Microstructure
  - Thermal Neutron Transmission Test
- Summary of TNTR Testing

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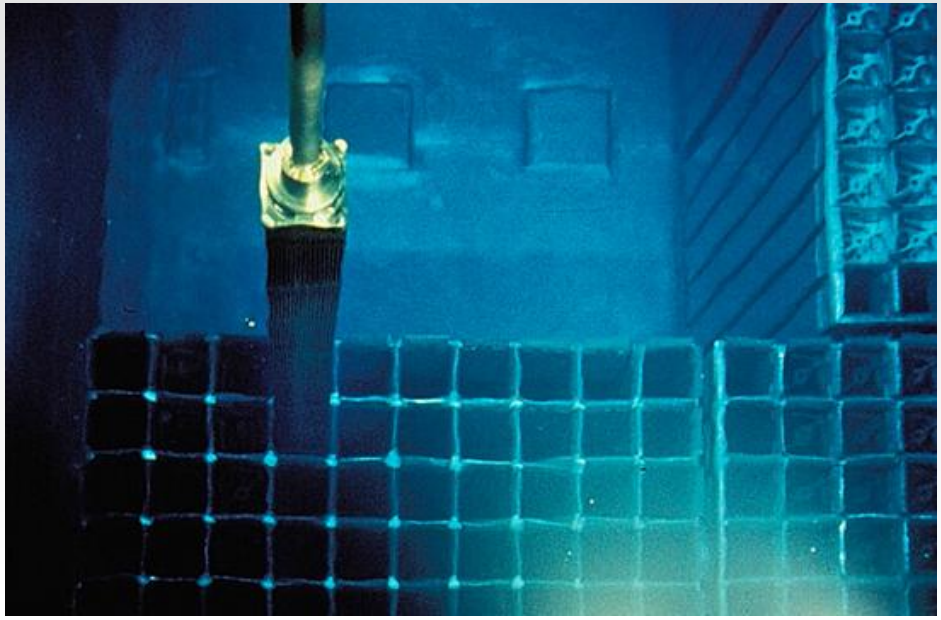
Why Use Borated Stainless Steel?

- Thermal Neutron Absorption with B-10 Isotope
- Corrosion Resistance
- Workability / Formability
- Structural Stability
- Historical Use for Nuclear Spent Fuel Racks



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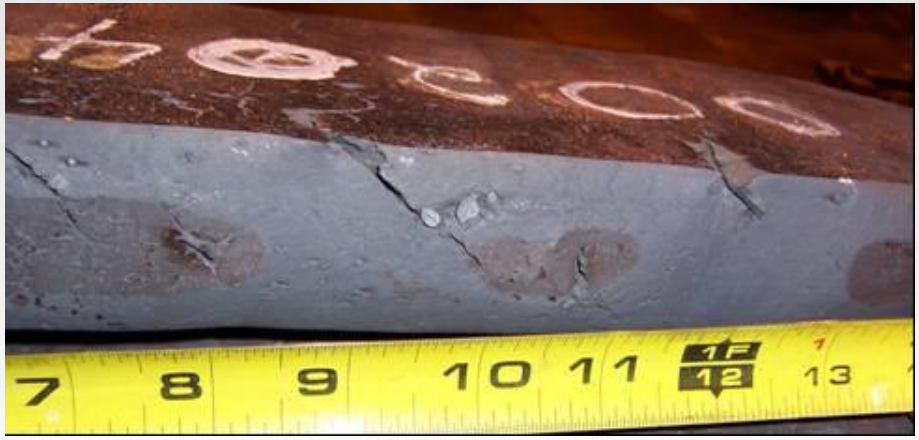
Why use Powder Metallurgy Technology?



Cast and Wrought Trials

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Hot Rolled Slabs

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Hot Rolling Coil

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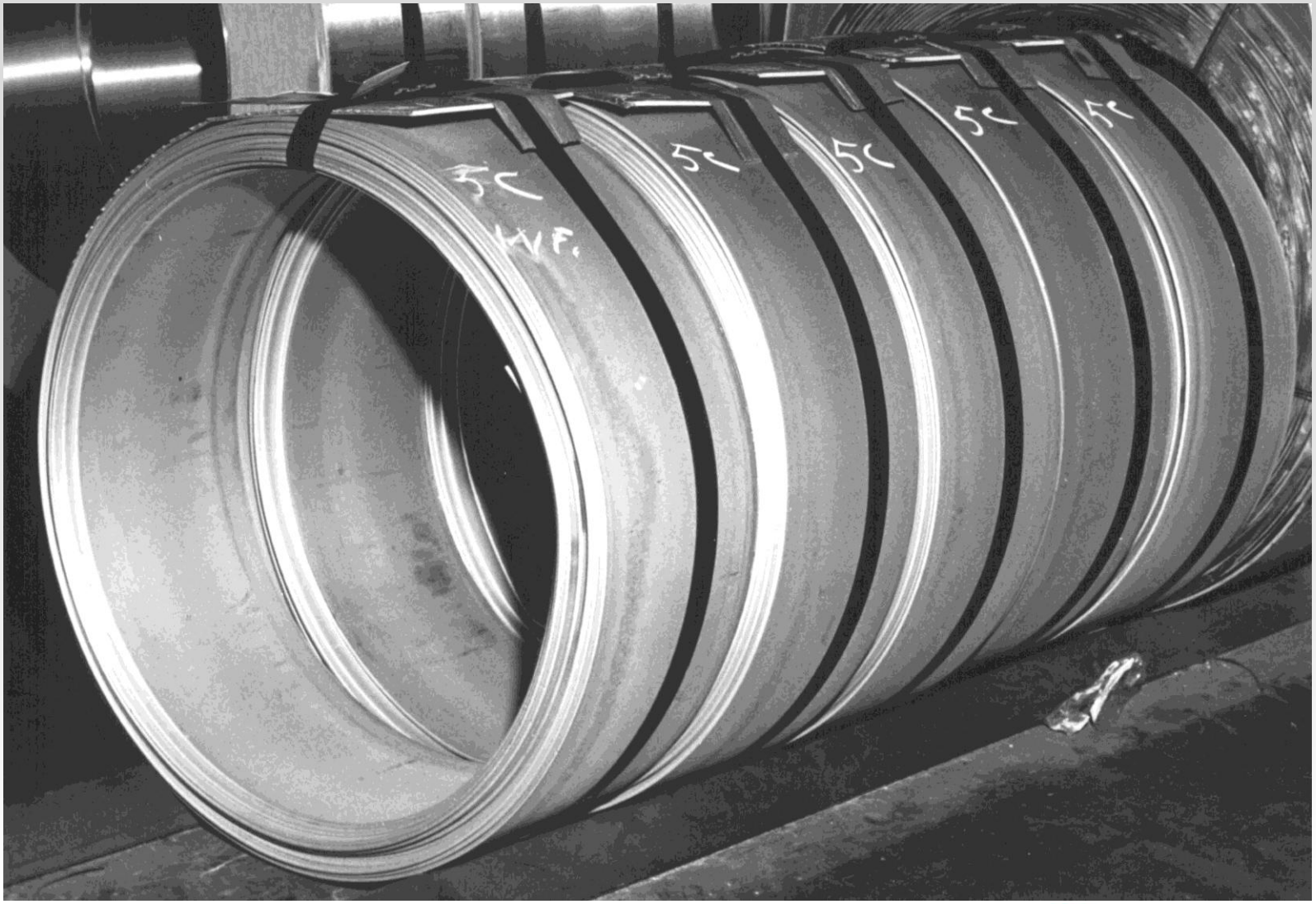
Hot Rolled Strip Coils



