PROJECT PREPARE OF COMPLETE EXTERNAL RENOVATION DURING OPERATION OF THREE LNG TANKS OF 100,000 m^3 CAPACITY EACH, USING COLD REPAIR AND COMPOSITE MATERIALS FOR COATING

Nabil MADANI, SONATRACH – AVAL Activity – LNG Division – Complexe GL-2/Z – Algeria

1. INTRODUCTION

SONATRACH GL2Z LNG plant is operating three LNG tanks of 100,000 m^3 capacity each since 1980, due to proximity of the Mediterranean sea and a chemical plant, heavy corrosion occurred issued from saline wind and aggressive agents like ammoniac and sulphates. Re-coating is done each three years and doesn't eliminate corrosion problems; a definitive solution has to be found to extents the period between two maintenance's at leas at ten years.

1.1. Tanks outline

Owner	SONATRACH, Algeria
Manufacturer	TKK, Japan
Number	03
Capacity each	100,000 m^3
Date of construction	1979
Liquid handled	LNG (92% methane, 7% ethane, 0.3% nitrogen)
Internal pressure	1.05 bar abs.
External dimensions	Height: 34.4 m, Diameter: 68 m
Type of construction	Double shell with inner suspended roof and outer dome

Table 1. Tanks outline

1.2. Purpose

Renovating LNG tanks must take in to account special safety precautions and orienting the renovation project to composite materials is necessary because of the two following main reasons:

1- Design modifications to repair or eliminate humidity traps were not possible because of prohibition of hot repair, for this reason, cold repair offers an efficient alternative.
2- Classic coatings and paints don't offer reliability for long period, composite material coatings offers a higher protection performance.

The main steps for preparing this renovation project are as follow:

a) Inspection and identification of scope of work.
b) Re-engineering of structures to avoid corrosion and humidity traps.
c) Blasting methods technical selection.
d) Cold repair methods and product choice based on technical performances.
e) Methodology to select high performance coating products.
f) Work and safety procedures.
g) Corrosion follow-up system and tools.

1.3. Tanks description

GL2Z tanks are double shelled with perlite and foam glass insulation; the suspended roof is covered with a layer of loss perlite and hangs on the dome roof. A free vent is installed on suspended roof. Perlite between internal and external shell plates is under 2 bars nitrogen pressure.

Boil-off gas is extracted from a 36" line, LNG supply can be done from a 20" top line or through bottom lines, LNG extraction can be done through LNG bottom lines.

Access facilities are spiral, radial and peripheral walkways, added to this; internal tank valves (ITV) platform, central platform and dome manholes access structures.

See following figure (fig. 1) for more details.

