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Thermographic inspection of marine composites

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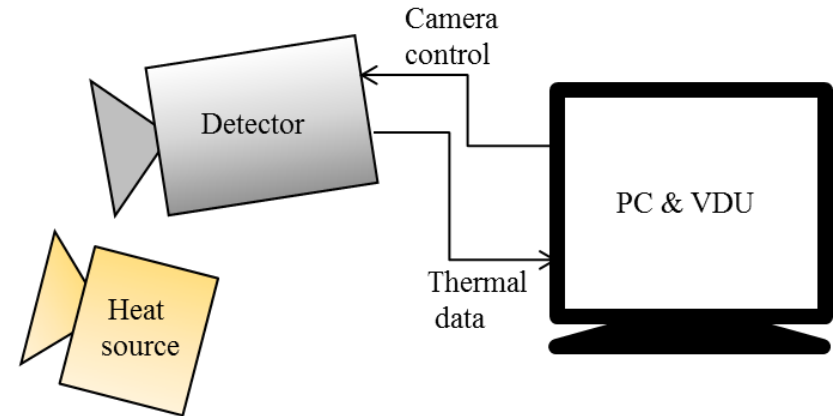
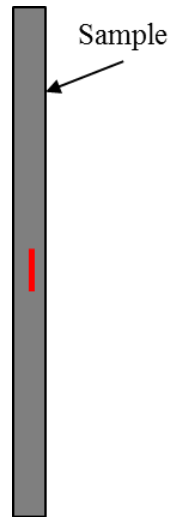
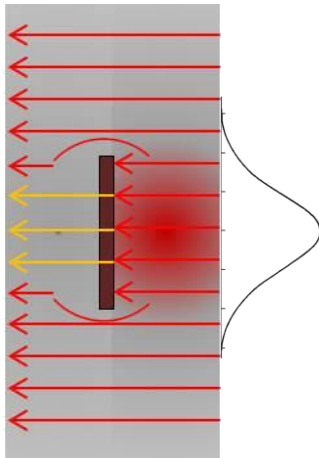
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Thermography

- Detecting defects
 - Pulsed and Pulse Phase Thermography
- Impact of defects
 - Thermoelastic Stress Analysis

Pulsed / Pulse Phase Thermography (PT/PPT)

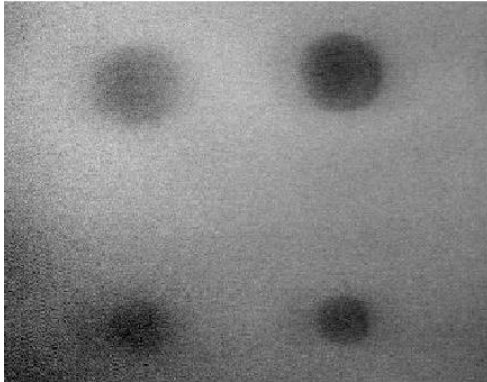
- Apply heat pulse to surface of material
- Thermal front propagates material
- Surface temperature monitored by IR detector



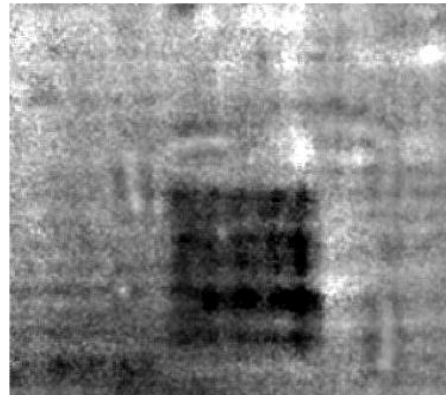
- Volume of differing thermal properties under the surface results in an area of differing temperature on the surface
- Deeper or smaller defects are able to be found via application of an FFT on the thermal data as surface effects are removed

