Essential testing in Submarine Pressure Hull Weld Acceptance: Victoria Class Subs

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Abstract

There is a growing interest in welding and weld approval issues for the Victoria Class submarines. It was accordingly requested by NDHQ DGMEPM that we provide a presentation at this conference on this subject.

There are two main issues. The first is testing for weld approval. DREA recommends that Dynamic Tear transition testing and Explosion bulge testing be the primary special tests for approvals. The first addresses all impact issues and the latter addresses all explosive strain issues. The Australians and the Americans use these two tests but the British rely more on CTOD and crack starter bulge tests.

The second issue is choice of weld process. For 18 years DREA has been able to meet the strength, impact and explosive strain requirements for submarine welds [1]; first with conventional T.I.M.E. welding (1982), then with analog pulsed GMAW using TIME gas or C5 or C10 gas (1988) and more recently pulsed digital T.I.M.E. GMAW (1998) as well. [2]

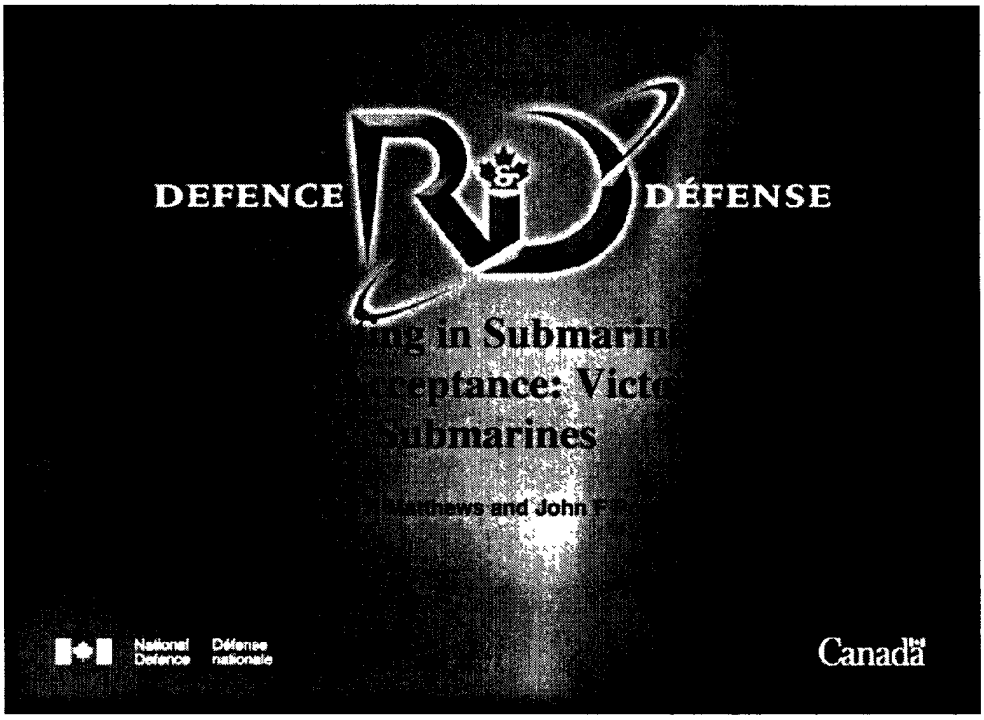
The underlying technical issue is strength. The Australians, the British and the Americans lowered the strength of the weld to improve the impact performance. The Australians went to E10018 and managed to find consumables that passed the tests (DT and explosion bulge). The British as it turned out lowered their strength from E11018 which they used on the first two Upholders to E9016 for the last two. That's a 20,000 psi strength reduction to promote improved toughness and to pass the impact tests. The Americans have dropped to E10018 more recently. There are two concerns; first, will the reduced strength result in undermatching and strain concentration in the welds and failed tensile and failed explosion bulge, and second, is it really necessary to drop the strength to find a weldment with acceptable toughness.

