Analysis of Data from NIST Technical Note 1858

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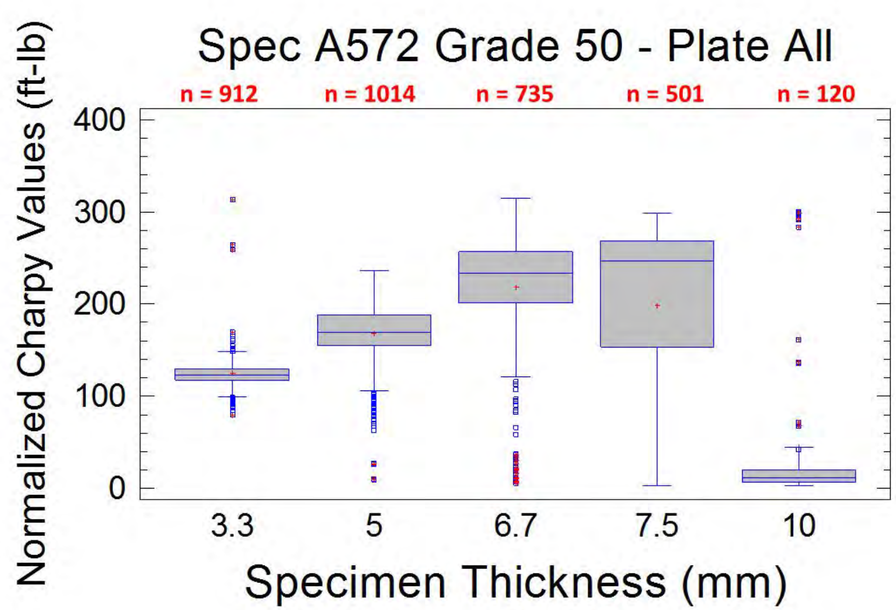
UAB

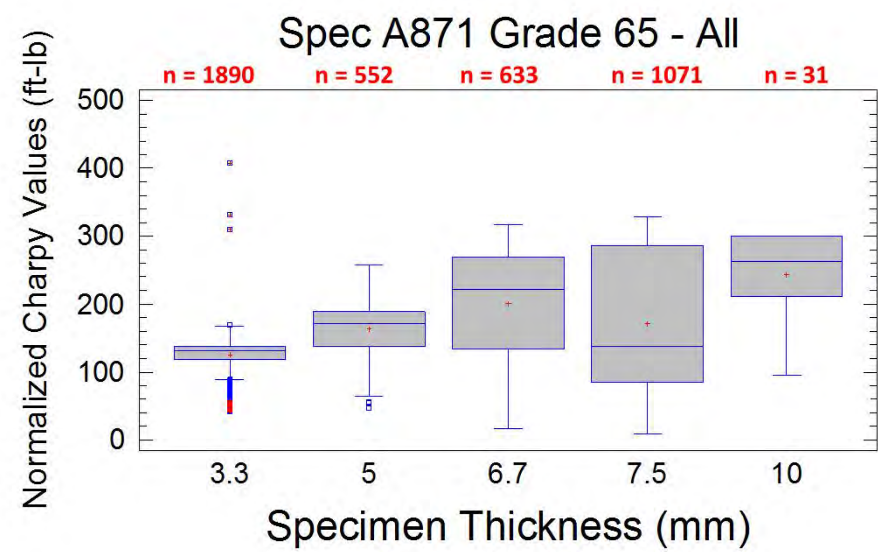
- **There are limitations to the values produced by a Charpy test**
- **One limitation is that specimen width will change the ductile-brittle transition**
  - **caused by a decrease in tri-axial stress at the notch tip in the reduced width specimens**
  - **increases the volume of steel plastically deformed during the test and hence increases impact values**
- **Charpy impact values are not a material property and they are affected by the size of the specimens tested**
  - **dynamic tear test and the drop-weight tear test were developed to allow full thickness plate to be tested.**

All tests at -20F, perpendicular notch orientation, and longitudinal specimen orientation. Normalized for area by dividing by ratio of specimen thickness divided by 10 (Table 9). All plate locations (plate middle, plate outside, plate tail)



n = number of individual values

Normalized Charpy values vs. specimen thickness – all



n = number of individual values

Normalized Charpy values vs. specimen thickness – all

Question

Does the DBTT shift allowed in Table 9 (ASME Boiler and Pressure Vessel Code, Table UG-84.2) work? Wallin or Towers?

$$\Delta T = 51.4 * \ln(2 * (t/10)^{0.25} - 1) \quad (1)$$

$$\Delta T = 0.7 * (10 - t)^{2} \quad (2)$$

where T = temperature (C)
t = width (mm)

- **If 15 ft-lb is designated by the customer as ductile, then 3.8 ft-lb/0.1 inch width is the minimum requirement – shown as the horizontal red line**
- **The customer also requires a test temperature of 30C (the vertical red line) and the steel thickness only allows a ½ size (5mm) specimen to be tested**
- **The 5mm Charpy impact curve crosses the 30C line at about 12.5 ft-lb/0.1 inch (25 ft-lb actual)**
- **If the customer wanted this value converted to a full size specimen using Table 9 only, the value would be 50 ft-lb**
- **But the graph also shows that a 10mm full size specimen only produces 5 ft-lb/0.1 inch (20 ft-lb actual)**

- **For a ½ size specimen, ASME, Wallin, and Towers recommends a temperature shift of 11C (green line), 19.7C (yellow line), and 17.5C (blue line), respectively**
- **These lines cross the 5mm DBTT curve at values ranging from 5 to 7.5 ft-lb/0.1 inch 20 to 30 ft-lb actual), much closer to the value from the 10mm specimen.**

