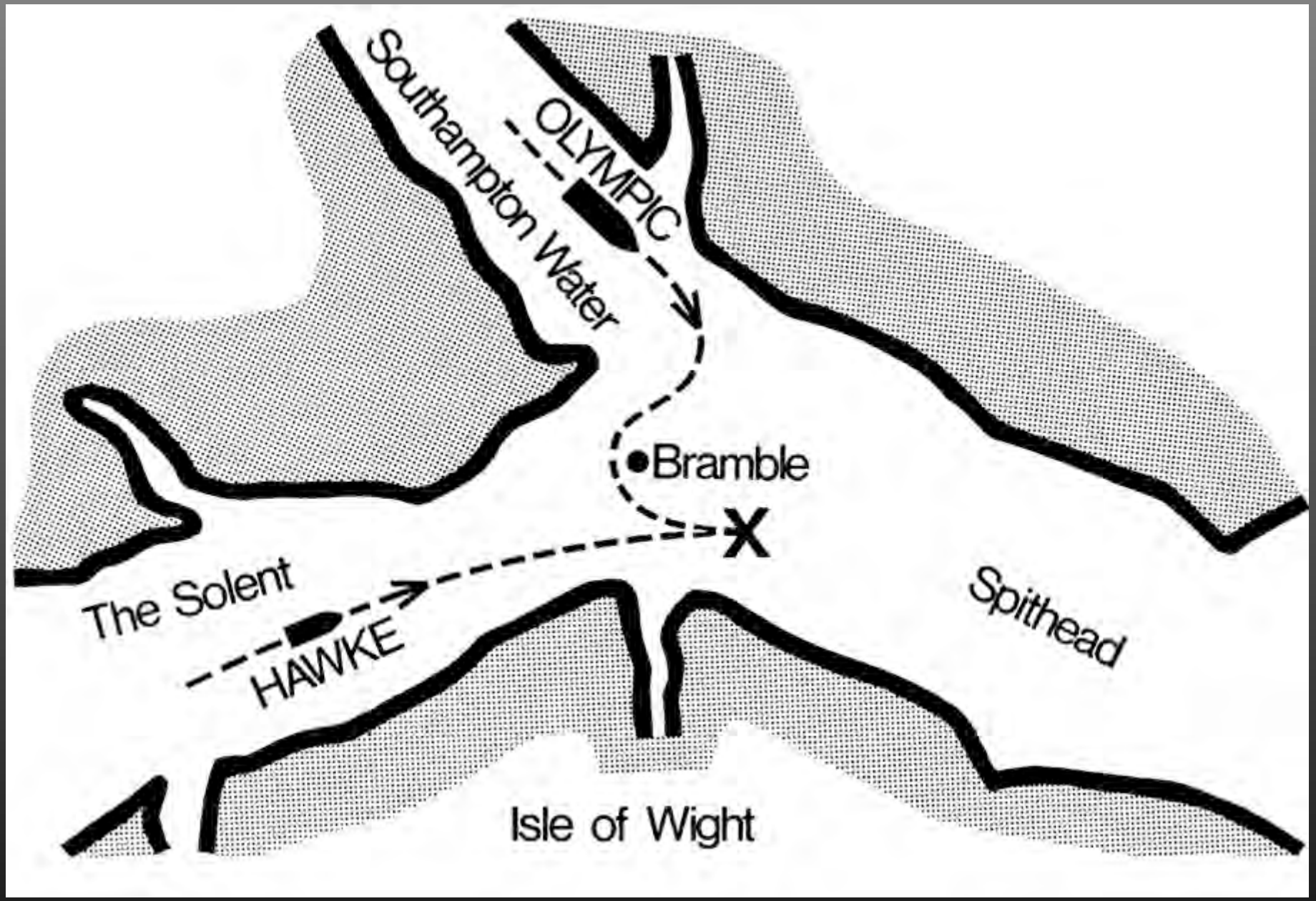

Southampton Water
OLYMPIC
Bramble
X
The Solent
HAWKE
Spithead
Isle of Wight

Steel Chemistry

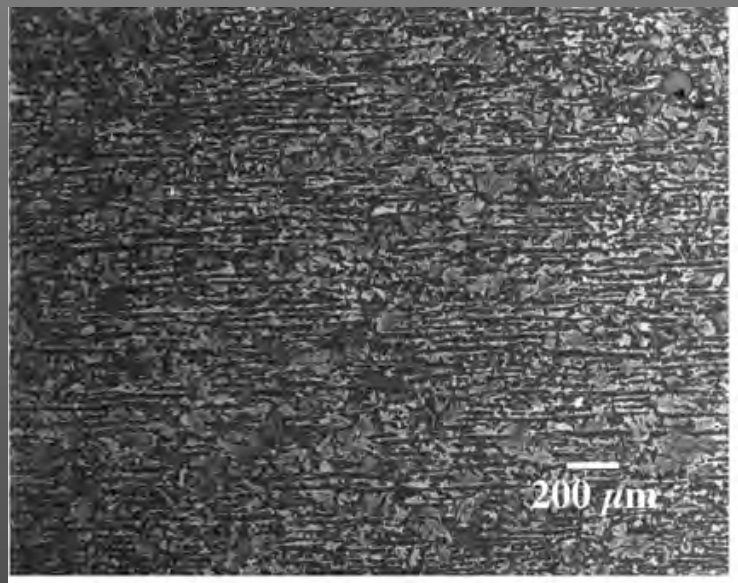
Element	1991 (CANMET)	1996 (UMo)	1996 (Beth. St.)	AISI 1018 (ASM)
Carbon	0.20%	0.21%	0.21%	0.18-0.23%
Sulfur	0.065%	0.069%	0.061%	0.05% max
Manganese	0.52%	0.47%	-	0.60-1.0%