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Cold Rolling Strip

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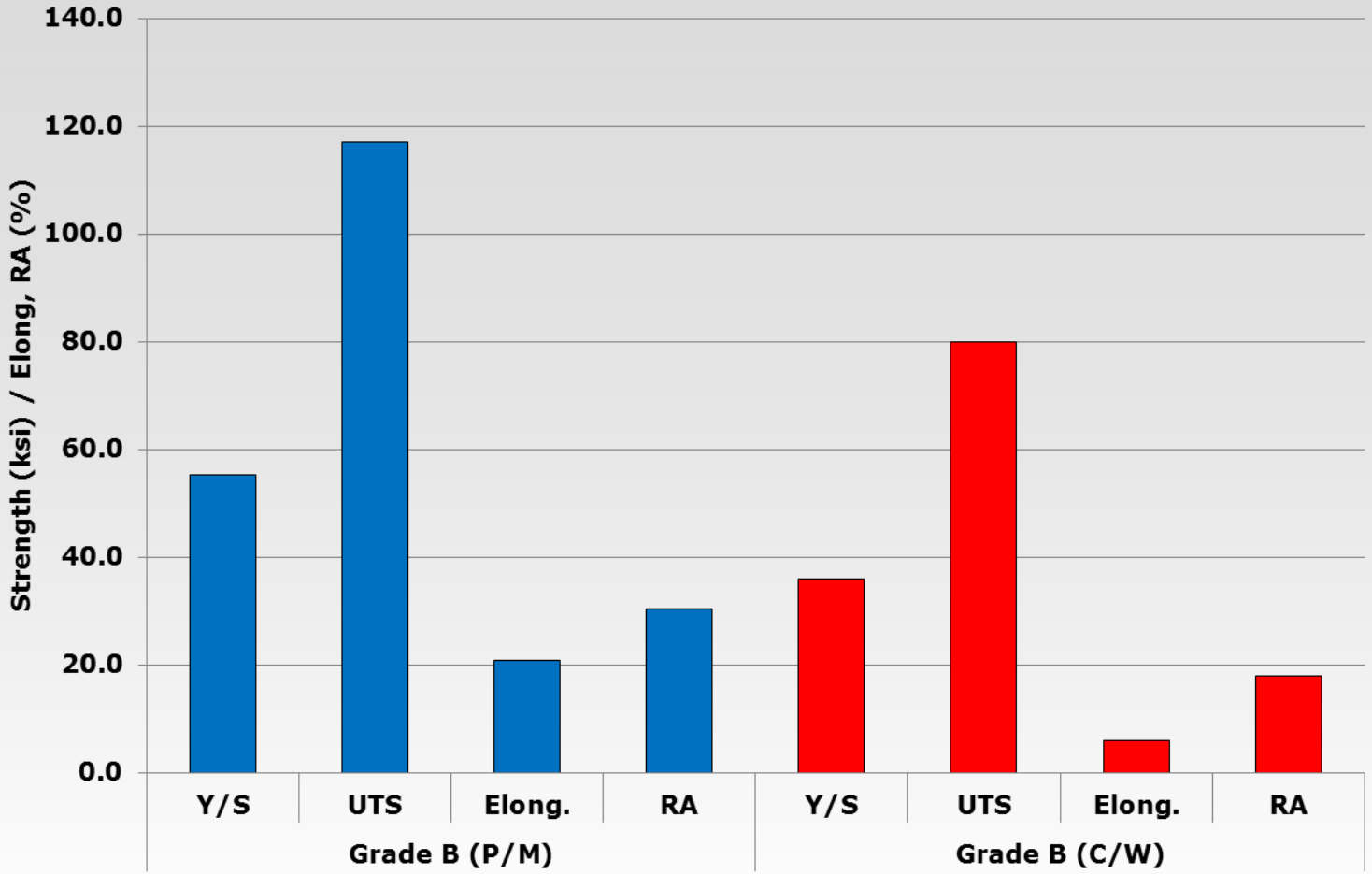
Grade B Comparisons – ASTM A887, 304B7



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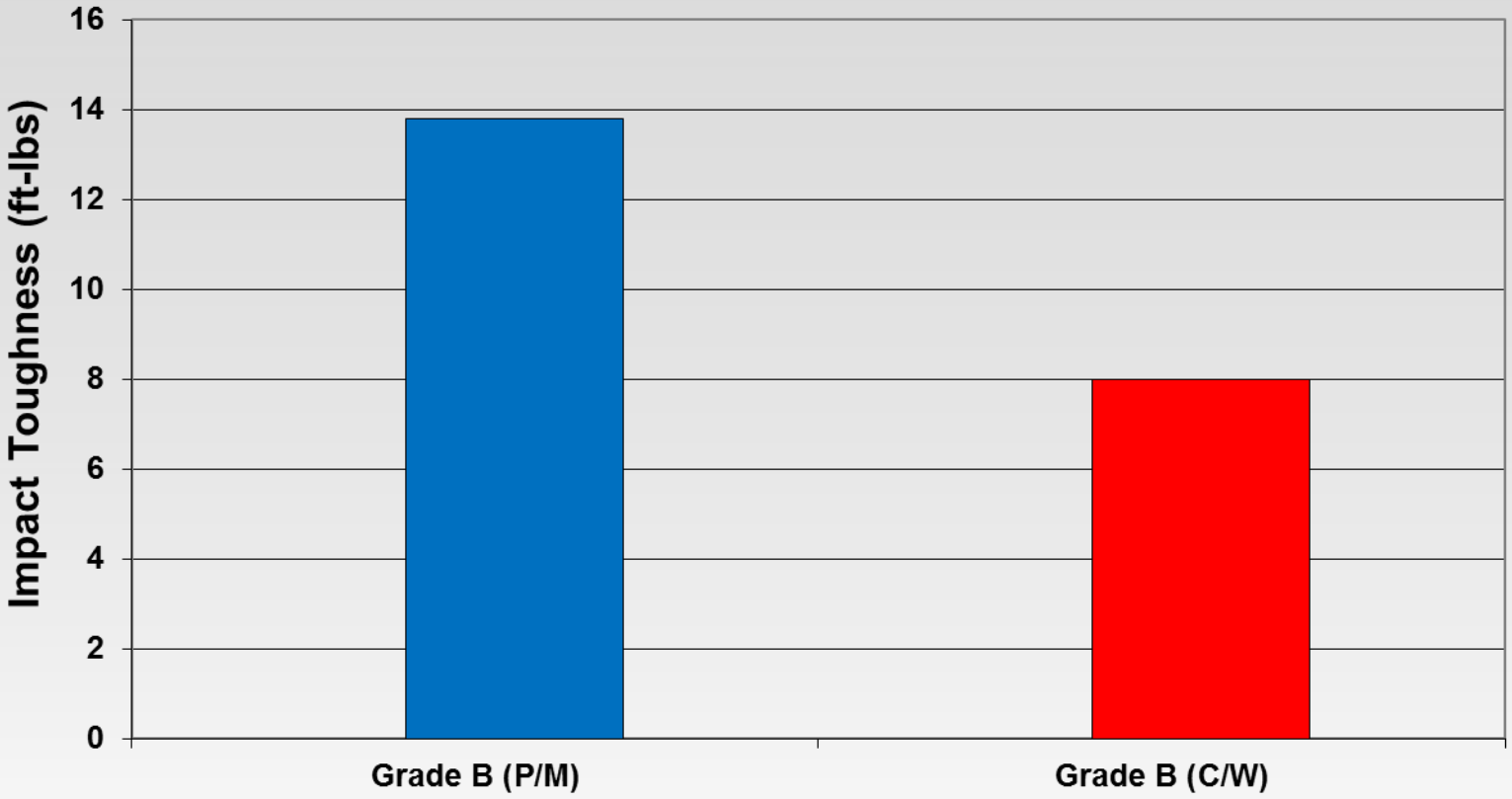
Grade B Comparisons – ASTM A887, 304B7