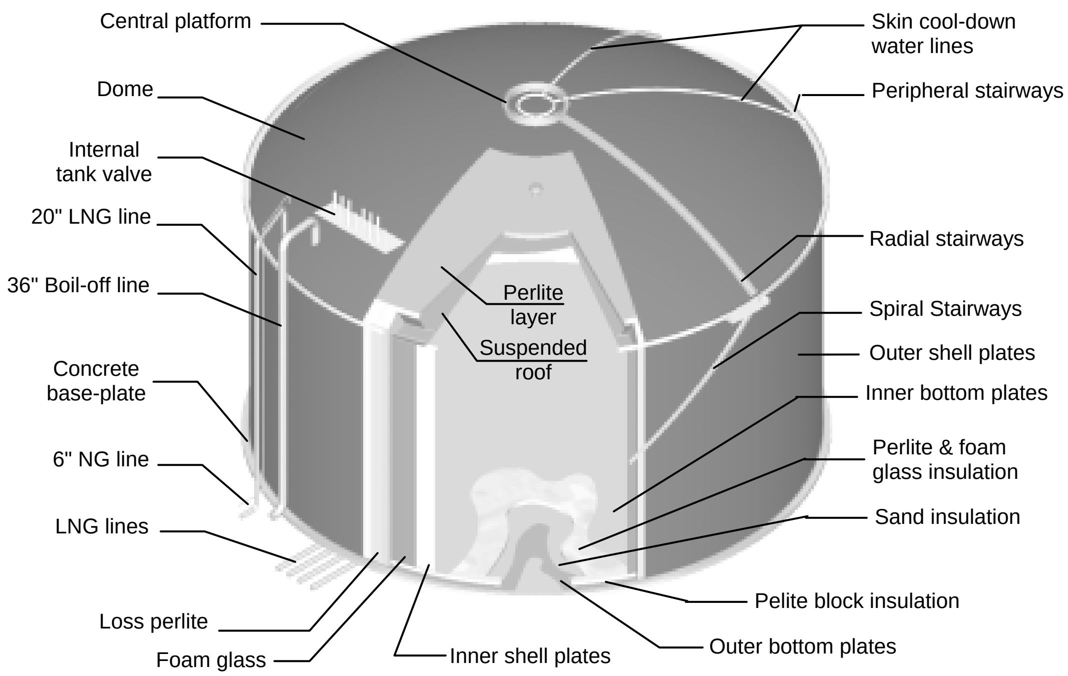

Figure 1. Tank overview

2. TANKS INSPECTION

2.1. Visual inspection

The dome-roof inspection-report [1] done on GL2Z LNG tanks provided a precious data concerning corrosion damages. Repartition of micro-leaks on the dome roof indicates that most of them are located under radial stairways. Other micro-leaks are located on the north-western quadrant of the dome, which is less exposed to sunlight and more exposed to marine wind. Radial stairways and other access structures are made by full plates, their supports are corners welded to dome plates, this kind of construction provides ideal humidity traps and contributes to corrosion expand. From collected data and visual observations, inspection can also determine critical areas for gas leaking to provide special safety precautions when blasting those areas.

The shell cold-points inspection report [2] gathering four infrared snapshots of tank-shell (fig.2) and corresponding to the fore quadrants is essential to detect cold-points, these can indicate perlite insulation defaults. Before applying any composite material for coating or repair, checking the temperature of application is important, for this reason, temperature of outside metal-skin of tank-shell must be in the range of temperature for material application. Eliminating cold-points can be necessary before any work start. The visual inspection will give a precise cartography of gas leaks, cold points and heavy corroded areas and should give enough information to establish a safety-working environment.

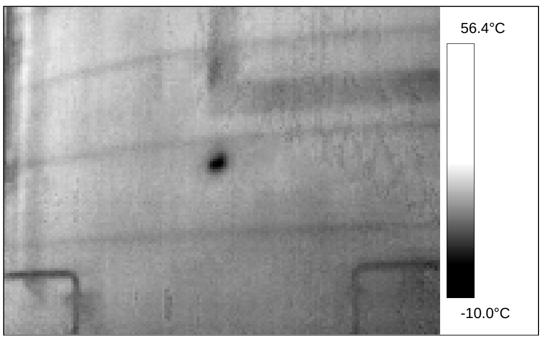

Figure 2. Cold-point infrared snapshot

2.2. Deep inspection

After visual inspection, a deeper inspection must be done. This inspection includes measurements of plate's thickness and pits depth.

Thickness can be taken on three points located on each plate, points are chosen to cover an appreciable area, minimum and average measurements are to be reported. Possible big differences between thickness on the same plate can be observed, in this case, retaken the measurement or re-calibrating the instrument is necessary. Plates showing an advanced state of degradation should have more than three thickness measurements, those kinds of plates are to be identified on the visual inspection. Generally, only the dome-plates are concerned by thickness intake, shell-plates could also, depending on tank condition. Resins could be used on the plate in order to improve the measurement quality. Thickness measurements should be token by qualified persons and using adequate procedures. Cartography of plate's thickness should be made with critical area localisation if any.

Visual inspection will localise pits on plates, important pits are to be measured and reported with their exact location.

The purpose of thickness and pits depth measurements is to localise areas with an important ratio “metal-loss versus area”, and also the ratio “number of pits and leaks versus area”, this data is needed for determining the method of repair. Those ratios represents concentration of pits, leaks and metal loss, depending on this, repair can be done using patches made from the same material, fibber glass patches, plugs or direct application of cold repair product.

3. RE-ENGINEERING OF STRUCTURES

Tanks inspection revealed that access ladders and platforms creates many humidity and water traps, some access facilities are fixed with dome-plates by metallic corners, those are mostly up-oriented facing the slope of the dome-roof. Water, moisture and humidity can easily be trapped and provide ideal conditions for corrosion. Some supports like line bumpers assembly are impossible to repair by hot welding, designing new ones with cold-welding fixation is possible.

3.1. Supports re-engineering and repair

Boil-off gas line (36") and LNG upper line (20") are supported by vertical supports welded to shell-plates, inspection revealed that collars and crossbars of the supports located out off the insulation are in bad condition, specially bumpers connection (see figure 3. where new design is drawn on old one), bumpers are also completely destroyed and impossible to repair.

