MC INTERPRETATION OF THE TSE DATA

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John Merkle's December 2003 Presentation

Logic Underlying RT_{T0}

1. The proposed definition of RT_{T0} , relies heavily on the large size of the PVRC database, in order to demonstrate consistency, and justify the conclusion of functional (i.e. statistical) equivalence with RT_{NDT}.

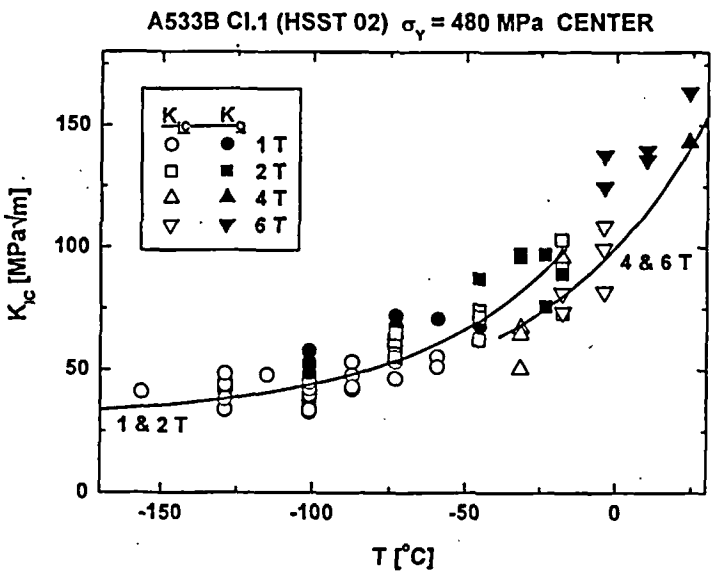
2. An important, but unstated, assumption has been made in the course of defining functional equivalence. RT_{T0} has been shown to index the ASME K_{Ic} curve in such a way that it has the same statistical significance with respect to 1-T size adjusted fracture toughness data as the same curve, indexed by RT_{NDT}, has with respect to E-399-valid K_{Ic} data.

3. But 1-T size-adjusted data are generally higher than valid K_{Ic} data.

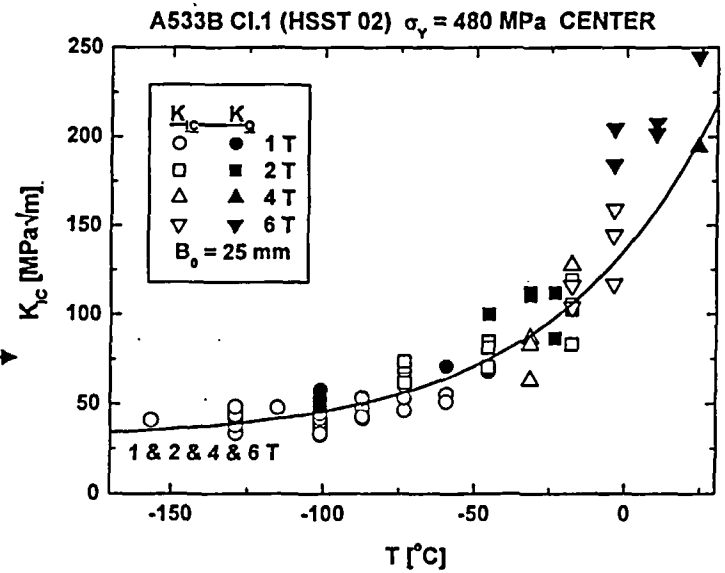
4. The unstated assumption is that the Weibull size-effect is universal. Implicitly, K_{Ic} as a size-independent material property, beyond a certain size, is assumed not to exist.

5. Although the Weibull size-effect is observed to effectively operate for relatively small, geometrically two-dimensional, laboratory specimens, no general proof of its universal applicability exists. This is especially true for shallow, finite-length, surface cracks subject to multiaxial nominal stresses and steep stress gradients.

