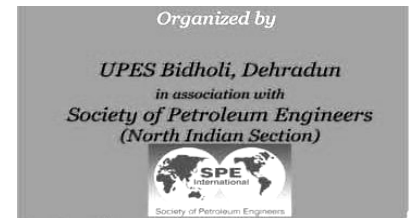




November 25-26, 2006



## Title:

**Developments and Experience in non-metallic alternatives to combat corrosion in the oil and gas business**

## Authors:

**John Simpson, Gokulnath Radhakrishnan  
Maxtube Limited, Dubai**

This paper was prepared for presentation at the 2006 "Effective environment Management through Continual Corrosion Control" conference organized by the University of Petroleum and Energy Studies, Bidholi, Dehradun in association with Society of Petroleum Engineers (North India Section) held in Bidholi, Dehradun, India, 25–26 November 2006.

## Abstract

New petroleum development work in this century will focus on getting oil and gas from deeper and challenging fields exposing process equipment to extremes of temperatures, pressures and corrosive fluids. More water from maturing fields and fields requiring pressure support using water or gas or simultaneous injection of both bring the transportation conduits both downhole and on the surface in contact with a potent combination of corrosive fluids. The high oil prices provide a cushion for oil companies to procure CRA materials for combating corrosion. In the meantime, a few technologies have emerged from the non-metallic industry offering fit for purpose solutions. This paper introduces 2 such products in the seminar along with a few case histories from Companies who have implemented alternatives with savings in cost. One product is a GRE lined tubular and another is a reinforced thermo plastic flowline. The paper shall also illustrate the concept of Life cycle cost analysis using principles set in ISO 15663: "Petroleum and natural gas industries – life-cycle costing" to justify additional capital expenditure spent on equipment today but with a longer life time compared to a lower capital expenditure, but repeatedly incurred.

### 1.0 Introduction

Frequent and unexpected replacement of casing, tubing, and flow lines on account of corrosion is a major cost factor in the transportation of petroleum fluids from reservoir to the production facilities.

This topic has been addressed and discussed by the industry but no definitive conclusions have been reached and the industry would accept that there is no one single solution that has solved the "corrosion problem".

This paper provides information on two solutions, their benefits, limitations and some insights into applying value for water injected, oil produced among others. All these are

applied into the concept of Life cycle concept analysis, which helps to finally decide on the best solution for the application.

### 2.0 GRE and Polyethylene barriers:

Materials chosen for corrosion resistance do not necessarily provide the required mechanical strengths and vice versa. Limitations apart from corrosion factors are imposed by process conditions such as temperatures, pressures, ambient conditions, ability to maintain, costs and economics.

GRE and Polyethylene are two such alternatives among many that have been evaluated and found suitable for some applications. However, their technical characteristics have limited their application coverage widely; a short recap is presented below:

#### GRE

- Expensive compared to steel options
- Need to be buried to protect piping from mechanical impact
- Possible restrictions in ID on OD restricted conduits such as tubing
- Requires specialized manpower to handle the connections, bends and tees.
- Suitability of resins to handle various acid treatments
- Temperature limitations

#### Polyethylene

Conventional pipe solutions for transporting fluids under high pressure such as oil and gas have been made from Carbon steel. However, such pipes are susceptible to corrosion, expensive in installation and in maintenance. Methods such as cathodic protection or chemical inhibition need continual support over the life time of the installation.

Polyethylene (PE) tubes have been used for more than 40 years, but the material is used only at low pressures below 7 bars for the limitation of its mechanical resistance. Much research work has been involved in the development of pipes for high-pressure transport applications to overcome the problems of metal pipes.

