
NATIONAL TRANSPORTATION SAFETY BOARD
E PLURIBUS UNUM

# Metallurgical Findings

- Results from accident tank cars
- Charpy impact testing
- Future tank car standards

# Tank Car Shell Fractures

- Four of five tank car shells had brittle fractures

- One tank car shell fracture surface had some ductile features

# Material Fracture Toughness

- Fracture toughness characterizes the ability of a material to resist fracture – energy required to grow a crack
- Fracture toughness of steels can vary greatly; depends on composition, processing and temperature
- Charpy V-Notch values are a common measure of dynamic fracture energy

# Accident Shell Material Charpy Values

| Tank Car Number | Energy (ft-lb) at 36˚F | |
|---|---|---|
| | Longitudinal Specimen | Transverse Specimen |
| 19 | 52 | 18 |
| 20 | 35 | 32 |
| 22 | 28 | 20 |
| 24 | 13 | -- |

# Adverse Effects of Low Energy Fractures

- Low tank car impact resistance
- Rapid and un-arrested crack propagation
  - Catastrophic fracture and separation
  - Possible fragmentation
  - Rocketing of tank cars and fragments

# Approaches to Increase Fracture Toughness (Charpy Energy)

- Optimize chemical composition
- Refine grain size
- Control rolling process
- Normalizing heat treatment

# Heat Treatment

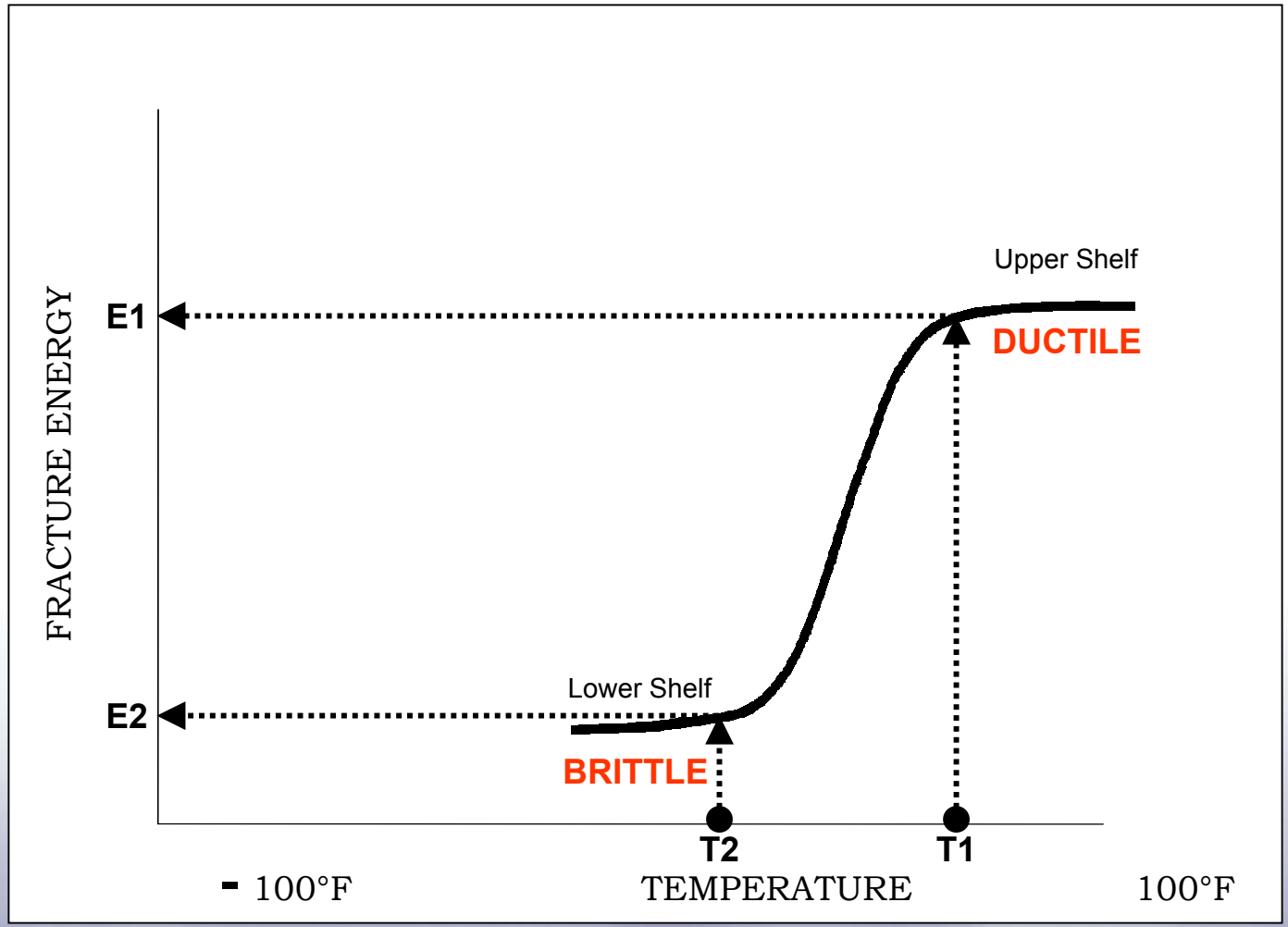
- Normalizing heat treatment
  - Steel plate heated to approximately 1,600° F
  - Followed by air cooling
- Normalizing lowers the ductile-to-brittle transition temperature (DBTT) and increases the fracture energy