Phosphorus	0.01%	0.045%	-	0.04% max
Nitrogen	0.004%	0.0035%	-	0.0025%
Oxygen	-	0.013%	-	-

Mechanical Properties

Plate recovered in:	1996	1991
Yield Stress	38 ksi (262 MPa)	41 ksi (280 MPa)
UTS	62.5 ksi (430 Mpa)	62.6 ksi (432 MPa)
Percent Elongation	29	31

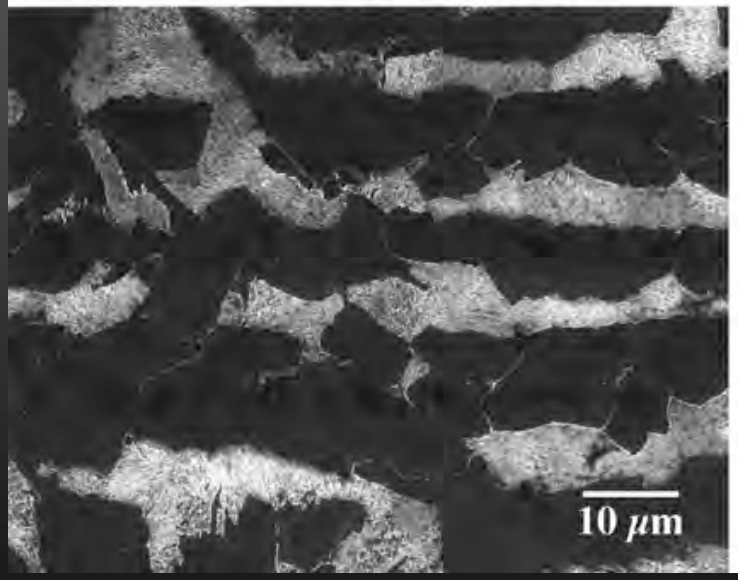
(Design Spec: 10-15 tons/sq. inch yield, 30% elongation)

