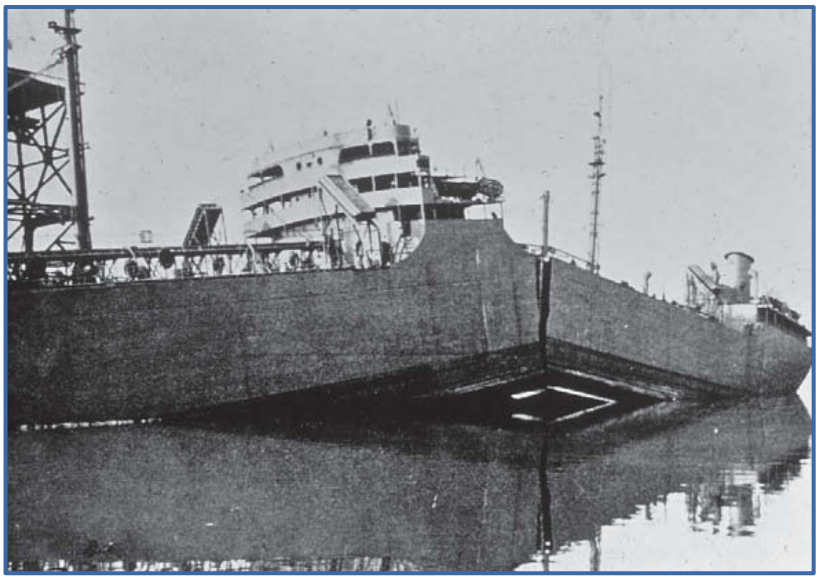
(1) Liberty Ships – Structural Failures

The failure of many of the World War II Liberty ships is a well-known example of the brittle fracture of steel that was thought to be ductile.

Some of the early ships experienced structural damage when cracks developed in their decks and hulls. Three of them catastrophically split in half when cracks formed, grew to critical lengths, and then rapidly propagated completely around the ships' cross section. The figure shown below is of one of the ships that fractured the day after it was launched.



Subsequent investigations concluded one or more of the following factors contributed to each failure:

- When some normally ductile metal alloys are cooled to relatively low temperatures, they become susceptible to brittle fracture; that is, they experience a ductile-to-brittle transition upon cooling through a critical range of temperatures. These Liberty ships were constructed of steel that experienced a ductile-to-brittle transition. Some of them were deployed to the frigid North Atlantic, where the once ductile metal experienced brittle fracture when temperatures dropped to below the transition temperature.

- The corner of each hatch (i.e., door) was square; these corners acted as points of stress concentration where cracks can form.

- Weld defects and *discontinuities* (i.e., sites where cracks can form) were introduced by inexperienced operators.

Remedial measures taken to correct these problems included the following:

- Lowering the ductile-to-brittle temperature of the steel to an acceptable level by improving steel quality (e.g., reducing the sulphur and phosphorus impurity contents).
- Rounding off hatch corners by welding a curved reinforcement strip on each corner.
- Installing crack-arresting devices such as riveted straps and strong weld seams to stop propagating cracks.
- Improving welding practices and establishing welding codes.

Additionally, structural steels were developed with vastly improved resistances to catastrophic brittle fractures. Detailed analyses of these failures advanced the understanding of crack formation and growth, which ultimately evolved into the discipline of fracture mechanics.