# AAR Approach

- Normalizing heat treatment specified for tank cars manufactured after Jan. 1, 1989

- Five catastrophically failed tank cars were built in 1976 with non-normalized shells

# Ductile-to-Brittle Transition Temperature (DBTT) Curve for Steel



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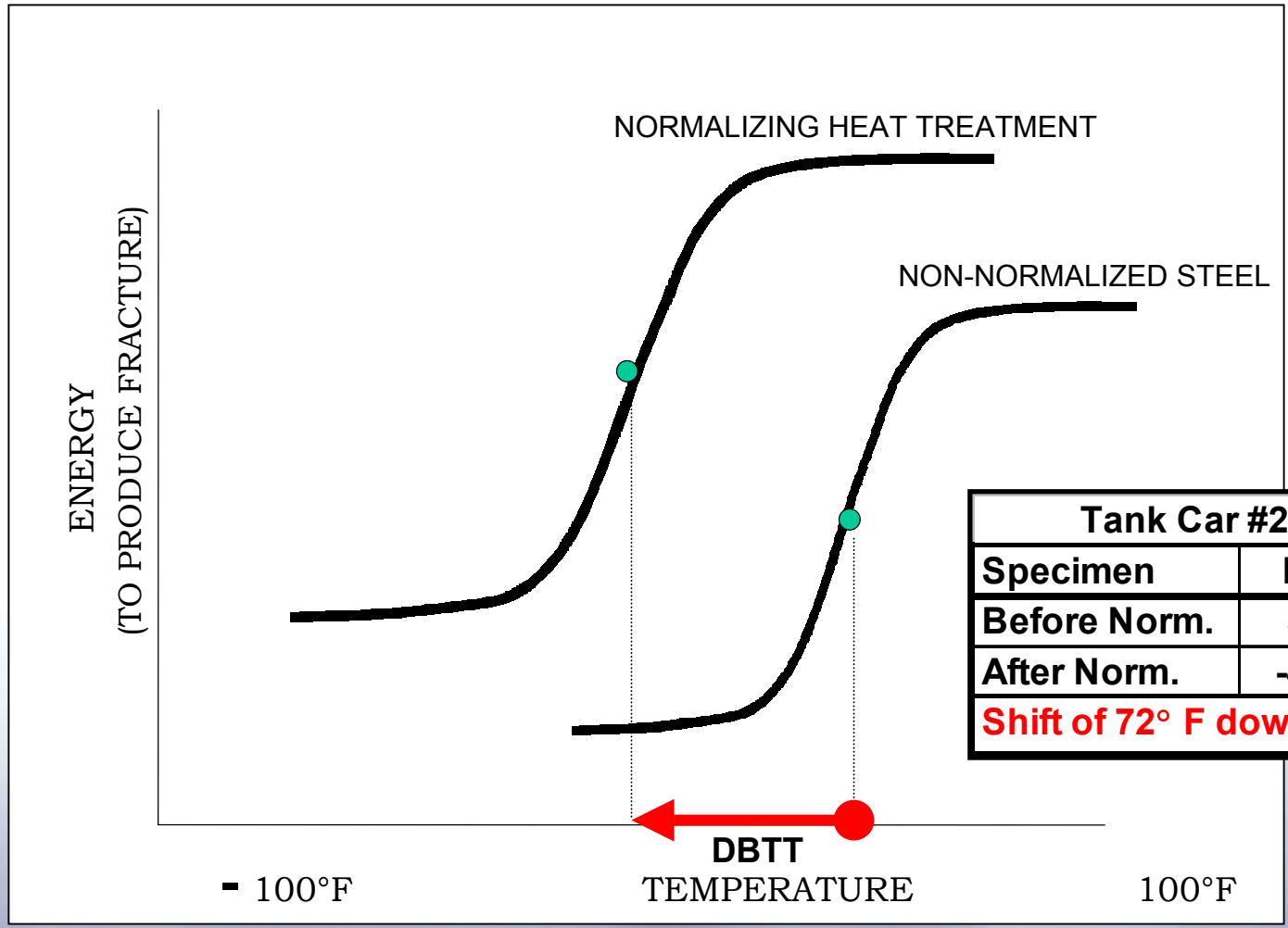


| Tank Car #22 | |
|---|---|
| Specimen | DBTT |
| Before Norm. | 32° F |
| After Norm. | -40° F |
| Shift of 72° F downward | |

