In building gas and LNG plants, the key objectives for owners and EPC contractors include excellent plant integrity to give lowest life cycle costs, building the plant with zero accidents and keeping within budget and schedule. FTI, the materials manufacturer and developer, has delivered over 1 million m$^2$ of FibaRoll and FibaShield cladding materials, which significantly help to achieve these objectives.

**Plant integrity**

Especially in gas and LNG plants, integrity and efficient running are supported by well designed insulation systems installed and operating correctly. Unfortunately this objective is undermined when water is able to enter the insulation and degrade the performance of the insulation. The consequences of extensive water ingress depend on the relevant operating temperatures but include inefficient plant performance, gas boil-off and corrosion of the steel being insulated - corrosion under insulation (CUI).

**CUI**

CUI refers to the external corrosion of vessels and piping fabricated from carbon manganese, low alloy and austenitic stainless steel underneath cladding and insulation. CUI is a major problem responsible for many major leaks that lead to health and safety incidents and unscheduled shutdowns.

CUI is caused by water or moisture being present on the steel underneath the insulation. The speed of corrosion is affected by the amount of water present in the insulation, contaminants such as chlorides and sulfides present, and the operating
Image: Part of the Sakhalin site fully insulated and clad.
temperature. It is generally recognised by oil and gas operators, and in publications such as ‘CUI Guidelines’, that the operating temperature range of -4 °C (25 °F) - 175 °C (347 °F) is where CUI is most likely to occur. A complete analysis of the causes of CUI are discussed in ‘Corrosion-under-insulation (CUI) guidelines’ a European Federation of Corrosion publication.

**Cause of water entry**

Some of the most common causes are inadequate long term sealing at terminations, weak sealing between sheets of cladding and damage from foot traffic (see Figure 1) or other sources of impact. Corrosion of metallic cladding is common in marine environments and in some areas even 304 stainless steel is subject to corrosion from purely environmental exposure. In low income areas simple theft of metal cladding is a major issue.

**Non-metallic cladding**

As an answer to these problems, FTI has developed a non-metallic cladding system called FibaRoll, which seals well at terminations (see Figure 2) and is strong enough to withstand foot traffic. It is also fire retardant as well as being UV and chemical resistant. By sealing the insulation system, water entry is prevented and as a result CUI is prevented.

The properties of ‘UV curing GRP’ are specified in CINI and specified for use by a number of the oil and gas majors. Generally the specification requiring the use of these materials as insulation cladding is in the cold/cryogenic range from -190 °C - +175 °C, which is the uppermost temperature in the CUI range. In addition to this range of temperatures are operating temperatures, which normally operate outside this range but cycle within it. CINI is a partnership of Dutch owners and insulation specialists who developed a comprehensive guide to best practice in industrial insulation called the CINI Manual ‘Insulation for Industries’.

**Fire and smoke**

FibaRoll exceeds the properties laid down in CINI, especially in relation to fire performance notably achieving ASTM E84 15/50 and the Epiradiateur Test NFP 92-501 to M1 standard. These tests cover smoke as well as fire and when subjected to the International Maritime Organisation’s Smoke and Toxicity test MSC 61(67) 1996 there were no traces of hydrogen chloride, hydrogen bromide, hydrogen fluoride, hydrogen cyanide or sulfur dioxide. Unlike many organic materials, fire performance has not been achieved by the use of halogens or other substances in the formulation, which could cause stress corrosion cracking of stainless steels or hazardous smoke in case of fire.

Although fire retardant, these materials are not fire barriers. FTI has a certified system with an intumescent coating from Akzo Nobel known as Chartek, which gives a jet fire rating when tested in a propane jet fire for the test regime UK Health and Safety Executive OTI 95 634.

**Constructability**

Mechanical strength helps to provide long term integrity by withstanding damage from foot traffic but also allows innovation in construction methods. Metal cladding is too easily damaged to allow insulation before erection. However, FTI systems FibaRoll and the pre-insulated piping system, FibaShield are able to take most of the damage experienced during construction.

This allows vessels and piping to be insulated prior to erection (see Figure 3) with the following benefits:

- No damage to coatings meaning less CUI in the future.
- Removal of 80% of labour from site leading to improved health and safety.
- Improved quality control as a result of insulating and cladding in a workshop/at ground level rather than in the field where weather undermines quality and difficult access limits control by inspectors.
better control of schedule because pre-insulation does not depend on other steps in the construction chain to be completed.

- Simplified design at supports, improving plant efficiency (cold supports) and removing a common cause of water ingress (pipe shoes for hot).

- Significant reduction in scaffolding during construction.

- Lower dependence on highly skilled metal workers.

**Damage to coatings during construction and operations**

A major cause of CUI is due to damaged coatings. Often this is purely mechanical damage to the coating during construction and it is common to have to repair 25 - 40% of coated pipe as a result of handling damage. If a coating is well specified and is undamaged mechanically there is a great chance that CUI will not occur. If a pre-insulated pipe is handled during construction rather than a coated pipe, there will be minimal if any mechanical damage to the coating. Therefore, pre-insulating pipe has real benefits in preventing CUI and lengthening the maintenance free period.

Another product from the company that avoids coating damage is the Fibawearpad, which effectively isolates the pipe from its support and prevents damage to the coating during operation from movement or vibration and subsequent crevice corrosion. This is often the most common cause of corrosion on existing plants leading to leaks and piping failure (see Figure 4).

**Modular construction**

It is becoming more common to build LNG plants in shipyards remote from the construction site and sail them to the construction site often over thousands of kilometres away. If the cladding system is not well sealed the insulation and steel underneath is bound to be exposed to seawater. Using a well sealed system is therefore crucial if this construction methodology is adopted.

