



# GOODWIN STEEL WB ALLOYS

## Superior Properties for Super Duplex Steel Castings, Forgings and Weld Metal



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“PARTNERS IN THE DEVELOPMENT OF  
6A-G SUPER DUPLEX STEEL”

## Conventional Super Duplex Grades



<b>Material</b>		<b>C</b>	<b>Si</b>	<b>Mn</b>	<b>S</b>	<b>P</b>	<b>Ni</b>	<b>Cr</b>	<b>Cu</b>	<b>W</b>	<b>Mo</b>	<b>N</b>
A995 Gr 6A	Min	-	-	-	-	-	7.0	24.0	0.5	0.5	3.0	0.2
	Max	0.03	1.0	1.0	0.025	0.045	8.5	26.0	1.0	1.0	4.0	0.3
UNS32760	Min	-	-	-	-	-	6.0	24.0	0.5	0.5	3.0	0.2
	Max	0.03	1.0	1.0	0.020	0.03	8.0	26.0	1.0	1.0	4.0	0.3
Zeron100™	Min	-	-	-	-	-	6.0	24.0	0.5	0.5	3.0	0.2
	Max	0.03	1.0	1.0	0.010	0.030	8.0	26.0	1.0	1.0	4.0	0.3
A182 F55	Min	-	-	-	-	-	6.0	24.0	0.5	0.5	3.0	0.2
	Max	0.03	1.0	1.0	0.015	0.035	8.0	26.0	1.0	1.0	4.0	0.3

6A-G Super Duplex meets the chemistry requirements of the above grades, but with much improved low temperature impact properties and pitting corrosion resistance.

### How Does 6A-G Work?

“The production parameters used to produce 6A-G Super Duplex limit the development of sigma ( $\sigma$ ) and other deleterious precipitates. Sigma phase has a negative effect on the impact properties of SDSS even when present in very small concentrations.”

# Sigma Phase: 6A-G Vs. Conventional ASTM Grade 6A

<b>Figure 1A: 6A-G- 300mm Section 1/2T Location</b>	<b>Figure 1B: Conventional SDSS – 300mm Section 1/2T location</b>
<b>≈0.31 % Sigma Phase</b>	<b>≈2.3 % Sigma Phase</b>
	
Sigma precipitaion on the austenite/ ferrite interface	Initiation of sigma precipitaion has commenced as in Fig 1A but then continued to grow into the ferrite phase

# Improvements Summary of Utilising 6A-G Super Duplex

## G48 Method A Pitting Corrosion Improvements Using 6A-G

Material	Conventional Test Temperature A890/995 6A	New Test Temperature <b>6A-G</b>
Parent	50°C	<b>60°C</b>
Weld 'as welded'	40°C	<b>50°C</b>
Weld 'PWHT'	50°C	<b>60°C</b>
Acceptance	No pitting; weight loss max 4g/m <sup>2</sup> for 24 hours	

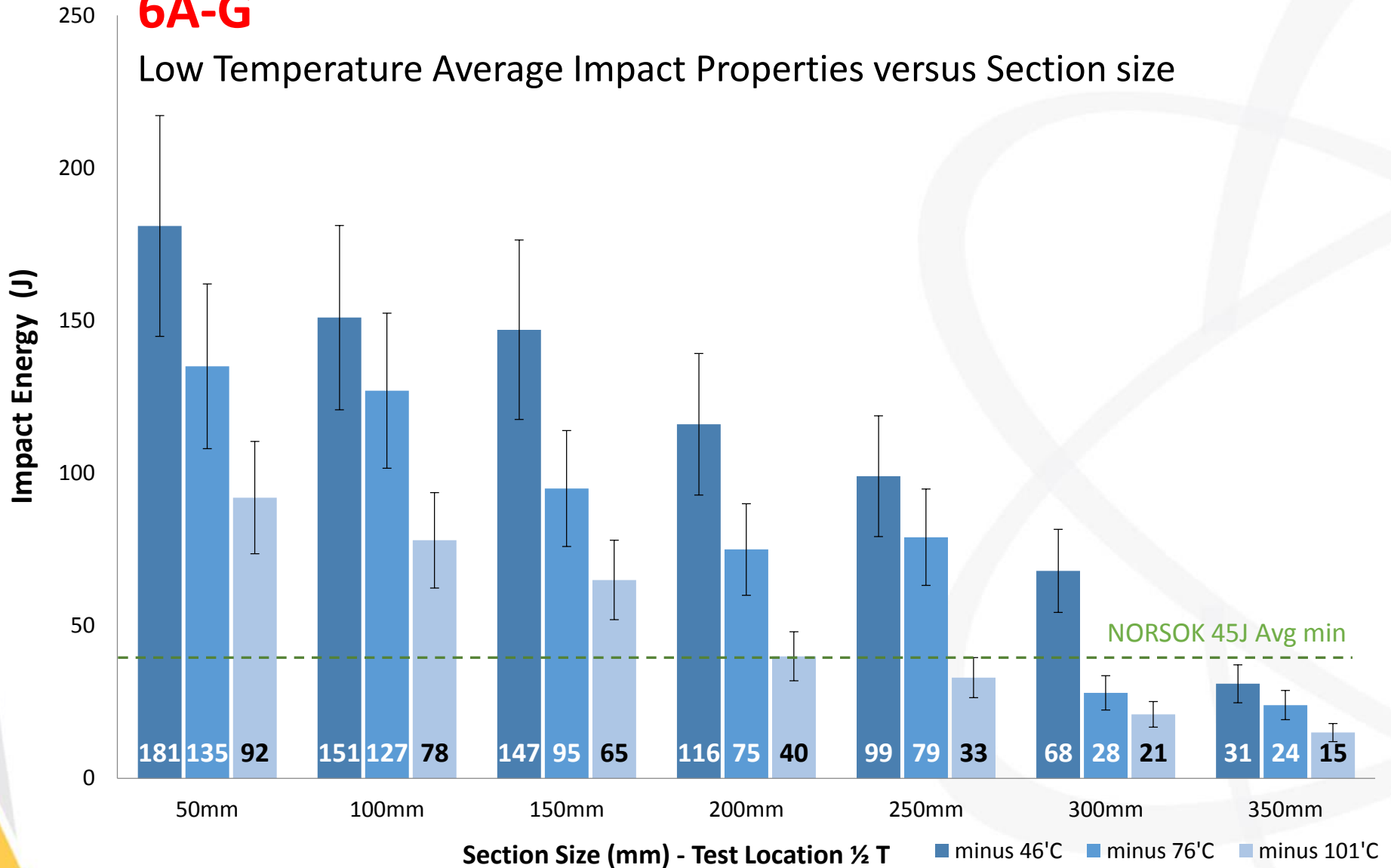
## Low Temperature Impact Property Improvements Using 6A-G