The HSST-02 plate

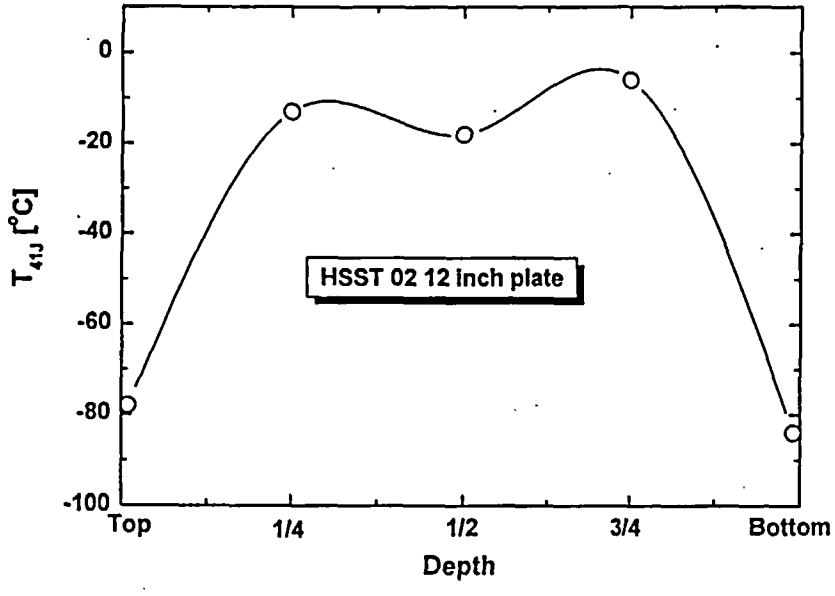


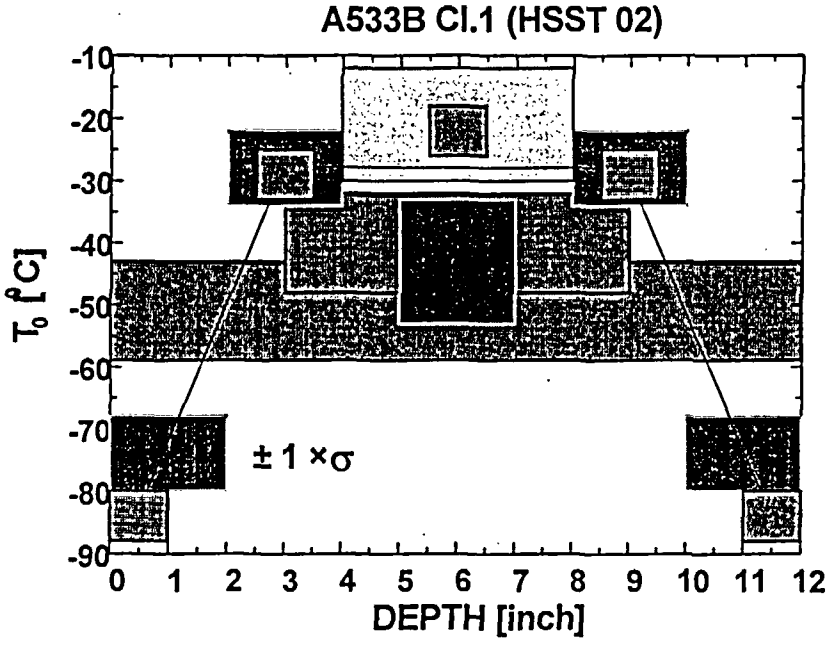
Size effec t



The HSST-02 plate show size effect from 1T to 6T

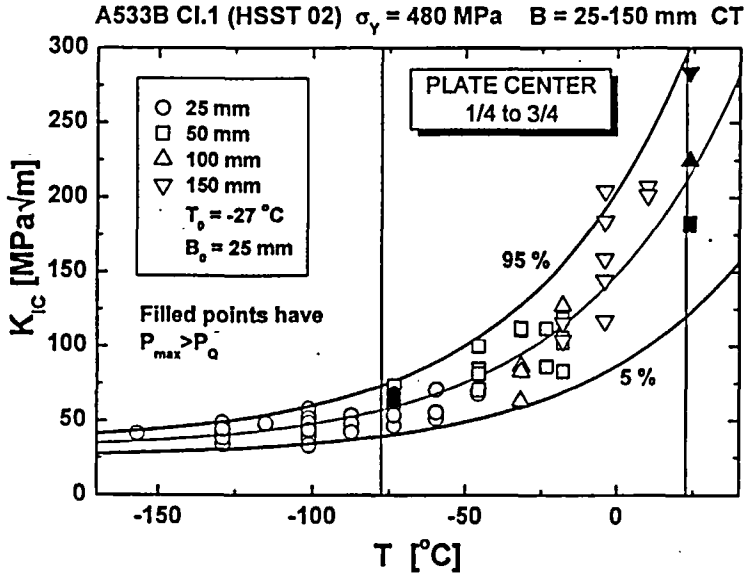
Inhomogeneity in HSST-02

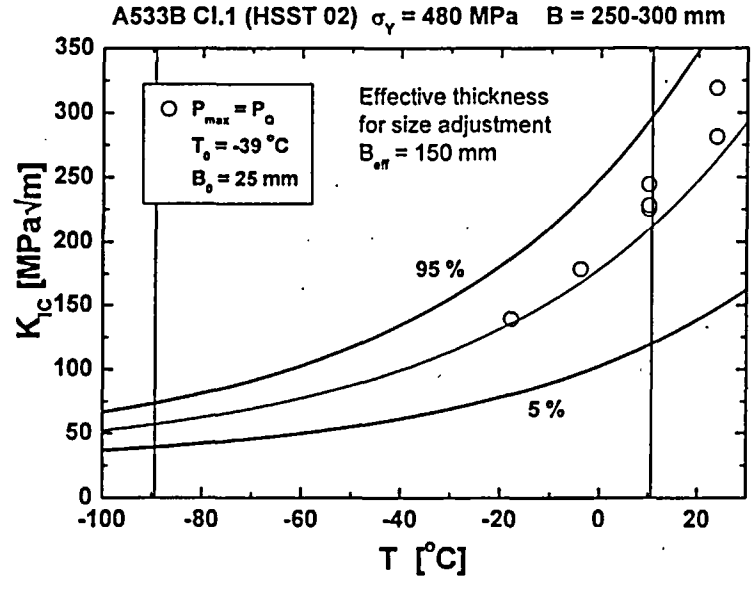




Only 6 inch of the center of the plate has uniform toughness. Large 10T-12T specimens behave effectively as 6 T specimens.