Collars of vertical support can be cold-repaired because corrosion is located only outside insulation add to this the fact that repairing under insulation is impossible due to boil-off gas circulation that produce frosting.

Installing new bumpers assembly is necessary; a new connection crossbar can be manufactures on factory by hot welding and cold-fixed on the collar. A stress study of the assembly is necessary to check if it can support lines dilatations.

Using cold repair material to eliminate humidity traps can be done by designing chamfers around the join between support and plate, this gives an advantage considering that supports are numerous and hot repair is prohibited.

Figure 3. Bumpers crossbar replacement

3.2. Access ladders replacement and compressing ring chamfering

Major of micro-leaks on dome-roof are located under radial stairways (see figure 4.); because of their design, full plates stairways provides a shadow zone on the dome-plates. This type of construction contributes to humidity stagnation that is responsible of corrosion providing gas leaks.

Replacing radial stairways and access ladders on the dome-roof by light structures hot galvanised is technically the most suitable solution, those new structures should have grating plates and cold-welded with dome-plates via crossbars. This design eliminates the shadow zone and provides ideal profiles for avoiding humidity traps. Dimensions of meshes of new structures plates should be standard and avoid crossing of small tools or metallic parts.

The joint between compressing ring and dome-roof first plate produce a water trap because of the thickness difference, creating a chamfer by cold-repair product to smooth the slope is the ideal solution.

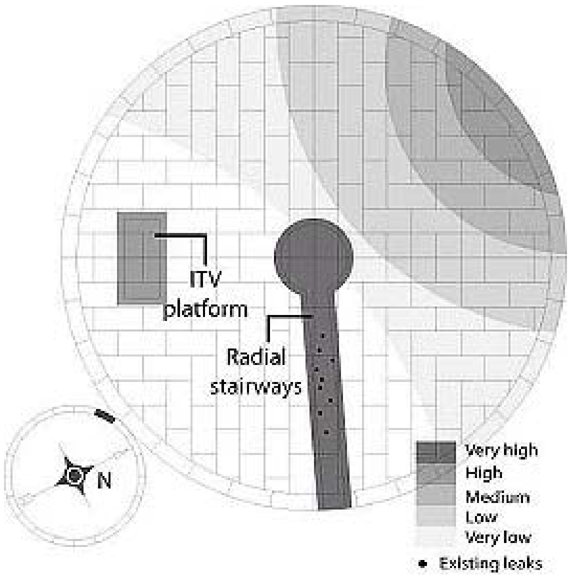

Figure 4. Micro-leaks probability on dome-roof

3.3. Other structures

Some metallic structures like water deflector located under the peripheral stairways provide an ideal residues and humidity traps, especially where deflector plates are bending and original space with compressing ring for evacuating water is reduced or doesn't exist. Also, bird excrements cakes on the water deflector that is totally occluded, this situation provide a corrosion all around the shell compressing ring because of stagnation of organic residues. The probable cause of this problem is that plates of the water deflector are rigidly fixed which doesn't permit movements to compensate dilatation or a manual rearrangement of the evacuation space, redesigning oblong holes for fixation and straightening deflector plates will eliminate the stagnation problem.

Peripheral stairways are made by full plates with four holes on each plates for water evacuation, this is not enough to eliminate water stagnation, adding holes is necessary for a better water evacuation.

4. BLASTING METHODS TECHNICAL SELECTION

Removal of old coating is the most critical work done on LNG tanks of that dimensions, several blasting methods are available but considerations has to be made concerning the safety and the ecological aspect.

Atmospheric blasting (non-recycled blasting) on big tanks constitute major risks for an LNG plant, GL2Z LNG plant made an unfortunate experience where dust and scraped paint were pulverised in the atmosphere due to blasting, dust token by wind has plugged some electrical motors filters that caused partial shutdown of the plant. As a first specification, blasting shall be done without pulverisation.

Due to classification of the working area, blasting is to be non-spark, static electricity produced from the rubbing of the blasting material with the base metal will be evacuated by electrical grounding of the tanks, for this reason, an interlock system must be installed on grounding cable to cut-off blasting if grounding is not available or presents problems.