Material	Test Temperature	New Impact Property Minimum s
ASTM A995 6A	-46°C	45J avg; 35J single
<b>6A-G</b>	<b>-46°C</b>	<b>140J avg; 105J single*</b>
<b>6A-G</b>	<b>-76°C</b>	<b>90J avg; 65J single*</b>
<b>6A-G</b>	<b>-101°C</b>	<b>60J avg; 45J single*</b>

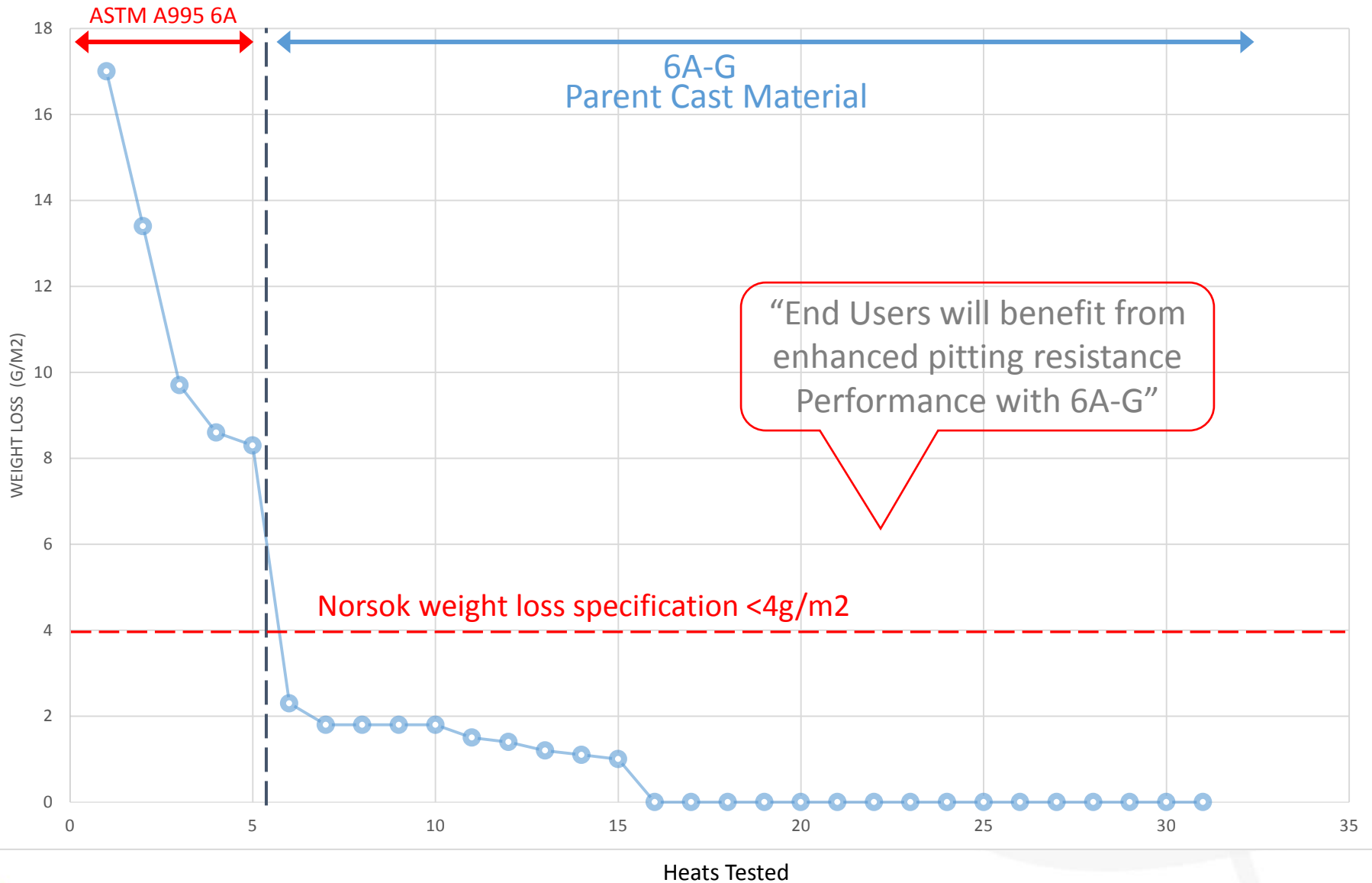
\*Test location is 1/2T position from a 100mm section