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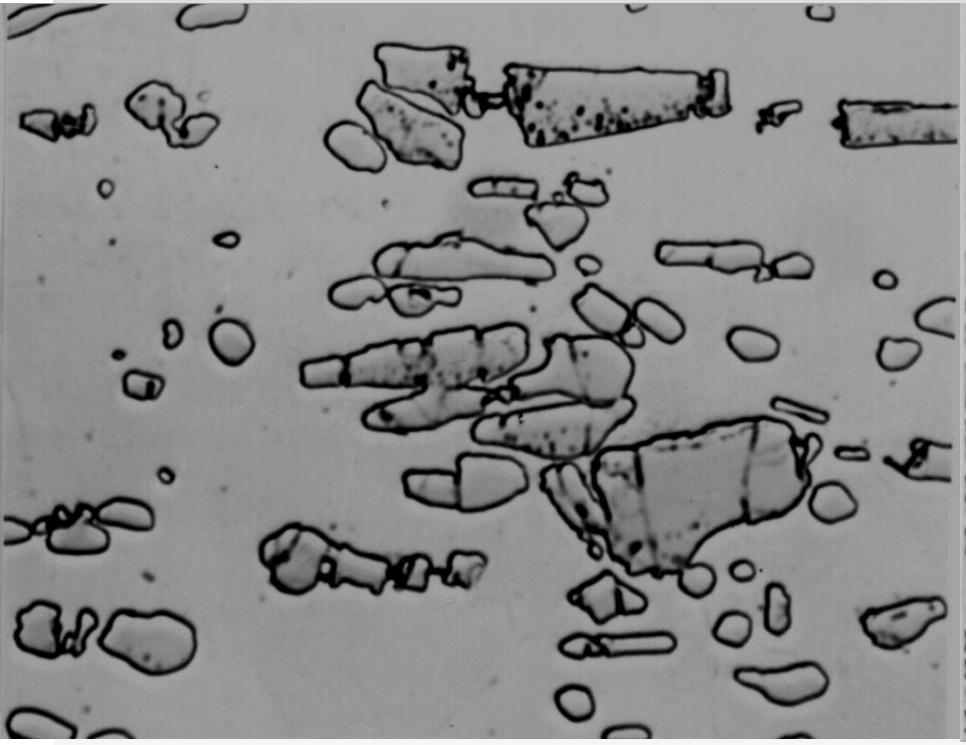
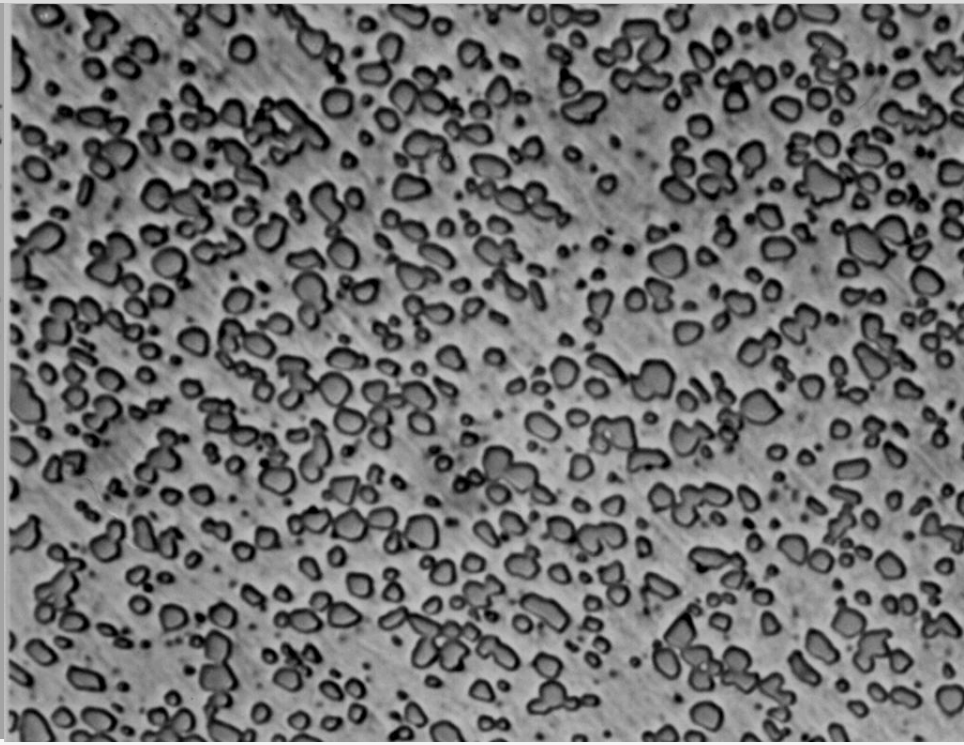
Microstructural Comparisons

1.2% Boron Grade B (C/W)



1.75% NeutroSorb (PM)



1000X Longitudinal Section

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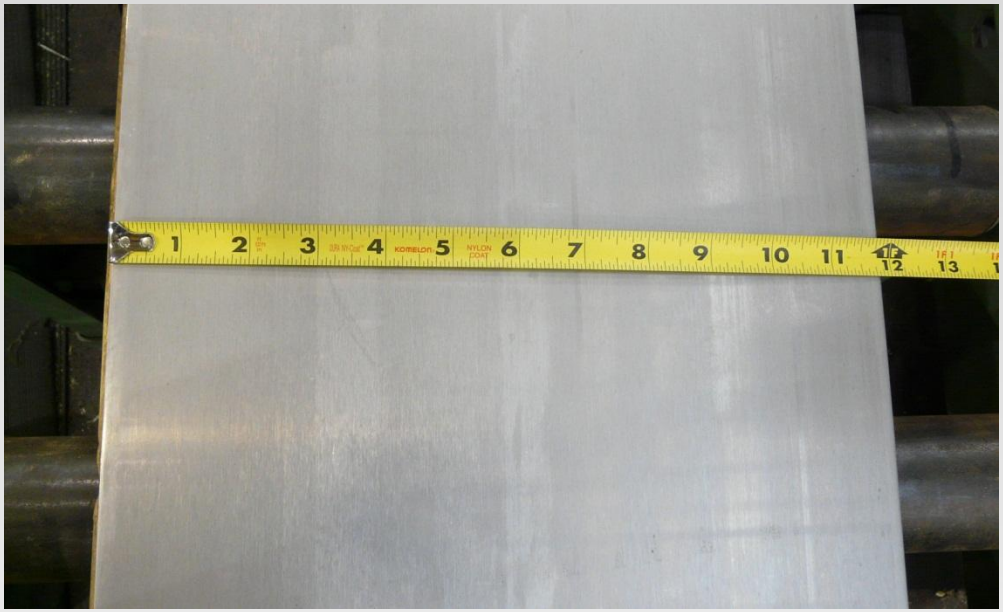
Finishing – Slit, Cut-to-Length



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Inspection and Testing – JEN 3

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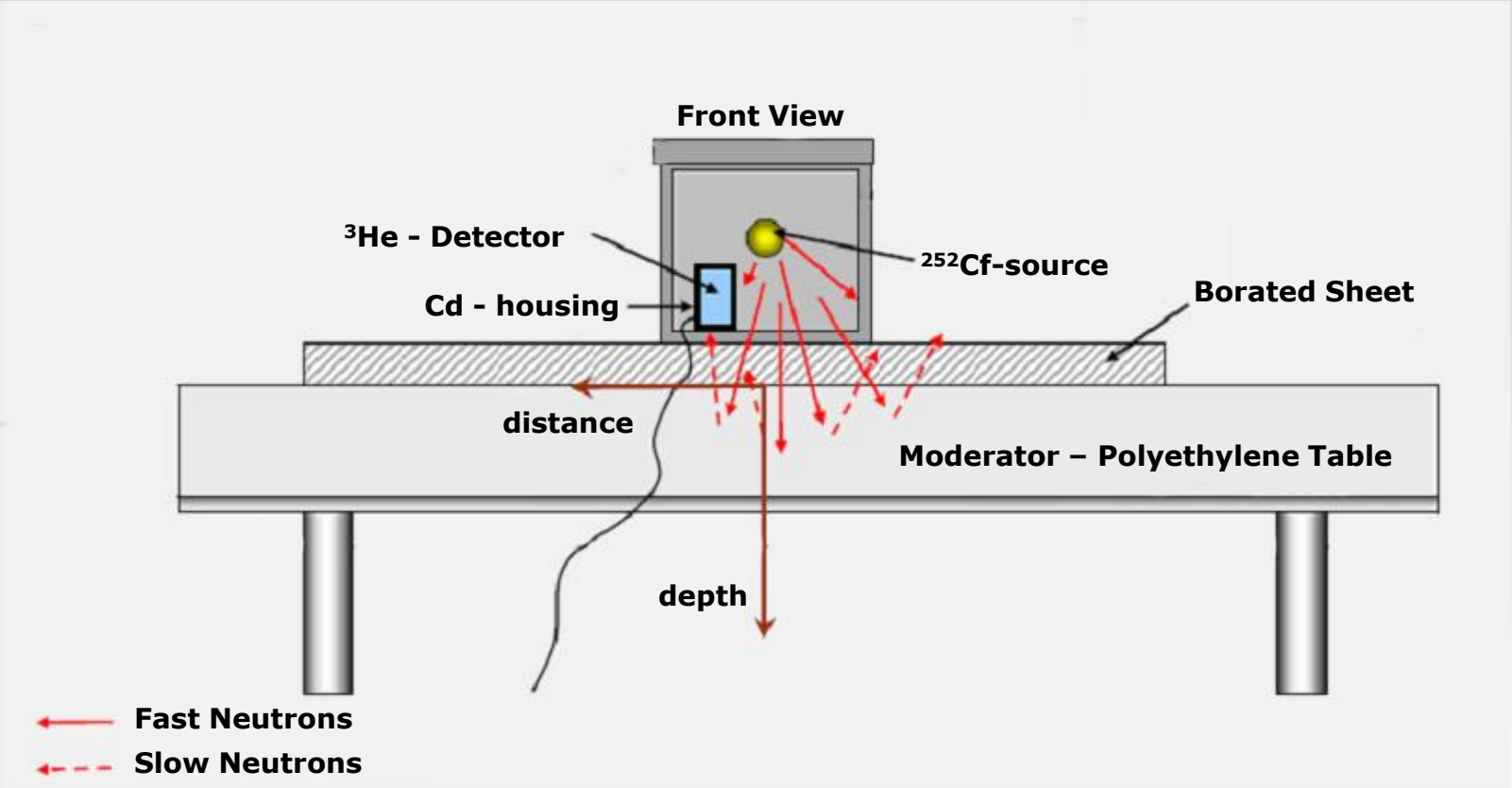
Schematic of JEN3 Device



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DuoSorb Stainless Steel Alloys: Objectives

- Provide superior neutron absorbing capabilities over existing ASTM A887 BSS alloys
- Demonstrate hot and cold fabricability
- Demonstrate weldability
- Demonstrate improved corrosion properties
- Demonstrate mechanical properties required for selected applications
- Compete with neutron absorbing metal matrix composite materials

