



# Mission Critical Metallics® for Electrical Energy

## The Application and Properties of ATI NuShield™ Borated Stainless Steels

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## **ATI NuShield™ *Borated Stainless Steels***

The ATI NuShield™ family of borated stainless steels offer the superior performance of powder metallurgy processing. The uniform, fine dispersion of boron containing particles resulting from the P/M process imparts superior neutron absorption and enhanced toughness and ductility.

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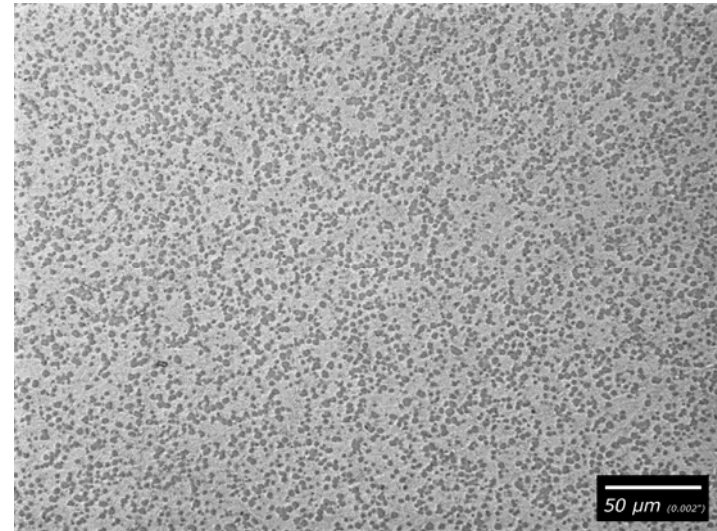
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## Introduction: Advantages of Powder Metallurgy

- Superior Properties
  - Uniform microstructure
    - High Ductility
      - Formability
      - Good toughness
      - Process-ability
        - High ductility at high boron
    - Excellent Neutron Absorption
    - Improved Corrosion Resistance





## Compositions per ASTM A887-89

UNS	Type	C	Cr	Ni	B	Other <sup>B</sup>
S30460	304B	0.08	18.0-20.0	12.0-15.0	0.20-0.29	0.10N
S30461	304B1	0.08	18.0-20.0	12.0-15.0	0.30-.049	0.10N
S30462	304B2	0.08	18.0-20.0	12.0-15.0	0.50-0.74	0.10N
S30463	304B3	0.08	18.0-20.0	12.0-15.0	0.75-0.99	0.10N
S30464	304B4	0.08	18.0-20.0	12.0-15.0	1.00-1.24	0.10N
S30465	304B5	0.08	18.0-20.0	12.0-15.0	1.25-1.49	0.10N
S30466	304B6	0.08	18.0-20.0	12.0-15.0	1.50-1.74	0.10N
S30467	304B7	0.08	18.0-20.0	12.0-15.0	1.75-2.25	0.10N
S30403	304L	0.03	18.0-20.0	8.0-12.0	-	0.01N

<sup>A</sup> Concentrations are the maximum, unless a range or minimum is indicated.

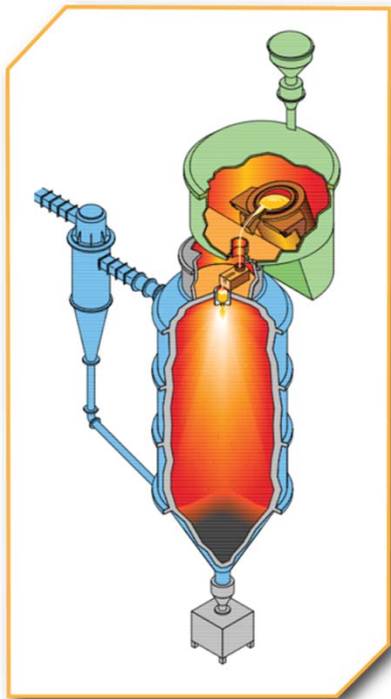
<sup>B</sup> Cobalt concentration shall be 0.2 max, unless a lower concentration is agreed upon between the purchaser and the supplier.