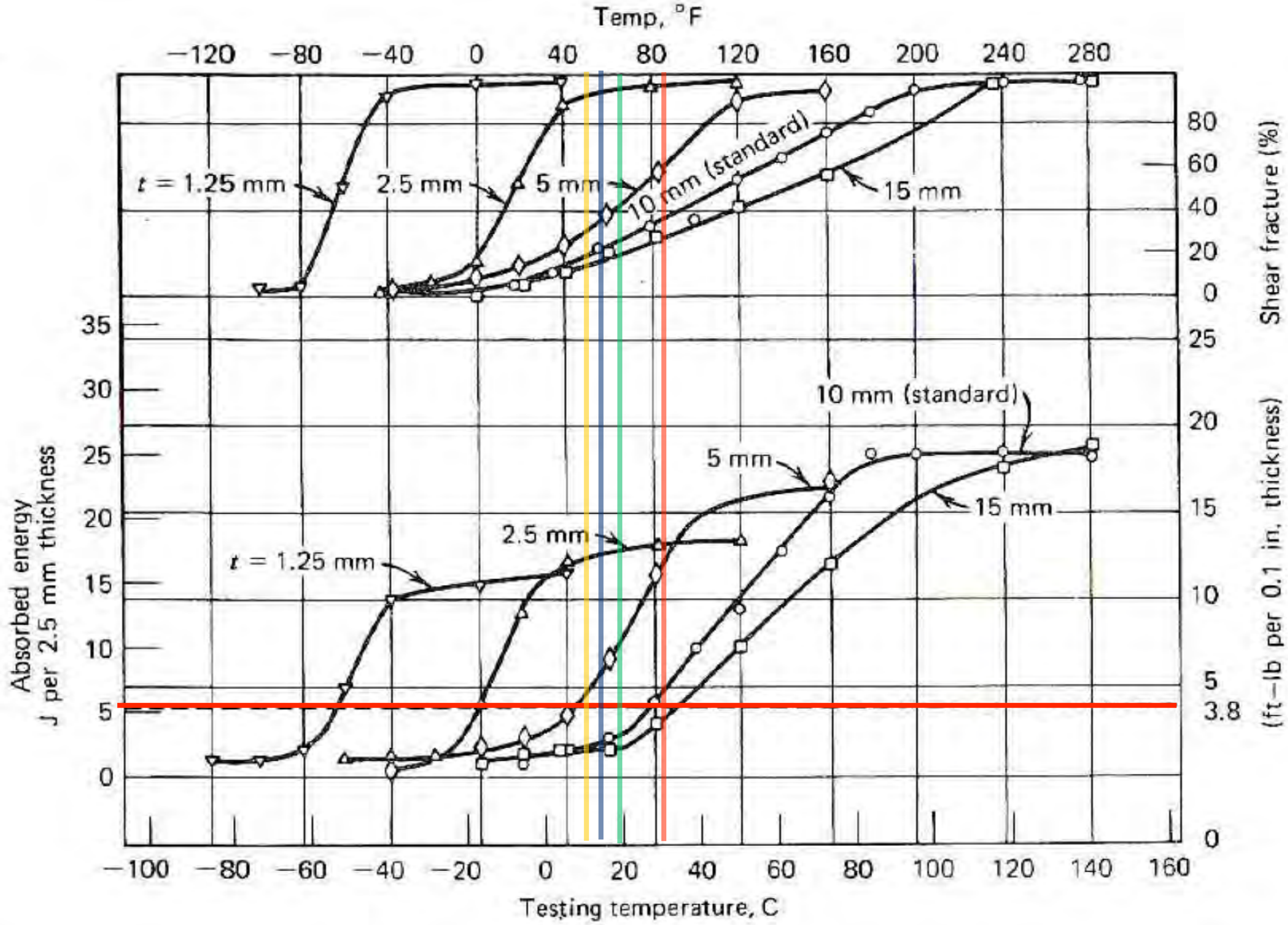


FIGURE 9.11 Adjusted energy-temperature curves and shear fracture–temperature curves for 38-mm-thick plate of A283 steel tested with Charpy V-notch specimens of various thicknesses. Absorbed energy defined at 5.2 J/2.5 mm (3.8 ft-lb/0.1 in.) of specimen thickness.[6] (Reprinted from *Welding Journal* by permission of the American Welding Society.)

- Calculate curve fit equations as per NIST TN 1858
- Use equations to predict impact value at reduced test temperature as per ASME/Wallin/Towers
- Compare to actual impact values

$$Y = A + B \tanh \frac{X - DBTT}{C}$$

Full Size

						A+B		
-198	12.27	15.82	12.58	A	63.5			
-150	24.61	18.76	34.24	B	47.9		111	111.4
-120	27.44	30.46	9.145	C	35.7			
-90	64.04	63.23	0.654	D	-89.8			
-60	96.89	96.27	0.383					
-30	106.2	108.2	3.87					
21	107.8	111.3	11.78					
50	120.4	111.4	81.61					
100	125.8	111.4	207					
	x^2		361.3					