# 6A-G

## Low Temperature Average Impact Properties versus Section size

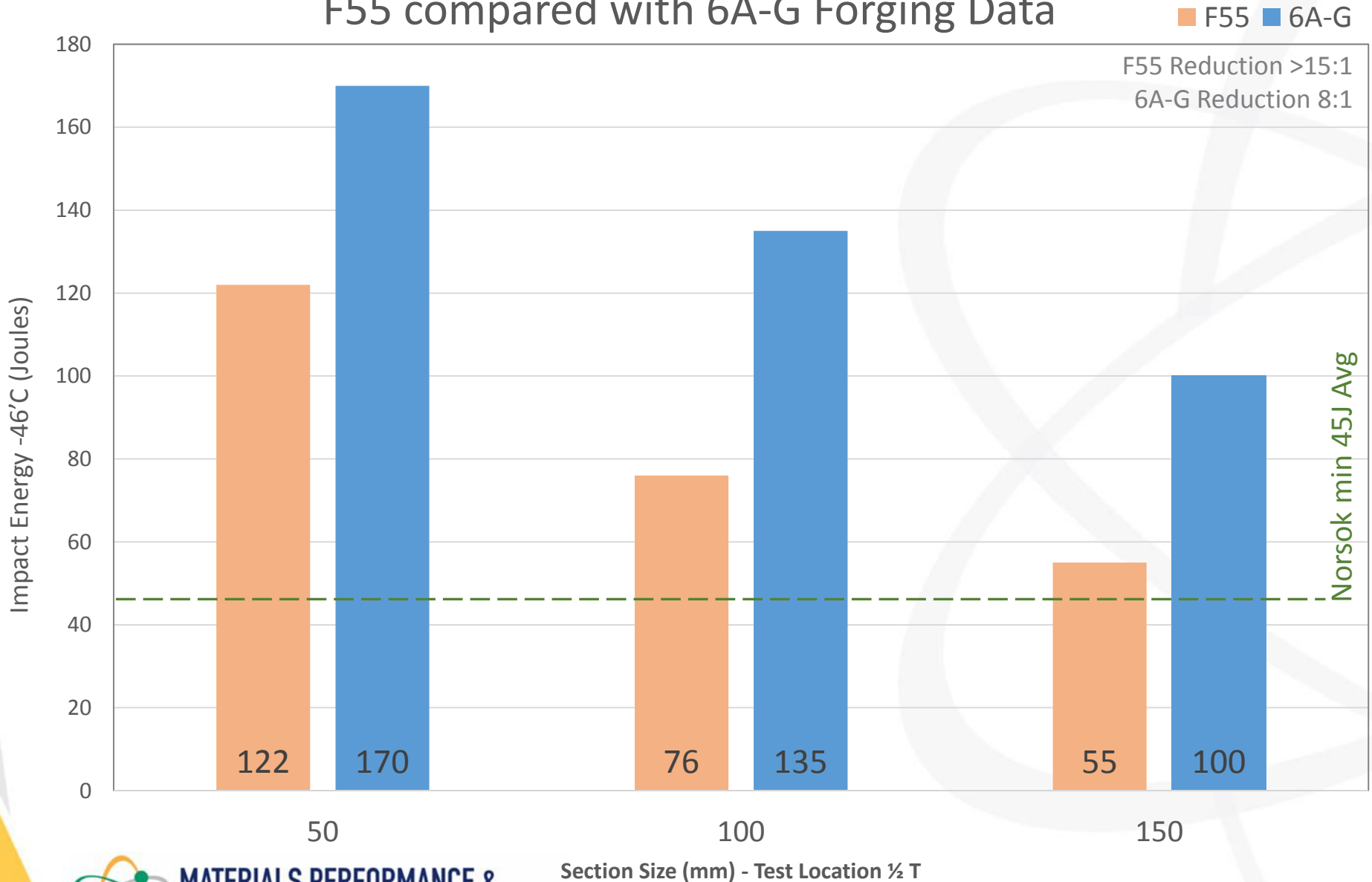


# ASTM G48 Pitting Resistance Test Results – 24hrs at 60°C