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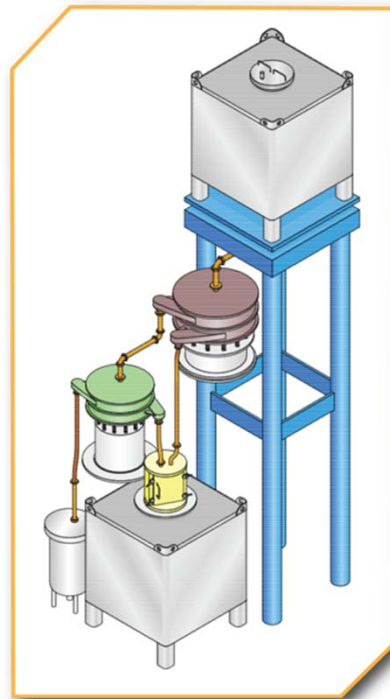
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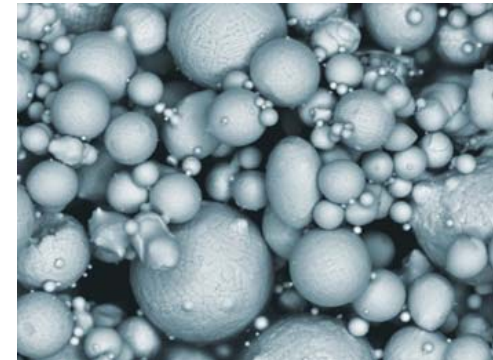
## P/M Processing