PT / PPT data examples

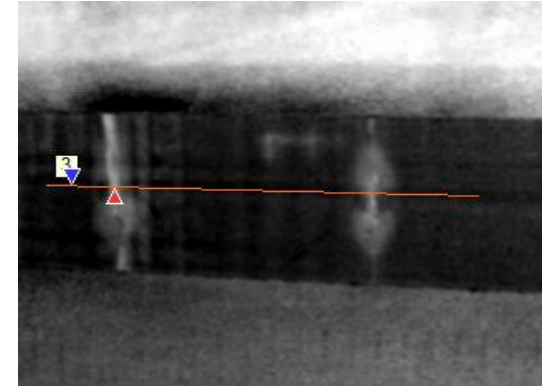
CFRP laminate with
PTFE inserts at 0.4 and
0.6 mm



GFRP face sheet with PVC
foam core with PTFE
inserts, depth 1.8 mm

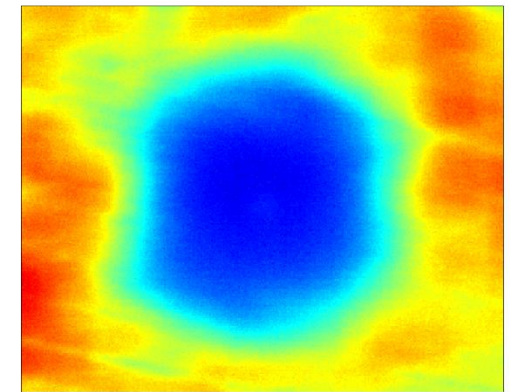
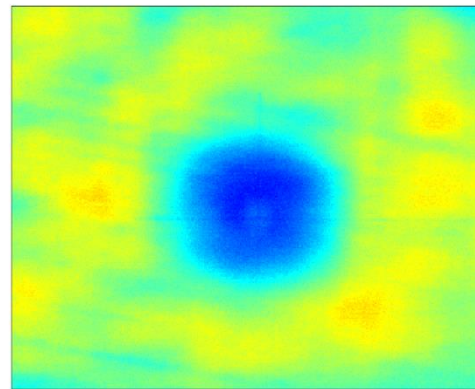


GFRP face sheet with PVC
foam core with 2 x 40 J
impact damage

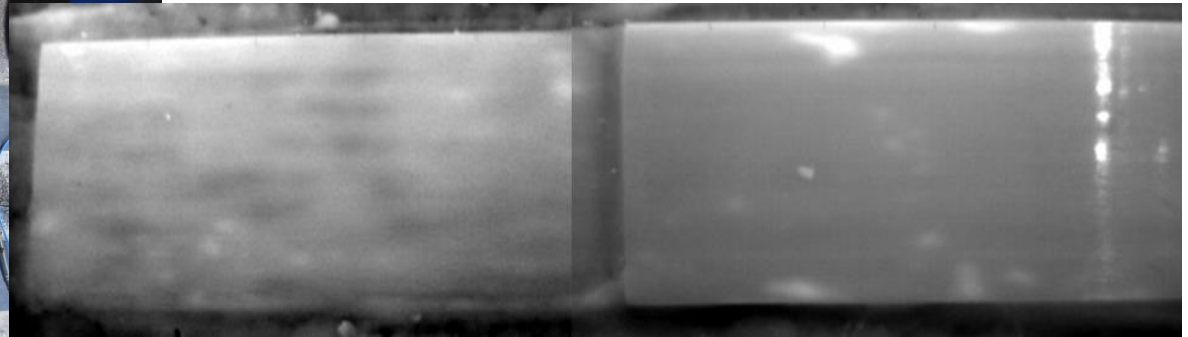
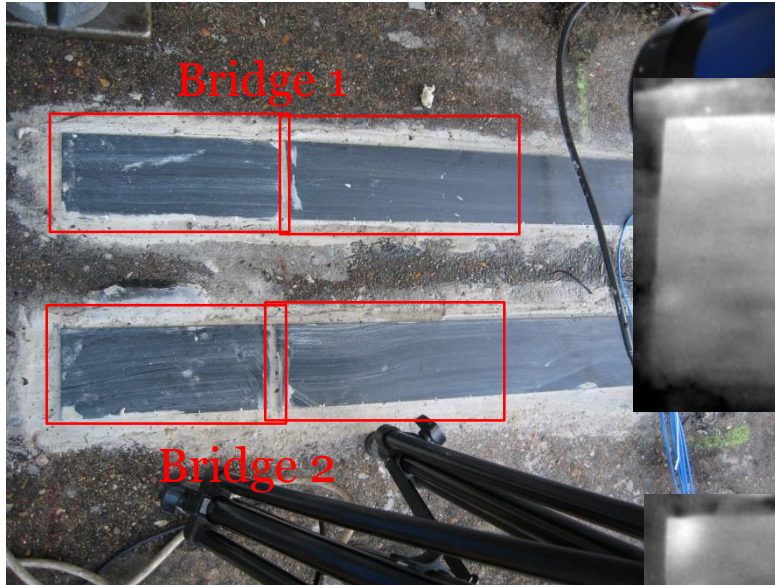