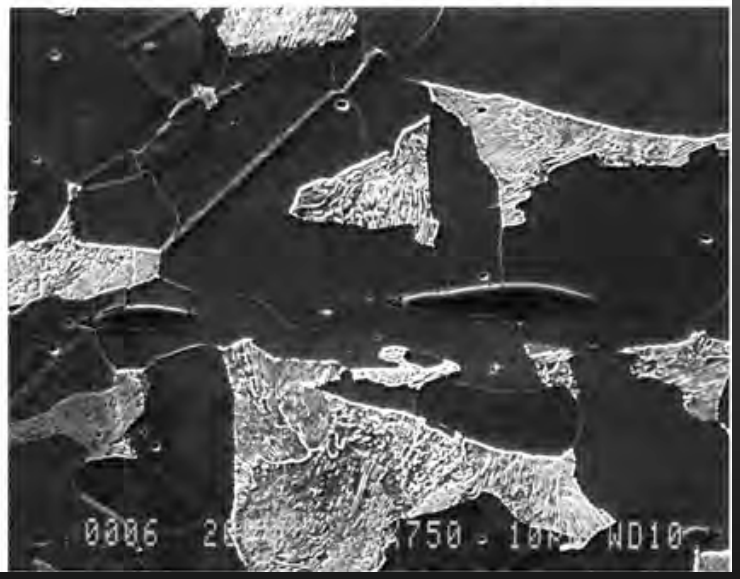
Microstructure of Hull Steel

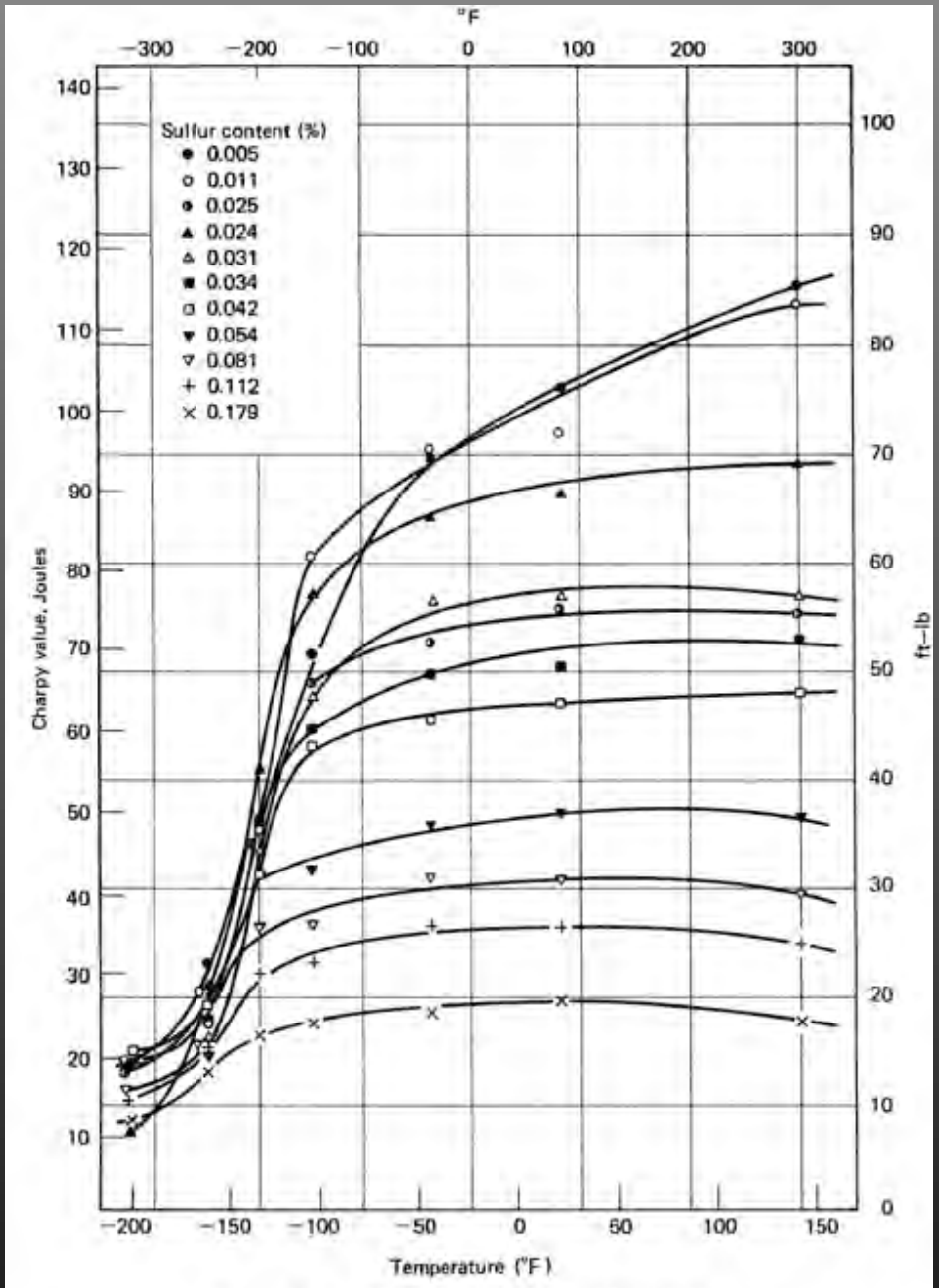


AISI 1018 1" Hot-Rolled Plate

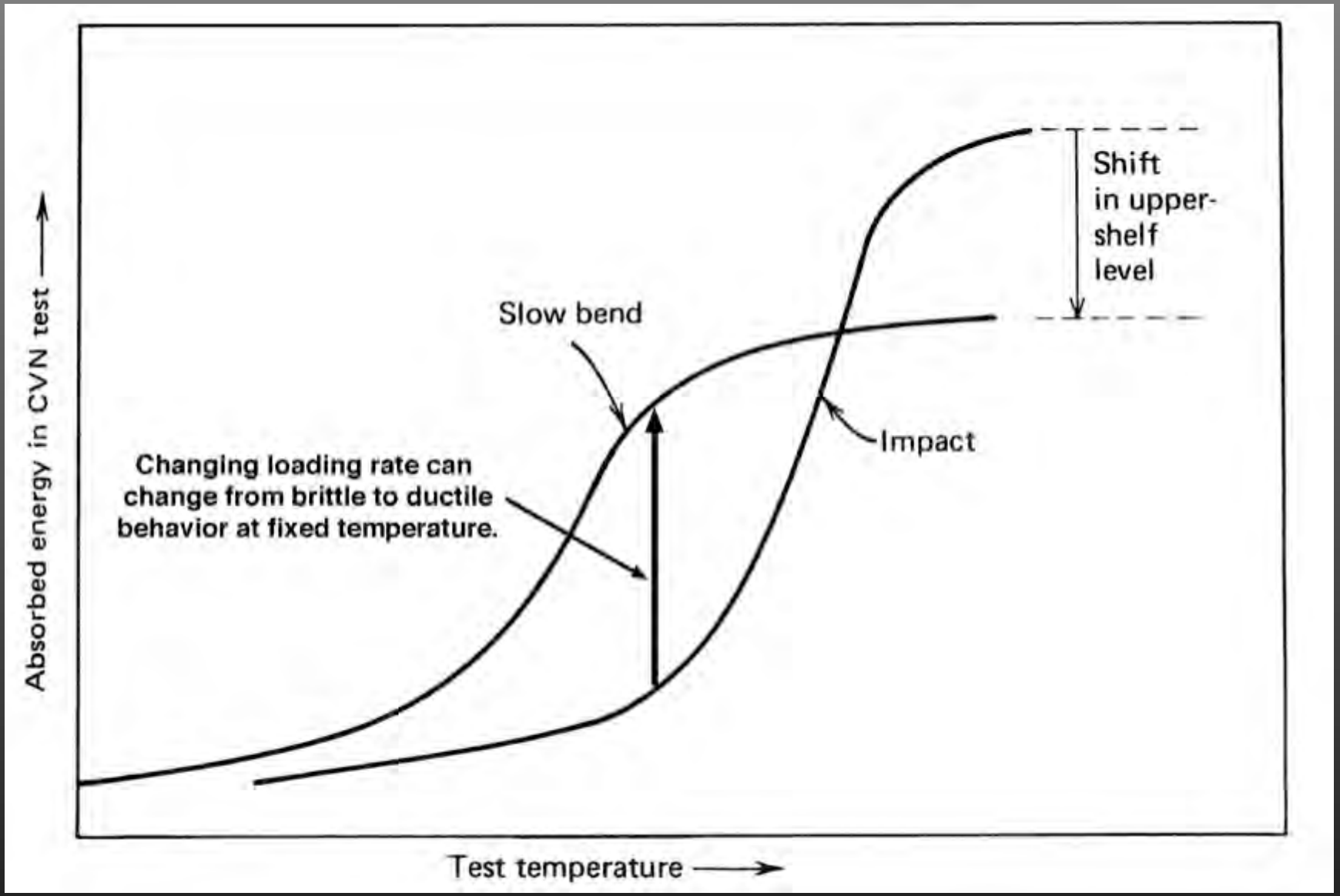
Titanic Hull Plate





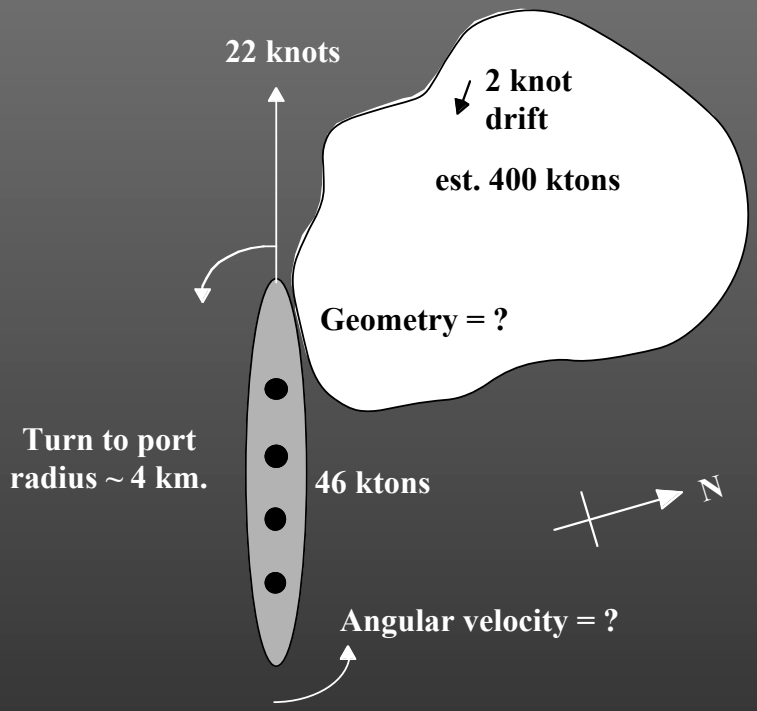


Birkle, Wei and Pellissier, Trans. ASM 55 (1962) p. 981.


Absorbed energy in CVN test
Test temperature
Shift in upper-shelf level
Slow bend
Impact
Changing loading rate can change from brittle to ductile behavior at fixed temperature.

However,

- the impact with the iceberg was not felt by most passengers
- the lateral motion of the ship was negligible



The impact energy (and strain rate) is a very sensitive function of the impact angle.

Is Charpy appropriate?

What loading rate corresponds to the iceberg collision?

FRA says Charpy is good for railroad car collisions in a switching yard (15-20 mph).