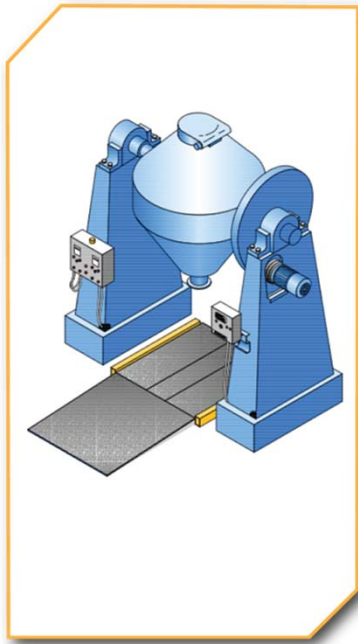
Melt/Atomize



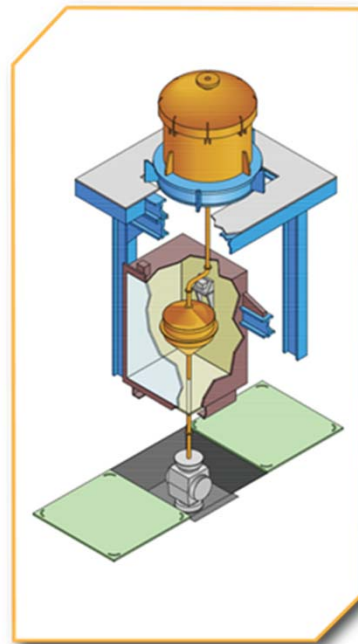
Screen



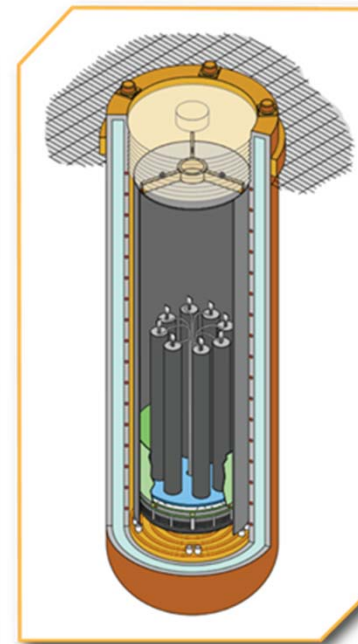
## P/M Processing



Blend

