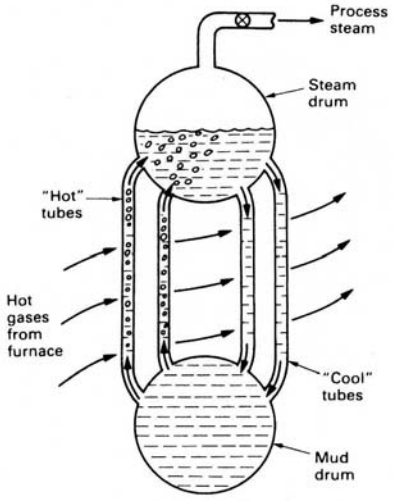
Case Studies in Steel

Boiler Explosion

Background

- Water-tube boiler used to generate steam in a chemical plant
- Steel tube working pressure: 50bar (5MPa)
- Water temperature: 264^{o}C
- Steel tube
  - dimensions:
    - 10m long, OD 100mm, 5mm wall thickness
  - composition:
    - Fe – 0.18%C, 0.45%Mn, 0.20%Si

Schematic of water-tube boiler



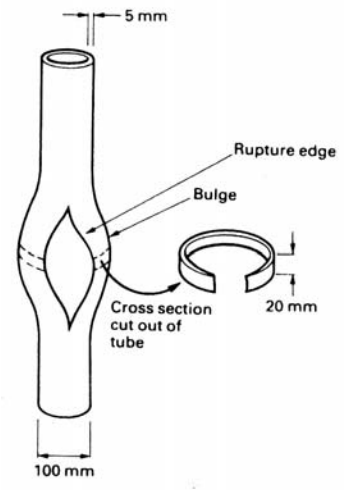
200 steel tubes

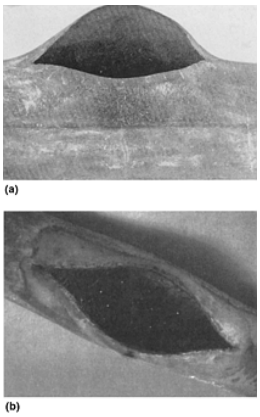
- dimensions:
  - 10m long,
  - OD 100mm,
  - 5mm wall thickness
- composition:
  - Fe – 0.18%C, 0.45%Mn, 0.20%Si

Problem

- Some “hot” tubes became overheated and started to bulge
- Operations continued
- Eventually one burst and contents of boiler discharged into the environment

Burst tube





Investigation

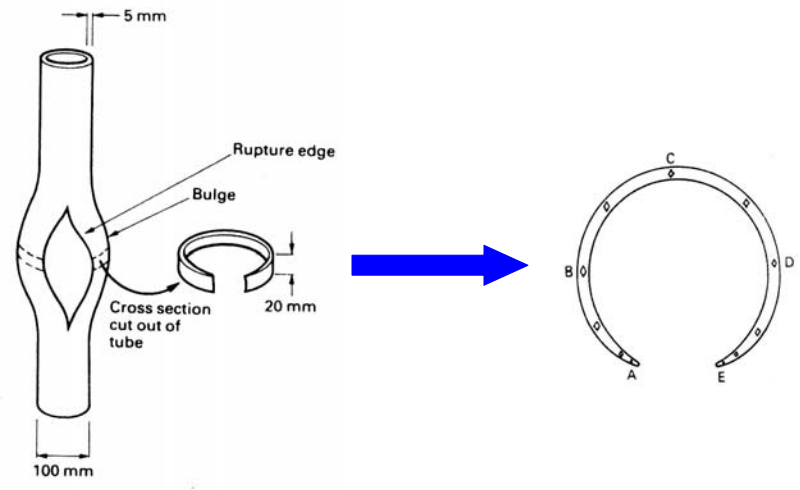
Hardness measurements:

- Cut out a 20mm length of tube through centre of failure
- Sections of unused (new) tubes obtained

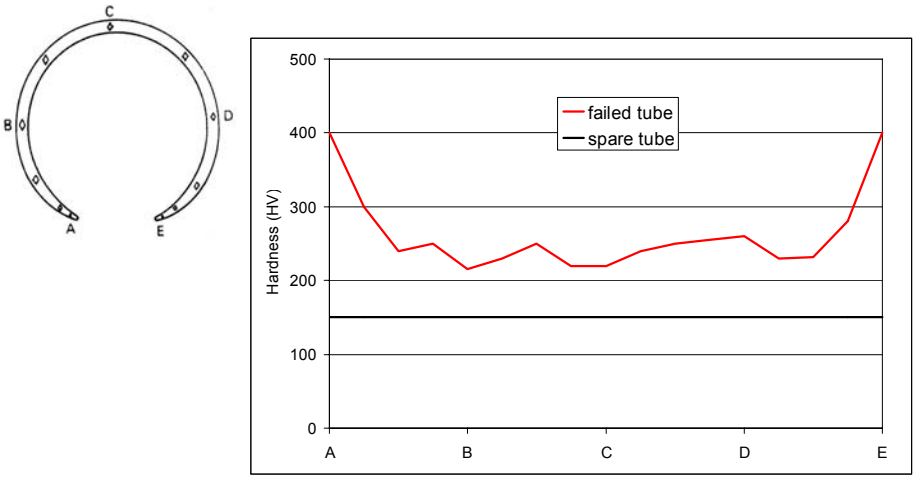
Metallography:

