Corrosion under insulation (CUI) is the corrosion of external surfaces of metal components under thermal insulation. CUI is an internal problem that can cause failures in areas that are not periodically tested and also not normally given much importance and coverage during periodic NDT inspection using conventional methods.

In many of these cases, catastrophic failures caused by CUI have had serious environmental and economic ramifications.

It is important to understand the conditions that promote CUI and identify the locations that are susceptible to this type of degradation in order to establish an effective CUI program.

Hence it is also important to be aware of the different types of CUI detection technologies including their advantages and limitations in order to identify and locate areas affected by CUI and thereby isolating their potential for failure.

CONDITIONS AND CAUSES OF CUI

The American Petroleum Institute recognizes CUI as a special concern faced by users of process piping systems. In the interest of standardizing an approach to locating and controlling CUI, the API 570, Inspection, Repair, Alteration and Rerating of In-service Piping Systems Code specifies the following areas as susceptible to CUI:

- Areas exposed to mist over spray from cooling water towers.
- Areas exposed to steam vents.
- Areas exposed to deluge systems.
- Areas subject to process spills, ingress of moisture, or acid vapors.
- Carbon steel piping systems, including those insulated for personnel protection, operating between 25° F and 250° F (-4° C and 120° C). CUI is particularly aggressive where operating temperatures cause frequent condensation and re-evaporation of atmospheric moisture.
- Carbon steel piping systems that normally operate in-service above 250° F (120° C) but are intermittent service.
- Dead legs and attachments that protrude from insulated piping and operate at a temperature different than the active line.
- Austenitic stainless steel piping systems that operate between 150° F and 400° F (60° C and 204° C). These systems are susceptible to chloride stress corrosion cracking.
- Vibrating piping systems that have a tendency to inflict damage to insulation jacketing providing a path for water ingress.
- Steam traced piping systems that may experience tracing leaks, especially at the tubing fittings beneath the insulation.
- Piping systems with deteriorated coatings and/or wrappings.
- Locations where insulation plugs have been removed to permit thickness measurements on insulated piping should receive particular attention.

The API 570 Code provides an initial overview of CUI and is intended for use as a general guideline for a CUI program. It is not intended as a definitive long-term solution to the CUI problem. Other factors affecting the extent of CUI not covered in API 570 include:

- Plant Design
- Service Temperature
- Coating Type
- Insulation Type
- Weather Barriers
- Plant Maintenance Practice
- Plant Inspection Practice
- Plant Modification Practice

A successful CUI program takes into account all relevant factors of existing components as well as the design of proposed new construction. Quality Assurance of the coating and insulation of new piping systems can be the best tool in preventing CUI as poor workmanship during construction can be a major factor contributing to this condition. Choosing the appropriate coating and insulation materials during modifications or repairs is also recommended. Some of the solutions being tried in the industry are using special non-zinc coatings or using various corrosion inhibitors. These techniques have been used with various successes.

**INSPECTION TECHNIQUES**

**Insulation Removal:**

The most effective and direct method is to remove the insulation and check the surface condition of the pipe. But this is associated with huge cost and time to perform the inspection. Moreover periodic inspection is impossible with this technique.

**Guided Waves:**

Guided wave inspection named by many end users is technically a, “long range inspection”. The guided wave inspection is a volumetric inspection used mainly to determine the pipe integrity as a rapid screening tool for corrosion. “Guided Waves” are ultrasonic waves guided by the geometry of the object in which they propagate. Due to very less attenuation loss these waves transmit along the whole circumferential of the pipe propagating in the planer.
direction. These wave travel across the straight stretches of pipe to several meters. Bends supports, welds, type of insulation and coating adds to attenuation loss.

The guided wave is generated by placing the probe ring or can term as an array of probes generating sound on both side of the pipe. Usually it is placed by removing the insulation on that particular location. These transmitted waves reflect back from the anomalies thereby generating signals and giving information about the distance from the ring and as well the loss of energy.

![Figure 1. Guided Wave Ring on the pipe.](image)

Various wave modes are used in inspection for full coverage and reliability requirements. Among many waves torsional and longitudinal waves have found to have more adaptability basically using two mode of operation i.e. Symmetric Mode or Ant symmetric Mode. Many guided wave mode exists in a particular component. Certain modes are sensitive to corrosion. It is very important to select the mode to fulfil the inspection objectives. In many cases multi modes are used to cover the full thickness coverage and for identification of wall loss due to corrosion.

**Profile Radiography:**

Sections of pipe wall are exposed using Iridum 192 and Cobalt 60 for high thickness pipe wall. A comparator block is used to calculate the remaining wall thickness of the pipe. (Figure 2.) Though this is an effective tool but is limited to small area coverage and on large diameter pipes. In addition the radiation hazard is associated with the usage of this technique.