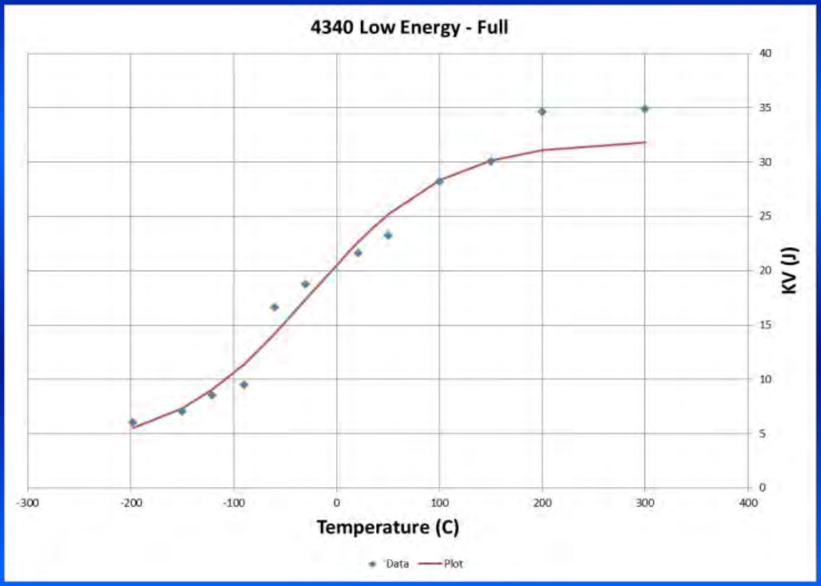
3/4 Size

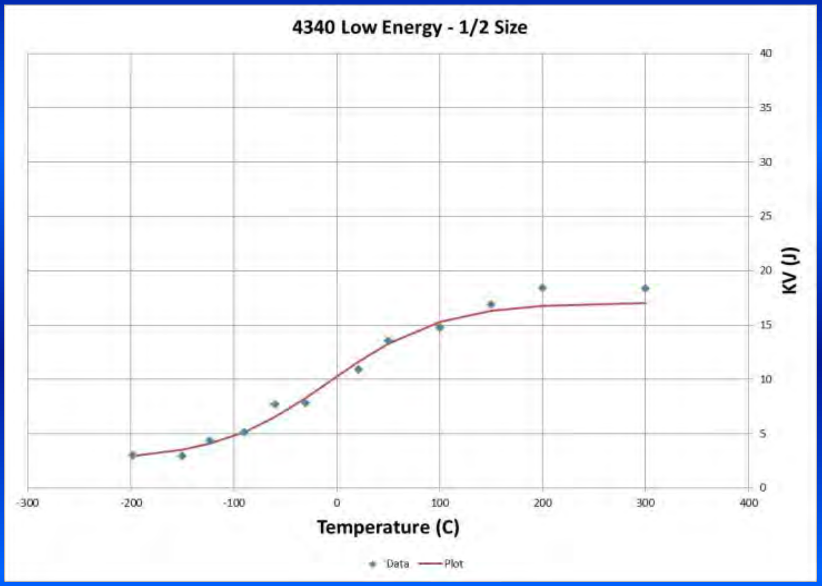
						A+B		
-198	13.2	15.44	5.011	A	47.3			
-150	17.51	15.58	3.73	B	31.8		79	79.1
-120	20.23	18.87	1.851	C	18.5			
-100	33.29	36.53	10.5	D	-93.5			
-90	56.57	53.23	11.14					
-60	71.12	77.44	40.01					
-30	78.4	79.03	0.402					
21	79.84	79.1	0.548					
50	87.16	79.1	64.96					
	x^2		138.1					