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DuoSorb Concept

- Two Major Elements
  - Boron
  - Gadolinium

- Ability to Absorb Thermal Neutrons
  - Boron – ^{10}B Isotope
  - Gadolinium – ^{155}Gd and ^{157}Gd isotopes

- Neutron Capture Cross-Section

Isotope	Barns(b)
^{10}B	3,800
^{155}Gd	60,900
^{157}Gd	255,000

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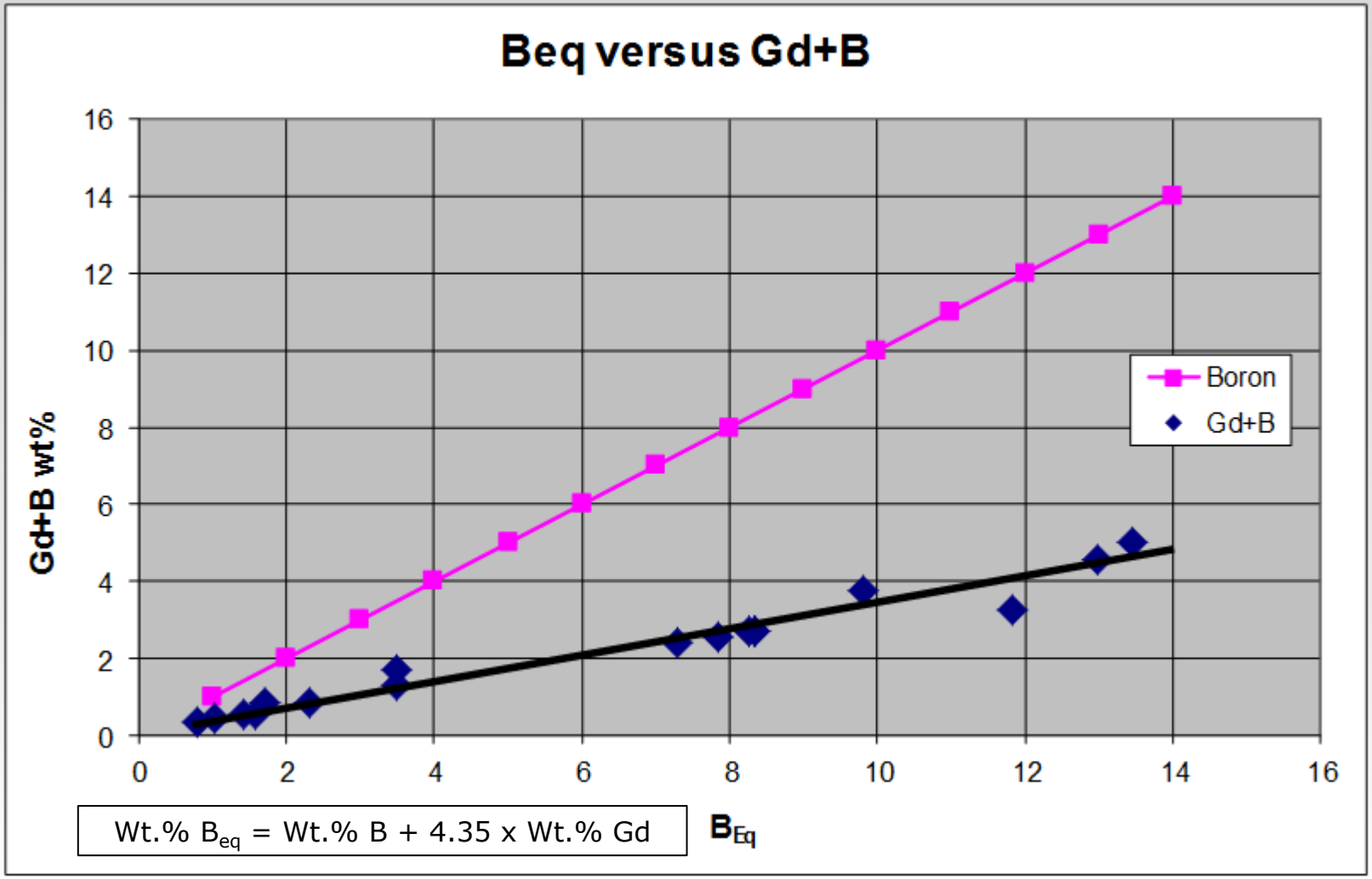
Composition Design



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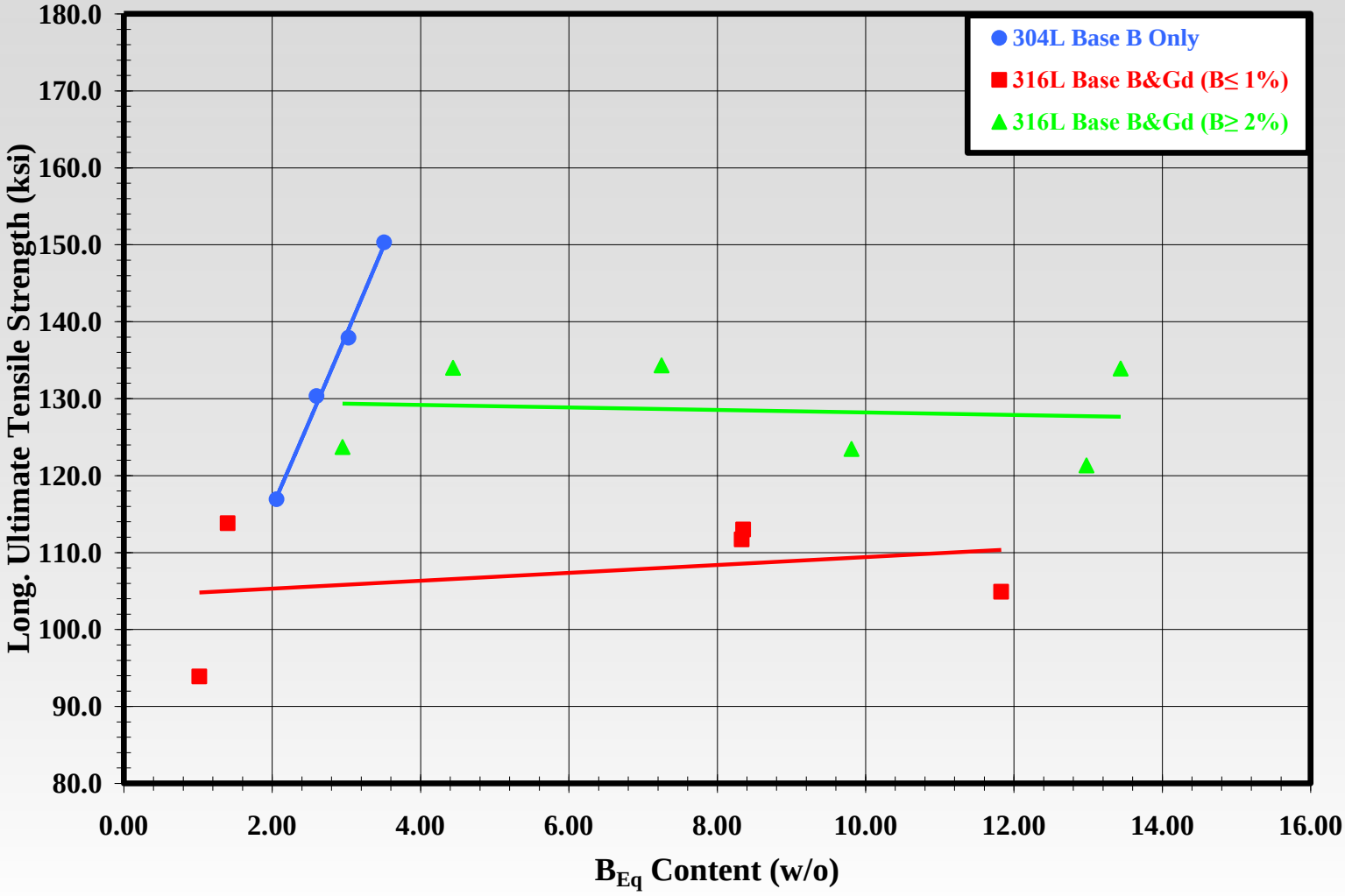
Tensile Strength Evaluation