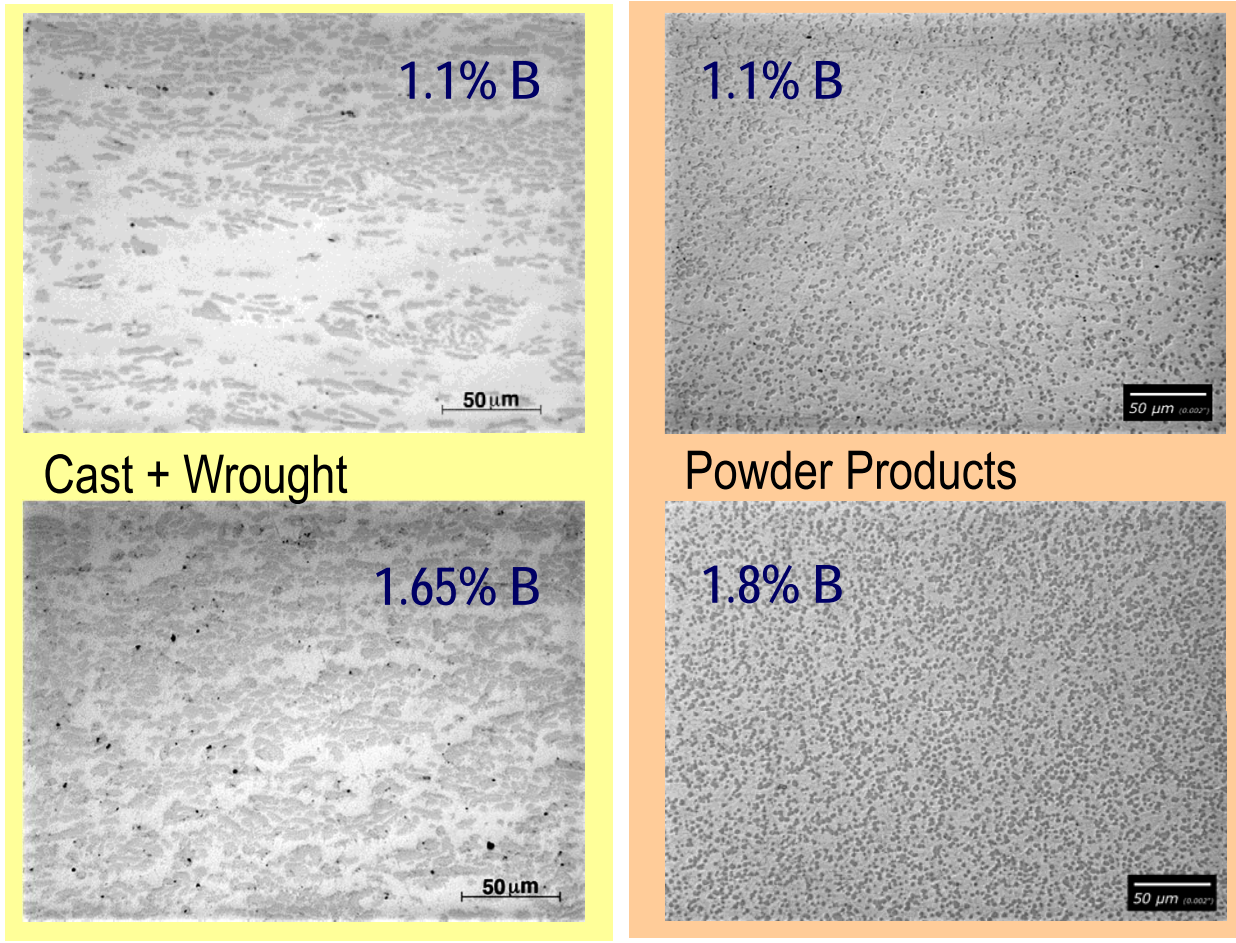


Load



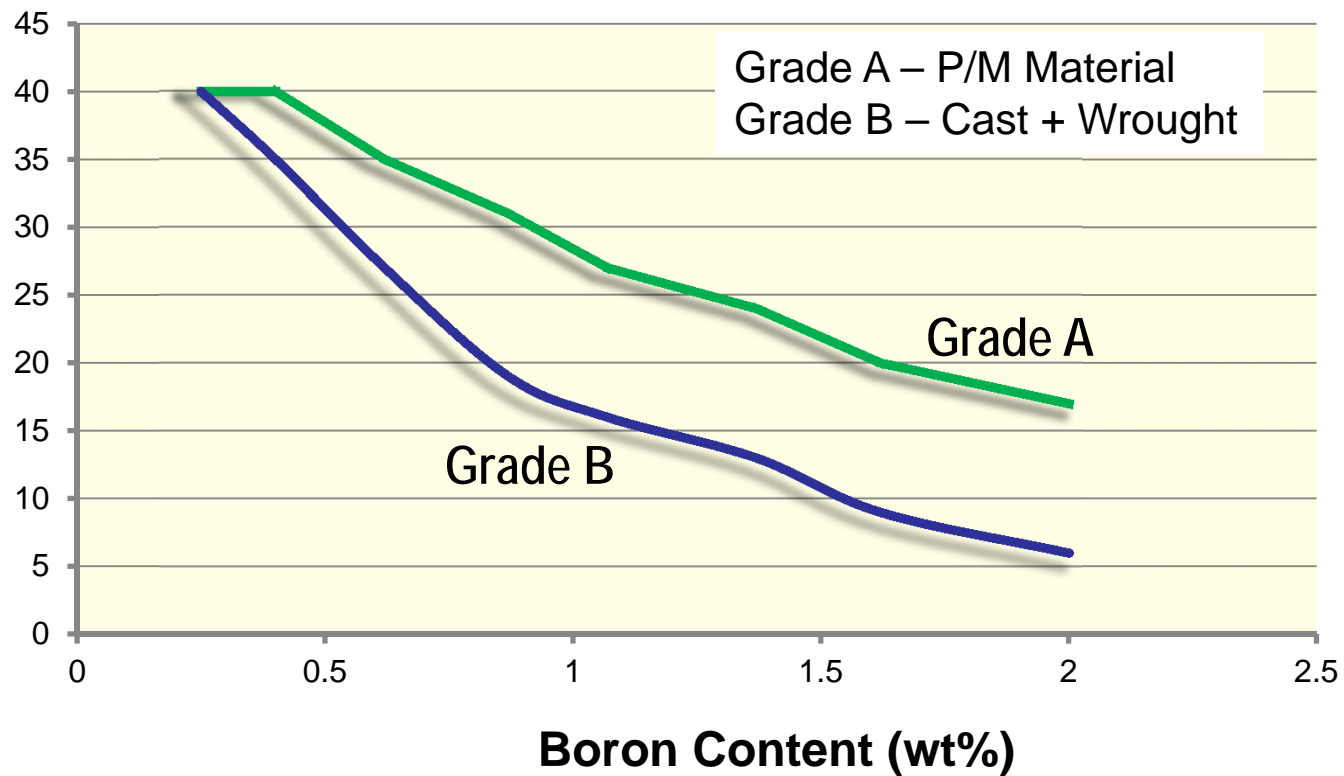
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# Microstructure Comparison