The test that shows if dropping the strength is OK is the explosion bulge. But the British stopped using the test. In Canada, John Porter has efficiently conceived an underwater test and carried out this test for 15 years. TIME welding is a real alternative to dropping the strength of the weld.

FMF Cape Scott has been conducting a test program this past winter to evaluate these issues and to compare the performance of the UK recommended E9016 and FCAW consumables to the TIME process.

[1] J.R. Matthews, C.V. Hyatt, and J.F. Porter, "Future Treatment of Weld Acceptance: The Significance of Incomplete Fusion Discontinuities in Low Structural Transition Temperature GMAW Weldments, Materials Evaluation, April 2001

[2] D.S. Begg and J.R. Matthews, "Toughness Envelope Definition of Pulsed Gas Metal Arc Welds in HY80 Steel", 9th CF/DRDC Meeting on Naval Applications Of Materials Technology, June 2001



Overview

- Background and Transition Curve
- Shear Lip and Plastic Zone Size Relationship
- Quantitative Fracture Mechanics and DT
- Demo of Multi Media Book

Background

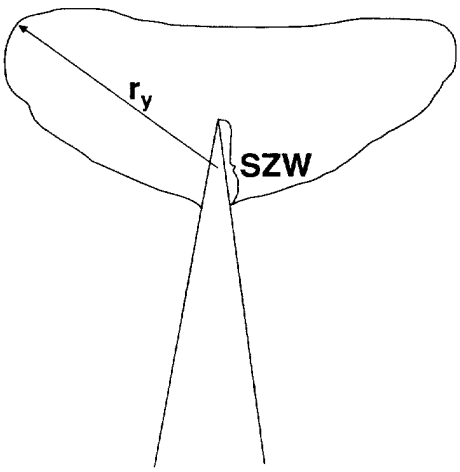
- In 1970s three Schools of Thought on Fracture Control
  - Metallurgy Cv
  - Quantitative Fracture Mechanics K J
  - Pellini DT Explosion Bulge

In year 2000

- Many follow Quantitative Fracture
- Small trend to Metallurgy DT

Universal Fracture Property

- Plastic Zone Size ryc
- Energy itself DTE
- Stretch zone width SZW
- Shear Lip s



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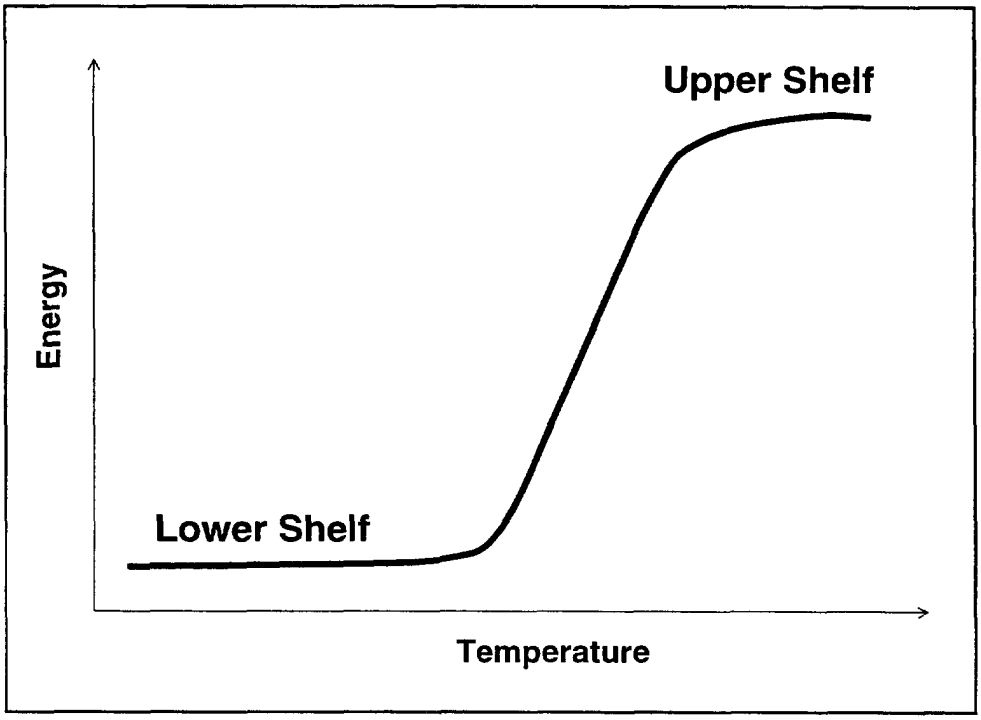
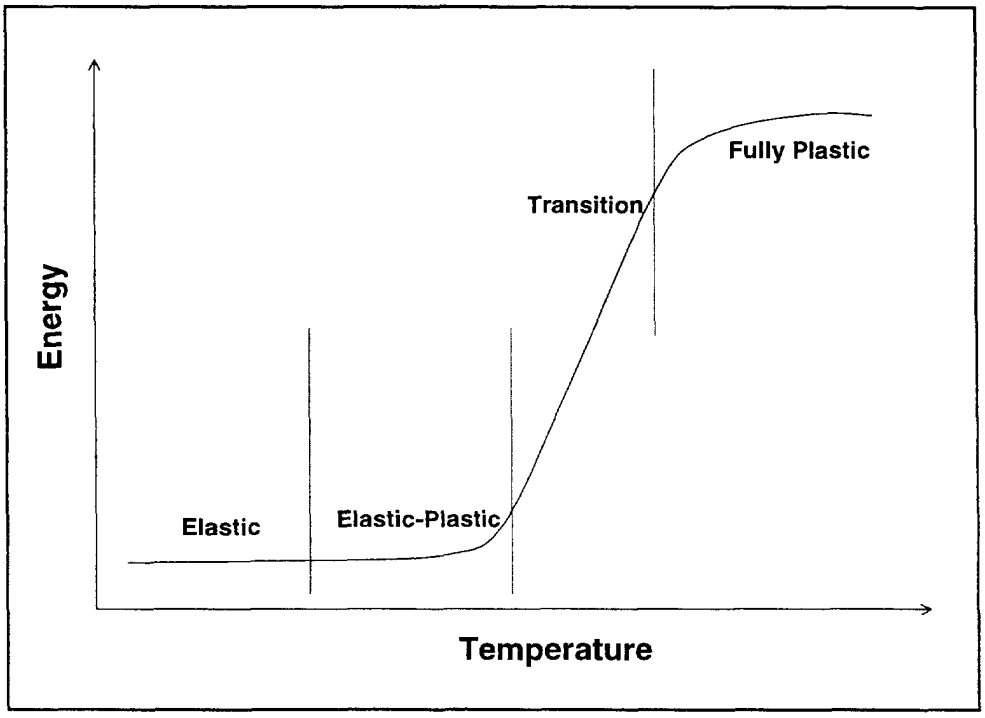
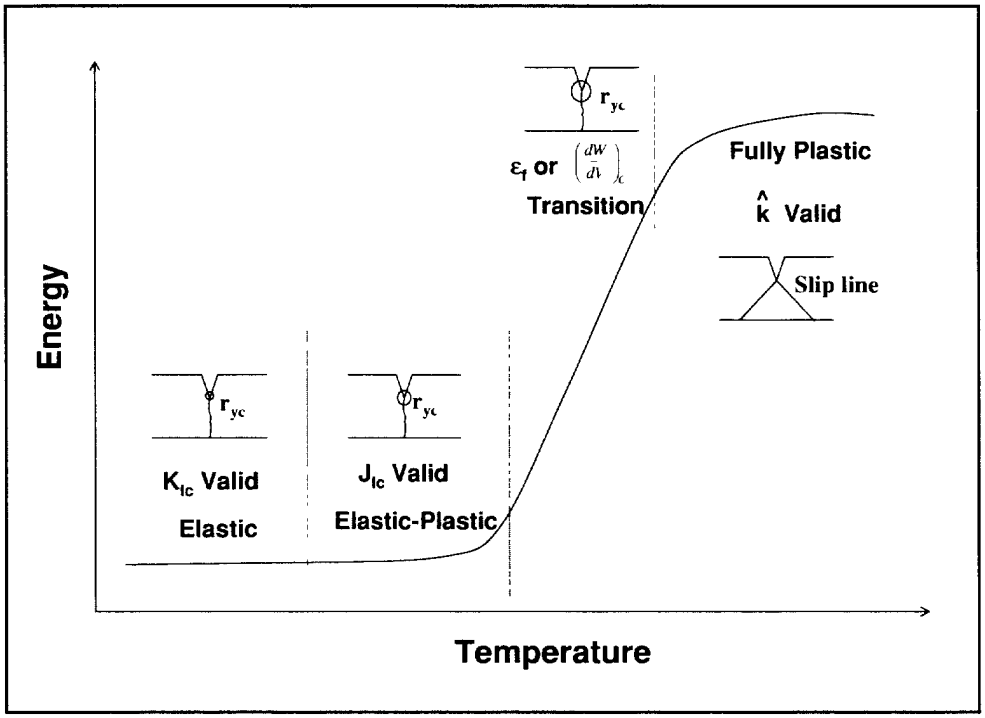
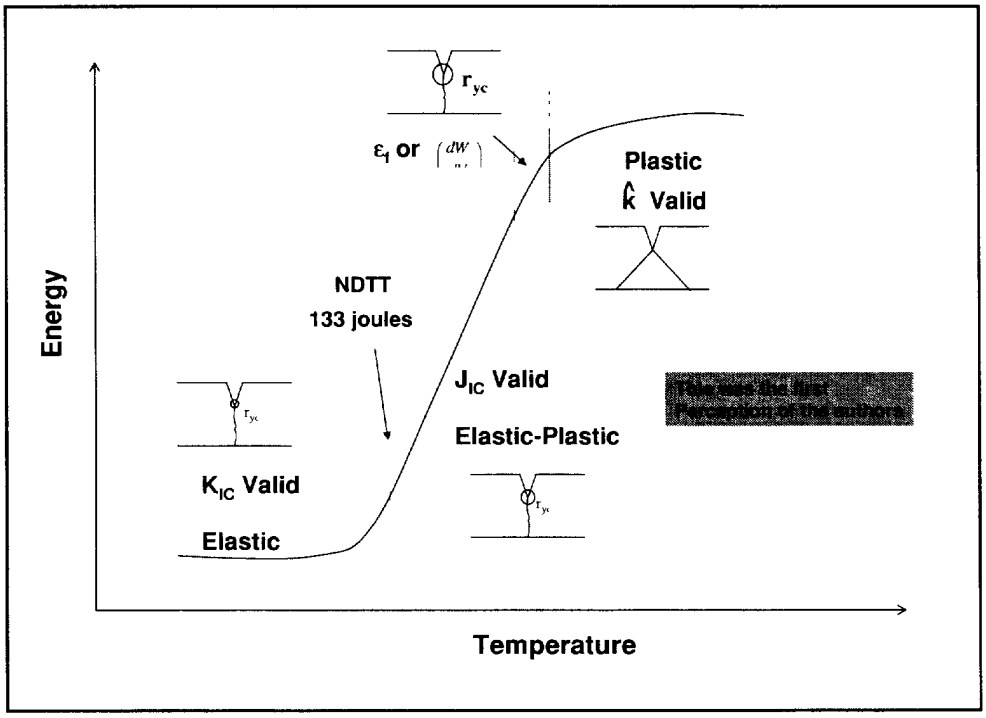

Upper Shelf
Energy
Lower Shelf
Temperature


Fully Plastic
Transition
Energy
Elastic
Elastic-Plastic
Temperature


Energy
Temperature
r_{yc}
ε_f or $\left(\frac{dW}{d\bar{v}}\right)_c$
Transition
Fully Plastic
$\hat{k}$ Valid
Slip line
K_{Ic} Valid
Elastic
J_{Ic} Valid
Elastic-Plastic


Energy
Temperature
r_{yc}
ε_f or $\left(\frac{dW}{d\bar{v}}\right)_c$
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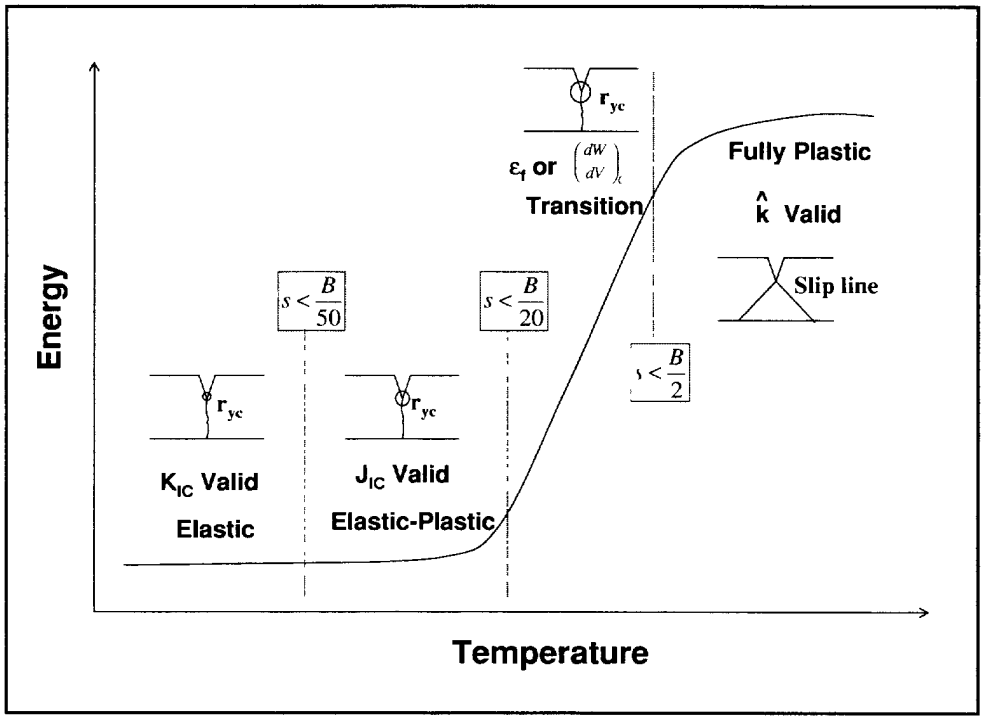
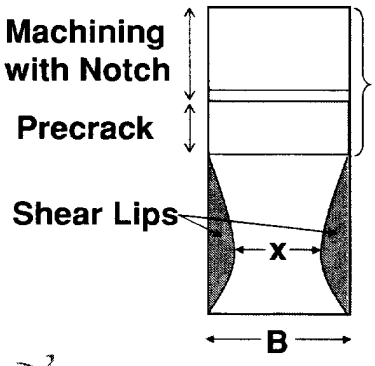
$\hat{k}$ Valid
NDTT
133 joules
K_{IC} Valid
Elastic
J_{IC} Valid
Elastic-Plastic