Vary heating stimulus to work in
different materials or with different
thicknesses/depths

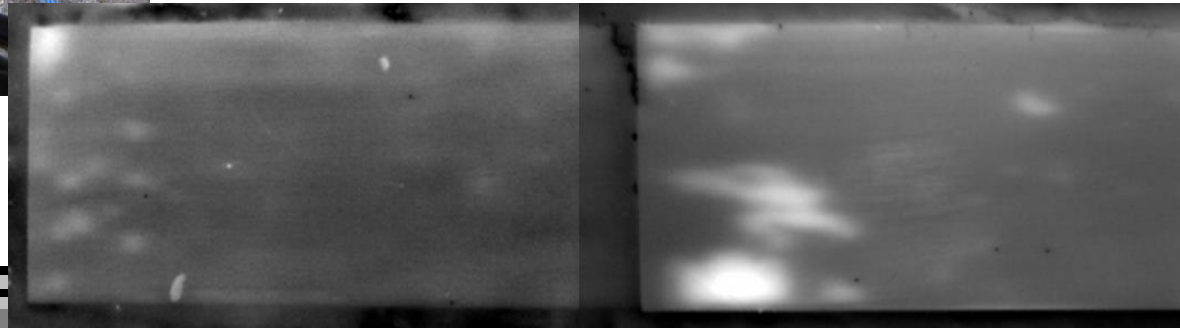
e.g. Flash lamp(s)
Hot water
IR heat lamp



NPL CFRP Bridge Reinforcement

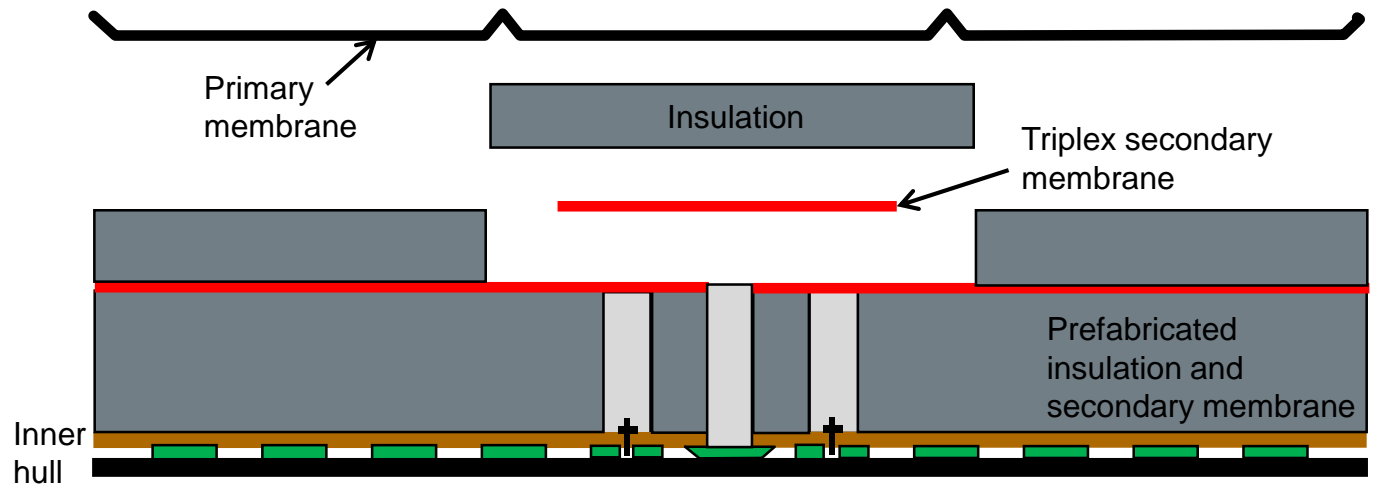
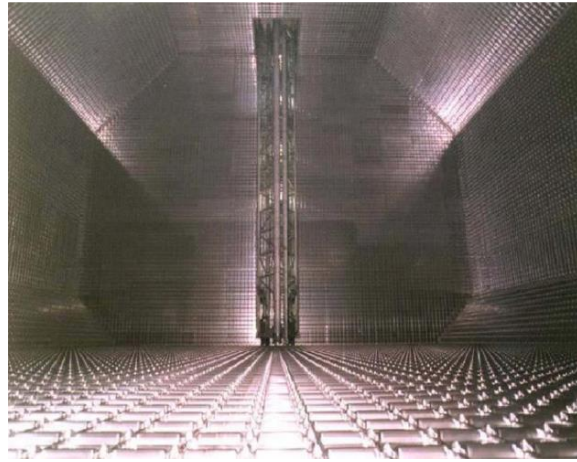