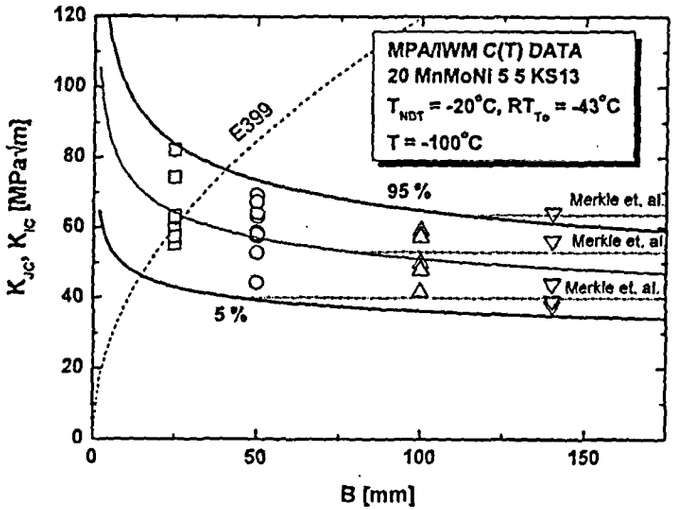
Proper analysis of HSST-02

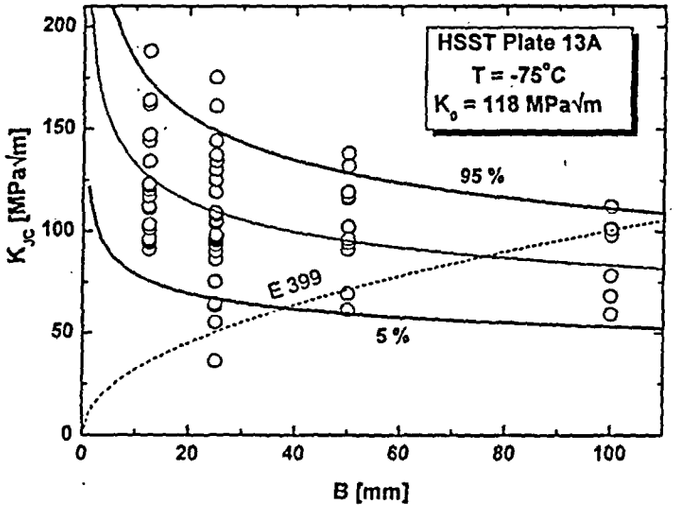




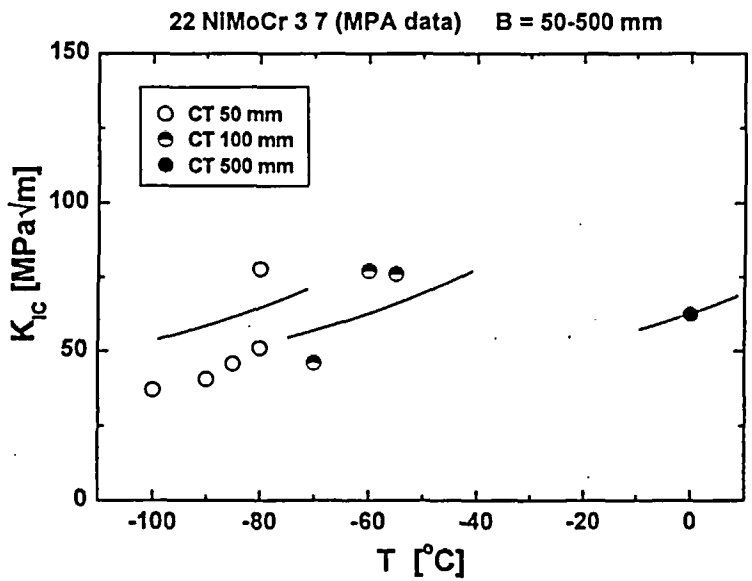
When the large specimens are analysed as effectively having 6T thickness, the result is comparable with small specimen KIC data.

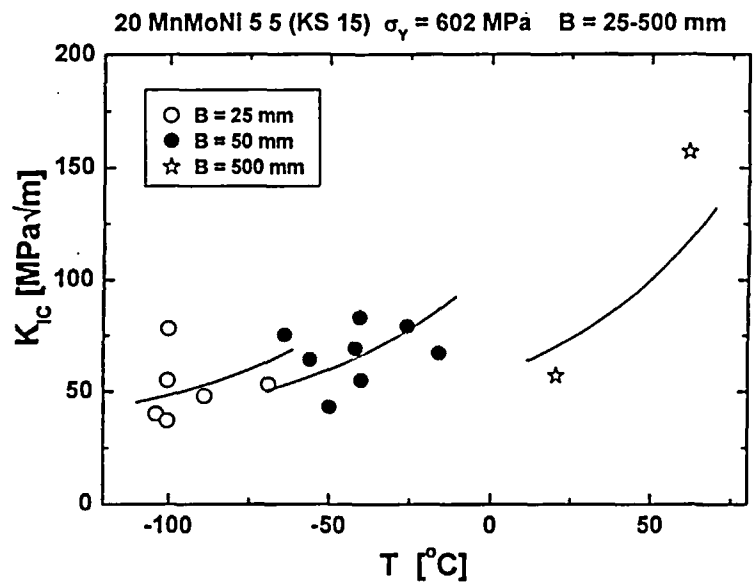
Size effect data



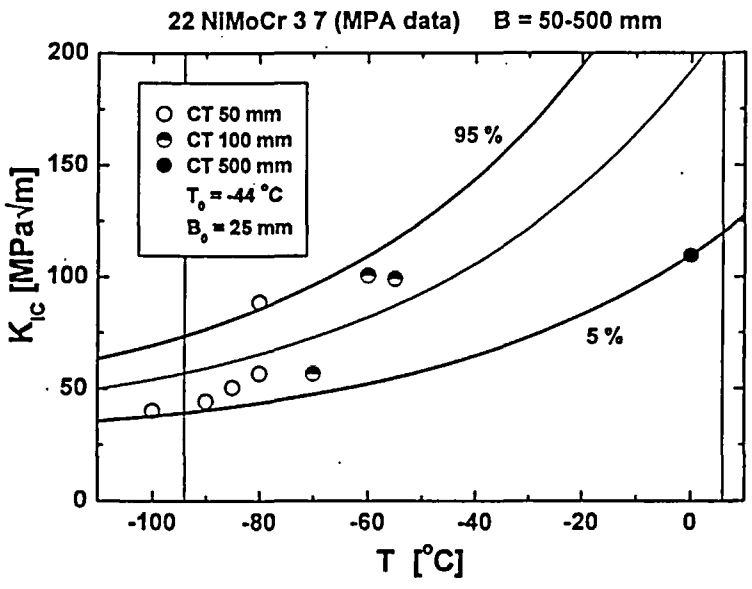


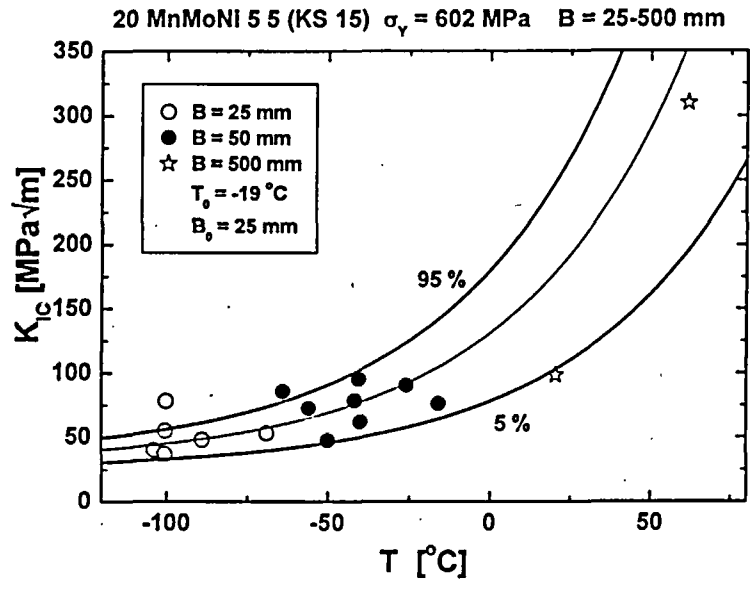
German data


22 NiMoCr 3 7 (MPA data) B = 50-500 mm
CT 50 mm
CT 100 mm
CT 500 mm
K_Ic [MPa√m]
T [°C]
150
100
50
0
-100
-80
-60
-40
-20
0