Blasting shall obtain an SA 2-1/2 cleanness degree (depends on owner standard) specified on the SSPC (Steel Structures Painting Council) standard. When inspection, comparison should be made with original pictures. Owner shall specify to the contractor the specifications of the paint to be removed; some paints like zinc primary coatings are hard to remove and cleanness degree could be negotiated according to this.

Roughness degree shall be according to coating manufacturer minimum requirements; owner shall inform the contractor about the original roughness of the plates.

Based on those requirements, blasting methods can be limited on three methods:

4.1. Recycled dry blasting

This method use a conventional blasting machine with a recycling system, as soon as the shot strikes the base metal, a vacuum mechanism will suck the compound to a recycling system that separate the blasting material from the removed paint, this permits the reuse of the shot and avoid pulverisation of dust.

Unfortunately, recycled dry blasting machines are limited in operation area, places like dome-roof are impossible to blast with this method because of the slope, also places behind access ladders and supports where displacements are limited.

4.2. Water jet blasting

Blasting can also be done with shot mixed with clean water to avoid pulverisation, most recent water blasting machines can trap each shot grain in a water bubble, and this considerably decrease water consumption. Some water blasting machines are available with a recycling system but in majority, water will trickle along the tank plates and recovery facilities for water and residues shall be considered.

Water jet blasting presents some major disadvantages because generally, it can only obtain the original roughness of the base metal that may not be the minimum roughness required by coating manufacturer. Also, water blasting produce a wet film on base metal which reduce much more the pull-off strength of the first coating and can accelerate the natural corrosion of the base metal, in this case corrosion inhibitors can be used but mostly those can also damage pull-off strength or other characteristics of the first coating.

4.3. Sponge blasting

Sponge blasting uses the same principle as the water jet blasting but with sponges, this new technology provides many advantages like avoiding pulverisation and water films. Sponge blasting also procure a high range of roughness profiles as the dry blasting and is available with a recycled system that able a reuse of the shot which depreciate the operation cost.

4.4. Technical choice

In comparison, sponge blasting is the must suitable method for this application, regarding to the many advantages offered. In order to decrease blasting work cost, owner can also use the recycled dry blasting in flat and large areas and sponge blasting where access and displacements are difficult.

5. COLD REPAIR PRODUCTS TECHNICAL SELECTION

Cold repair products are made with composite materials which are different substances melted in different phases, basic composition are grains and particles reinforced with fibbers and mixed with polymers. Actually, specific standards for cold repair products are not available, for this reason, major manufacturers use their application references to show the efficacy of their products, commonly, application for marine repairs and ship-building are cited.

To determine the must suitable and efficient cold repair products, base metal physical and chemical characteristics should be identified, based on this; most important considerations for cold repair products are as follow:

5.1. Compressive properties

Cold repair products shall have a high compressive strength, this can be tested with ASTM D695 [3] standard. For reference, owner can specify a minimum of 600 kg/cm^2 depending on the geometry of the application and the nature of the base metal.

5.2. Flexural properties

Flexural properties of cold repair product can be tested with ASTM D790 [4], for reference owner can specify a range between 300 and 800 kg/cm^2 depending on application and loads. Some products can allow flexural strength near or higher than carbon steels; owner shall consider these characteristics following the repair geometry and the sticking position.

5.3. Shear properties

Shear strength can be tested with ASTM D1002 [5], the property value selection depends on the shear limits calculated for different application on the tanks especially supports sticking.

5.4. Other properties

Chemical resistance, cure times and temperature range for application are essential for controlling the product efficacy. Cure time is different from a manufacturer to another and should be inspected when application. Base metal temperature shall be between application temperature range when repairing. Most cold repair products offers a good chemical resistance against acids because of their composition, following the application, owner can ask for a specific chemical resistance.

Cold products shall have temperature expansion ratio near the base metal to avoid the creation of constraints when dilatation. It shall also have the same or a higher elasticity than the base metal to avoid destruction of repairs or sticking.

After cure time, products shall not present creeping or any defaults due to interactions with base metal or atmosphere.

Product shall be neutral and avoid galvanic reaction with the base metal.

In some special application like vertical supports for LNG lines, owner shall test on factory the resistance of the cold-welded structures with 50% overload.

Some other characteristics like Rockwell hardness (ASTM D785) and abrasion taber weight loss (ASTM D4060) can be specified by manufacturer.

6. COATING PRODUCTS TECHNICAL SELECTION

Today, some coatings are made with composite materials that offer a high protection performance. LNG tanks of that dimensions presents important areas in contact with atmosphere, traditional coatings do not offer a long period protection and degradation of painting is visible two years after maintenance work.