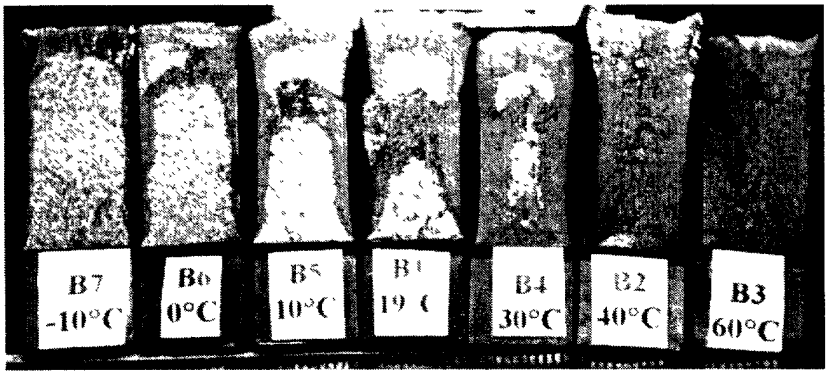
Shear Lip Size



0.45 < a/W < 0.55

$$s = \frac{B - x}{2}$$

Shear Lip vs Temperature



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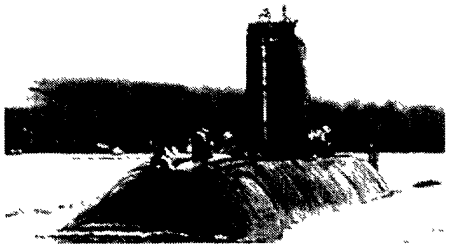
Consumable Acceptance Criteria

Proposed Canadian mods. to NES769:

- **Re-adopt explosion bulge as per US, Aus, and pre-1986 UK practice**
- **Adopt Dynamic Tear Transition criteria (690 J at -29°C) as per TTCP op. assign.**



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Why Conduct Explosion Bulge Trials ?

Only trial that adequately evaluates the full weldment system's ability to withstand high deformation plasticity without failure.

Explosion Bulge - Features

Full Weldment System:

- Full scale samples,
- Indiscriminately loads all elements of weldment equally,
- Interaction of weldment elements in a manner consistent with platform behaviour (weld metal mismatch effects)

High deformation plasticity:

- As per grounding, collision, explosive attack
- Up to 16% thinning required

Failure:

- Very non-ambiguous

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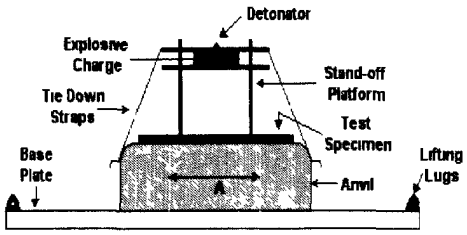
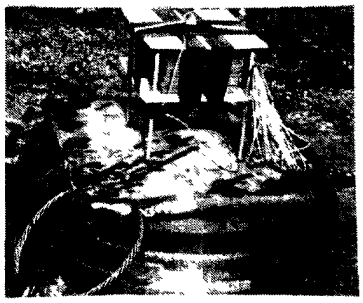
Explosion Bulge Trial Set-up





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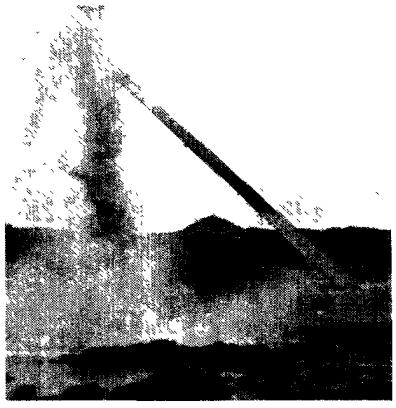
The Canadian Version

- Same configuration and pass/fail criteria as USN, RAN and pre-1986 RN (16% thinning for HY80, Q1N)
- Single shot evaluations conducted underwater (up to 60 lbs charges for 2" thick panels)
- Post trial examination includes surface strain mapping (weld metal strength effects)



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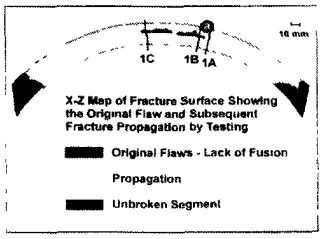
Support to Research Activities

Surface Strain Mapping:
•Influence of weld metal strength mismatch on high deformation response

Weld Defect Acceptance Study:

- **GMAW HY100 weldments passed EB evaluations despite severe lack of fusion**
- **Weldment examination must ensure superior structural transition performance**



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Conclusion

"At the head of this family of tests stands the explosion bulge test which has a high degree of realism in the submarine context" – J.C. Ritter