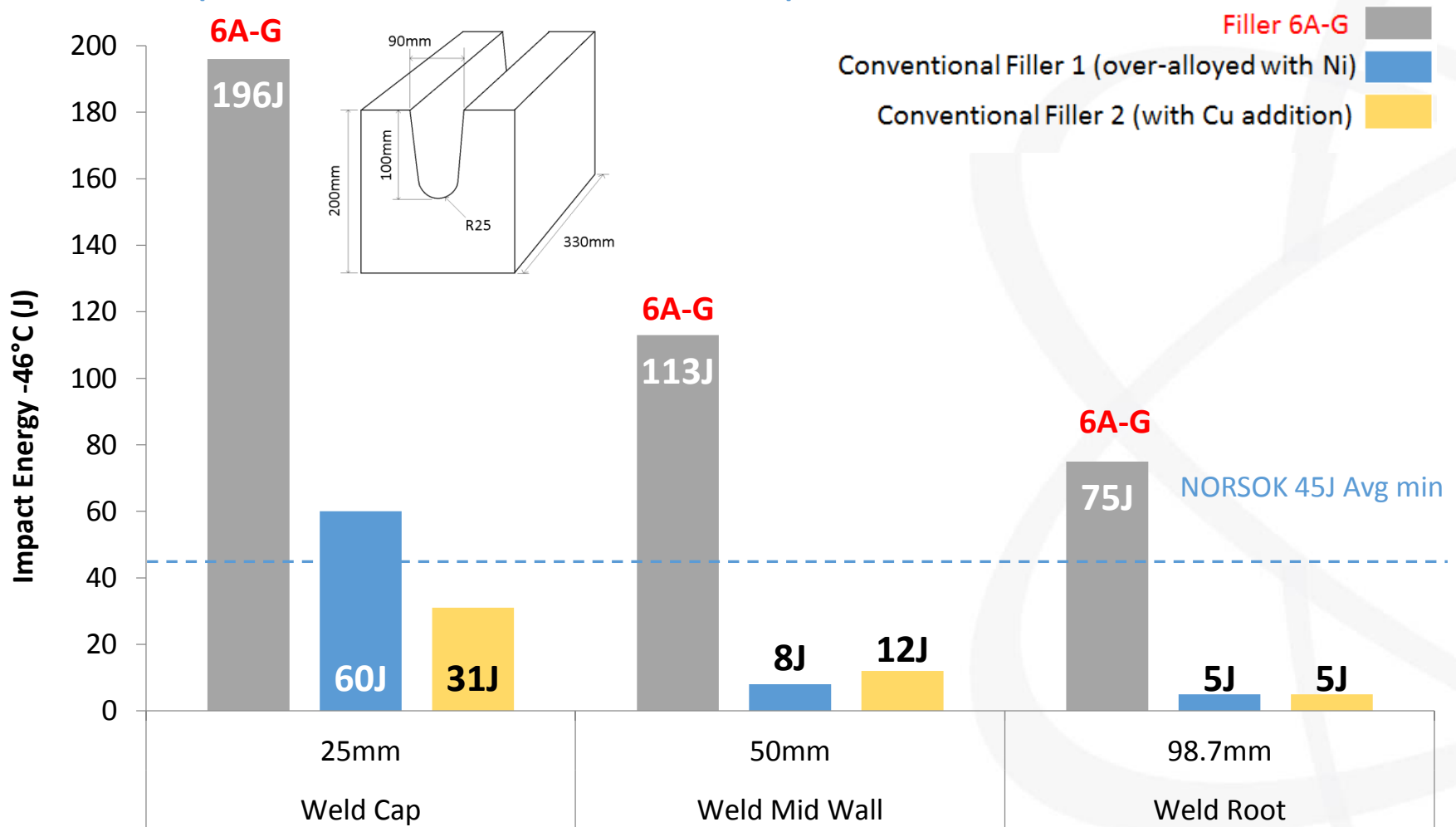
# 6A-G Forging Data

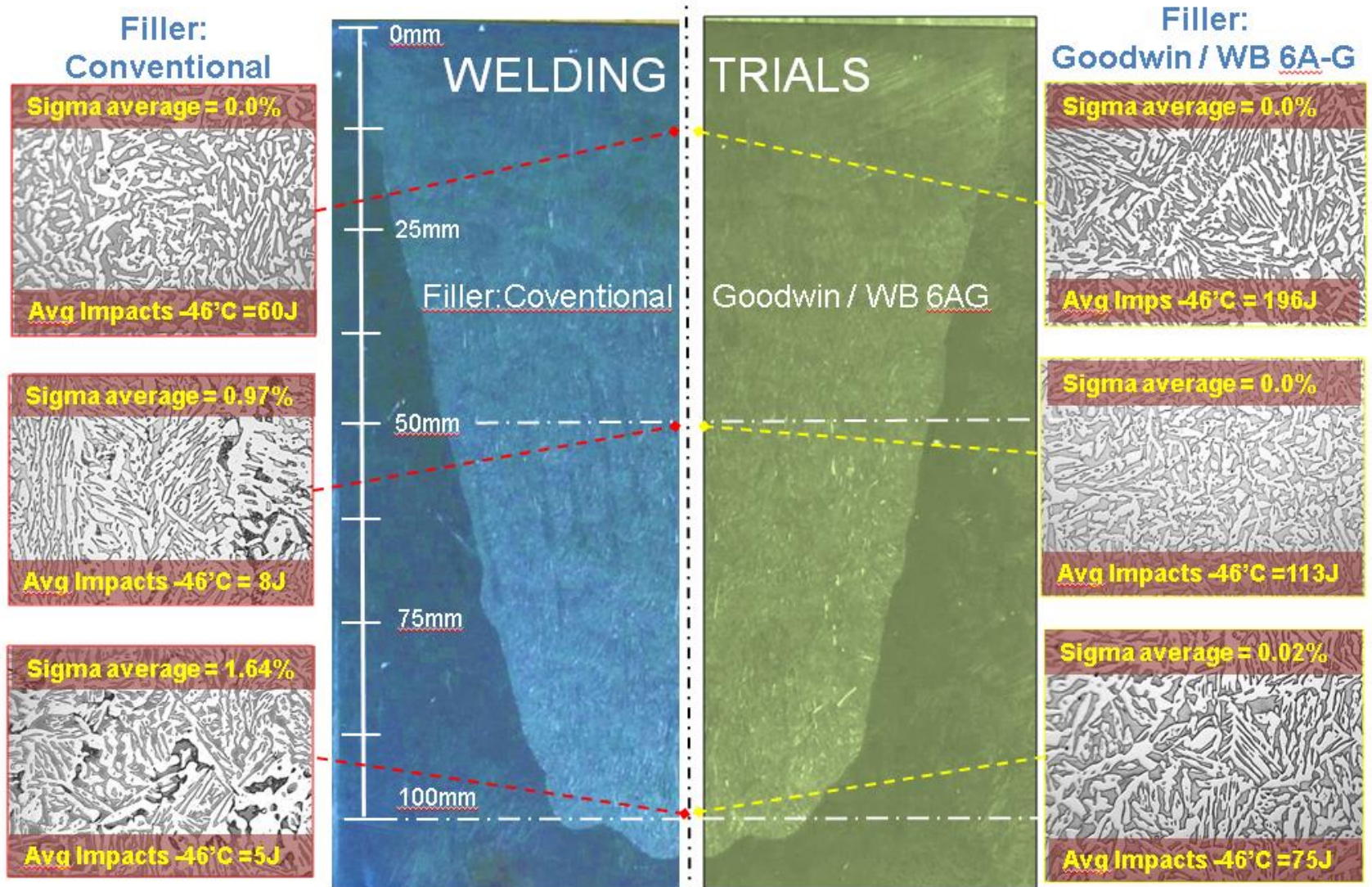
# F55 compared with 6A-G Forging Data



# 6A-G Welding Data

## Heavy Section 