HOIS-G-054 Guidance for Ultrasonic NDT for NII at Elevated Temperatures (up to 480°F)

HOIS project co-funded by The NZTC

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ESR Technology
Engineering, Safety & Risk

HOIS
Advancing NDT

Technical project developing guidance

Motivation

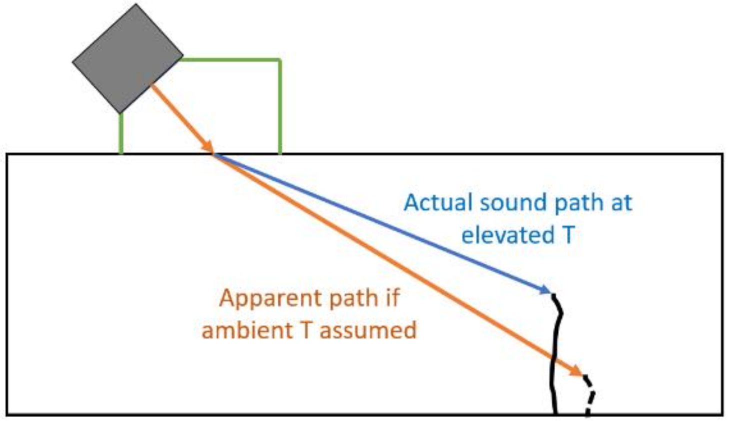
- Increased interest in Non-Intrusive Inspection (NII) of pressure vessels and other components
- Requires highly accurate corrosion mapping data and examination of welds to determine vessel condition.
- Up to about 160-180°F ultrasonic testing (UT) is reasonably unaffected by temperature
  - But challenges in performing UT at higher temperatures – specialist equipment needed
- Limited availability of good practice guides or standards

HOIS project initiated to extend applicability and benefits of NII to pressure vessels and other components at elevated temperatures up to 480 °F, typical of upstream operations

Scanning UT at up to 480°F

Challenges:

- Inspector safety
- Material property changes of steel with temperature:
  - Ultrasound velocity
  - Increased attenuation and scatter
- Material property changes in the probe shoe with temperature
- Requirements for high temperature probes, wedges and couplants
- Consideration of dwell time/duty cycle (depending on probe design used)
- Scanner considerations – materials, lubricants, magnetic wheels
- Lack of availability of good practice guides and/or standards



Change in probe delay and refracted angle affect apparent lateral and depth location of indication

HOIS trials

Multi-vendor trials on test pipes at up to 480°F using:

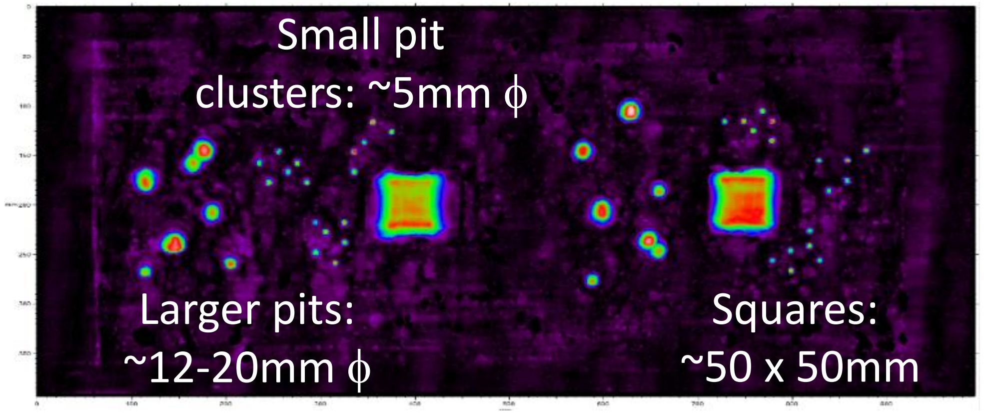
- 0° corrosion mapping
- TOFD
- Angled beam phased array

Variety of probes and cooling systems.

Some of the trials achieved results where sizing of remaining ligament was comparable with previous trials at ambient temperatures.

Detail trial report is available to HOIS members.

Lessons learned led to development of guidance.



Availability of guidance

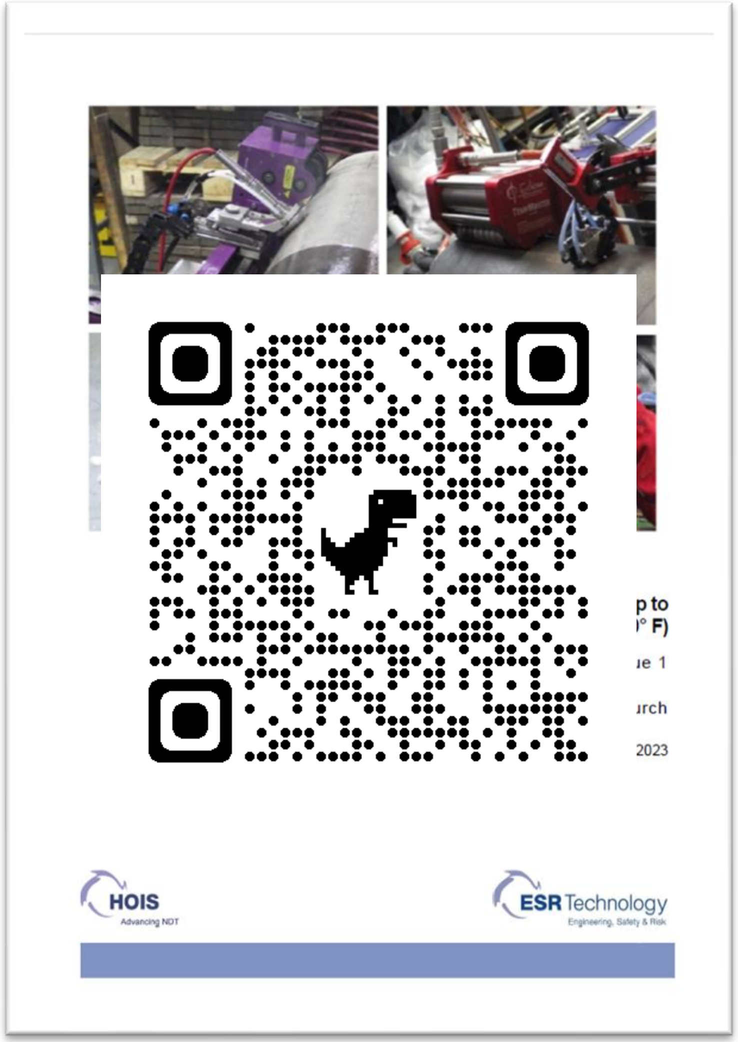
HOIS Advancing NDT

Freely available to HOIS members.

Publicly available through BINDT online store for £150.

Scope:

- Carbon Steel
- Max. temperature 450 - 480°F
- Highly accurate corrosion mapping data and examination of welds to determine vessel condition. **Not** point wall thickness measurements



Probe selection

Probe frequency

- Should be as high as possible, given constraints such as the increased attenuation and scattering.
  - For temperatures up to 480°F: a maximum probe frequency is likely to be 5 MHz.
  - At lower temperatures (up to 180°F): higher frequencies up to 10 MHz should be considered.

Probe bandwidth

- Well damped probes are preferred with short near-surface dead-zones.

Probe sensitivity

- Probes should have high sensitivity, due to the generally reduced signal levels that will occur at elevated temperatures. At ambient temperatures, piezo composite materials are often used to obtain high bandwidth probes with good sensitivity.

Probe dimensions

- Probe dimensions should be chosen bearing in mind the test component wall thickness/inspection range and the inspection used (corrosion mapping, TOFD, angled beam pulse-echo for weld inspection).

See related document HOIS Recommended Practice on Precision Corrosion Mapping

Selection of probes and delay lines/wedges

Selection of an optimum probe for inspection at elevated temperature is a major factor in obtaining high quality results, and hence needs careful consideration.

High temperature probes/wedges without active cooling

- Probe/shoe temperature changes in scan. Avoid where possible, except for TOFD of welds.

High temperature probes/wedges with effective cooling systems

- Usually preferable to uncooled probes.
- Can be used for corrosion mapping and weld examination.
- Leave in contact with surface before scanning to allow steady state T to be reached.

Ultrasonic probes designed for operation at elevated temperatures

- Some developed in earlier R & D projects.
- Now commercially available for pulse-echo, TOFD and PA.
- Leave in contact with surface before scanning to allow steady state T to be reached.
- Shown to be effective in HOIS trials.

Ultrasound velocity changes at elevated temperature

Test component:

- Carbon steel:
  - Ambient: velocity of 5920 m/sec
  - At 250°C: velocity of 5740 m/sec.
- Change in ultrasound velocity needs to be accounted for:
  - Measure component temperature e.g. temperature indicating sticks to measure the temperature of surface being inspected
  - Use best available information on how velocity changes with temperature, e.g. ISO 16809
  - Avoid use of a separate calibration block
- Thermal gradient in the component can normally be ignored.

For 20mm plate, apparent thickness increases by 0.6mm between ambient and 250 °C

Temperature dependence in shoe/wedge **larger** than in test material.

- Limited information on coefficients.
- ONDT website case study implied 3.5% per 55° C (factor 5 higher than steel)

Accounting for high temperature effects on ultrasound velocity in probe wedge

Probe type	Effect	Recommendation
0° pulse-echo	Change in arrival time of signal corresponding to zero depth in component (probe delay)	Single crystals – calibrate depth measurement using strong front wall echo. Twin crystal – calibration of probe delay using measurements of first and second backwall echoes in an uncorroded area of component: adjust probe delay until arrival time of first backwall echo is equal to time difference between first and second backwall echoes.
Angled beam TOFD	Change in probe delay	Calibration of arrival times using lateral wave signal allows for change in arrival time due to the altered velocity in the probe shoe.
Angled beam pulse-echo PA	Change in probe delay and refracted angle in test component will affect apparent locations of any indications in the component both laterally and in depth	Ideally: Modify focal law files to take account of velocity changes in probe wedge and material. Alternatively: use an unmodified focal law and include a high gain channel showing “backwall rumble” signals – these can be calibrated to that of known wall thickness measured using 0° probe in an uncorroded section of component.
Angled beam pulse-echo (single probe angle)		Not used in HOIS trials. Requires demonstration of effective method for correction

High temperature scanners

Effective scanners are commercially available which consider effect of temperature on

- Materials/lubrication
- Drive motors (if fitted)
- Electronics
- Magnetic scanner wheels.

Potential mitigations include:

- On-board cooling for any motors and magnets
- Cable handling systems designed to avoid contact with the scanned surface

High temperature couplants

Only use those intended for scanning UT, not spot measurement UT.

Use only within specified temperature range.

Must be applied and used quickly since they will tend to dry out or solidify and no longer transmit ultrasonic energy.

Dried couplant residue should be removed from the test surface and the transducer after scanning.

Consider methods for re-cycling on cost grounds.

Summary

Successful trial programme has led to development of specific key points of guidance which should give comparable measurement accuracy on high temperature components (up to 480°F) to that achieved at ambient temperatures.

Emphasis has been on scanning ultrasonic systems for corrosion mapping and weld inspection using TOFD and angled beam phased array.

Supports the safe extension of the applicability of non-intrusive inspection process to pressure vessels with operating temperatures up to 480°F (typical of upstream applications).

HOIS-G-054 is in the public domain: www.hoispublications.com

Acknowledgements

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