# Ductility Comparison

**Elongation %**



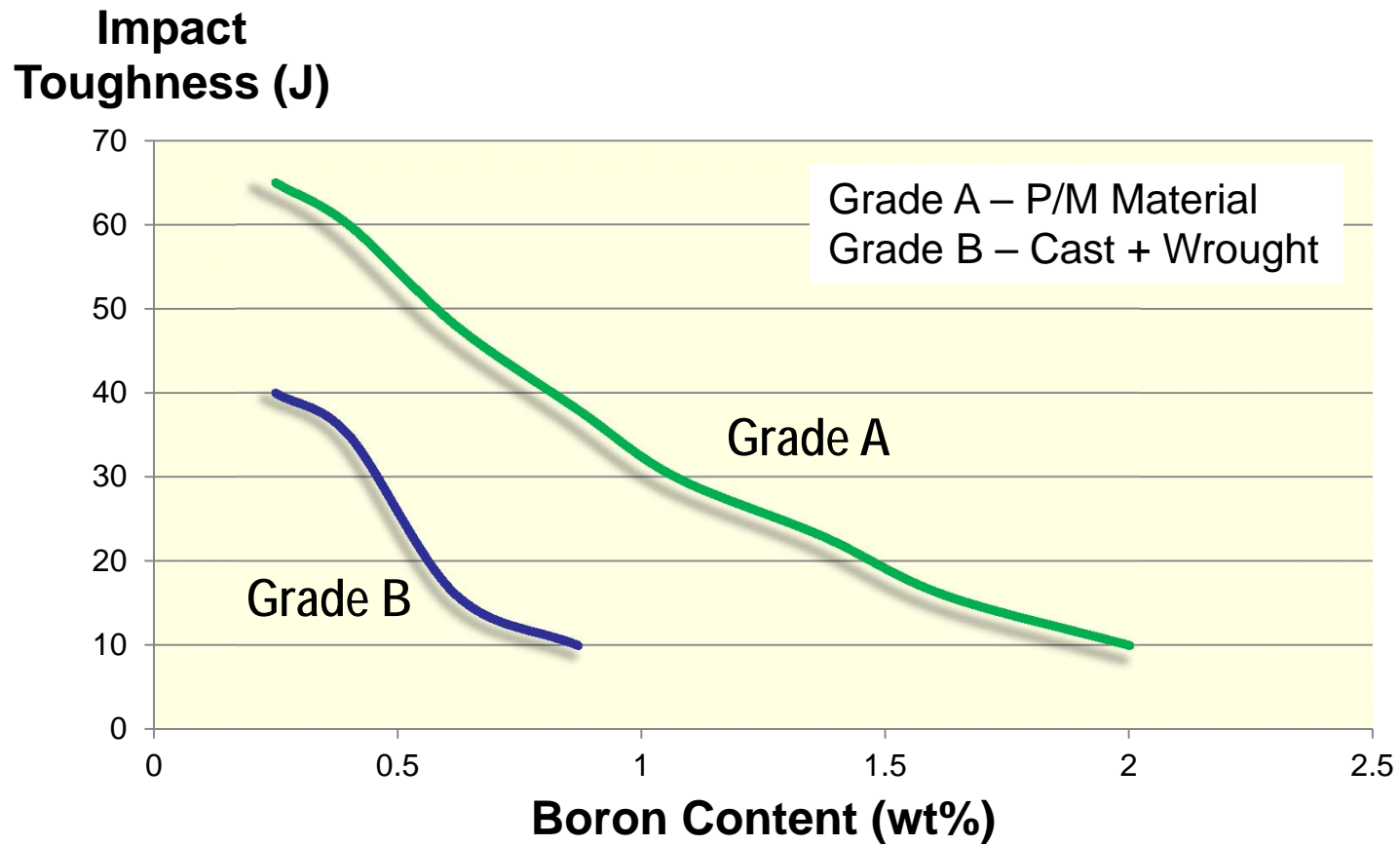
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# Toughness Comparison



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## Advantage of P/M – Testing Data

- Dramatically improved ductility and toughness.

ID	UTS (MPa)	YS (MPa)	%El	Impact (J)
P/M 304B7 1.8% Boron	754	351	21	30 (22 ft-lb)
P/M 304B5 1.4% Boron	772	303	35	42 (31 ft-lb)
C&W 304B5 1.4% Boron	634	303	18	14 (10 ft-lb)
ASTM 887-89 304B7 Type A	515	205	17.0	14 (10 ft-lb)
ASTM 887-89 304B7 Type B	515	205	6.0	-

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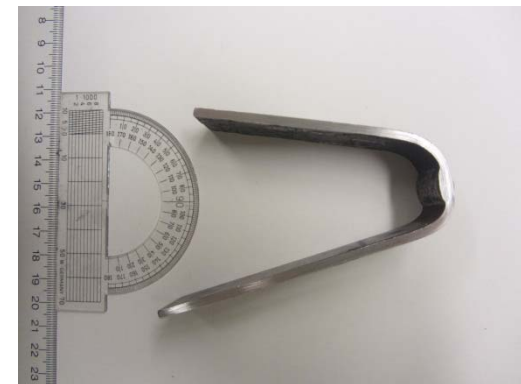
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## Formability/Weldability