Slow Three-Point-Bending Results (ASTM E-399-81) (Orientation = T-L)

Sample Number	T (^{o}C)	Toughness (MPa - $m^{1/2}$)
B1	0	55
B2	0	58
B3	0	49
B4	25	68
B5	25	64
B6	25	71

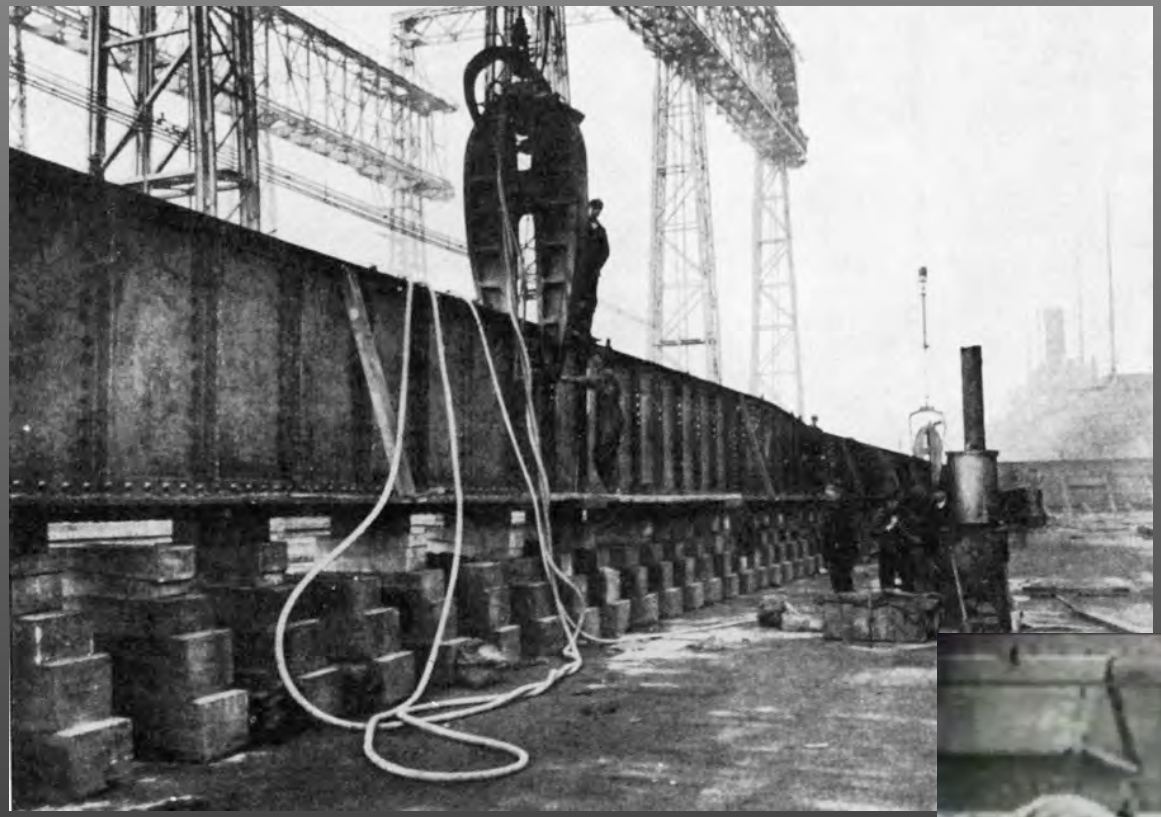

5 cm

Bottom Line

- Steel was state-of-the-art for 1911.
- Appreciable low temperature toughness.
- “Brittle Steel Theory” is wrong.