- Failed tube

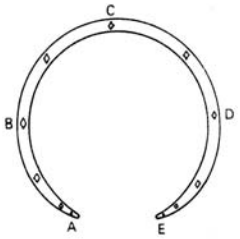
Investigation



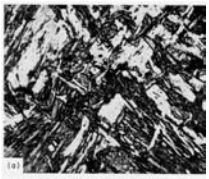
Hardness measurements



Microstructures



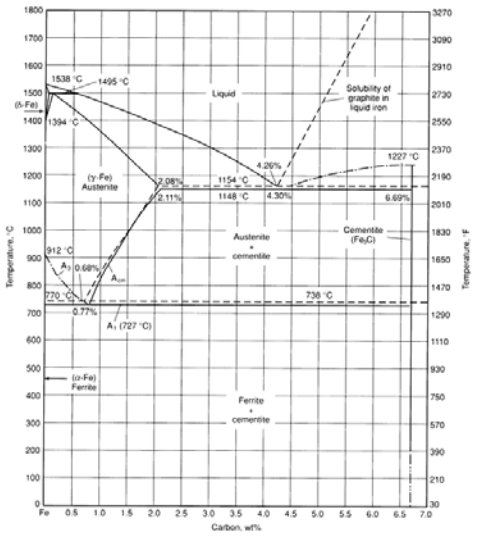
A



B

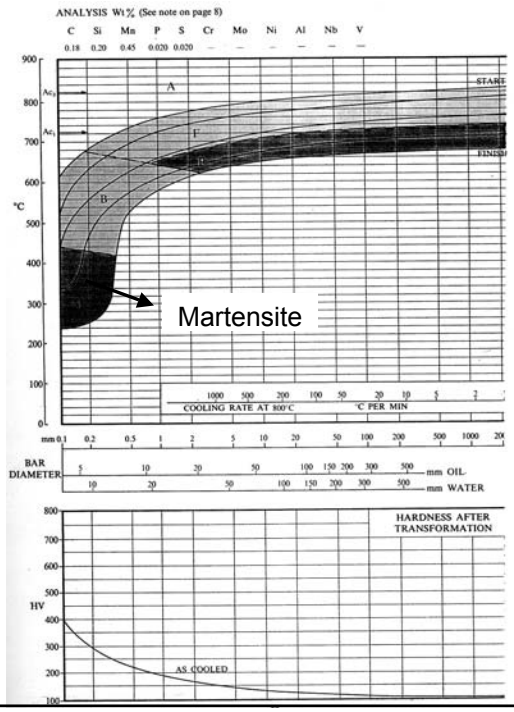
C

Fe-C phase diagram



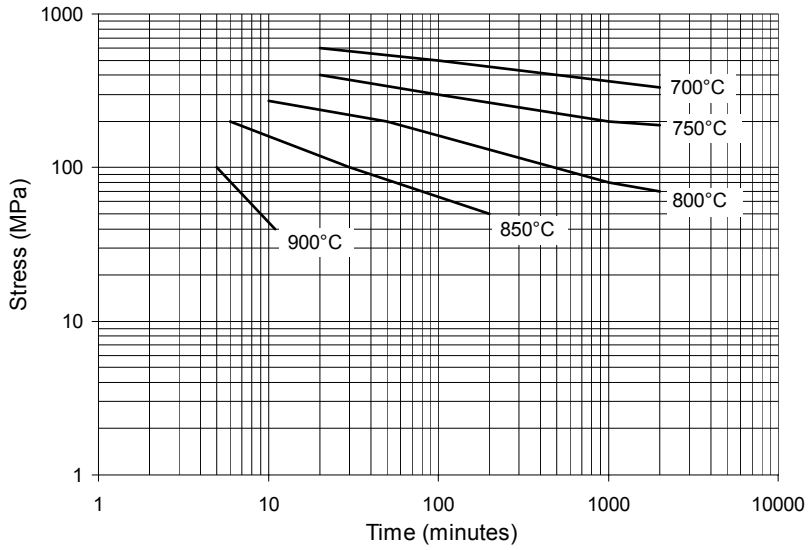
A_3 temperature for the steel tube is:

____^{o}C



CCT diagram

Stress rupture data



Thermal history

- Thermal history experienced by ruptured tube (peak temp/ cooling rate)

  Location “A” _____

  Location “C” _____

Microstructure

Ruptured tube:

Location “A” _____
Location “B” _____
Location “C” _____

Spare tube: _____

Stress state in tube

$\sigma_{hoop} = \frac{Pr}{t}$ _____ MPa

$\sigma_{radial} = 0$ _____ MPa

$\sigma_{axial} = \frac{Pr}{2t}$ _____ MPa

P = internal pressure (MPa)

r = radius of tube (mm)

r = thickness of tube (mm)

Stress rupture data

Time to failure (minutes)

- @ 900^{o}C: _____
- @ 850^{o}C: _____
- @ 800°C: _____

Explanation