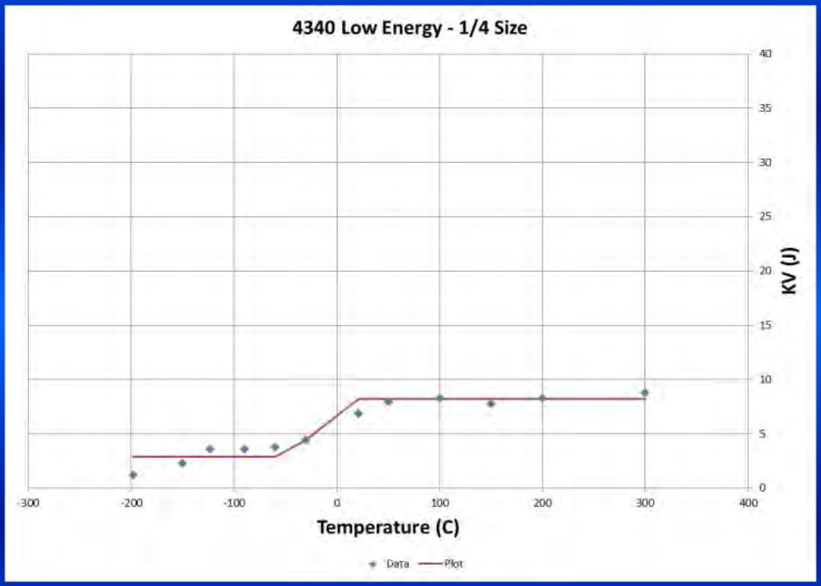
1/2 Size

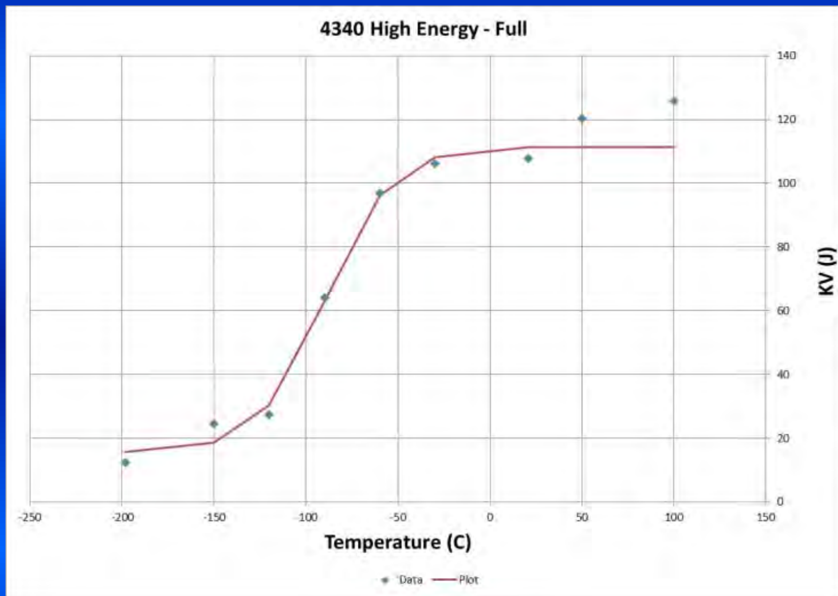
						A+B		
-198	10.82	12.12	1.689	A	29.2			
-150	10.97	12.12	1.322	B	17.0		46	46.2
-120	14.73	12.21	6.327	C	8.1			
-100	21.55	21.66	0.011	D	-96.2			
-90	40.19	40.09	0.01					
-60	45.06	46.2	1.289					
-30	45.79	46.2	0.168					
21	47.9	46.2	2.89					
50	51.97	46.2	33.29					
	x^2		47					

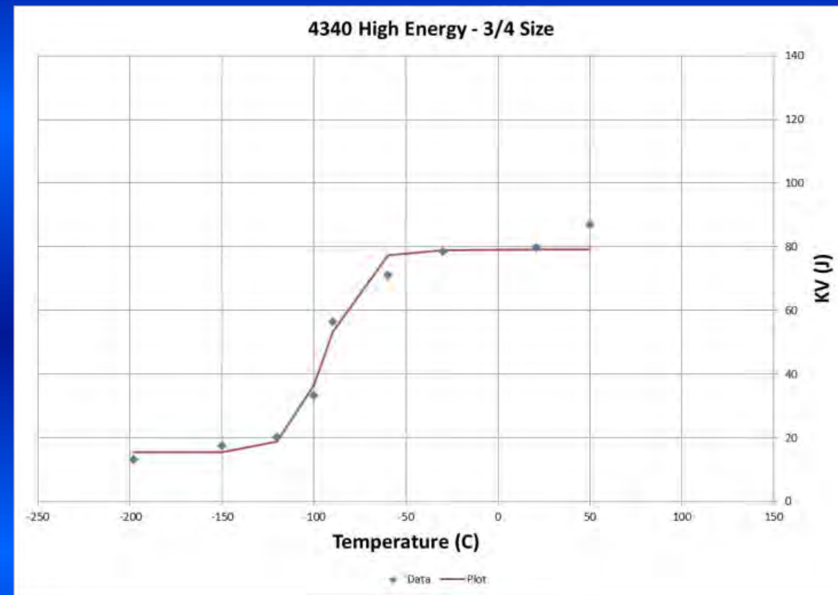
- **4340 High Energy Data - KV**
- **Used Excel Solver**
- **Constraint – A+B = average of all values with > 95% SFA**
- **Almost all DBTT values matched NIST including LE and SFA**