![Figure 2: Profile Radiography](image)
Ultrasonic Thickness Measurement:

This is very precise and highly accurate tool but is limited with very small area coverage. Pockets are made in the insulation where in the probes are used to take the measurement only on the spot. Moreover This is an effective method, but limited to a small area. (Figure 3.) The insulation purpose is compromised with cut pockets made for measurement.  

Infrared:

In the right conditions, infrared can be used to detect damp spots in the insulation, because there is usually a detectable temperature difference between the dry insulation and the wet insulation. Corrosion is a distinct possibility in the areas beneath the wet insulation.

Neutron Backscatter:

This system is designed to detect wet insulation on pipes and vessels. A radioactive source emits high-energy neutrons into the insulation. If there is moisture in the insulation the hydrogen nuclei attenuate the energy of the neutrons. The instrument's gauge detector is only sensitive to low energy neutrons. The count displayed to the inspector is proportional to the amount of water in the insulation. Low counts per time period indicate low moisture presence.  

As stated above, neutron backscatter is used to detect wet insulation under pipe and vessels. The theory is that where there is moisture, there is a high likelihood of corrosion. Neutron Backscatter inspection is also one of the fastest inspection techniques used today, allowing hundreds of feet of pipe to be tested in a single day. It is also fairly inexpensive compared to the other techniques.
Real Time Radiography:

Fluoroscopy provides a clear view of the pipes outside diameter through the insulation, producing a silhouette of the pipe outside diameter (OD) on a TV-type monitor that is viewed during the inspection. No film is used or developed. The real-time device has a source and image intensifier/detector connected to a C-arm. (Figure 5.) There are two major categories of RTR devices on the market today; one using a X-ray source and one using a radioactive source. Each has its own advantages and disadvantages, however the X-ray systems deliver far better resolution than the isotope type equipment. The X-ray digital fluoroscopy equipment operates at a maximum of 75 KV, a low level Mediation source, but the voltage is adjustable to obtain the clearest image. This allows for safe operation without disruption in operating units or even confined spaces. The radiation does not penetrate the pipe wall as more powerful gamma-ray or X-ray would, instead it penetrates the insulation and images the profile of the pipe's outside wall. The radiation is generated electrically so the instrument is perfectly safe when the power is off, whereas the Iridium 192 used in wall shots produces gamma-radiation constantly, even when shielded within the camera. Therefore the gamma-ray camera always needs careful supervision and control during all operations, including transportation and shipping. The systems with the electrically generated X-rays are far more convenient for shipping.

Figure 5

One of the main limitations of the system is the C-arm. The manufacturer has had success in checking pipes up to 24 inches in diameter but these systems were not originally designed for the field. This limitation has been addressed and the systems available today are more robust. There will always be some percentage of piping where real-time X-ray cannot be used. Finally, while the X-rays are low energy, they are still radiation, and so the system must be used with extreme caution.

CUI PROGRAM METHODOLOGY.

Identifying and evaluating potential degradation caused by CUI are important steps in the assessment of the likelihood of piping failure. In order to implement a cost effective CUI program, it is proposed that a risk-based inspection (RBI) approach be used. An RBI assessment consists of the systematic evaluation of both the likelihood of failure and the associated consequence of failure. In evaluating the likelihood of degradation, the following components are examples of known contributors to CUI:
- Areas exposed to cooling water towers, steam vents, and deluge systems
- Piping systems operating between 25°F – 250°F
- Age of insulation
- Location of insulation (areas with high traffic work areas where mechanical damage can occur)
- Cyclic Service

An RBI assessment would consist of labeling all known environments and conditions that contribute to CUI with a numerical value and assigning each process a value according to the consequence of failure should the process fail. This in turn would produce a risk matrix (Figure 6) that would be used in determining the priority of the inspection.

![CUI Risk Matrix](image)

An example of how the matrix can be used is a brine piping system that remains on-line (not cyclic) and is located on the top tier of the pipe rack in the battery limits. Because of these variables, the piping would be considered to have a low likelihood and consequence of failure. In turn, the system would be assigned a low RBI number (2A) and would be placed on the lower left end of the matrix.

**CONCLUSION:**

The cornerstone of any successful CUI program is a thorough visual examination of the insulated piping. The visual inspection is used to note any immediate deficiencies and to create the RBI matrix. After an inspection priority plan is established a suitable technique is selected as appropriate with applicability providing a reliable result. Currently among all the inspection methods as stated above with advantages and limitations, Guided wave technique is now mostly used and appreciated for its accuracy, repeatability and reliability in CUI detection. Complete removal of the insulation may be required in certain areas, but this should only be done after all other methods have been exhausted.
REFERENCES: