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TO:

HID Regulatory Inspectors

HID Discipline/Topic Specialist Inspectors (Process Safety, Mechanical, Ionising Radiation)

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## **UNDERLAGGING CORROSION OF PLANT AND PIPEWORK**

### **PURPOSE**

This semi-permanent circular introduces the issue of underlagging corrosion (ULC) of plant and pipework. It gives a brief overview of the causes of corrosion and preventive measures that may be taken. Techniques for detecting ULC are also highlighted.

### **BACKGROUND**

1. The problem of ULC of process plant and pipework is associated mainly with steel components. Failures have occurred, with loss of containment, due to localised corrosion progressing undetected beneath insulation.

### **CAUSES**

2. Steel corrodes when it is in contact with water and has a free supply of oxygen. When plant and pipework are insulated there is usually a space in which water can collect on the metal surface with access to air. The ingress of water into the lagging is often caused by one or more of the following:
  - a. poorly designed and/or installed protective finish or cladding;
  - b. cladding joint sealant breakdown;
  - c. mechanical damage to the protective finish; or
  - d. cladding removed and not properly replaced (common around valve boxes).

3. When water penetrates the lagging it tends to collect at low-lying sections of plant and pipework and around discontinuities, e.g.-
  - a. the base of vessels;
  - b. pipework supports;
  - c. the intersection between nozzles and vessels;
  - d. the underside of elbows and horizontal pipe runs; and
  - e. drain legs.
  
4. ULC may be influenced by the chemical nature of the insulation material. Some cladding materials contain free chlorides which may promote ULC. Chloride stress corrosion cracking should be considered for austenitic stainless steel at temperatures of 65°C and above. This is of particular importance for coastal sites and offshore installations where chloride contamination will be enhanced. For high carbon stainless steel grades at temperatures of 50°C and above, intergranular attack and chloride stress corrosion cracking cannot be ruled out. Insulating materials applied on zinc-rich coatings should preferably have neutral pH values as the coating may deteriorate in the presence of water with low or high pH values.
  
5. Surface coatings may provide protection against corrosion if the lagging becomes wetted, though proper selection and application are particularly important. Coatings should be compatible with the insulating material and suitable for use at the anticipated temperature. Coatings applied to poorly prepared or hot surfaces are much more likely to break down. Particular attention should be given to proper application at welds
  
6. Experience indicates that many factors influence the risk of ULC including whether trace heating is installed (a high risk factor). In particular, operating temperature greatly affects the risk of ULC. The following table indicates the likely risk of ULC for mild steel pipework, without trace heating, under various operating regimes:

Operating Temperature	Risk Of ULC		
	Painted Pipework	Painted Pipework	Painted/Unpainted Pipework
	<10 Years Old	<10 Years Old	>10 Years Old
	Intermittent Operation	Continuous Operation	Intermittent or Continuous Operation
< -30 °C	Low - Medium	Low	Medium

-30 °C to 30 °C	Medium	Low - Medium	High
30 °C to 120 °C	High	High	High
>120 °C	Medium	Low	Medium

7. At low temperatures the corrosion mechanism is suppressed and at elevated temperatures moisture in the insulation material should evaporate during start-up. However, even where the risk of ULC is generally considered low, the increased risk during periods when the plant is shut down should not be discounted. The problem may be exacerbated by frequent plant cycling between operating and shutdown conditions.
8. In general terms, experience has shown that the most critical temperature range for ULC is 30°C-120°C. US data for carbon-manganese steel indicates typical corrosion rates of 0.5 mm/year at 80°C under lagging.

## PREVENTIVE MEASURES

9. The following points should be borne in mind, and included as part of any system to prevent ULC:
  - a. the need for lagging should be assessed and only applied where its use can be justified. Where lagging is required for personal protection only, consideration should be given to alternative forms of protective coverings which do not give rise to the risk of ULC e.g. use of guards to protect personnel from hot surfaces;
  - b. lagging should be designed and installed to inhibit or reduce the potential for ULC. Attention should be given to preventing ingress of water, e.g. at cutouts for valves and equipment, and other contaminants, e.g. gearing oil from stirrers at vessel tops or chemical leaks at valves and flanges. Consideration should be given to the ease of removal and replacement of lagging bearing in mind the maintenance and inspection needs of the underlying plant. Lagging and any surface treatments should be properly restored to original specification or better after work on plant requiring removal:
  - c. management systems should encourage prompt reporting and remedial repair of physical damage to lagging;
  - d. ULC should be addressed as part of the planned preventive maintenance schedule for the site;
  - e. inspection and monitoring systems should ensure comprehensive coverage of all plant (vessels and pipework) including 'running' plant (pumps, valves etc) which may be subject to ULC. It is essential to consider items exposed to localised cooling/heating effects and the

effects of outage periods for components operating at high temperature which may promote ULC in plant or pipework which would otherwise be excluded from the survey; and

- f. during the design of new, replacement or modified plant the risk of ULC should be considered and the design specification for vessels and piping materials and lagging should be selected to inhibit or reduce the potential for ULC.