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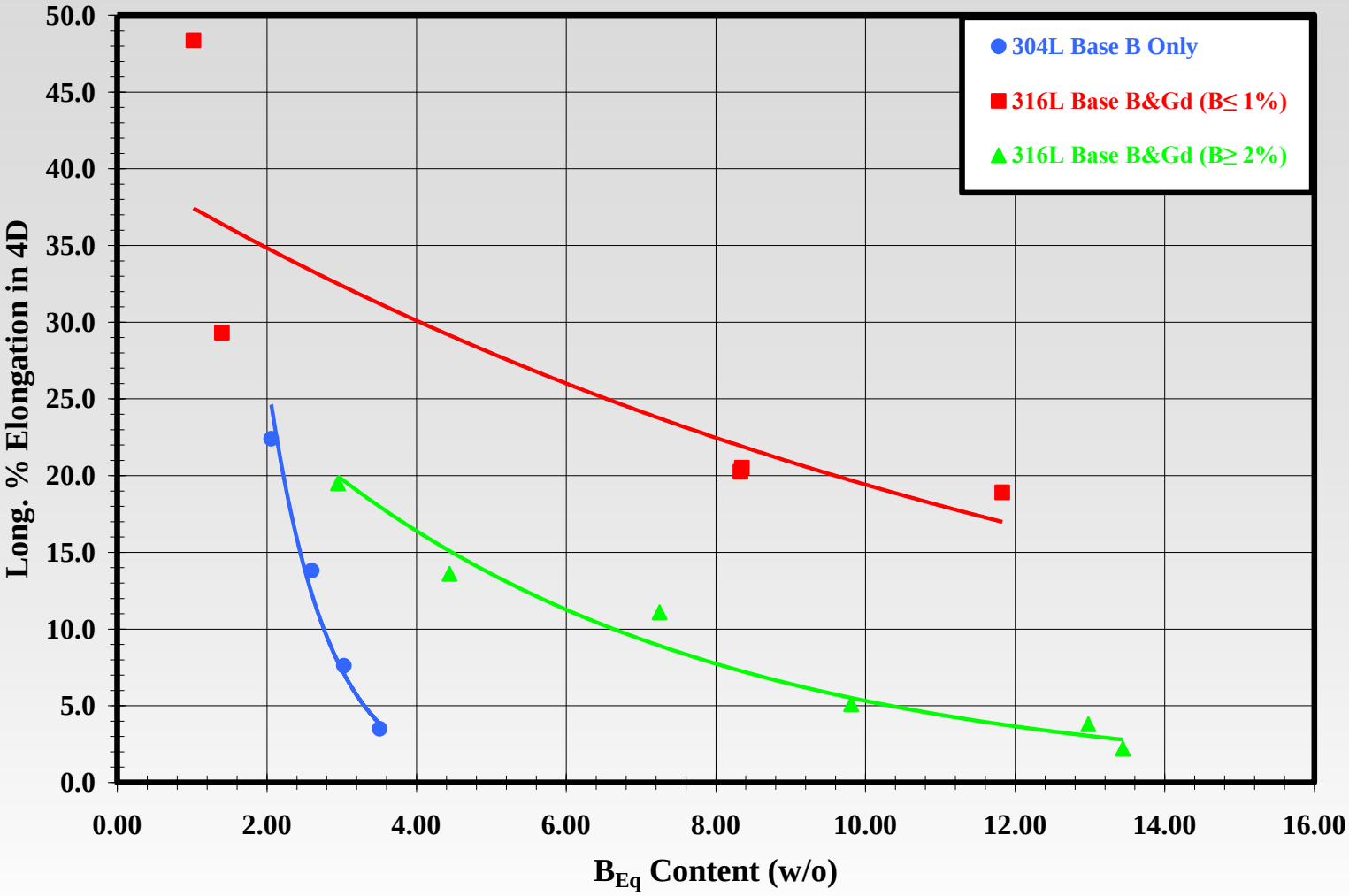
Tensile Elongation Measurements



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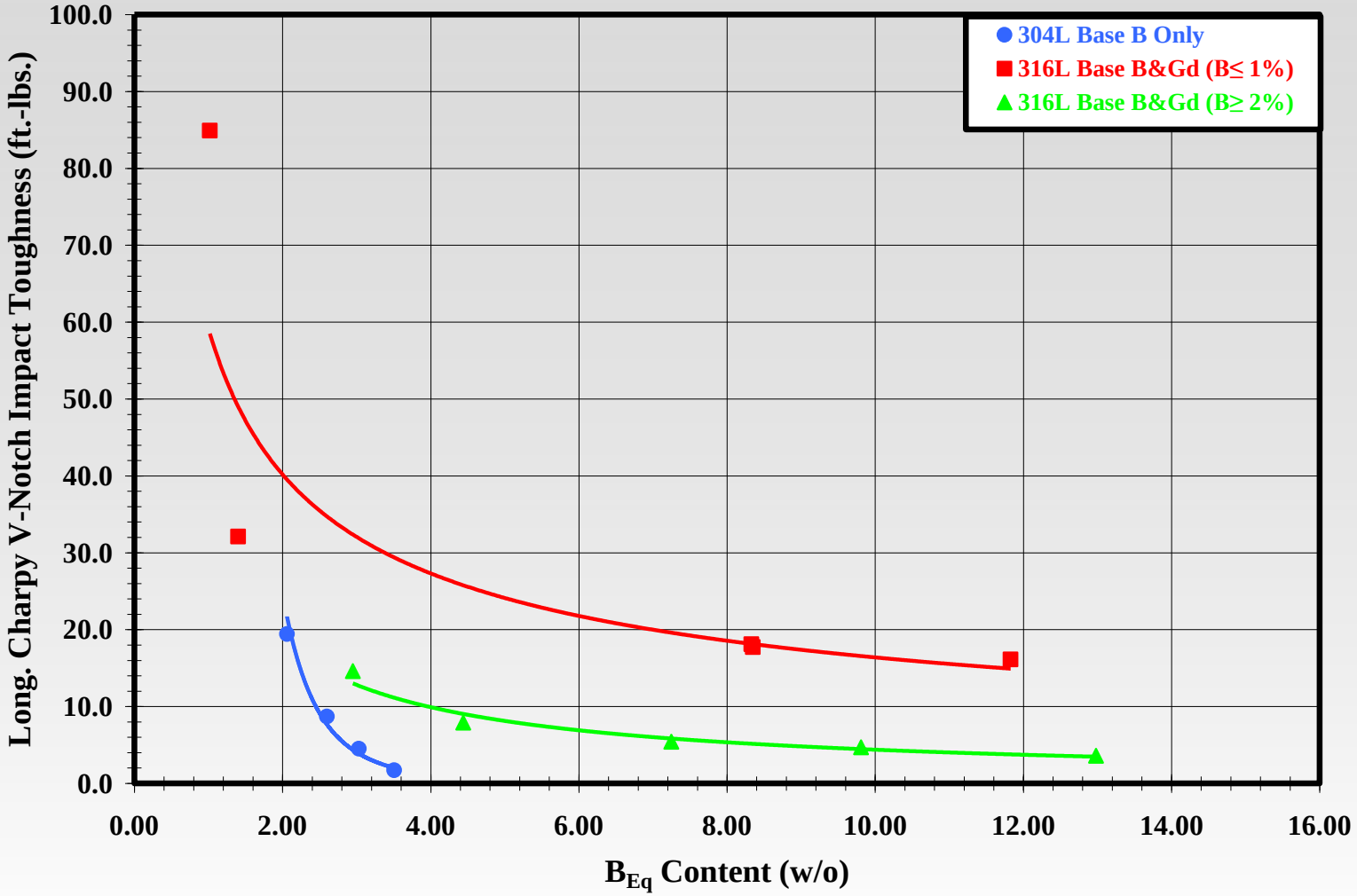
Charpy V-Notch Impact Toughness