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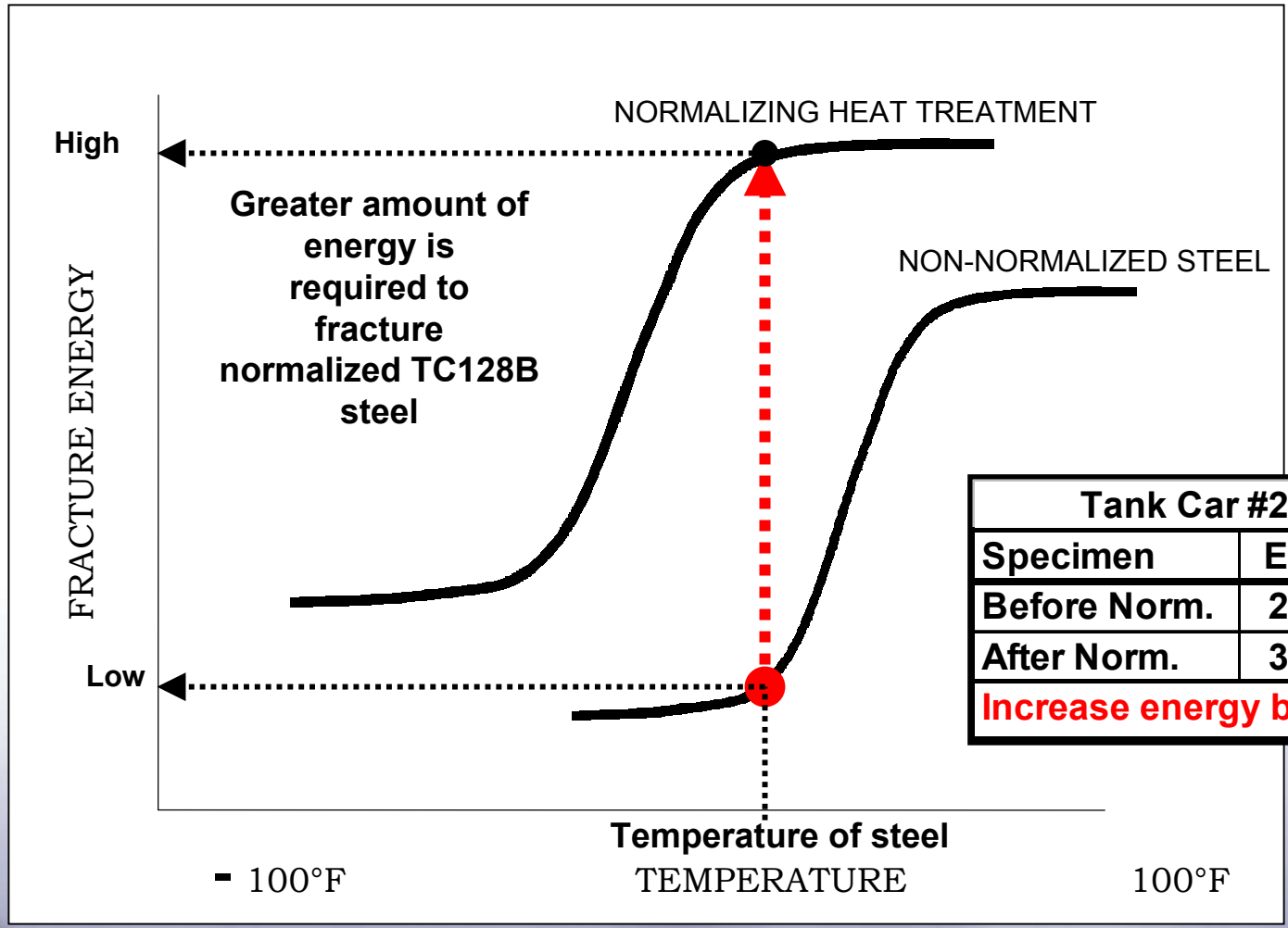


| Tank Car #22 | |
|---|---|
| Specimen | Energy |
| Before Norm. | 20 ft-lb |
| After Norm. | 36 ft-lb |
| Increase energy by 80% | |

# Conclusion

The low fracture toughness of the non-normalized steels used for the tank shells of the five tank cars that catastrophically failed in this accident contributed to the cars' complete fracture and separation.

# Current Status of Material Requirements – Impact Resistance

- Impact resistance test for “cold temperature” service only
- Lack of adequate testing standards for impact resistance for all tank cars carrying class 2 hazardous materials
- Testing orientation

# Recommended Materials Performance Standard

- Specify a fracture toughness standard
- Flexibility to choose
  - Chemical composition
  - Grain size
  - Rolling process
  - Heat treatment

# Conclusion

A materials standard to define the minimum level of dynamic fracture toughness for the material in all tank cars that transport class 2 hazardous materials over the entire range of operating temperatures would provide greater assurance that the tank car materials will perform in a safe manner in accident conditions.

# Predictive Model for Accident Conditions

- FRA proposes to develop a model to predict impact loads during accidents
- Completion of this research is important
- The resulting predictive model must also be validated


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