- Epoxy adhesive ~1.5 mm thick
- UD CFRP ~ 1 mm thick

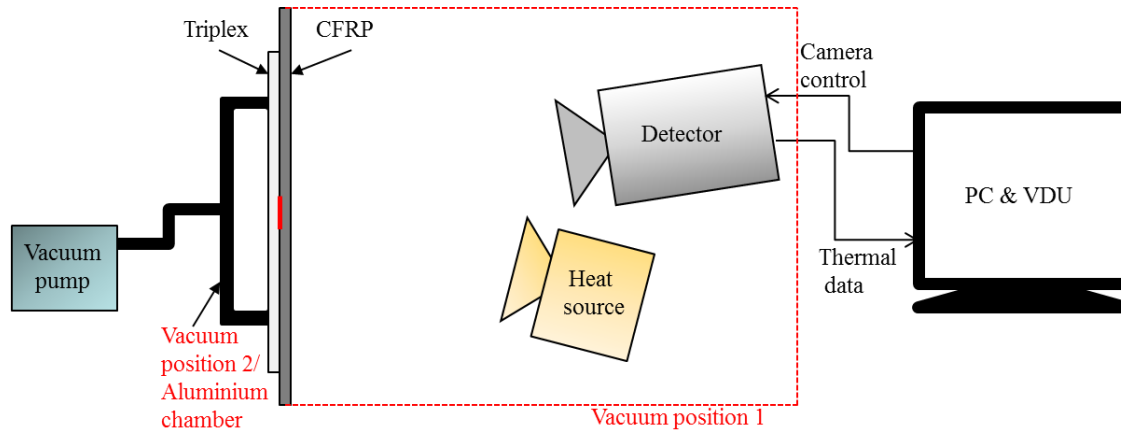


LNG Membrane inspection

- Mk III Membrane style LNG Carrier
- LNG transported at -164°C
- Aim: Provide method of NDE for 50+km of adhesive bonds used to form secondary membrane during construction