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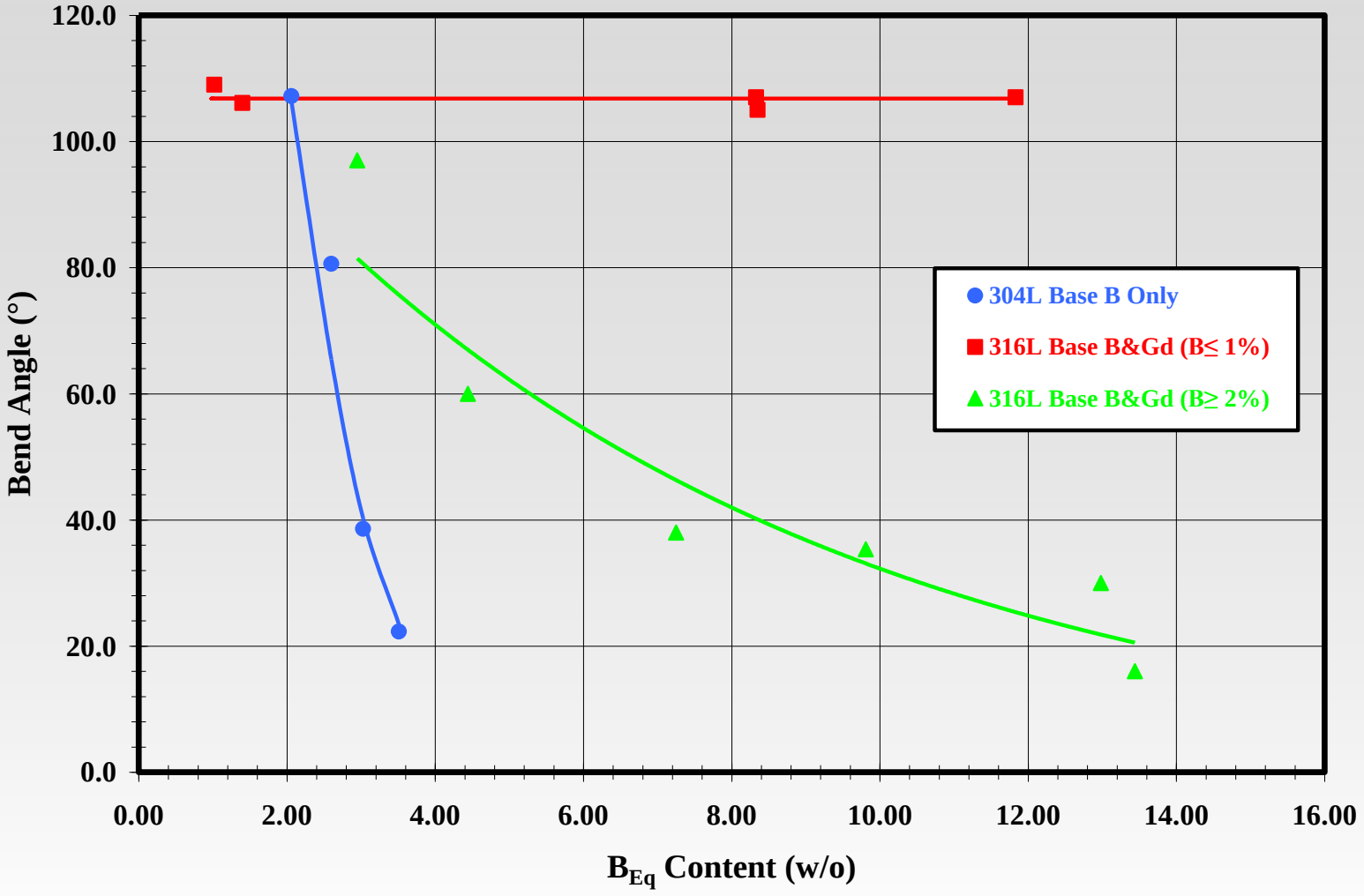
Bend Angle Measurements



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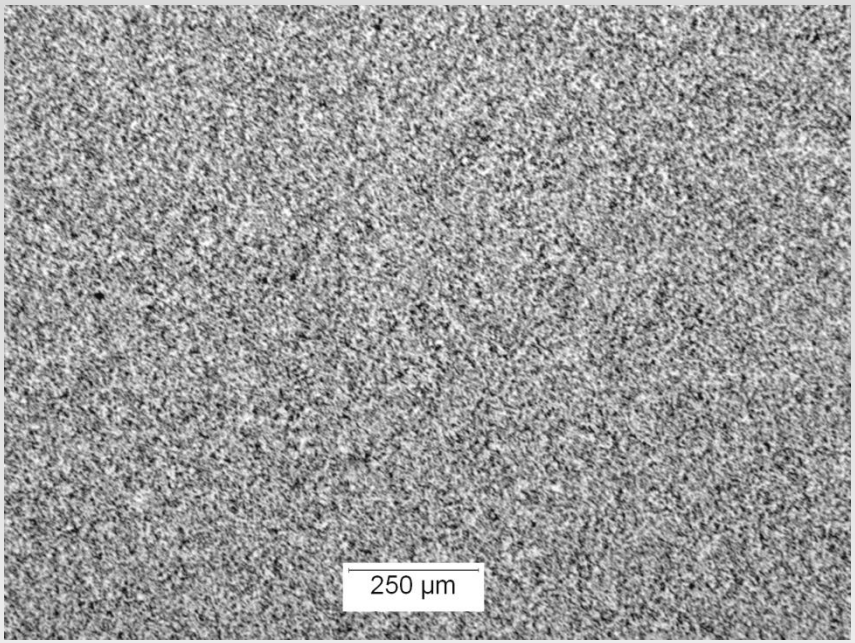
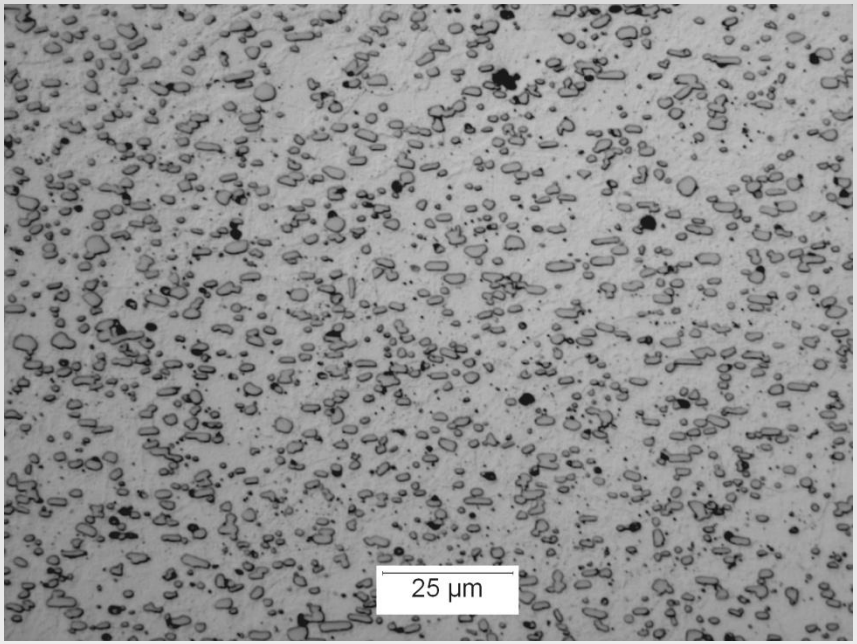
DuoSorb Alloy Microstructure





Uniform microstructures in Gd+B stainless steels

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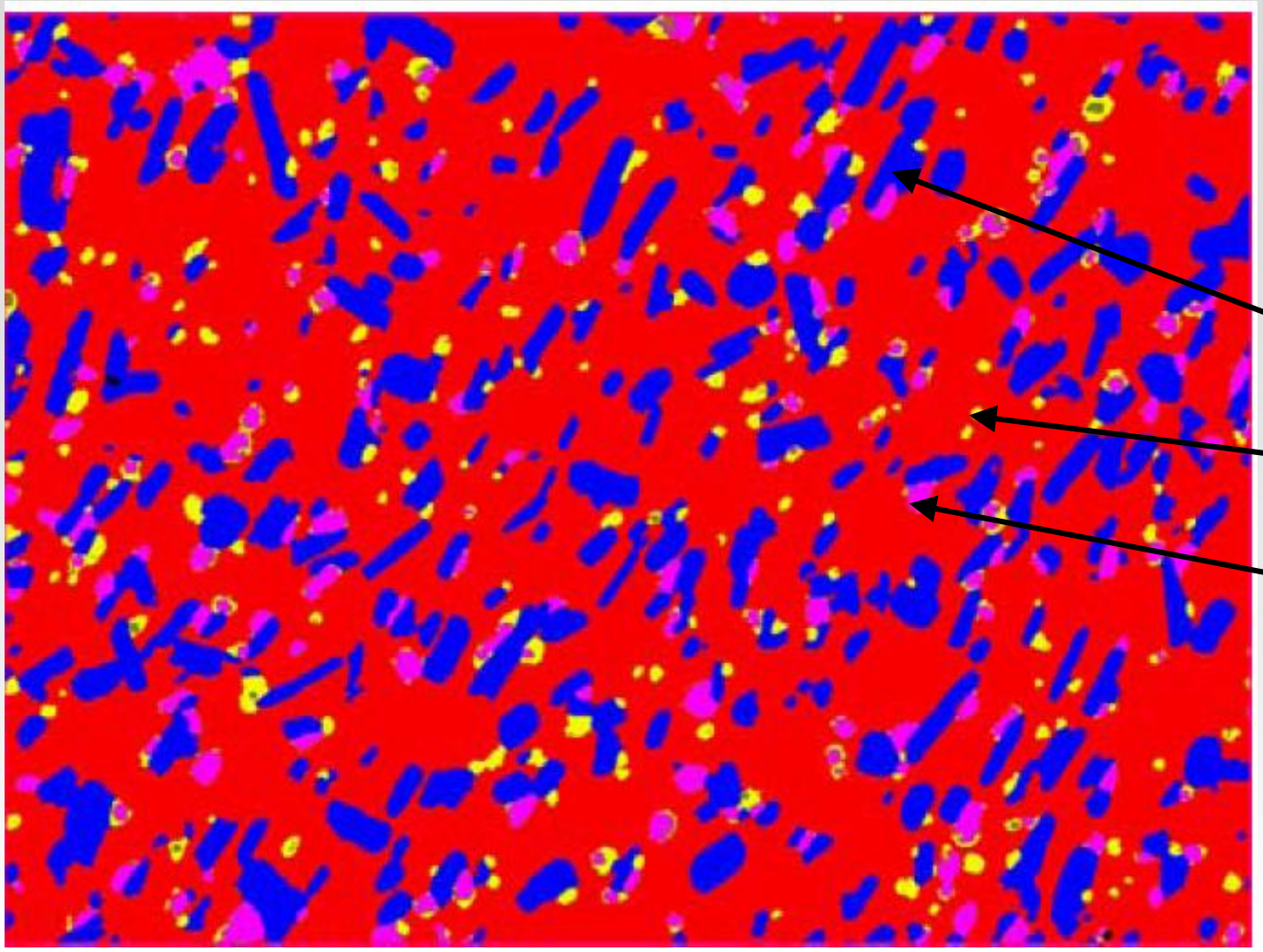
DuoSorb Backscatter SEM Image