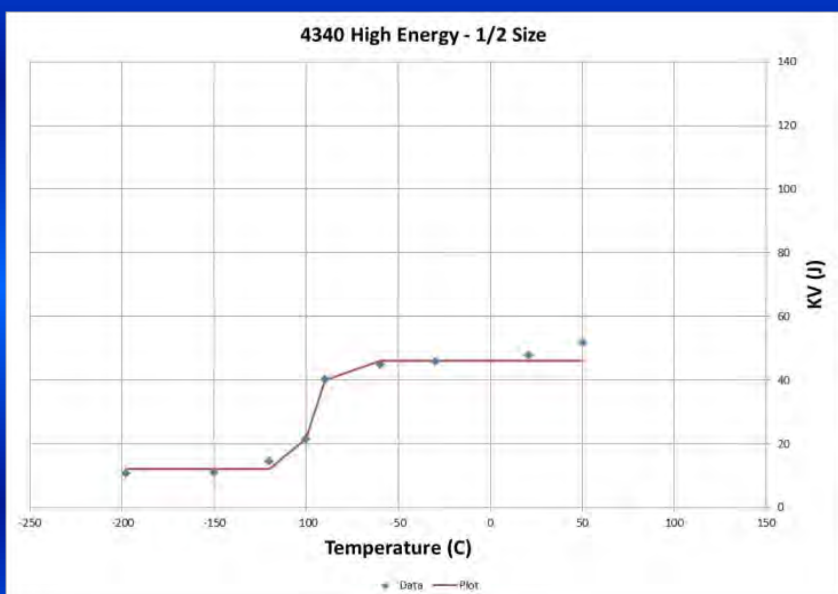

4340 Low Energy - Full
Temperature (C)
KV (J)
Data
Plot

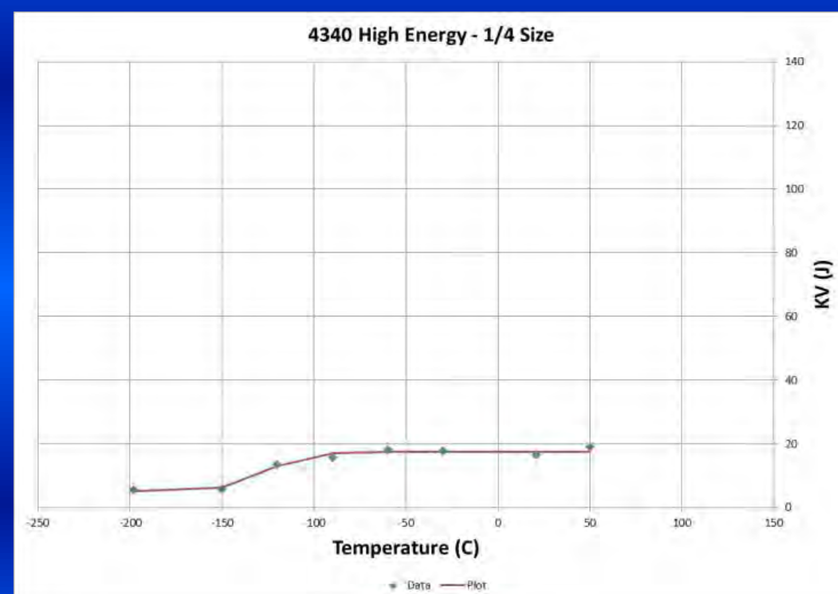

4340 Low Energy - 1/2 Size
Temperature (C)
KV (J)
Data
Plot

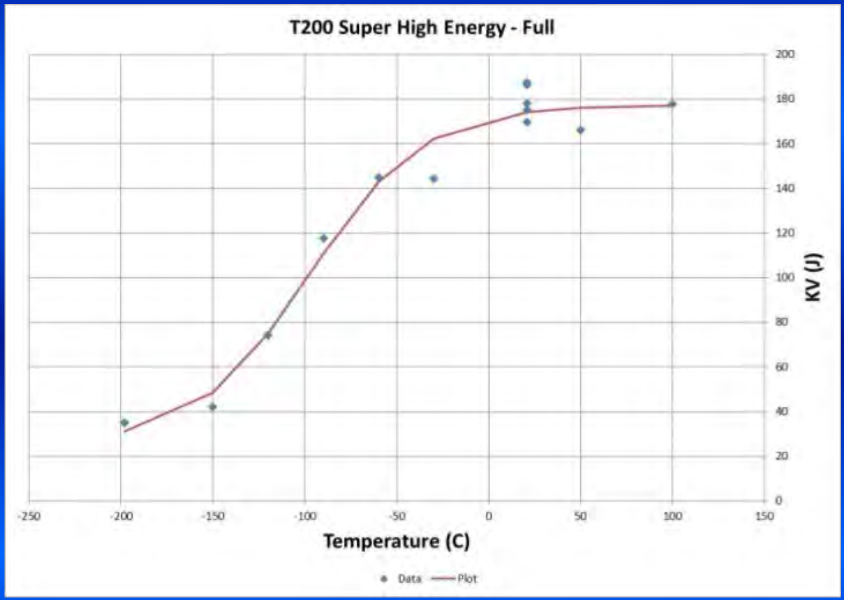

4340 Low Energy - 1/4 Size
Temperature (C)
KV (J)
Data
Plot


4340 High Energy - Full
140
120
100
80
60
40
20
0
KV (J)
-250
-200
-150
-100
-50
0
50
100
150
Temperature (C)
Data
Plot

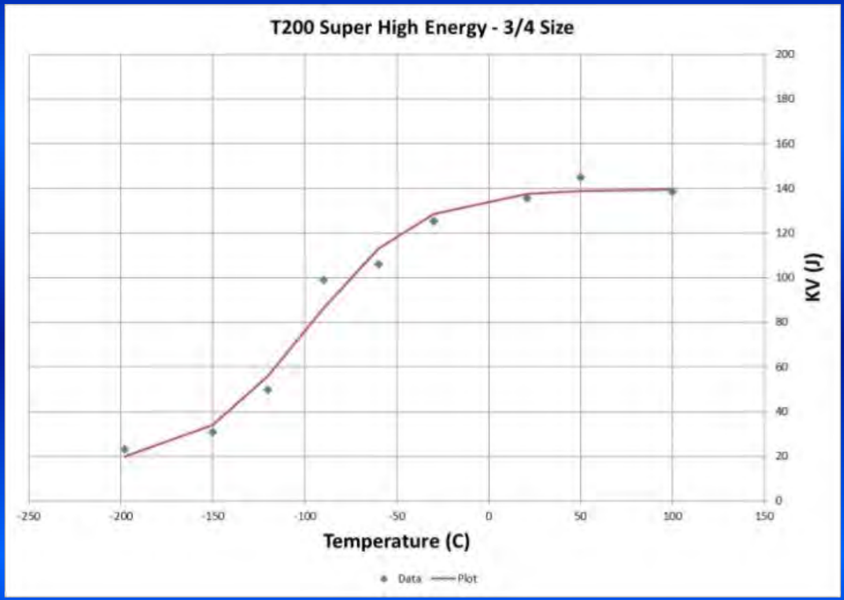

4340 High Energy - 3/4 Size
140
120
100
80
60
40
20
0
KV (J)
-250
-200
-150
-100
-50
0
50
100
150
Temperature (C)
Data
Plot


4340 High Energy - 1/2 Size
140
120
100
80
60
40
20
0
KV (J)
-250
-200
-150
-100
-50
0
50
100
150
Temperature (C)
Data
Plot