- Low mechanical and hoop strengths
- Temperature limitation
- Collapse tendency under depressurizing if applied as a liner

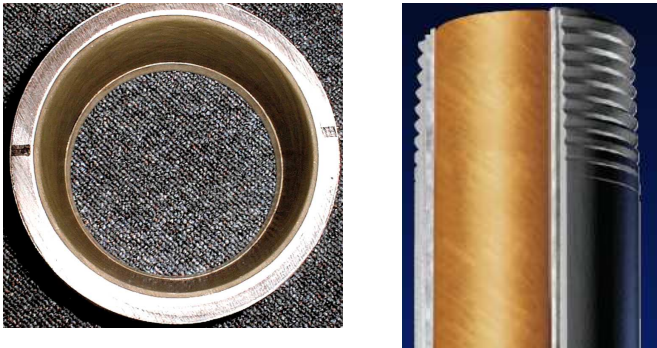
### 3.0 Reinforced solutions with GRE and Polyethylene barriers

This paper presents two specific product solutions that combine the corrosion resistant properties of GRE and PE while the mechanical strength is imparted by low alloy carbon steel and aramid fibers respectively. The former is applied on downhole tubulars and the latter on flow lines. A short summary of the products is presented in the following sections:

#### 3.1 GRE lined Low alloy Carbon steel solution for downhole tubulars

A GRE liner is inserted and grouted inside low cost carbon steel tubing using cement. The GRE liner imparts the corrosion resistance to steel by isolating corrosive oilfield fluids and gases from the steel. The finished product has the combined high strengths of the steel with the corrosion resistance of GRE, to provide long lasting corrosion protection.

Cross sectional view and cut view of the finished product appear in pictures below:



#### 3.2 Reinforced thermoplastic pipe for flow line applications

A Reinforced Thermoplastic Pipe (RTP) is an innovative product - a non-metallic, multi-layer product, capable of being produced in long continuous lengths and spooled on reels for easy storage, transportation and installation.

Cross sectional view and finished product in a reel appear in pictures below:



Further sections shall provide more details of the above solutions, their benefits and limitations.

### 4.0 GRE protected Tubular systems

#### 4.1 External and Internal protection systems

The GRE product is applicable for both internal and external protection of steel tubulars. It takes the shape of a liner in case of internal protection and a wrapping in case of external protection



The external wrap is applied on external surface of tail pipes below the packer, where they are exposed to corrosive well bore fluids. Similar conditions exist in tubing exposed in annulus in dual completion systems and simultaneous production and injection wells.

#### 4.2 Internal protection – GRE lined tubulars

The low alloy carbon steel tubing is lined with a GRE liner manufactured as per the size and weight of the tubing. The annulus is pumped with a specially prepared cement (Grout) mixture and allowed to dry to form a backing for the GRE. Internal pressures are conveyed to the steel by the layers of steel and cement. Specially manufactured pump caps allow for the liner to be placed concentric to the OD of the seamless tubing, which in turn restores the concentricity on the ID as well.

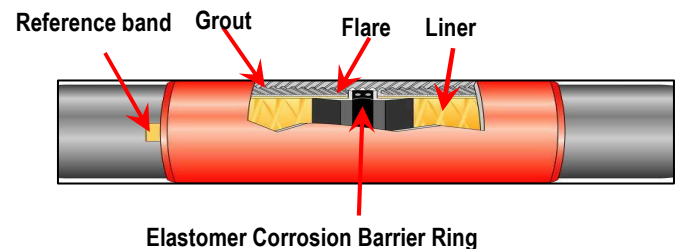
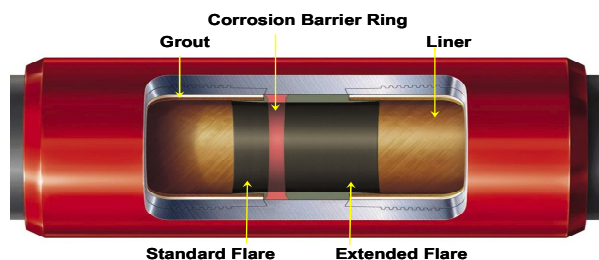


Illustration - API connection lined with GRE liner

L shaped cylindrical flares are placed at the end of the box and the pin connections to protect the exposed surfaces of metal, cement and the GRE liner. During the running process, a Corrosion barrier ring (CBR) is placed in the J area of the connection to achieve total isolation of the steel and threads from the fluids.