100mm weld Impact properties in the "PWHT" condition (Notch Location: Weld metal centre line)



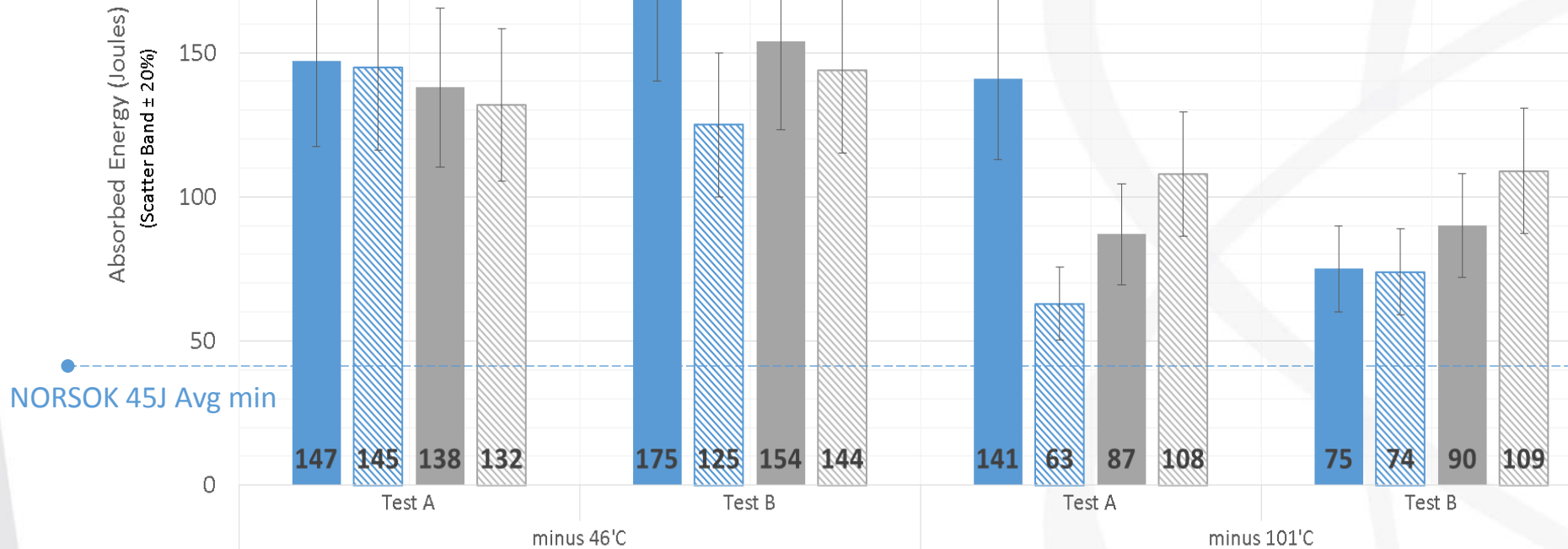
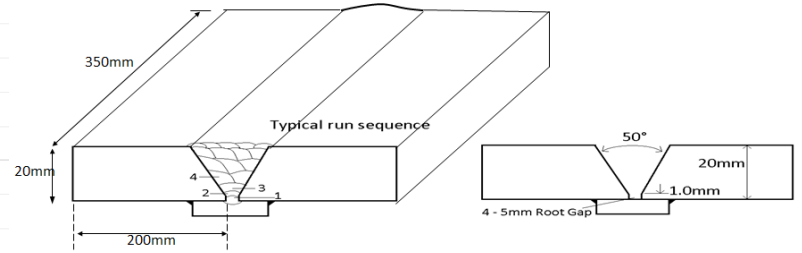


**Post Weld Heat Treated Condition: Solution Treated & Water Quenched  
100mm Groove weld in a 200mm x 200mm x 330mm Test Block**

# 6A-G Avg Impact Values 'As Welded Condition'

20mm Thick Weld Test Plate (Test Location T/2)

**Test Temp -46°C & -101°C**

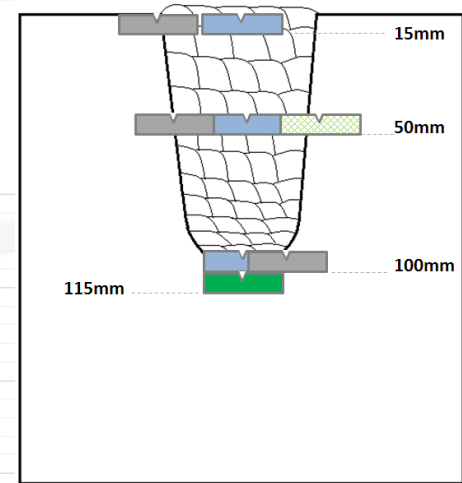


■ Weld 10mm Depth	147
▨ Fusion/L 10mm Depth	145
■ F/L +2mm 10mm Depth	138
▨ F/L +5mm 10mm Depth	132

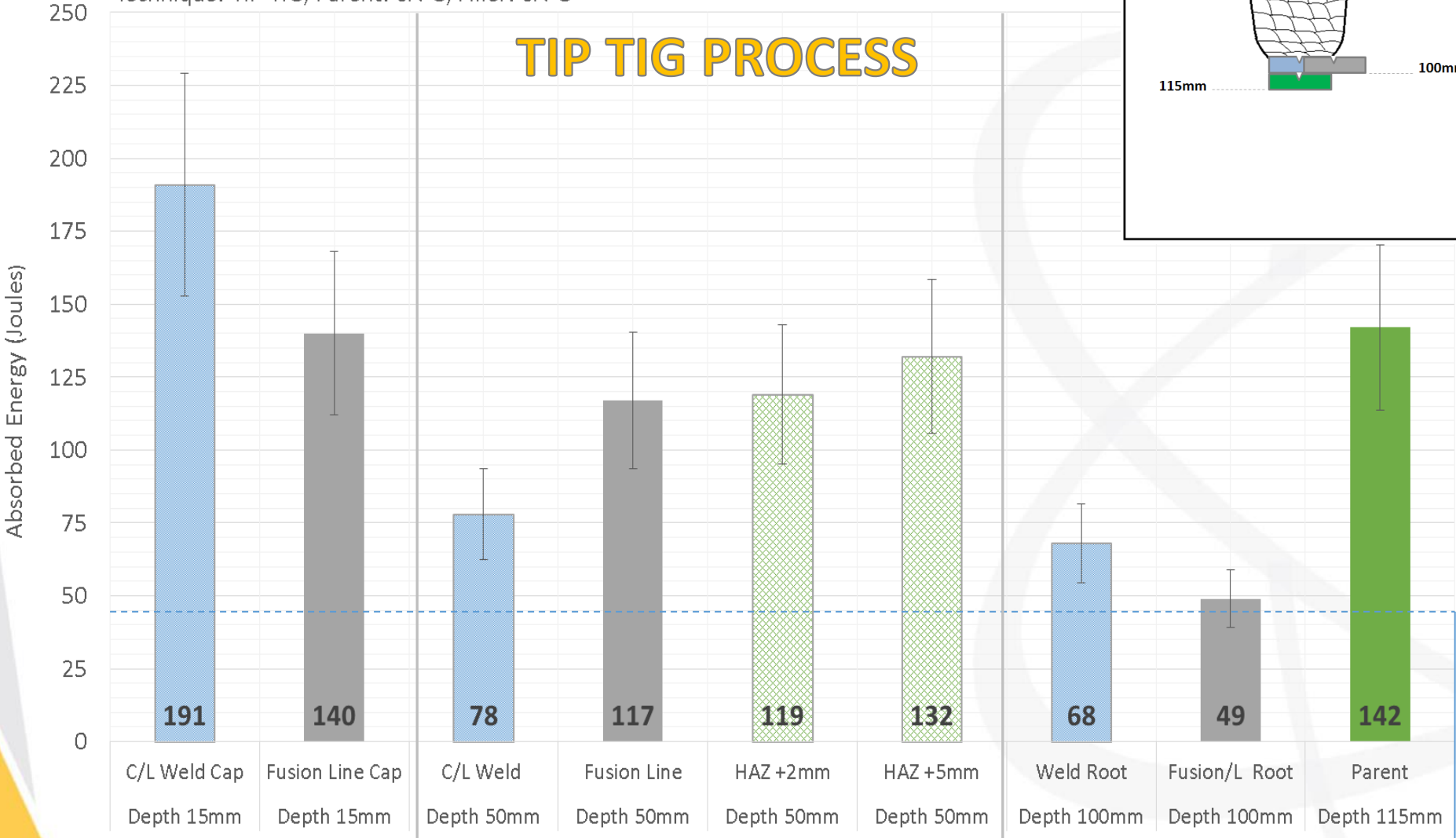
# 6A-G Average Impact Values - Test Temperature : -46'C