ATI 304B7™ P/M

Test Specimen	Transverse	Longitudinal
12.7[mm] radius to 180°	Pass	Pass
6.4[mm] radius to 180°	110°	Pass
6.4[mm] radius to 90°	Pass	Pass
3.2[mm] radius to 90°	83°	77°

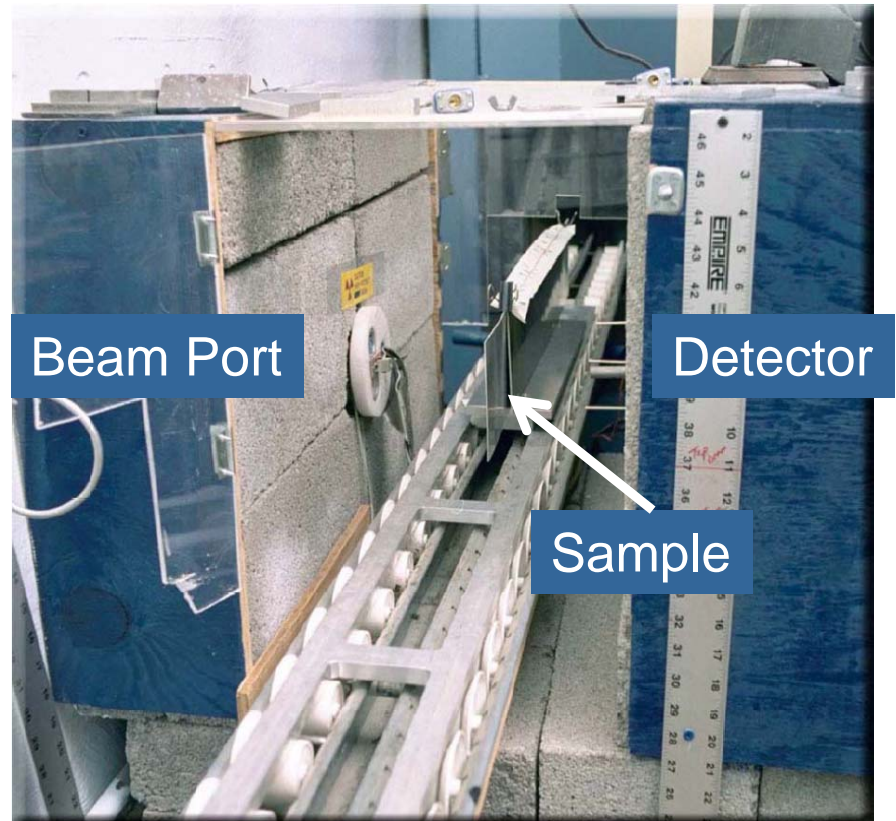


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## Neutron Attenuation Testing