The completed connection is a holiday free system, robust enough to handle the high velocities and also withstand tools lowered for well intervention. The system is engineered in such a way that no compromises are done to the torquing levels on the connection in the rig. In case of API connections, the CBR comes in three different sizes to allow for the tolerances in the API threads which can be upto 1/8<sup>th</sup> of an inch.

In case of premium connections, flares and CBR's are fabricated to very minute tolerances marching with the design of the premium threads configuration and shoulder design. A single size and set of CBR and flare is applied in these completions as the threads are built to very high tolerances and the CBR's / flares are manufactured from one single sized mould designed for the connection under consideration.



**Illustration - Premium connection lined with GRE liner**

The unique design does not interfere with the torquing recommendations and requirements when running completion, while offering a gas tight metal to metal connection behind the CBR and the flare.

#### 4.3 Benefits of the GRE liner

- The GRE liner can be applied on both new and used tubulars meeting the application specifications
- Offers superior corrosion protection, proven resistance to extensive wire line interventions
- Extremely smooth internal surface (0.00021" / 6 μ)
- Extremely favourable Hazen-Williams' coefficient of friction C-factor, C=150 for GRE compared to CS which is approximately 100)
- Eliminated need for corrosion inhibitor injection and minimizes water treatment needs with respect to the downhole environment.
- Restores Concentricity on liner allowing for better driftability

#### 4.4 Case studies

##### 4.4.1 Case study – Oil Producers

Customer: Middle East  
 Process: 3% CO<sub>2</sub>, 104 deg C, watercut 67%  
 Problem: Customer was changing his low allow CS tubing every 12 months, high alloy tubing costs were prohibitive

Solution: L80 tubing with Duoline 20, used tubing lined with GRE  
 Condition: Tubing producing for last 3 years with no traces of corrosion

##### 4.4.2 Case study – Oil Producers – ESP wells

Customer: Middle East  
 Process: 5% CO<sub>2</sub>, 3% H<sub>2</sub>S, 87 deg C, watercut 45%  
 Problem: Customer was using 13CR and tubing required pull out for pump replacement before tubing failure. 30% of the 13CR threads required recutting before rerunning, incurring rig time and inventory costs

Solution: L80 tubing with Duoline 20  
 Condition: Pump replacement frequency remains the same, but rejection rate for rethreading is now a fraction, a benefit from use of low allow Carbon steel

##### 4.4.3 Case study – Gas producers

Customer: China  
 Process: 20% CO<sub>2</sub>, 11% H<sub>2</sub>S, 88 deg C  
 Problem: Metallurgy demanded was Alloy 625 – Super Duplex CRA for this application, economically prohibitive

Solution: L80 tubing with Duoline 20  
 Condition: Wells producing for the past 4 years

##### 4.4.4 Case study – Sea water injection

Customer: North Sea  
 Process: Untreated seawater, 37 deg C  
 Problem: Metallurgy demanded was Duplex Stainless steel – 25 CR, economically prohibitive

Solution: L80 tubing with Duoline 20  
 Condition: 1996-2001, injection stopped, tubing pulled out, inspected and reported liner intact

##### 4.4.5 Case study – WAG wells

Customer: North Sea  
 Process: Untreated seawater + Gas, 90 deg C  
 Problem: Metallurgy demanded was Duplex Stainless steel – 25 CR, economically prohibitive

Solution: C 95 tubing with Duoline 20  
 Condition: 1996-2001, injection stopped, tubing pulled out, inspected and reported liner intact

**4.4.6 Case study – Acid gas disposal well**

Customer: North America  
 Process: Produced water and 100 mmcf/d gas, 40% H<sub>2</sub>S, CO<sub>2</sub> 60%, 37 deg C  
 Problem: Metallurgy demanded was Duplex Stainless steel – 25 CR, economically prohibitive  
 Solution: L80 tubing with Duoline 20  
 Condition: 1997-till date in operation