**Economics**

Table 1 compares a traditional system of PIR, mastics and stainless steel 304 to a system using FibaRoll or FibaShield Pre-insulated Pipe applied to a straight 12 in. pipe with 140 mm of PIR insulation.

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**Table 1. Comparison of a traditional system of PIR, mastics and stainless steel 304 to a system using FibaRoll or FibaShield Pre-insulated Pipe applied to a straight 12 in. pipe with 140 mm of PIR insulation**

<table>
<thead>
<tr>
<th></th>
<th>Traditional</th>
<th>FibaRoll</th>
<th>FibaShield (including Field Weld)</th>
</tr>
</thead>
<tbody>
<tr>
<td>US$ per LM</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Material cost</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PIR/adhesive/PAP foil</td>
<td>162</td>
<td>162</td>
<td>90</td>
</tr>
<tr>
<td>Mastics or PAP</td>
<td>124</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>Stainless or FRP</td>
<td>97</td>
<td>40</td>
<td>45</td>
</tr>
<tr>
<td>Total material costs</td>
<td>383</td>
<td>207</td>
<td>140</td>
</tr>
<tr>
<td>Labour cost</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PIR/adhesive/PAP foil</td>
<td>125</td>
<td>125</td>
<td>44</td>
</tr>
<tr>
<td>Mastics or PAP</td>
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<td>15</td>
<td>1</td>
</tr>
<tr>
<td>Stainless or FRP</td>
<td>48</td>
<td>22</td>
<td>5</td>
</tr>
<tr>
<td>Total labour cost</td>
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<tr>
<td>Total cost</td>
<td>638</td>
<td>369</td>
<td>190</td>
</tr>
<tr>
<td>Total hours</td>
<td>17</td>
<td>11</td>
<td>3.33</td>
</tr>
</tbody>
</table>

**Notes:**

1. Traditional systems of cold and cryogenic insulation use a primary reinforced mastic vapour barrier underneath the metallic cladding. The reason for using mastic is that PAP foils are easily damaged, especially when working with metal jacketing. When working with non-metallic cladding materials such as FibaRoll, it is viable to use PAP foils. PAP foils are cheaper, quicker and easier to work with than mastics and provide a better vapour barrier than mastics by approximately four times.

2. Labour cost is based on an hourly cost of US$ 15/hr. In developed countries where labour costs are higher, savings will be greater.

3. The percentage reduction in man-hours in applying PAP foil/FibaRoll when compared to mastic/scrim/stainless steel increases as the complexity of the application increases, i.e. savings on the equivalent size of bend/tee/vessel top, etc. will be greater.

4. All options account for direct costs only. The indirect costs of FibaShield Pre-Insulated Pipe production are generally a little higher but this is not significant as a unit cost on projects over a few kilometres.

5. There are many indirect cost savings with the FibaShield Pre-Insulated Pipe including savings at supports, scaffolding and retouching.

6. With the FibaShield system the insulation is continuous with joints only at field welds/fitting/bends. This continuous pouring system improves the insulation value over a manually applied jointed system installed with shells by approximately 10%.

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Avoiding repairs to sheet metal
Although the negative aspect of foot traffic on metallic cladding is often associated with plants post startup, it is also often a pre-commissioning problem as well. This not only means repairs and replacement to metal cladding before handover to the owner but also means that often the insulation is wet as well as meaning that CUI is already underway before the plant is even running.

Apart from the negative long term integrity viewpoint, the repairs and replacement of sheet metal are costs that are often borne by the EPC contractor. FTI supplied approximately 250 000 m² of FibaRoll to a major petrochemical project in China with virtually no repair or replacement required. In contrast generally 5 - 10% of metal cladding would have been expected to have been replaced.

Health and safety
Working with non-metallic cladding systems is one way of reducing minor incidents such as cuts, which occur from handling sheet metal and especially stainless steel.

Pre-insulation of pipes or vessels in a workshop away from the job site reduces labour hours onsite and reduces the health and safety risks.

Training and design
As part of the overall service provided by FTI there is often a requirement for training, QC/inspection and design to ensure that correct application techniques are used and attention is paid to the design requirements of these materials. This can cover application of tees/bends, etc. to stress analysis on pre-insulated pipes at supports.

Case studies
- In a current project in Singapore, FibaRoll has been used to clad over cellular glass and PIR insulation materials on several process vessels horizontally at ground level to good effect (see Figure 6). Insulating at ground level made it easier to withstand the driving rain common to that part of the world. In total approximately 300 contractors have been trained in Singapore by FTI for work on this site.
- Pre-insulated pipes have been used for LNG rundown lines for over 20 years in diverse locations such as Oman, Australia and Nigeria. Based on the classic shear-key system, FibaShield is fast and economic to produce. FTI also utilises the system for lines running at other operating temperatures. Pre-insulated piping is ideal for construction, expansions and turnarounds to help hit schedule and minimise hours onsite.
- Sakhalin LNG is one of the largest LNG production plants ever built and posed many problems, least of all the very cold winters. FTI supplied over 300 000 m² to this plant for a range of operating temperatures including hot and cold in conjunction with PIR or Foamglas (see title image).

Conclusion
These systems are specified by some of the leading oil and gas majors and supported by a group of professionals at FTI and its contracting partners. They not only assist in the building of plants but also provide support to deliver efficient insulation systems and lowest life cycle costs. LNG

References
2. CINI Manual published by the CINI (Commissie Isolatie Nederlandse Industrie) Foundation.