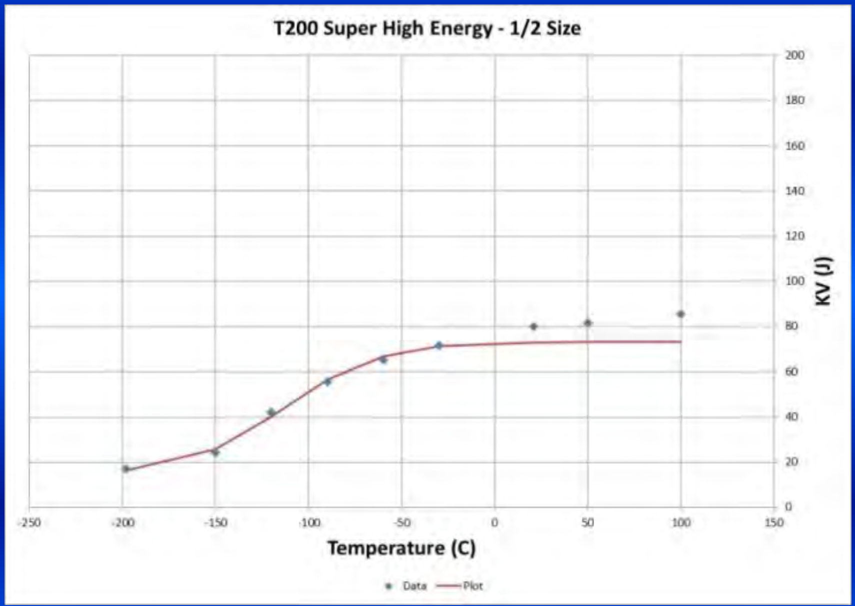

4340 High Energy - 1/4 Size
140
120
100
80
60
40
20
0
KV (J)
-250
-200
-150
-100
-50
0
50
100
150
Temperature (C)
Data
Plot



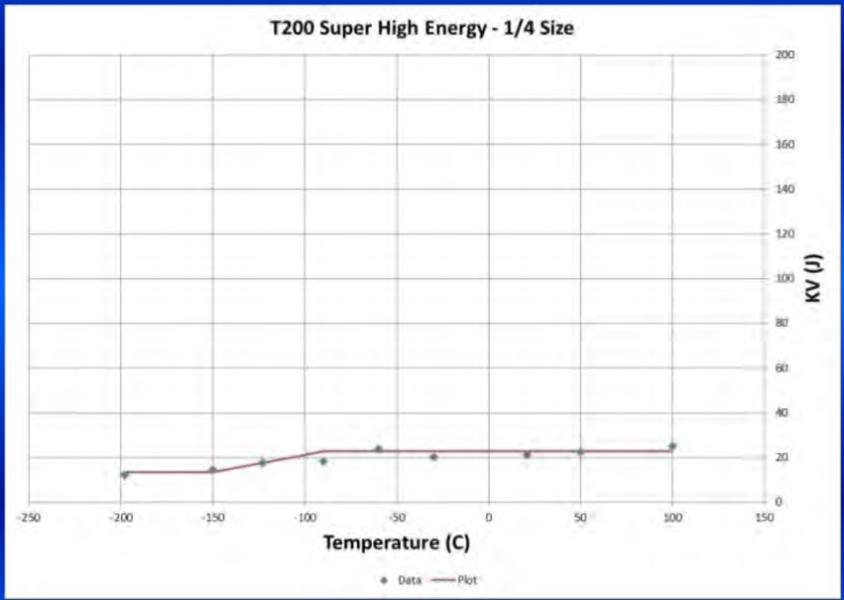
T200 Super High Energy - Full
Temperature (C)
KV (J)
Data
Plot



T200 Super High Energy - 3/4 Size
Temperature (C)
KV (J)
Data
Plot



T200 Super High Energy - 1/2 Size
Temperature (C)
KV (J)
Data
Plot



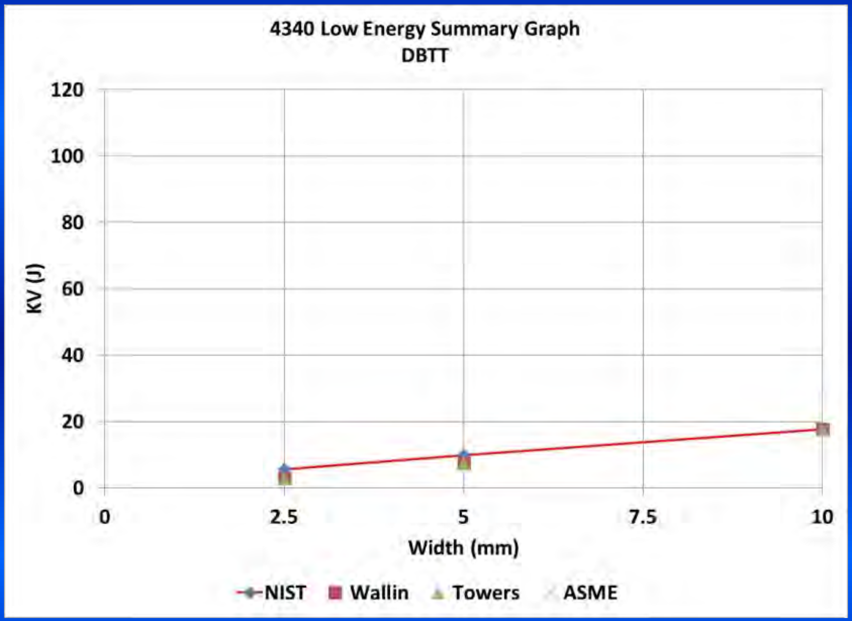
T200 Super High Energy - 1/4 Size
Temperature (C)
KV (J)
Data
Plot