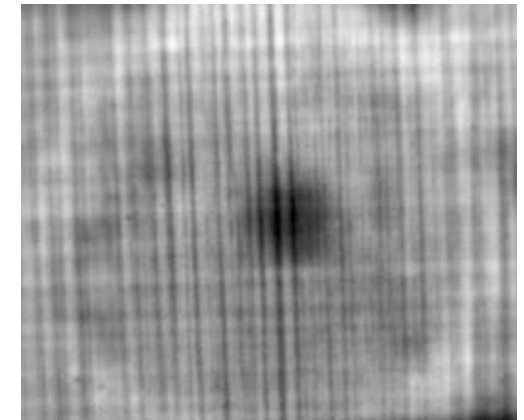
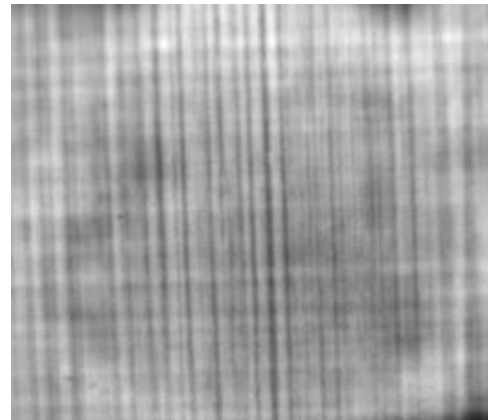
Kissing defect detection



- PPT relies on their being a thermal property contrast
- Kissing defects do not have a contrast as they have no volume associated with them
- System must be changed to enable kissing defect detection

- Application of a small load can be used to open the defect
- Unloaded and vacuum loaded PPT data

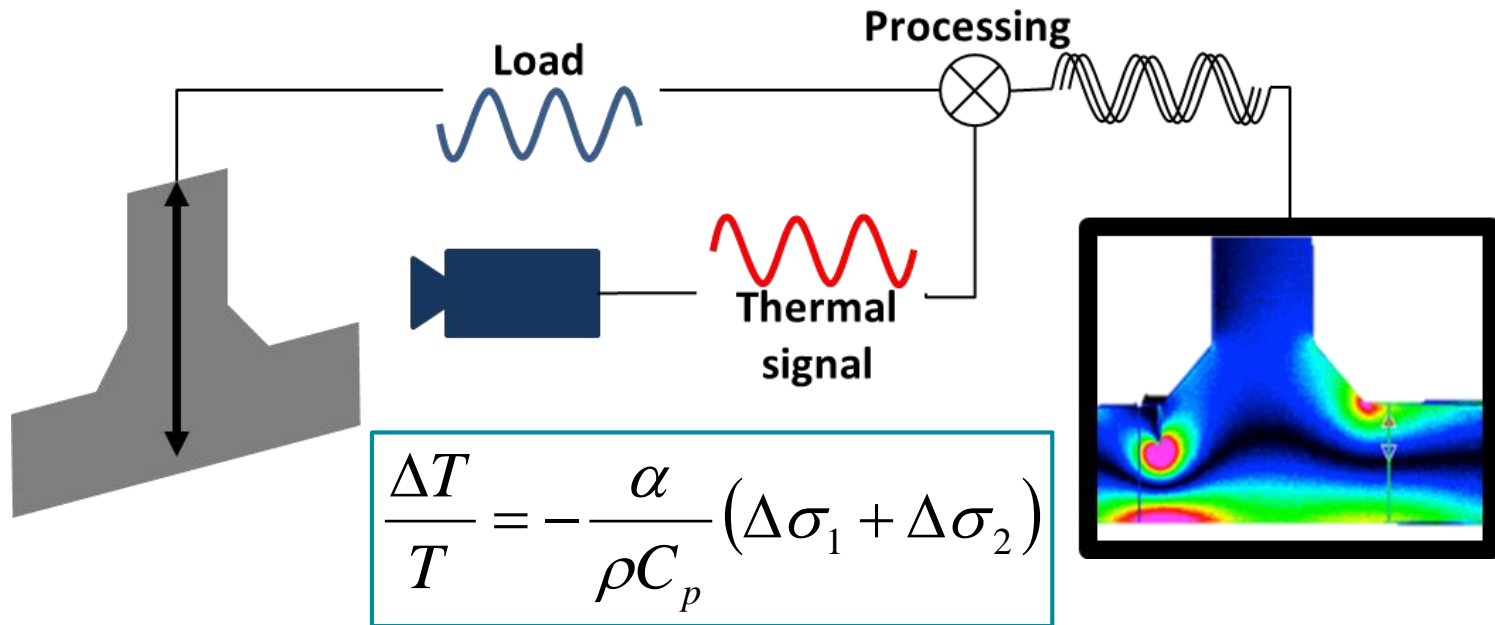
Tighe, R.C., Dulieu-Barton, J.M. and Quinn, S.
Experimental Techniques (2017). DOI:
10.1007/s40799-017-0200-7