Rivets

Riveting



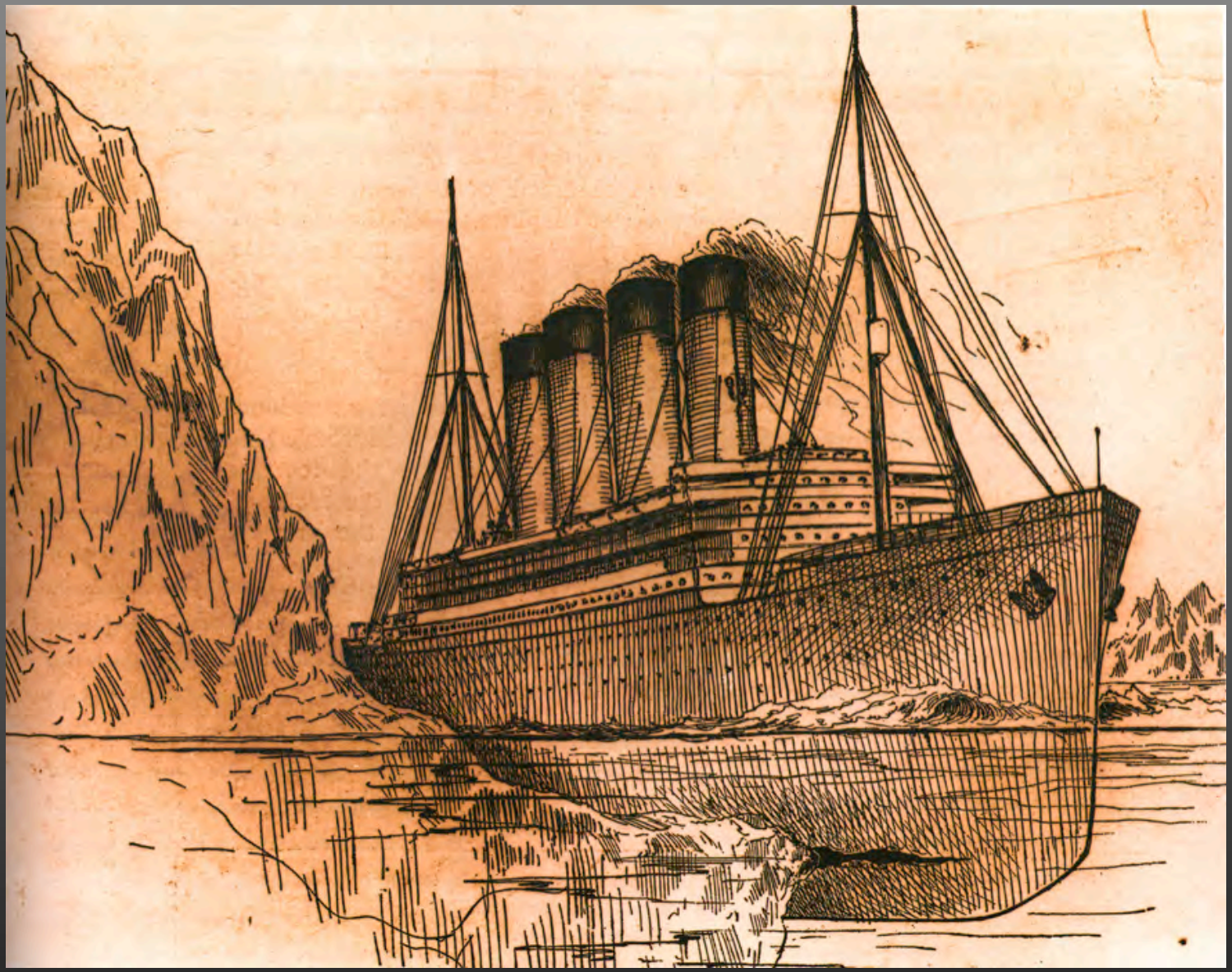
- 3,000,000 wrought iron and steel rivets
- Hand and hydraulically driven
- Total weight = 1,550 tons

(courtesy Discovery Communications)

Was there a problem with the riveting?

- Historical evidence from Olympic
- Eyewitness testimony
- Sonar evidence
- Metallurgical forensic evidence

Sonar Imaging of Wreck



(from *Illustrated Times of London*, April 16, 1912)

New images of parted seams in damage area

- Located by counting plates
- Right where Fireman Barrett said it was

(courtesy Discovery Communications)

Rivet Metallurgy

Wrought Iron Rivets

- Commercially pure iron with 1-4% incorporated slag
- Puddled, extruded into a bar, and formed into rivets

Mechanical Properties (avg.)

Orient.	YS	UTS	%
Long.	27 ksi	48 ksi	14
Trans.	18	20	2

(Source: Making, Shaping and Treating of Steel, USS, 1957)

How can a rivet fail?

- Mid-shaft failure

- Head "pops" off

- Cupping