**4.4.7 Case study – Gas Producers**

Customer: North America  
 Process: 4% CO<sub>2</sub>, 18 ppm H<sub>2</sub>S, 140 deg C  
 Problem: Metallurgy demanded was 22 CR, economically prohibitive  
 Solution: L80 tubing with Duoline 20  
 Condition: 1997-till date in operation

**4.4.8 Case study – Paraffin control**

Customer: North America  
 Process: CO<sub>2</sub>, high paraffin content  
 Problem: Temperature loss in the tubing string, paraffin deposition in top 600 feet  
 Solution: Lined with Duoline 20  
 Condition: Completely eliminated Paraffin deposition by insulating the heat of the fluids and by retarding the deposition by offering a smooth internal surface

**4.4.9 Case study – Scale control**

Customer: North America  
 Process: Water injector  
 Problem: BaSO<sub>4</sub> scaling – the hardest of the scales to break, frequent interruptions by acidizing.  
 Solution: Lined with Duoline 20  
 Condition: Delayed frequency of the acid jobs by retarding scale deposition. Scales are easily removed as the do not adhere to the GRE surface. Reduced downtime and savings on rig costs

**4.5 Application benefits of GRE lined tubing**

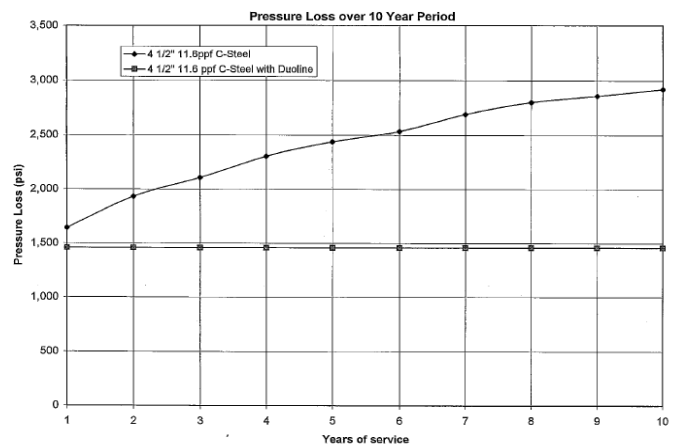
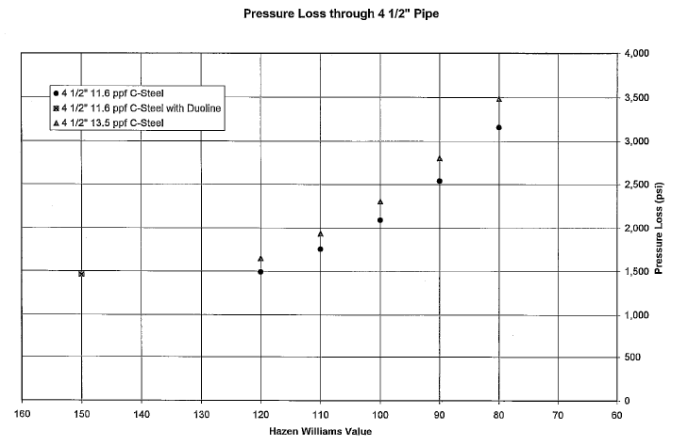
**4.5.1 Retardation of scale, paraffin build ups**

Build up of scales, paraffin's and asphaltenes is accelerated if the flow through surface is rougher. The internal surface of GRE is finished to a low 0.00021" / 6 μ levels of smoothness that retards and makes difficult for the adhesion to occur. Though ID reduction is inevitable, the delayed occurrence of the same brings down the number of rig calls over a specific period of time, there by offering Life cycle cost savings and increased revenue because of reduced downtime

**4.5.2 Lower frictional losses**

Internal liner of the GRE has a Hazen-Williams' coefficient of friction C-factor, C=150 for GRE; for a new Carbon steel tubing this is around 100, which deteriorates over time increasing roughness followed by increased frictional losses. Though an ID reduction results from the installation of the GRE, the tubing allows more fluids than carbon steel tubing over its life time for the same energy costs incurred for pumping