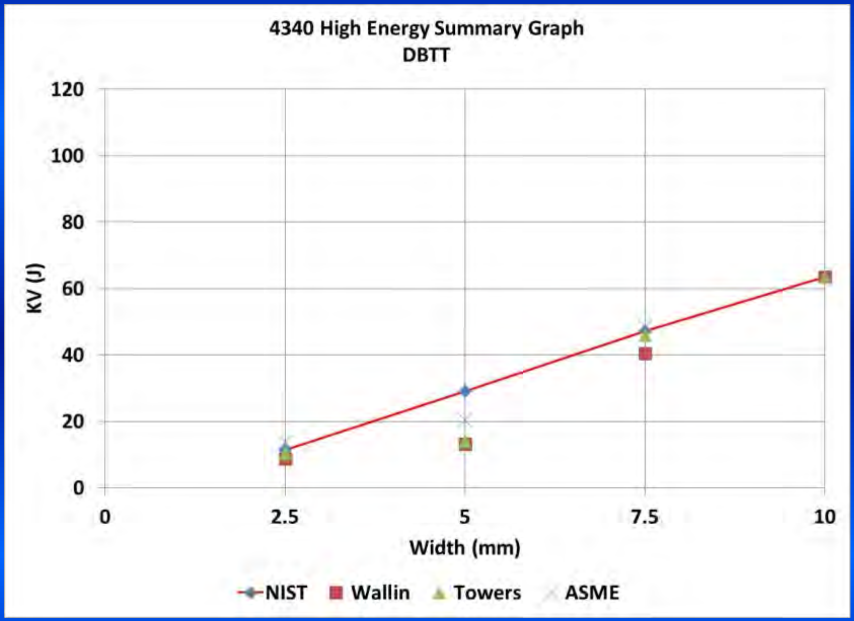
	NIST	DBTT	Wallin	Towers	ASME
	T	Delta T			
4340 High Energy					
10	-89.8	0	0.0	0.0	0
7.5	-93.5	-3.7	-7.7	-4.4	-3
5	-96.2	-6.4	-19.7	-17.5	-11
2.5	-126	-36.2	-45.3	-39.4	-28
at DBTT	J	J	J	J	J
10		63.5	63.5	63.5	63.5
7.5		47.3	40.5	46.1	48.5
5		29.1	13.3	14.2	20.4
2.5		11.4	8.8	10.4	13.7

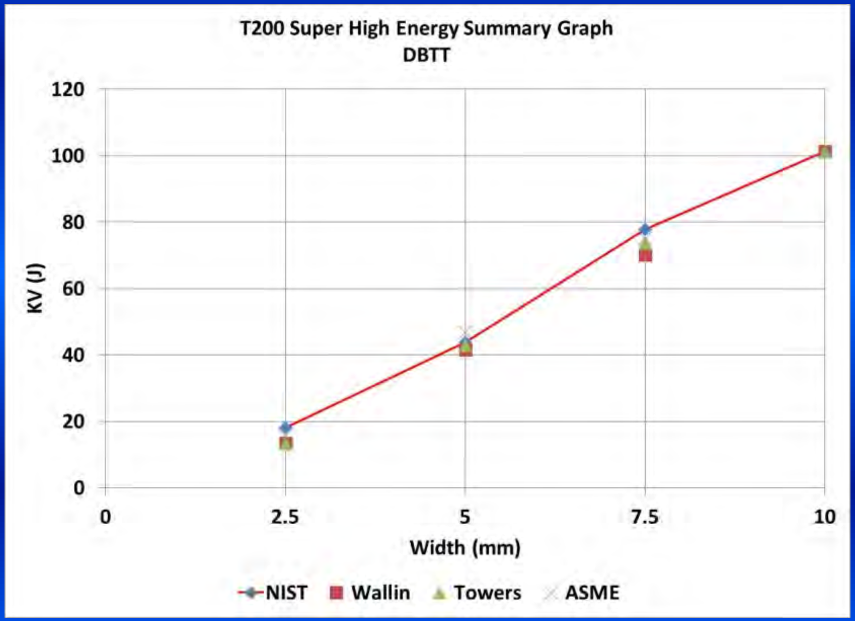
- **4340 High Energy data - KV**
- **At DBTT – should be most sensitive to DBTT shift**

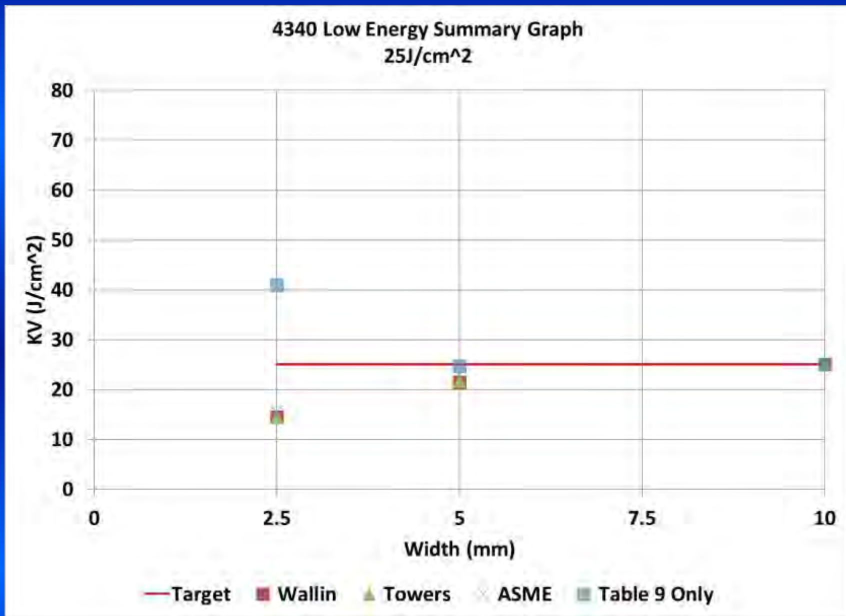
			35J/cm^2	28J or 20 ft-lb in a full size specimen			
		NIST		Wallin	Towers	ASME	Table 9 Only
	J	T	Delta T				
4340 High Energy							
10	28	-124	0				
7.5	21	-115	9	-7.7	-4.4	-3	
5	14	-107	17	-19.7	-17.5	-11	
2.5	7	-144	-20	-45.3	-39.4	-28	
35J/cm^2		J		J	J	J	J
10		28		28	28	28	28
7.5		21		16.4	16.9	17.1	17.7
5		14		12.1	12.1	12.1	12.2
2.5		7		5.4	5.5	6.1	12