PWHT Condition: Solution Treated

Technique: TIP TIG; Parent: 6A-G; Filler: 6A-G



## TIP TIG PROCESS



Norsok min 45J Avg

# Customer Trials....

## CUSTOMER #1 - WB6AG-T – 25.4 mm w/t 203.2mm o/d Parent: 13Cr Base Material

Condition	Weld Process	Sample Location	Test Temperature °C	Results (J) Average	Lateral Expansion (mm)
AS WELDED	GTAW	WCL CAP	-46	207	n/a
AS WELDED	GTAW	WCL MID	-46	122	n/a
AS WELDED	GTAW	WCL ROOT	-46	87	n/a
AS WELDED	GTAW	PARENT	-46	198	n/a
AS WELDED	GTAW	FL CAP	-46	155	n/a
AS WELDED	GTAW	FL MID	-46	145	n/a
AS WELDED	GTAW	FL ROOT	-46	78	n/a
AS WELDED	GTAW	FL +2mm	-46	124	n/a
AS WELDED	GTAW	FL +5mm	-46	154	n/a

## CUSTOMER #2 - WB6AG-T – 12.8mm w/t 255mm o/d Parent: 22Cr Base Material

Condition	Weld Process	Sample Location	Test Temperature °C	Results (J) Average	Lateral Expansion (mm)
AS WELDED	GTAW	WCL CAP	-50	178	n/a
AS WELDED	GTAW	WCL MID	-50	112	n/a
AS WELDED	GTAW	WCL ROOT	-50	69	n/a
AS WELDED	GTAW	PARENT	-50	213	n/a
AS WELDED	GTAW	FL CAP	-50	167	n/a
AS WELDED	GTAW	FL MID	-50	154	n/a
AS WELDED	GTAW	FL ROOT	-50	82	n/a
AS WELDED	GTAW	FL +2mm	-50	139	n/a
AS WELDED	GTAW	FL +5mm	-50	167	n/a