Comparisons of pressure losses in carbon steel and GRE lined tubing is presented hereunder for 4 1/2" and 7" tubing based on reduction of Hazen-Williams' coefficient of friction for Steel. Readers to note that the Hazen-Williams' coefficient of friction for GRE remains unchanged:

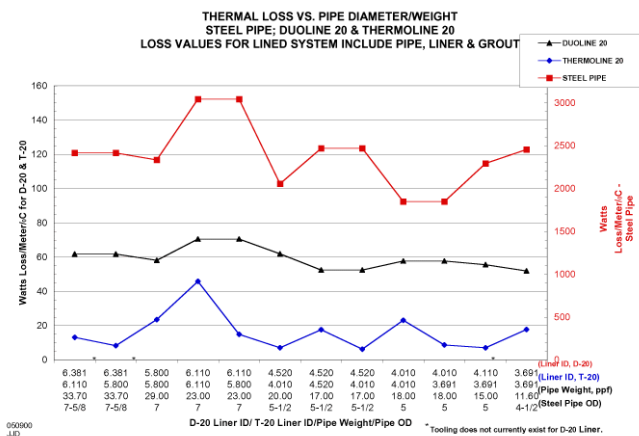


New bare steel 2-3/8" EUE tubing with a "C" factor of 130 would handle approximately 50 bbls/hr of water with a head loss of approximately 31 ft/1000 ft of pipe. 2-3/8" used steel tubing with a slightly rougher "C" factor of 100 would handle this quantity of water with a head loss of 50 ft/1000 ft. GRE liner with its very smooth interior surface should retain a "C" factor of approximately 150 and even though the internal diameter is somewhat smaller, it would handle 50 bbls/hr of water with a head loss of approximately 41 feet per 1000 ft.

### 4.5.3 Thermal insulation properties

GRE liner adds in its insulating properties as a secondary benefit, sometimes offering an excellent partnership solution for corrosion protection and insulation allowing for formation of scales or paraffin for shorter depths in the tubing from the surface.

With special grout additives, Advanced GRE Liner Systems provide a highly insulating layer between produced fluids and colder ambient environment, preventing costly paraffin or hydrate buildup. Examples include subsea flowlines, or deep-water tubing string designs. By keeping produced fluids above the critical cloud point, deposition inside the pipe can be significantly cut. Add this benefit to an extremely smooth internal finish on the GRE liner which is corrosion resistant, and the combination is a three way solution!



### 4.6 Special precautions in intervention in GRE lined tubing

Operating companies who have adopted the use of GRE lined solution develop internal control procedures for the selection, standardisation, running, rerunning and intervention through the GRE lined tubing

Readers should note that the GRE liner is a few millimetres thick designed with the required hoop stress strengths, but should not expect the properties of steel in terms of its hardness against sharp metal tools.

More information on the use of Wireline intervention, coiled tubing runs and acidizing is presented in documents listed under References at the end of this paper.

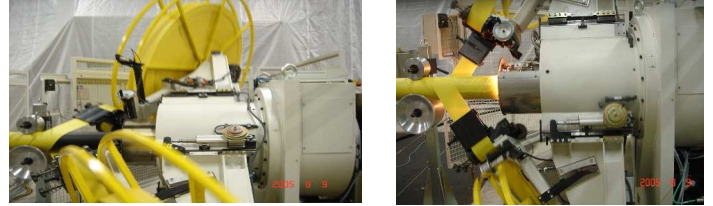
### 5.0 Reinforced thermoplastic solutions for flow lines

The RTP consists of three different layers as follows:

- A PE100 liner is used to contain the transported fluid
- A structure layer, which consists of even number (2 or 4) of balanced helical windings of continuous aramid or polyester reinforcement applied in performed PE tapes,

is used over the liner to provide the mechanical strength to withstand the loads applied during service and installation.