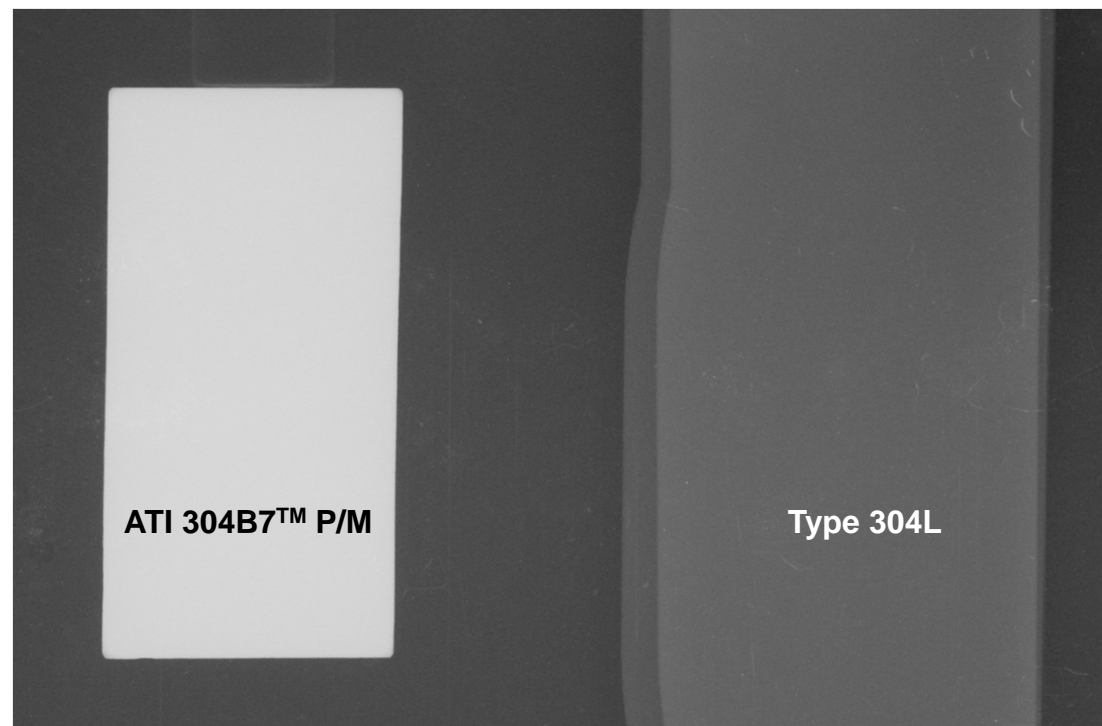


## Neutron Attenuation: Comparison between ATI 304B7™ P/M and 304L

Sample	Thickness mm (in)	Boron wt%	Areal Density (g/cm <sup>2</sup> )	I/I <sub>0</sub>
304-1 Baseline	2.67 (.105)	0.0001	0.00038	0.938
304-2 Baseline	3.30 (0.130)	0.0001	0.00047	0.867
P/M 1	2.72 (0.107)	1.84	0.007	0.258
P/M 2	3.30 (0.130)	1.80	0.008	0.217
P/M 3	6 (0.236)	1.80	0.015	0.098
P/M 4	10 (0.394)	1.80	0.026	0.063

I<sub>0</sub> – Incident Beam Intensity  
I – Transmitted Beam Intensity

## Neutron Attenuation: Comparison between ATI 304B7™ P/M and 304L



$t = \sim 3.3 \text{ mm}$

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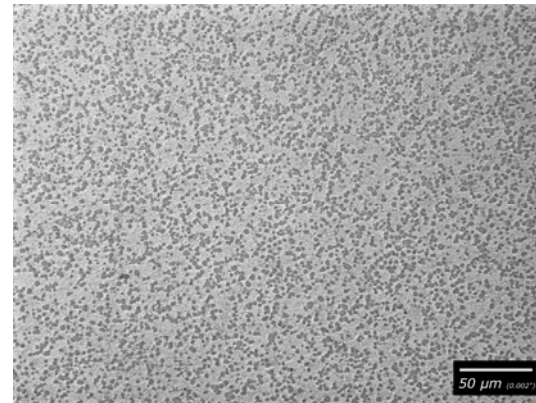
## Typical Properties of ATI 304B7™ P/M

	UTS MPa (ksi)	YS MPa (ksi)	%El	Impact J (ft-lb)
<b>Sheet<sup>1</sup></b>	758 (110)	335 (48)	19	N/A
<b>Plate<sup>2</sup></b>	738 (107)	338 (49)	24	22 (16 ft-lb)
<b>ASTM 887-89 304B7 Grade A</b>	515 (75)	205 (30)	17.0	14 (10 ft-lb)

1. Typical expected properties for sheet  $\geq$  2mm thickness.
2. Typical expected properties for hot-rolled plate between 5mm and 12mm thickness.

## Summary: Advantages of NuShield™ Borated Stainless Steel

- P/M process is used to develop a microstructure with a uniform , very fine distribution of chromium di-borides.
  - Higher ductility and better formability than ingot cast product.
  - High toughness for structural applications.
  - Low mean free path - excellent neutron absorption
  - Improved corrosion resistance







# ATI NuShield™ *Borated Stainless Steels*

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