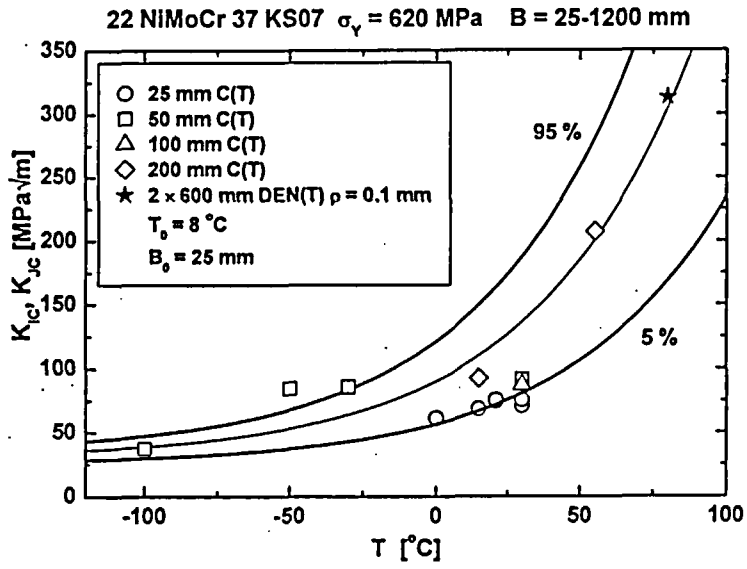

20 MnMoNi 5 5 (KS 15) σ_Y = 602 MPa B = 25-500 mm
B = 25 mm
B = 50 mm
B = 500 mm
K_Ic [MPa√m]
T [°C]
200
150
100
50
0
-100
-50
0
50

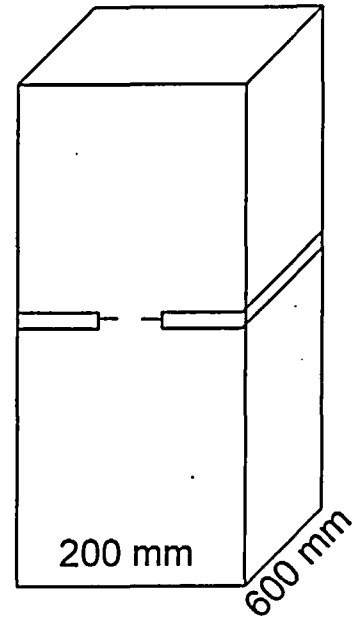
German data


22 NiMoCr 3 7 (MPA data) B = 50-500 mm
CT 50 mm
CT 100 mm
CT 500 mm
T0 = -44 °C
B0 = 25 mm
95 %
5 %
K_IC [MPa√m]
T [°C]
200
150
100
50
0
-100
-80
-60
-40
-20
0

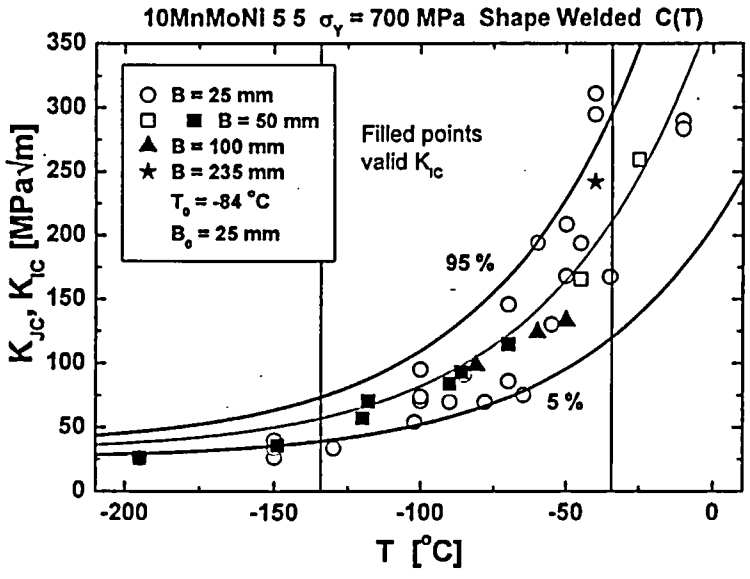

20 MnMoNI 5 5 (KS 15) σY = 602 MPa B = 25-500 mm
B = 25 mm
B = 50 mm
B = 500 mm
T0 = -19 °C
B0 = 25 mm
95 %
5 %
K_IC [MPa√m]
T [°C]
350
300
250
200
150
100
50
0
-100
-50
0
50

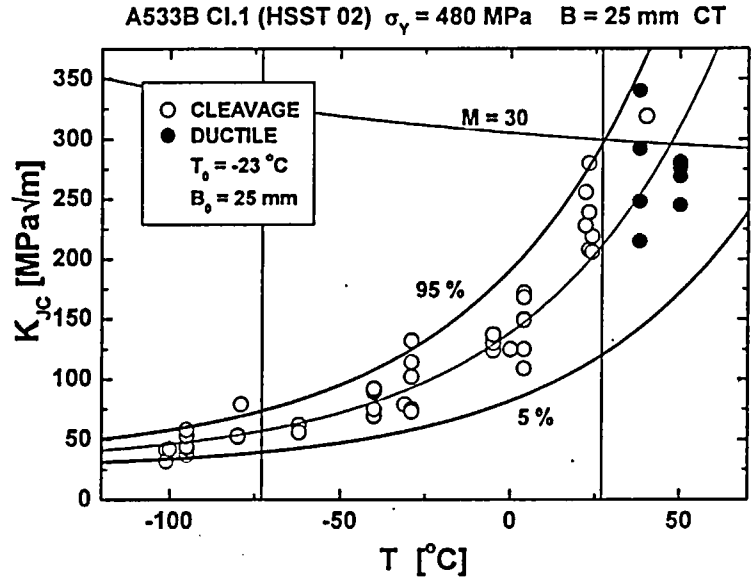
German data


22 NiMoCr 37 KS07 σY = 620 MPa B = 25-1200 mm
25 mm C(T)
50 mm C(T)
100 mm C(T)
200 mm C(T)
2 × 600 mm DEN(T) ρ = 0.1 mm
T0 = 8 °C
B0 = 25 mm
95 %
5 %
KIc, KJc [MPa√m]
T [°C]
350
300
250
200
150
100
50
0
-100
-50
0
50
100