To specify the most suitable products, it's evident that causes of heavy and quick corrosion on the tanks shall be identified and resolved. Inspection revealed that conventional paints are easily pullout by under-layer corrosion. Constraints developed by corrosion are near 150 kg/cm^2 that is higher than traditional paints that have a maximum resistance between 15 and 35 kg/cm^2.

Salt atmosphere resistance is also an important criteria for product selection, combining this property with the pull-off strength indicates the most important aspects for coating comparison.

Taking in consideration those two properties, composite materials offers a much higher efficacy comparing with traditional industrial coatings (see figure 5.)

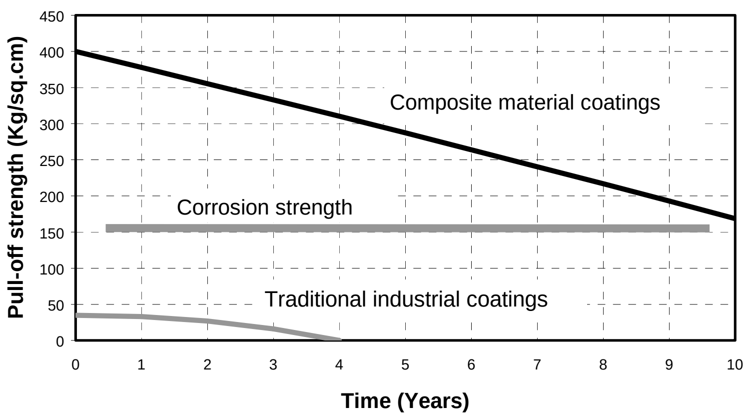

Figure 5. Pull-off strength comparison

Based on the previous comparison, it's evident that composite materials are suitable for a long period protection, in order to obtain the most suitable composite product; following are the important properties to take in consideration:

6.1. Pull-off strength

This strength is the most important criteria for coating selection, a composite material coating shall have a minimum of 200 kg/cm^2 pull-off strength being over the corrosion strength of 150 kg/cm^2 and tested with ASTM D4541 [6]. Owner shall take in consideration that pull-off strength decreases with time and higher is the original pull-off property, better and longer will be the protection.

Roughness, cleanness degree and contaminants will have an influence on the pull-off strength, for this reason, blasting shall comply with coating manufacturer specifications.

6.2. Salt fog resistance

The salt fog resistance tested with ASTM B117 [7] is the better indication for comparing aggressive environment resistance between different coatings made with composite materials. The cross option specified in the standard is the more demanding test and shall give results over 5000 hr.

6.3. Other properties

Composite material coatings can be assimilating to cold repair products concerning their mechanical resistance, for this reason, properties like dilatation, elasticity, flexural and compressive strengths shall be specified and checked.

Final coating layer shall have a good ultraviolet resistance tested with ASTM D523 and also a high impact resistance tested with ASTM D3281, final coating colour shall meet owner standards and can be specified in RAL or Munsell codes.

7. WORK AND SAFETY PROCEDURES

If LNG plants sub-contract their tanks repair or renovation to specialised companies, those have to submit procedure and quality manual to insure the safety, the quality and the control of the work. Owner will be responsible for commenting all work procedures and should check all deviations from it own procedures or standards. Following some of the most important procedures:

7.1. Organisation

Contractor shall have a hierarchical organisation involving as a minimum, a project manager, a safety supervisor, an inspection supervisor and a work supervisor. Interfaces between contractor and owner should be limited to one or two persons to avoid work-anarchy. Contractor shall obtain each day a work permit from owner and shall not work without. All work-procedures, modification-works, inspection reports, material reception, work schedule or any document related to the work shall be transmitted to owner for approval or information before any application at site. All verbal communications or documents to owner shall be furnished in paper and numeric format.

7.2. Safety procedures

Before any work start, contractor and owner shall define a clear safety procedure, any hot work on tanks area is prohibited. Contractor safety procedure shall be in accordance with owner safety procedure. When operating access facilities replacement, contractor shall install temporary access ladders and stairways to permit normal or emergency service of tanks. Owner shall guarantee a positive gas-pressure inside the tank. Installing temporary elevator on the tank can considerably accelerate work or emergency evacuation. Before any blasting, working-area shall be exempt from any gas leaks and supervisor shall check presence of gases, all leaks shall be immediately plugged until their final repair.