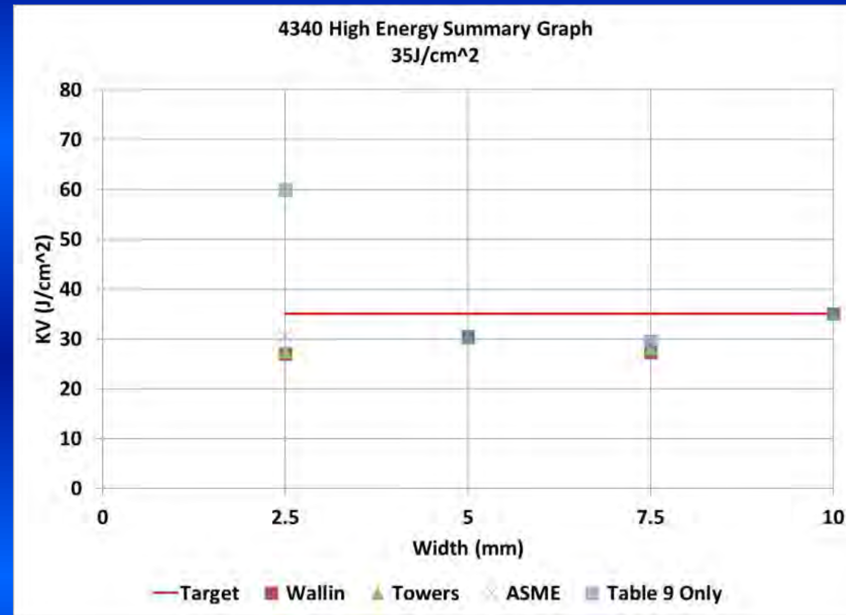
- **At 28J full size for 4340 and 56J full size for T200 – what most users are interested in**

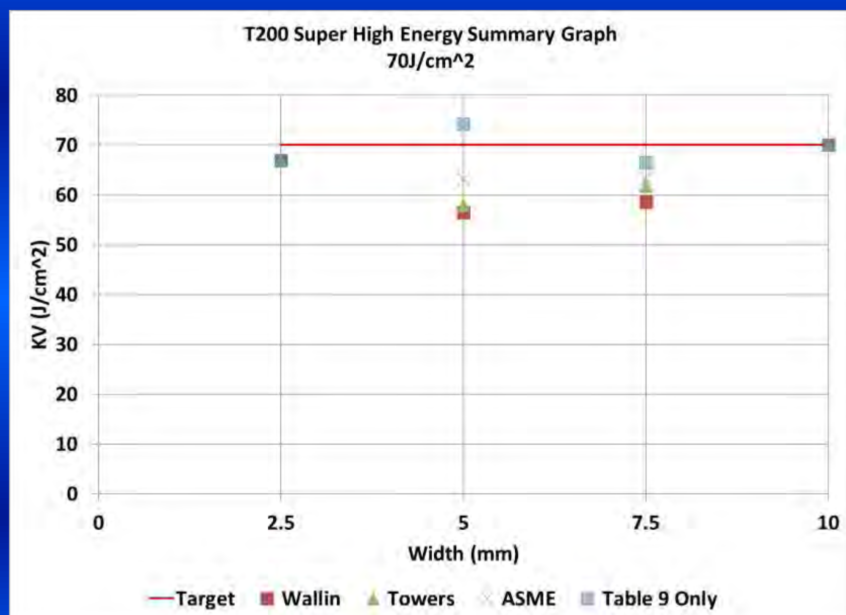

4340 Low Energy Summary Graph
DBTT
KV (J)
120
100
80
60
40
20
0
0
2.5
5
7.5
10
Width (mm)
NIST
Wallin
Towers
ASME


4340 High Energy Summary Graph
DBTT
KV (J)
120
100
80
60
40
20
0
0
2.5
5
7.5
10
Width (mm)
NIST
Wallin
Towers
ASME


T200 Super High Energy Summary Graph
DBTT
KV (J)
120
100
80
60
40
20
0
0
2.5
5
7.5
10
Width (mm)
NIST
Wallin
Towers
ASME


4340 Low Energy Summary Graph
25J/cm^2
KV (J/cm^2)
80
70
60
50
40
30
20
10
0
0
2.5
5
7.5
10
Width (mm)
Target
Wallin
Towers
ASME
Table 9 Only


4340 High Energy Summary Graph
35J/cm^2
KV (J/cm^2)
80
70
60
50
40
30
20
10
0
0
2.5
5
7.5
10
Width (mm)
Target
Wallin
Towers
ASME
Table 9 Only


T200 Super High Energy Summary Graph
70J/cm^2
KV (J/cm^2)
80
70
60
50
40
30
20
10
0
0
2.5
5
7.5
10
Width (mm)
Target
Wallin
Towers
ASME
Table 9 Only

Conclusions

- All three DBTT shift corrections work reasonable well and conservatively for the data available and the impact values selected
- Using area correction without DBTT shift correction (Table 9 only) can produce non-conservative values with ½ and ¼ size specimens