200 mm
600 mm

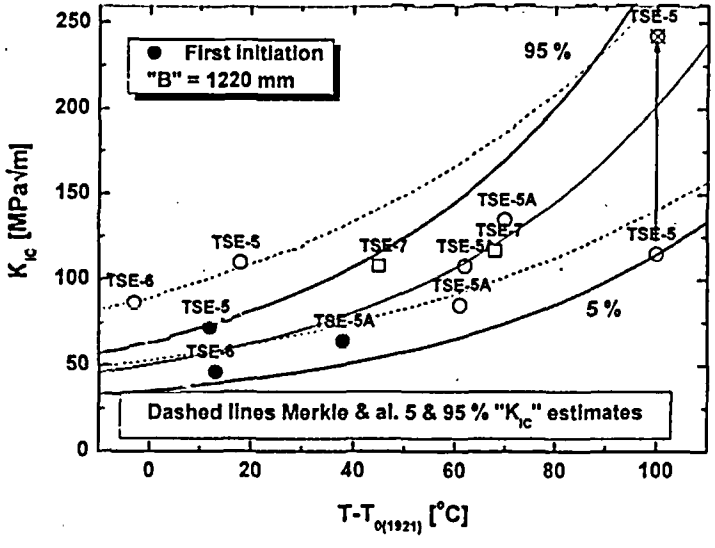
Equivalence of KIC and KJC

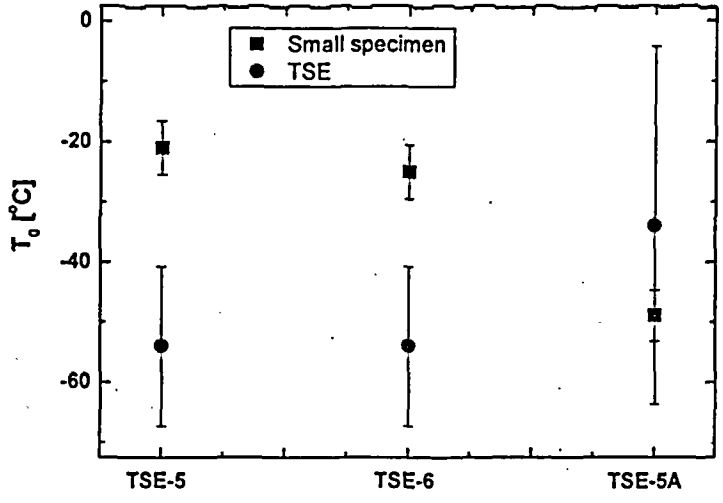




KIC and KJC yield same result with respect to Master Curve analysis.

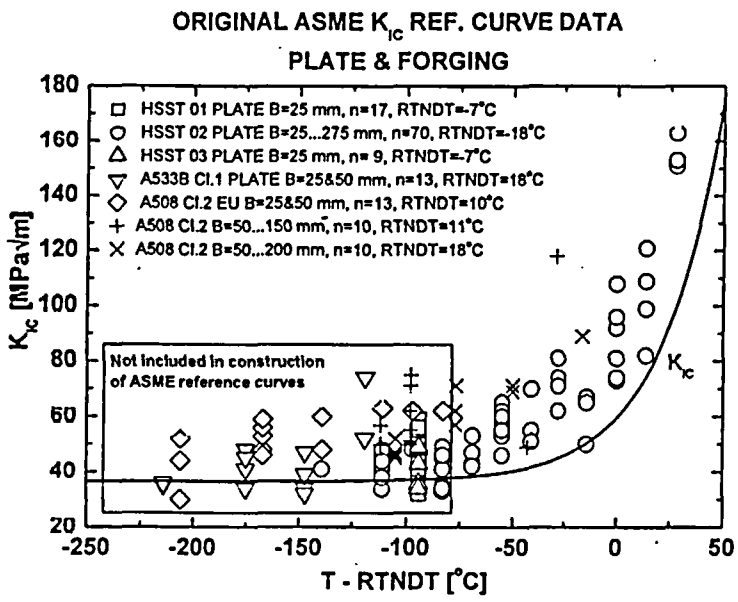
Master Curve analysis of TSE

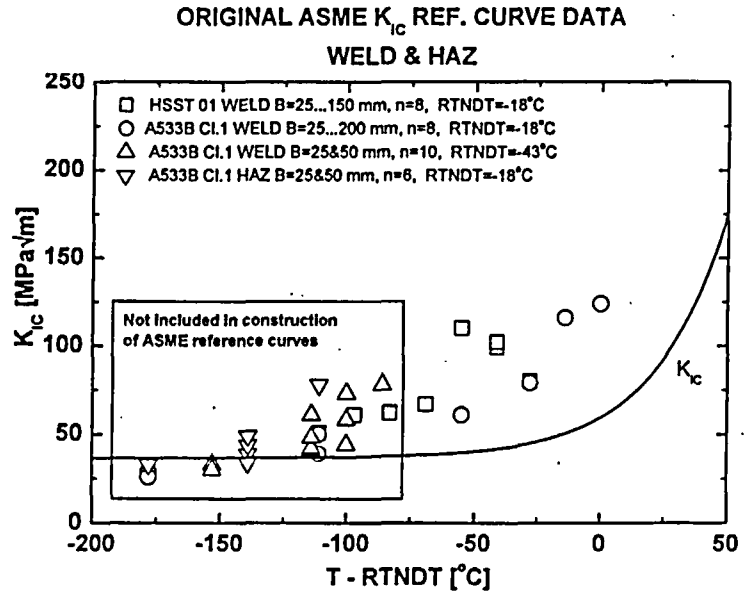




TSE-5 and TSE-6 slightly tougher than predicted based on MC (due to high secondary initiation values). TSE-5A slightly more brittle than predicted based on MC.