The owner's inspectors and safety supervisors shall have free access at all times to the work being performed by the contractor, they shall have complete authority for work stop or evacuation.

Workers shall be experienced and have certificates of ability to perform their work, for shell-plates working, workers shall have altitude-working ability certificate. Working on unstable or elevated areas shall be performed with harnesses. Any tools or portable instruments shall be strongly fixed to avoid falling-down.

All engines, motorised working facilities or blasting shall be non-sparks according to classification area Class 1, Group D, Division 1. The grounding of tanks shall be always checked by an automatic mechanism that will automatically stop the blasting via an interlock.

Contractor safety and supervision personal shall use radios for communication, and shall be in another range of frequency than owner.

7.3. Before an after-work inspection procedure

Preliminary inspection shall be performed by both owner and contractor inspectors to define the exact scope of work and the dangerous areas. It's suitable for the owner to call an approved technical organism for inspection and work reception approvals.

A surface control shall be performed after blasting to check the cleanness and the roughness of the metal. Before applying any coating or cold-repair product, surface shall be controlled to detect and eliminate any contaminants like salts or sulphates.

Coating inspection shall be performed by controlling wet and dry thickness of each layer, product consistence, cure time, final coating thickness, and application procedure delivered by coating manufacturer.

7.4. Cold repair procedures

Contractor shall transmit all cold repair procedures for different repair architectures like chamfering, touching-up, but weld, overlap weld, bevel weld, patching weld and special support fixation welding.

For each material used for cold repair, manufacturer shall provide as a minimum the specification sheet with the physical and chemical properties, the operating procedure, the safety data sheet, the packaging procedure and the toxicological data sheet. Cure times shall clearly appear and specified for different ambient temperatures.

For special repair or cold-weld strategic supports, a separate procedure and stress study shall be provided by contractor. If needed, load simulation test for material resistance control is to be done by contractor.

7.5. Coating procedures

As per cold repair materials, coating manufacturer shall provide all data sheets related to safety, operating, packaging and toxicology of their products, cure times shall clearly appear and specified for different ambient temperatures. Manufacturer shall also specify whether application of coating is done by spray gun, roller or both.

7.6. Cut procedure

Cutting or dissection of damaged structures and supports shall be non-spark, cool-down lubricants can be used, a permanent temperature control of the cut metal is necessary to avoid thermal conduction.

8. CORROSION FOLLOW-UP SYSTEM

To understand the utility of installing a corrosion follow-up system, LNG plants operators should ask this question; how many times in a year do they inspect or even visit their LNG tanks?

Based on GL2Z experience, LNG tanks appear always in good condition when being far, which is false. Also, corrosion develops degradation being exponential to time, and most of operators reacts when heavy corrosion occurred or is visible from far.

Today, soft tools are available to install an efficient system for corrosion follow-up, but it's up to owner based on inspection report to configure critical points or areas. A corrosion follow-up system is constituted from a database that include plates and tank auxiliaries co-ordinates with some data like original and real metal thickness, presence of pits and their dimensions, coating thickness and repair history for each maintenance. Follow-up inspectors shall define a special inspection schedule for critical points where control shall be more frequent and a normal inspection schedule for the other places. Inspection shall be visual, and dimensional for critical points, also, infrared snapshots of tanks shall be regular and included in the global inspection database.

When revising each time the inspection database, actual soft tools can anticipate corrosion by extrapolating previous data's and able operators to repair before heavy corrosion occur.

9. CONCLUSION

Preparing a renovation project of LNG tanks during their normal operation must take in consideration many special aspects. Using cold repair and composite material coatings offers a better guaranty for eliminating corrosion in safety conditions and for a long time. Having no specific standards, LNG plants hesitate using this technology. Composite materials present an ideal solution to thwart LNG terminals ageing and Sonatrach LNG plants constitutes example of this kind of applications.

This communication provides guidelines to prepare the project renovation and able LNG plants to establish precise specifications to avoid treating many offers and to have the best methods and products for this kind of application.

Economically, cold-wending costs approximately 30% less than a traditional hot welding and considering the fact that hot repair is not permitted because of safety considerations, cold-repair technology prevail because of the work possibility and the cost.

For composite material coatings, the operation cost will be higher than a traditional industrial coating; but, comparing the ratio quality – cost and the longevity of the protection, composite material coating is economically better.

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