## DETECTION

10. The inspection of plant and pipework for ULC can be extremely expensive if all lagging material has to be removed. Often windows are cut into the lagging for localised inspection. However, where selected areas of plant are exposed, confidence in the effectiveness of the examination depends on the ability of the inspector to identify the critical sections of pipework or plant. In an attempt to improve the selection process, a number of non-destructive testing (NDT) techniques can be employed to detect corrosion under lagging or to identify areas that may be susceptible to corrosion without the need to remove lagging. Each technique has advantages and disadvantages and they have different capabilities. The inspector should understand the capability and limitations of any technique applied. The results of the NDT examination can then help to target problem areas where further examination may be necessary. However for critical plant/pipework where no leaks are acceptable full insulation removal may be required to secure proper inspection.
11. Examples of some NDT techniques available for detecting corrosion under lagging include:
  - a. **Pulsed Eddy Current.** The decay of an eddy current pulse is monitored within a ferritic pipe or vessel and the signal is used to calculate the remaining wall thickness beneath a coil unit. This technique can indicate areas of localised corrosion averaged over the area of the sensor. There are limitations on the thickness and type of insulation through which the eddy currents can penetrate.
  - b. **Guided Wave Ultrasonics.** This remote screening technique can be used to look for degradation of internal or external pipe surfaces. It can be used where access is restricted and is suitable for long pipe runs. It can detect losses of cross-sectional area of 10% and upwards and is useful to identify areas for more detailed examination.
  - c. **Flash radiography\***. This is an established technique which produces high energy X-rays in very short pulses of about 50 nano-seconds duration. When used for detecting ULC, a tangential exposure is made using very fast film. A variation of the system was developed using an unshielded hand-held 'gun' that allowed unacceptable levels of radiation exposure to operators. HSE radiation specialists have considered that this adaptation of the technique should not be used.

- d. **Real-time imaging radiography\***. Developments in real-time radiography have been rapid in recent years and mobile systems are now available to carry out on-site monitoring with a direct visual display of the image. A specially built, shielded hand-held device is also available with this system that, it is claimed, gives negligible exposure to the operator.
12. Examples of some NDT techniques available for detecting moisture under lagging include:
- a. **Thermal imaging** (thermography). Detects temperature variations and has been widely used to detect breakdowns of thermal insulation of cryogenic storage vessels and thermal linings of furnaces etc. Areas of damaged and waterlogged lagging can be detected using this technique. Thermography does not give a definitive indication of corrosion, but highlights areas where corrosion may develop in the future. The possibility of intermittent wetting and drying-out of lagging, especially on hot plant and pipework, leading to a misleading result needs to be kept in mind.
  - b. **Neutron Backscatter\***. Neutron backscatter devices (hydrodetectors) can be used to locate areas of wet insulation on vessels and pipework, which are potential ULC sites. The system comprises a neutron source and detector assembly on the end of a telescopic pole allowing access to hard to reach areas. Typical screening rates are around 300m of insulated pipework per day.

\*Activities subject to the Ionising Radiations Regulations 1999.

13. Some NDT techniques currently under development include:
- a. **Lamb Waves**. A technique adopting cylindrical lamb waves which propagate along the pipe wall from a transducer. Echoes returning to the transducer would indicate the presence of defects. Tests on typical 3-inch and 6-inch diameter, schedule 40, pipework showed that inspection of at least 15m of pipe is possible from a single transducer position. Initial conclusions were that this technique has great potential for field inspection
  - b. **Magnetostrictive sensor (MsS) technology**. An American industrial research program is currently underway to develop a cost-effective and efficient field instrument for detecting corrosion in insulated pipes. The MsS instrument under development launches elastic waves in frequencies up to a few hundred kHz and detects the signals reflected from any defects. Early indications are that the entire cross section of the pipe wall can be inspected for internal and external surface flaws with lengths up to 100 feet surveyed from a single sensor location.

## **ACTION BY INSPECTORS**

14. Where ULC is foreseeable in plant and pipework containing hazardous fluids, inspectors should ask what arrangements the company have for:
- a. assessment and review of the need for lagging on new and existing plant, the suitability of the design and the materials used;
  - b. identifying critical areas for inspection, and monitoring plant and pipework for the presence of ULC; and
  - c. where damage to lagging is observed, the arrangements for assessing the extent of the damage and the securing of prompt and effective repair.

### **FURTHER INFORMATION**

For further information, please contact HID CI 5B, (VPN 523 3505)

### **REFERENCES**

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