2000X

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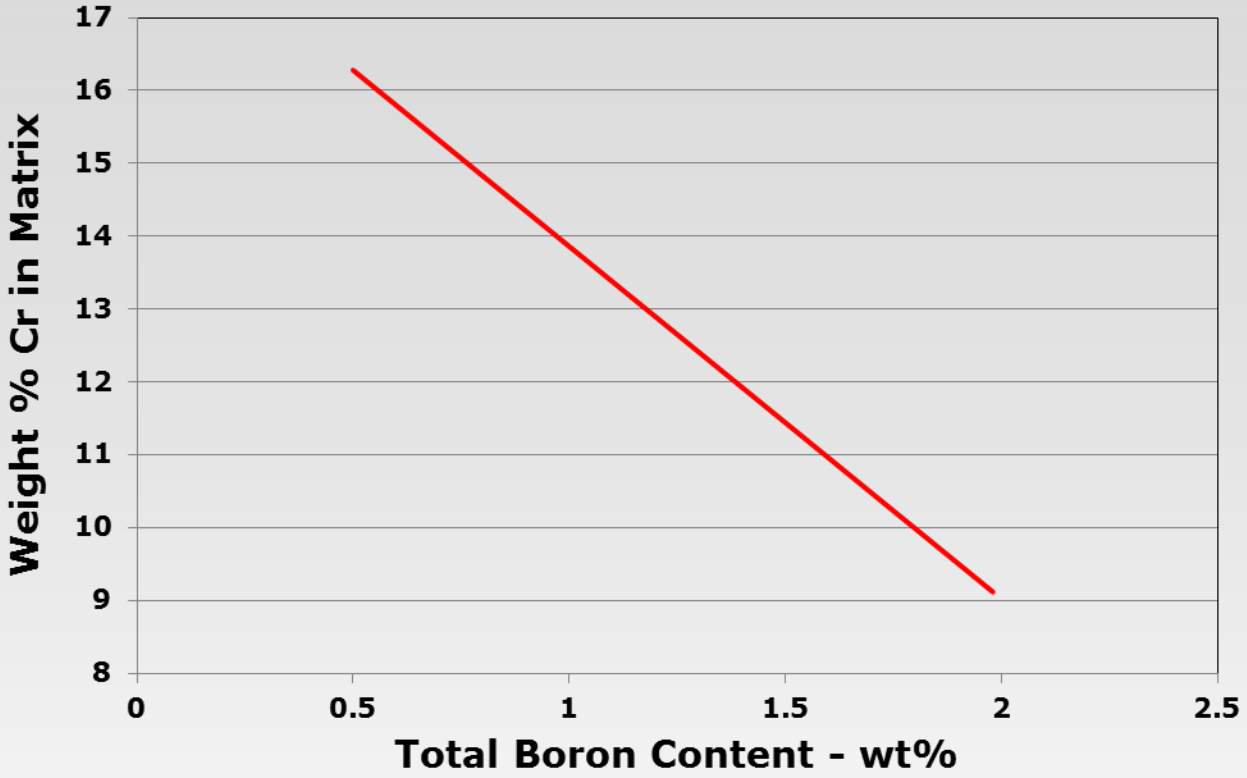
Corrosion Studies – 304B7



Boride Cr = 4.84 x B_{TOT}
Matrix Cr = Cr_{TOT} – Boride Cr

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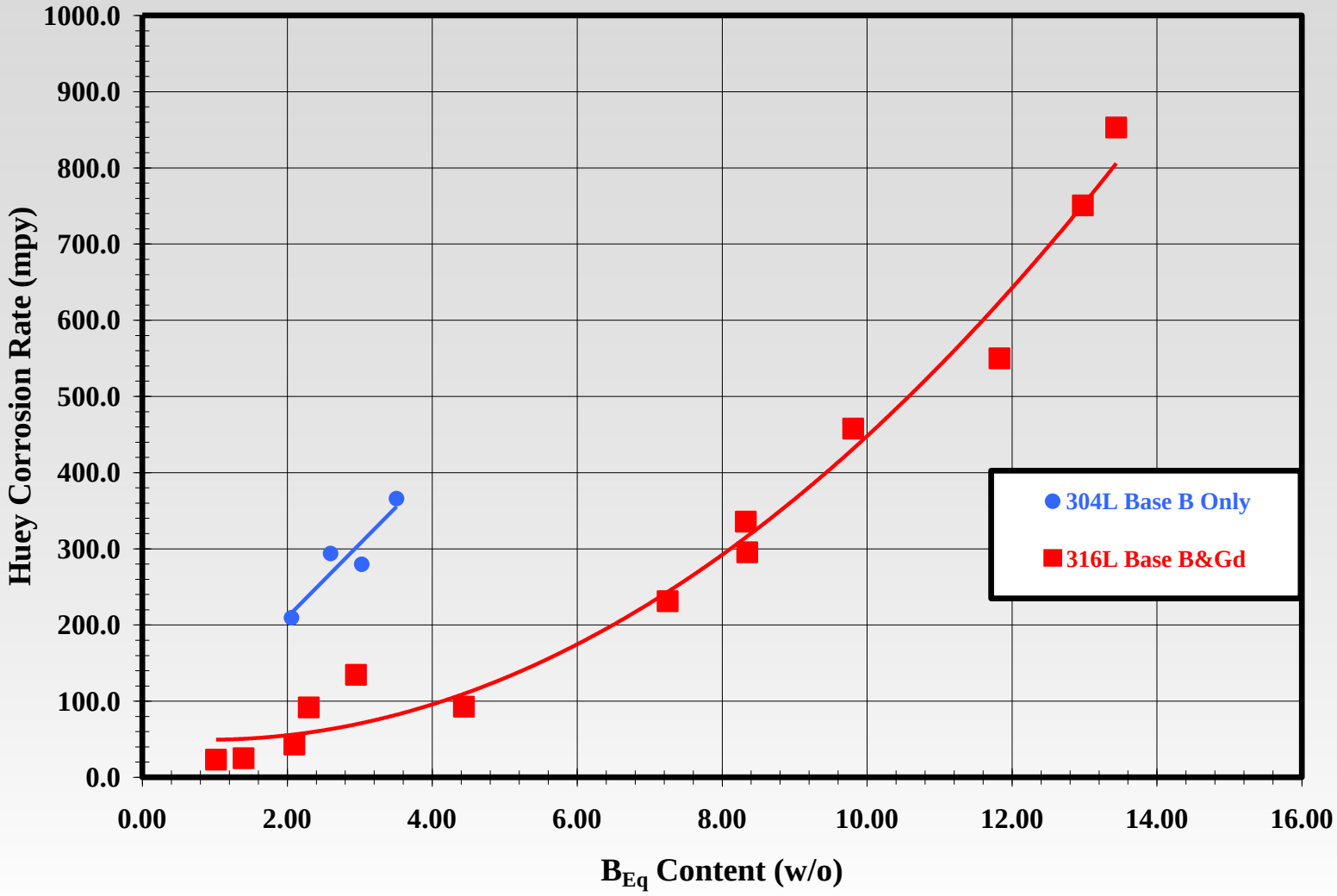
Corrosion Properties – A262 Practice C



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Reactor Beam Results (2.54mm[0.1”] thickness)

Material ID	Weight %		Isotope Content			Transmission Ratios	B_{eq} Calculation
	B	Gd	^{10}B	$^{155,157}Gd$	$^{10}B+^{155,157}Gd$		
Incident Beam	-	-				100%	0
173554	1.06	0.00	0.20	0.00	0.20	40.74%	1.06
173375	1.58	0.00	0.29	0.00	0.29	30.34%	1.58
172678	1.88	0.00	0.35	0.00	0.35	23.73%	1.88
182200	*1.24	0.00	1.12	0.00	1.12	3.16%	6.09
130880	0.28	0.17	0.05	0.05	0.10	45.08%	1.02
130760	1.14	0.22	0.21	0.07	0.28	25.86%	2.10
130879	0.97	1.45	0.18	0.44	0.62	6.39%	7.28
160105-1	1.02	1.68	0.19	0.51	0.70	5.60%	8.38
130877	0.69	2.56	0.13	0.77	0.90	3.75%	11.83