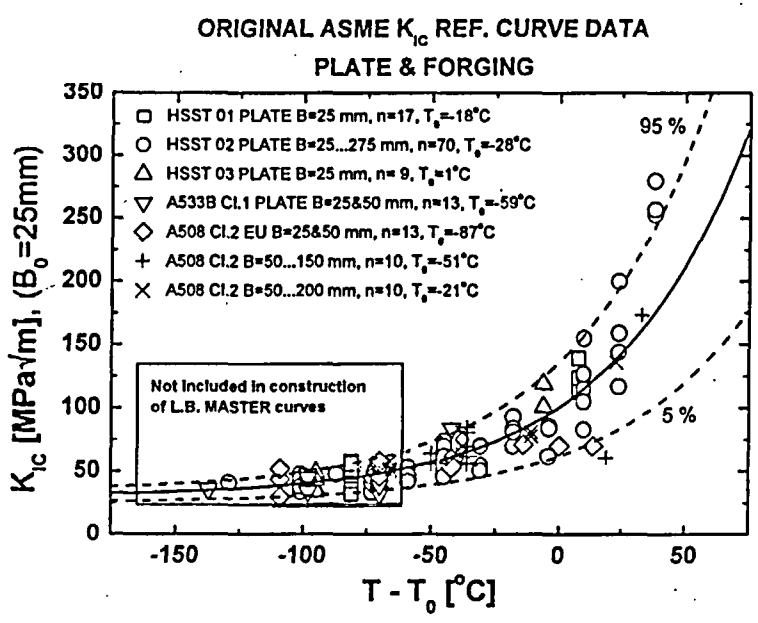
Significance of ASME Code Cases N-629 and N-631

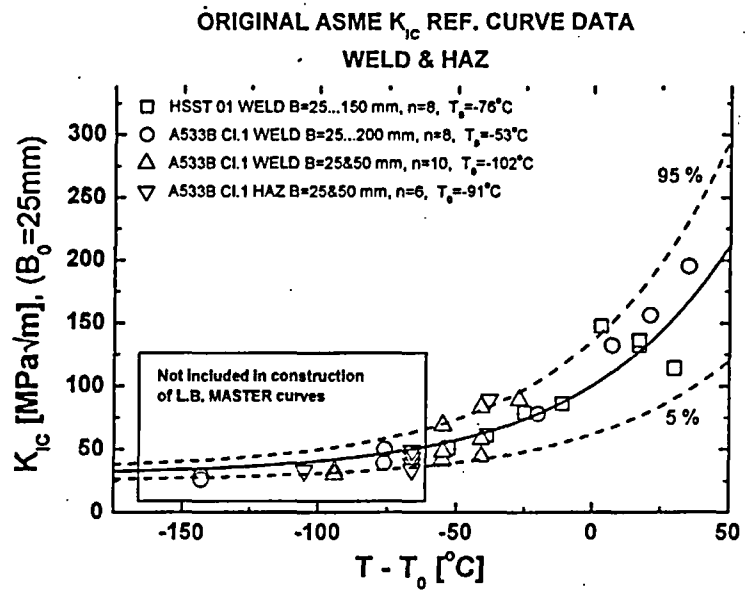




Original data used to establish ASME K_{IC} reference curve

Significance of ASME Code Cases N-629 and N-631



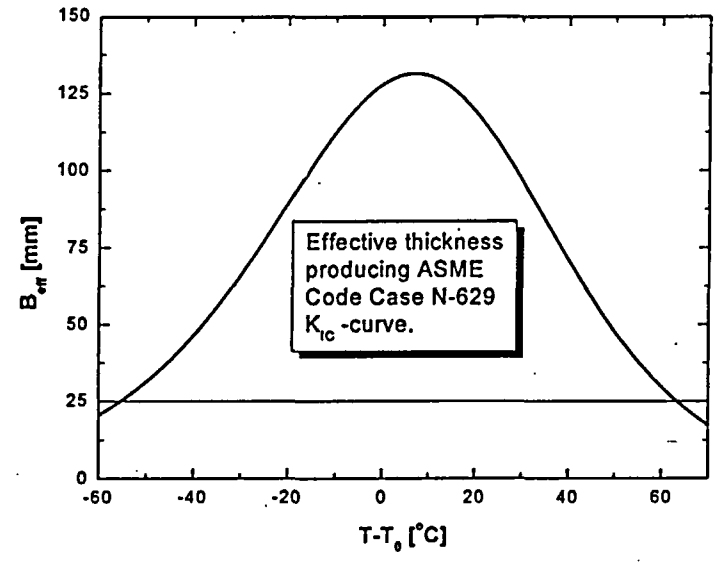


Master Curve analysis of original data used to establish ASME K_{IC} reference curve

Significance of ASME Code Cases N-629 and N-631

The definition of RT_{To} was taken as $RT_{To} = T_0 + 35°F$ ($RT_{To} = T_0 + 19.4°C$) so that it limits the unadjusted KIC data. This causes the ASME Code Case K_{IC} curve to be located below the 5 % Master Curve in the temperature region:

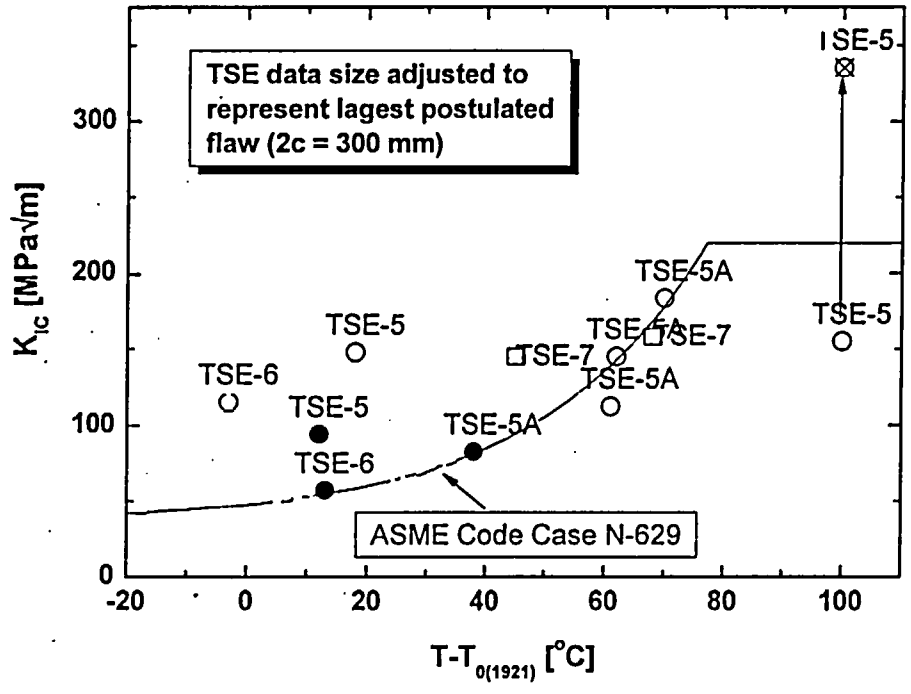
$-55°C < T-T_0 < +63°C$.