Thermography

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Thermoelastic stress analysis (TSA)



Measurement of a small reversible temperature change can be related to the change in the sum of the principal stresses

ΔT - change in temperature

ρ - density

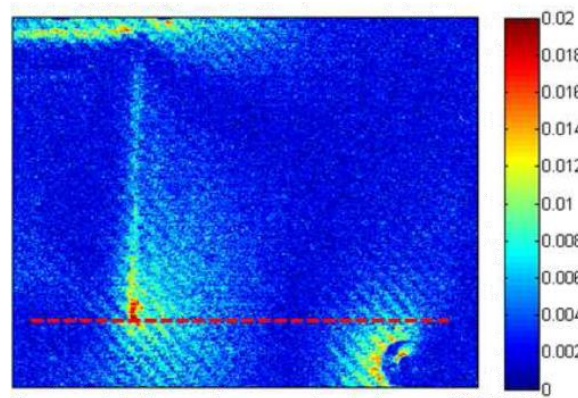
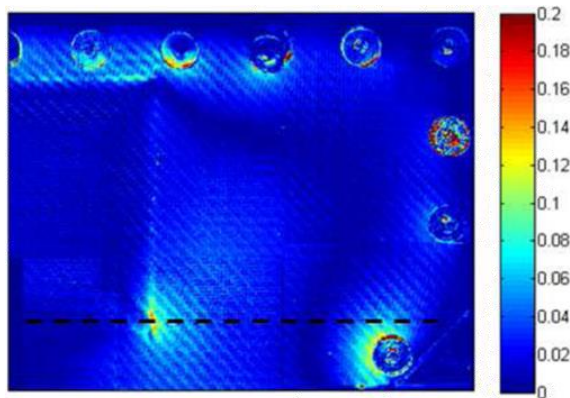
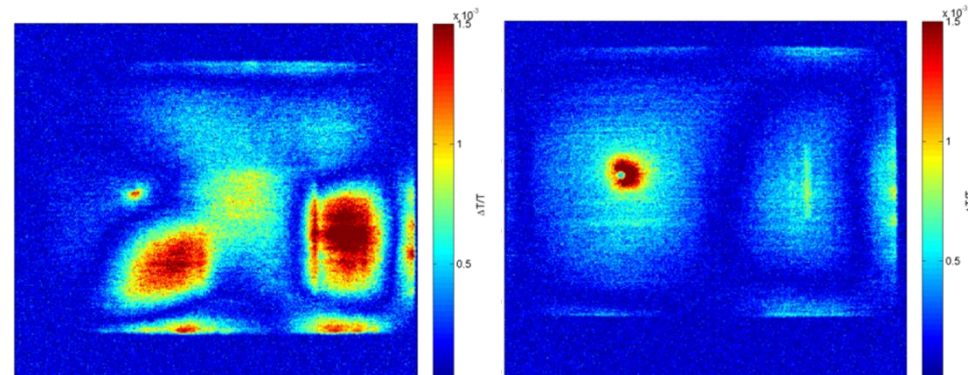
C_p - specific heat

$\Delta \sigma_1 + \Delta \sigma_2$ - change in the sum of the principal stresses

α - coefficient of thermal expansion

Onsite implementation

- Laboratory tests typically apply load using a servo-hydraulic test machine
 - Pneumatic and permanent magnetic shakers have been employed to provide loading
- GFRP – 0.9 mm thick
 - ‘Ply drop’ – square section of central ply removed
 - Ply cut – central ply cut transverse to fibres