* Contains 90% ^{10}B

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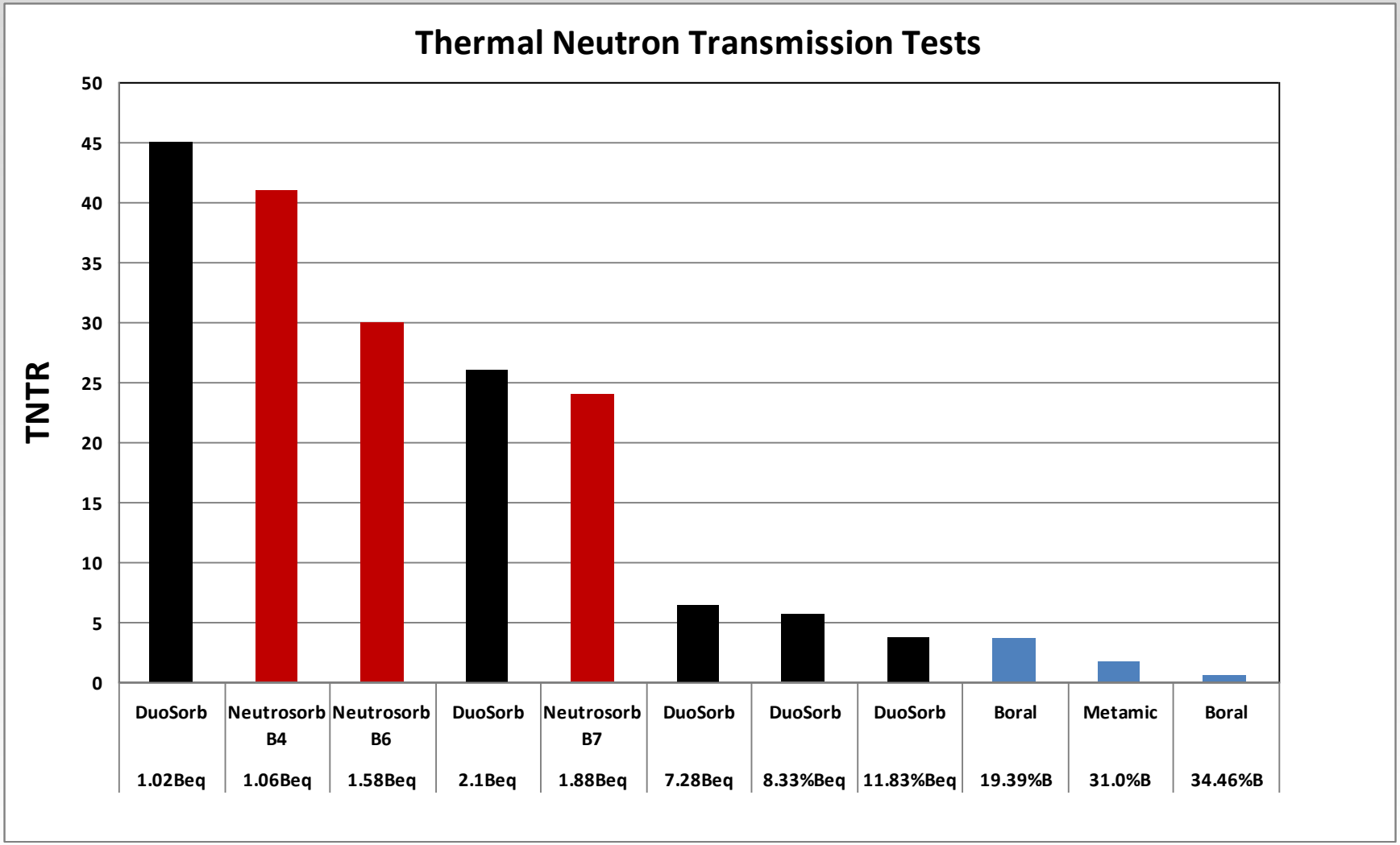
TNTR Tests for Various Materials at 0.1” Thick



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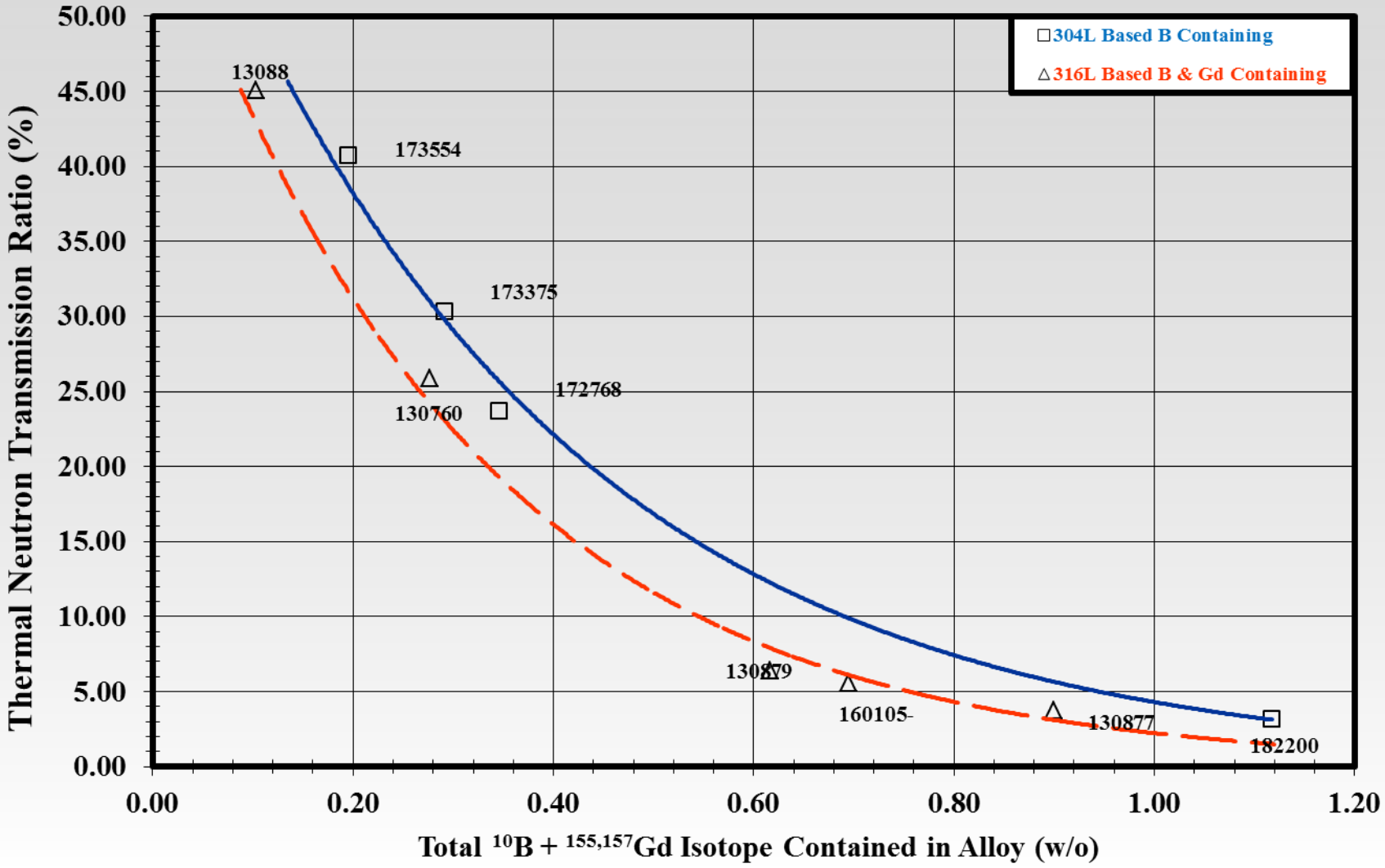
TNTR as a Function of Total B + Gd Isotopes



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Summary – TNTR Testing

- Better thermal neutron absorption is exhibited by Gd+B containing alloys than B only alloys when plotted as a function of total isotope $^{10}B+^{155,157}Gd$ content
- NETCO testing at Penn State Breazeale reactor showed the benefits of Gd+B on the thermal neutron transmission ratios (TNTR)
- All TNTR data was collected and reported under 10 CFR50 Appendix B and 10CFR21 quality assurance requirements
- Specific alloy compositions can be produced to satisfy a TNTR requirement by varying the Gd and B content in the material
- The TNTR of Gd+B materials can equal or approach the current composite neutron absorbers while at the same time providing better fabricability and long term corrosion resistance