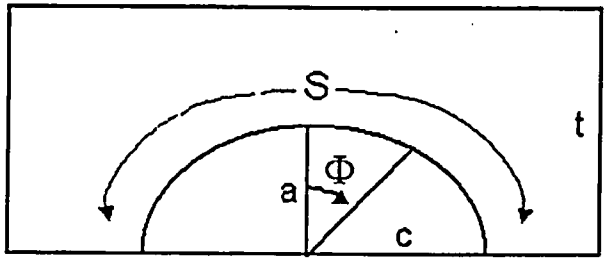
The definition of RT_{To} leads to an artificial size adjustment. I.e. in the temperature region where the Code Case curve lies below the 5 % Master Curve, the Code Case curve corresponds effectively to larger specimens than 25 mm.

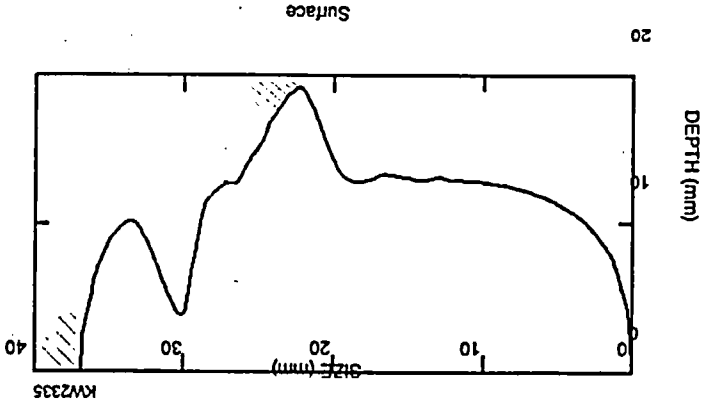
Significance of ASME Code Cases N-629 and N-631

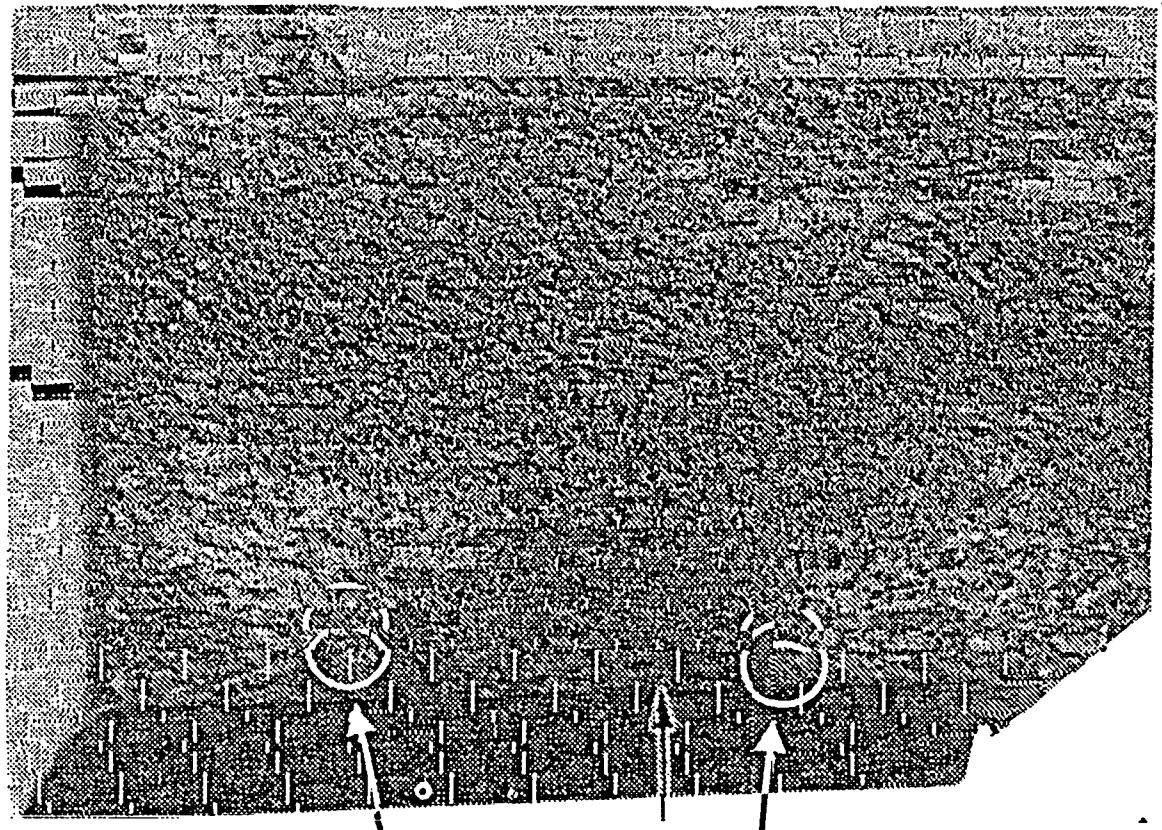
- The RT_{To} definition should be based on physically realistic flaw sizes, not postulated unrealistic "infinite" flaws.
- The largest postulated flaw in the ASME Code is represented by the quarter thickness flaw, which leads to a 2c value of approximately 300 mm.
- This means that the Code Case N-629 RT_{To} definition should be tested against 300 mm cracks.
- The TSE results can be used to test the Code Case N-629, provided the results are size adjusted to 300 mm crack front length with the Master Curve size adjustment.