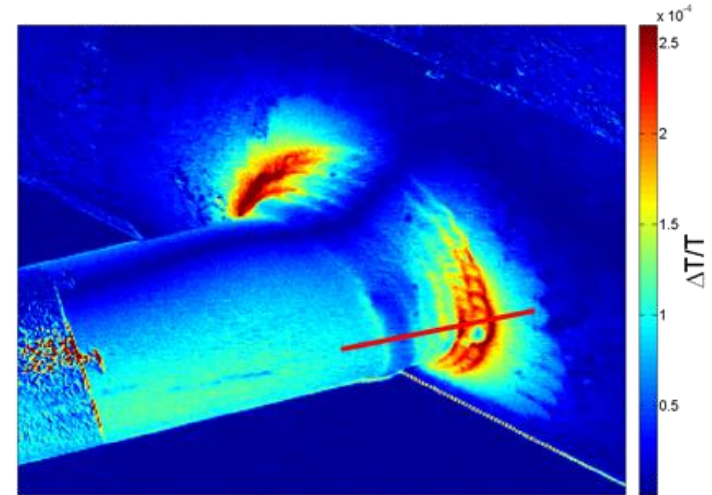
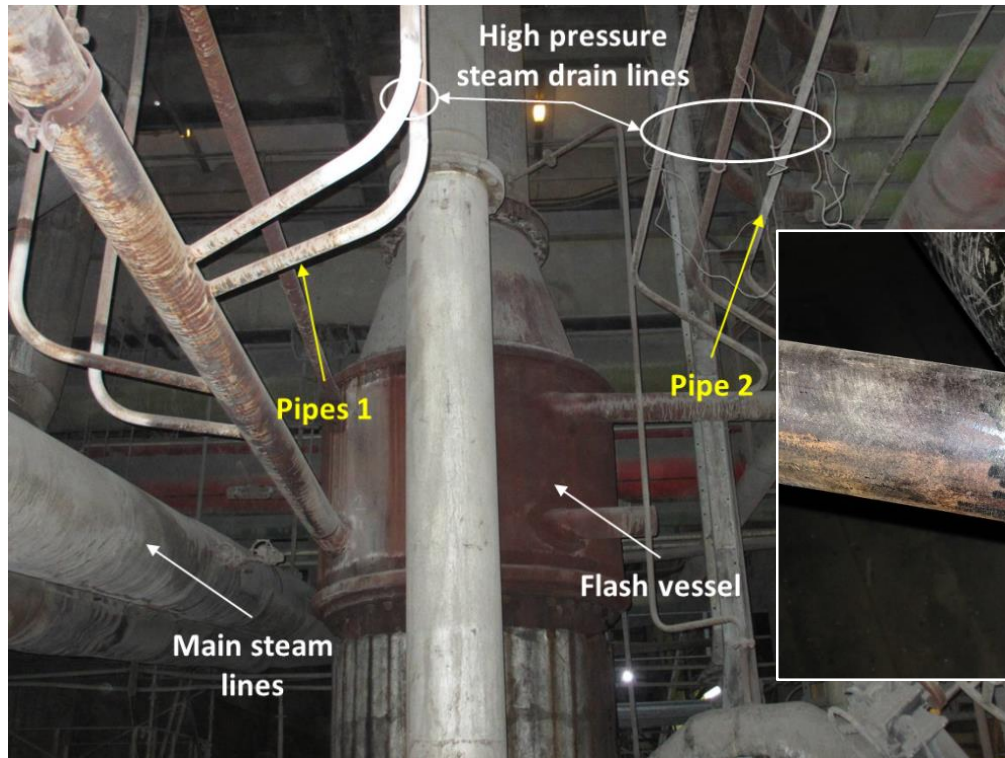


Representative secondary aircraft panel – CFRP with honeycomb core.

Dulieu-Barton, J.M., Fruehmann, R.K., and Quinn, S., Key Engineering Materials, 569, 3-10 (2013).

Onsite inspection

- Stress concentrations in/around welds can be assessed
- Pneumatic shaker driven



Tighe, R.C. et al., NDT & E International, 84, 76-88, (2016).

Thermography

- Pulsed and Pulse Phase Thermography
 - Defect detection
 - Tailorable approach to the situation
 - Each pixel gives value of thermal measurement so can be quantified

- Thermoelastic Stress Analysis
 - Provides information about the stress state
 - In-service or external loading required
 - Each pixel gives a value that can be calculated to be a stress

Thank you!

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