## CUSTOMER #3 WB6AG-T – 12.8mm w/t 255mm o/d Parent: 25Cr Base Material

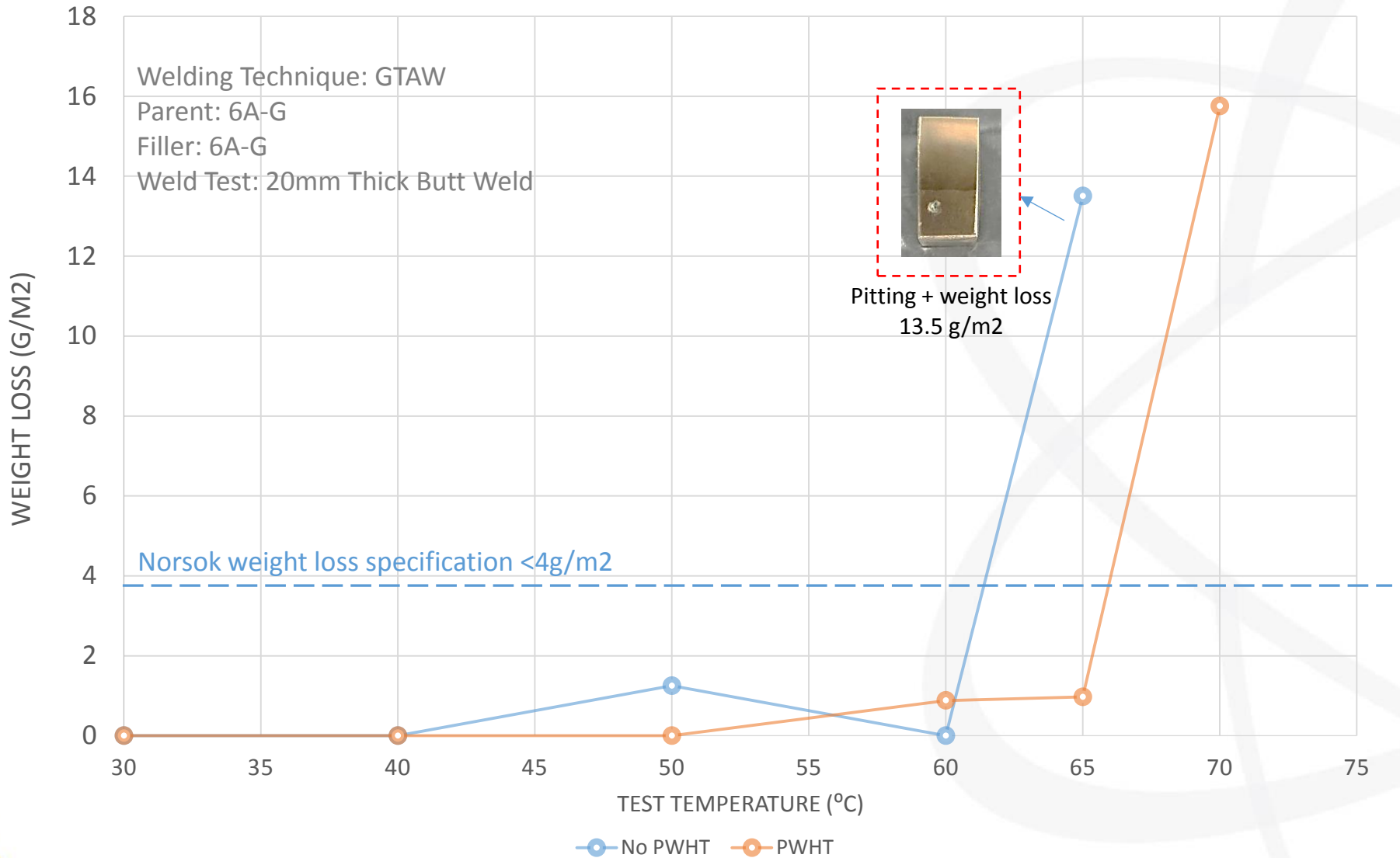
Condition	Weld Process	Sample Location	Test Temperature °C	Results (J) Average	Lateral Expansion (mm)
AS WELDED	GTAW	WCL CAP	-50	228	n/a
AS WELDED	GTAW	WCL MID	-50	278	n/a
AS WELDED	GTAW	WCL ROOT	-50	88	n/a
AS WELDED	GTAW	PARENT	-50	298	n/a
AS WELDED	GTAW	FL CAP	-50	222	n/a
AS WELDED	GTAW	FL MID	-50	210	n/a
AS WELDED	GTAW	FL ROOT	-50	101	n/a
AS WELDED	GTAW	FL +2mm	-50	149	n/a
AS WELDED	GTAW	FL +5mm	-50	198	n/a

### G48 Properties (24 Hour Duration)

Condition	Weld Process	Sample Location	Test Temperature °C	Results
AS WELDED	GTAW	WCL CAP	+50	No pitting or weight loss
AS WELDED	GTAW	WCL MID	+50	No pitting or weight loss
AS WELDED	GTAW	WCL ROOT	+50	No pitting or weight loss
AS WELDED	GTAW	HAZ	+50	No pitting or weight loss

“We normally find it difficult to achieve the G48 pitting corrosion test at 35°C, but with 6A-G we easily achieved our customer requirements”

# 6A-G - G48 Method A Test Results – Test Duration 24hrs



# CONCLUSIONS.....

## Benefits of Specifying 6A-G Super Duplex over Conventional ASTM Gr.6A Super Duplex

### Improved Corrosion Resistance

- Offers enhanced G48 method A pitting corrosion resistance values over conventional grades of 25% duplex steel on like for like sections with weight loss values  $<4\text{g/m}^2$  when tested for 24hrs.

### Improved Impact Properties

- Vastly enhanced low temperature impact properties over the conventional 25% Cr duplex steel grades giving a greater level of safety. Impact values meet the Norsok requirements at minus  $101^{\circ}\text{C}$ .

### Increased Section Sizes

- Crucially enabling heavier sections greater than 250mm to be successfully produced both in castings and forgings, while maintaining excellent through section impact strength and corrosion performance.

# CONCLUSIONS.....

“The performance of the new cast, wrought, forged and weld metal material substantially surpasses what has historically been possible to consistently achieve in terms of....”

- a) Low temperature impact properties.
- b) Pitting corrosion properties

“Both in the post weld heat treated and as welded condition”

“The low temperature performance of this new duplex steel also increases the envelope of operational conditions”

“The new 6AG super duplex material can be confidently operated at temperatures down to  $-101^{\circ}\text{C}$ ”

# Market Opportunities....

**Countries where ambient out of the sun temperature is  $>30^{\circ}\text{C}$**

**Desalination, oil & gas offshore & other appliances where line temperatures are  $> 40^{\circ}\text{C}$**

**Assisting the guarantee of impact resistance properties**

**To use the full corrosion capacity of 25% Cr super duplex (even in the "as welded" condition  $50^{\circ}\text{C}$  corrosion resistance not  $40^{\circ}\text{C}$ )**

**The opportunity to lower cost by substituting more nickel rich alloys such as 6%Mo Austenitic steels and obtain similar corrosion resistance & much lower component weight due to the higher strength of super duplex**

**To design thicker walled higher pressure pumps & valves in 25% Cr super duplex with cross section  $> 250\text{mm}$**

# Questions & Answers Stand A8

Enquiries for the 6A-G manufacturing licence or own branded distribution agreement for 6A-G welding consumables please email:

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