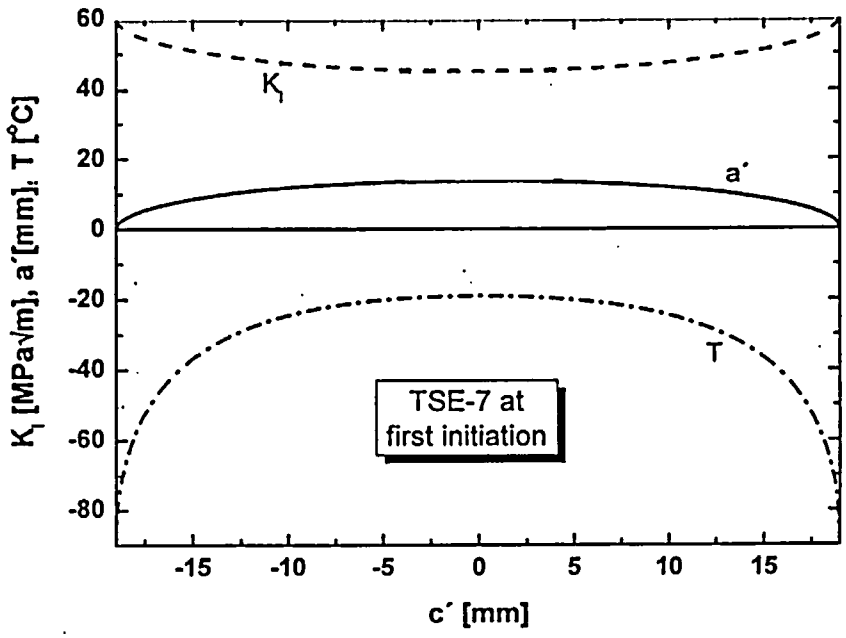
Master Curve analysis of TSE-7

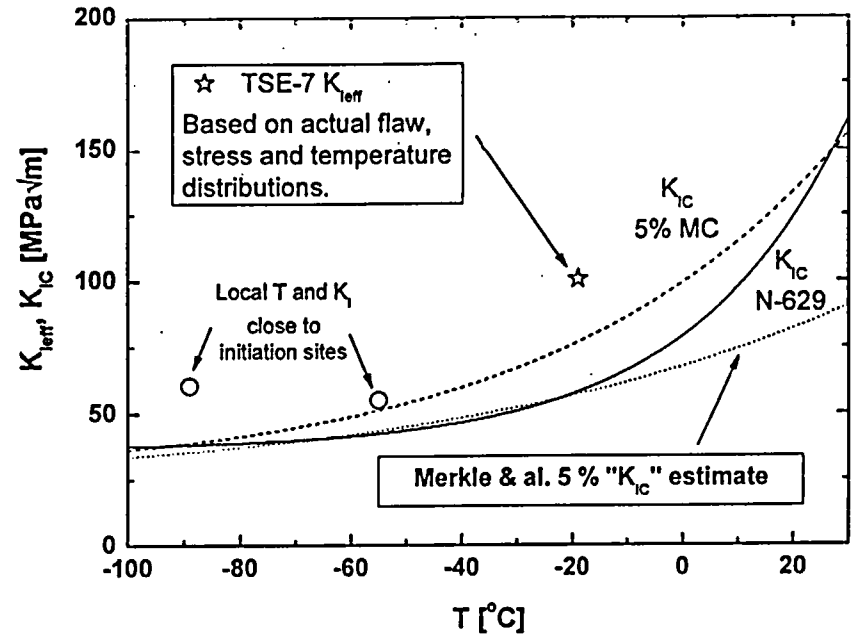






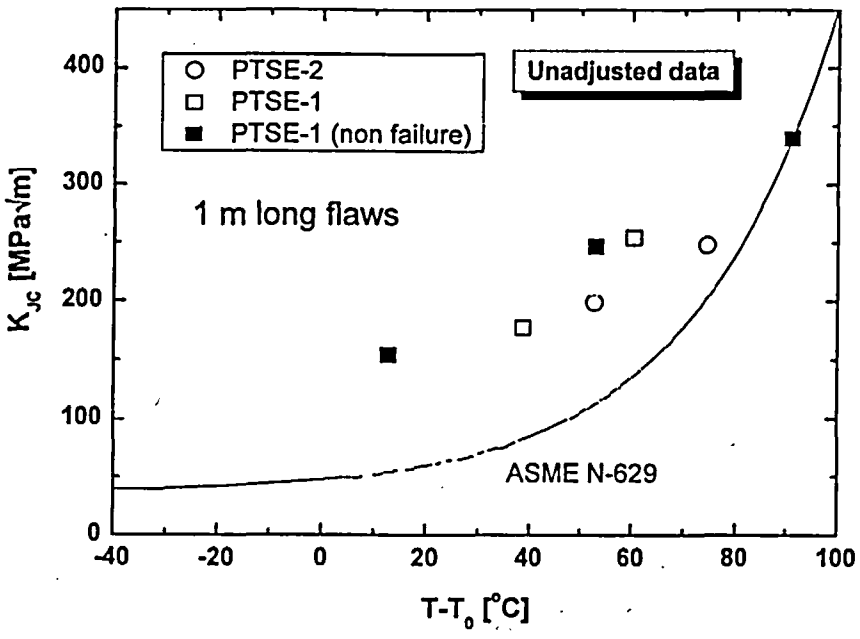
Master Curve analysis of TSE-7





$$K_{IeffTref} = \left\{ \int_0^s \left(\frac{K_{I\Phi} - K_{\min}}{K_{0\Phi} - K_{\min}} \right)^4 \cdot \frac{ds}{B_0} \right\}^{1/4} \cdot \left(K_{0Tref} - K_{\min} \right) + K_{\min}$$

Code Case N-629 description of PTSE-1 and PTSE-2



In the case of a real shallow crack undergoing mechanical loading, the constraint is so much lower that even very long cracks can still be conservatively described with the ASME Code Case, without any additional size adjustments.

This is the case with the PTSE experiments. The unadjusted failures occur well above the Code Case line. The TSE experiments have higher constraint, since they lack the mechanical loading and their K_I levels are low.

CONCLUSIONS

- KJC and KIC have equivalent descriptive capability of fracture toughness provided statistical size adjustment is performed. Also valid KIC results are affected by the statistical size effect.
- The largest specimens ever tested, indicate that the statistical size effect is in effect at least to a crack front length of 1 m.
- The Master Curve describes well the TSE data, when the statistical size effect is accounted for.
- The Merkle proposal does not provide a realistic description of the TSE data.
- The ASME Code Case N-629 contains an inherent size adjustment close to 150 mm.
- If the TSE results are transformed to represent the largest postulated flaw in the ASME Code (300 mm), the Code Case N-629 provides a satisfactory description of the data.
- Real 3D-flaws are well described by the MC and the ASME Code Case N-629.
- Realistic loading situations including mechanical loading, make the Code Case N-629 conservative even for 1 m flaws.
- Code Case N-629 requires no changes for the analysis of postulated flaws.