- An outer cover made by PE in either black or white color is added on the top of the structure layer to protect structure during installation and operation. Black cover is for underground application and white cover is UV protected for over ground application.



Typical applications of RTP are in the field of the upstream Oil and Gas exploitation industry, like for instance:

- Hydrocarbon Production Flow lines
- Oil well hook-up lines
- Water & gas injection lines
- Effluent water transportation
- Gas transport & distribution
- Firewater lines (buried)
- Temporary shunts during pipeline repair
- Thermal expansion loops

### 5.1 Characteristics of RTP

#### Pressure containment capability:

With PE reinforced by high tensile Aramid fiber, RTP can resist high working pressure.

The Nominal Pressure Rating (NPR) is defined by means of Short-term Burst Strength (STHP) with a safety factor of 3.75 as following:

$$\text{NPR} = \text{STHP} / 3.75$$

#### Climate Resistance:

The external cover of AEROSUN white RTP is made by PE100, for which oxidation inducing time is more than 150 minutes under 200deg C, so its service life is more than 15 years in the area where the sunlight intensity is 6.70GJ/m<sup>2</sup>

#### Gas penetration:

The penetration coefficient of PE80 and PE100 applied in AEROSUN RTP product to firedamp media is 0.056cm<sup>3</sup>/m·105Pa·d. It means the annual loss is 2.9 m<sup>3</sup> per kilometer for the 100 mm diameter RTP to transport 100% firedamp under 5 bar working pressure. The condition is the same as natural gas with 80 % to 90% firedamp.

### Temperature resistance:

The permitted working temperature of RTP is related to fluid media, working pressure and service life. The long term working temperature shall be between -40 and 65 deg C.

### Electrostatic resistance:

When transporting oil products, the relative movement between the liquid and solid, liquid and gas, form double electric layers and generate electrostatic forces. This kind of electrostatic deposits in the internal and external layers may harm people when touch. Mostly when in the dry climate area, a wet towel shall be covered on the pipe to remove the electrostatic charges just before repairing and connecting. To improve this electrostatic resistance carbon fiber as an alternative shall be employed instead of aramid fiber.

### 5.2 RTP – benefits

RTP has the following characteristics that provide superior solutions in the transportation industry:

#### Corrosion and erosion resistance:

The PE liner offers superior immunity to corrosion caused by most flowing common fluids and gases. This feature coupled with a reasonable price brings the RTP as a viable alternative to PE lines CS solutions, FBE coated CS solutions and standalone GRE pipeline solutions.

The smoothness and hardness of the PE liner also helps in keeping a check on the erosion and scaling on the inner surface which are quite prevalent in metal based flow lines

#### Reduction in Life cycle cost:

With corrosion resistance and pipe degradation estimated over a 20 year life, the RTP wins over alternative flow line solutions in the total cost of life cycle (customers are encouraged to compare costs of installing a long length RTP pipe against the direct costs associated with CS piping such as Cathodic protection, welding, burying, painting, inner lining and replacement charges and indirect costs such as time taken for installation, deferment if any in the transportation of the fluids etc. over the life of the service).

#### High energy efficiency:

Compared to Carbon steel pipes, RTP used for transporting water or gas at high pressure provides energy savings of upto 25% because of its smooth liner and resulting benefits in the friction factor.

#### High flexibility:

Based on the PE internal and external pipes, RTP can be bent to a great extent. As per Industry standards, the minimum installation bend radius of spoolable RTP is 25 times of the

nominal diameter. The specification makes it easy to be deployed in large length without joints and resist strong seismic movements with an axial elasticity of 1.5%.

#### Longer Lengths:

The RTP comes in long lengths before a joint is required. It is manufactured in road transportable coils in lengths up to 800 m, depending on the diameter that saves a lot on the cost of pipe fittings. They are supplied on a wooden disposable reel that fits on an installation trailer. A metal reel can be used for recoiling.

#### High resistance to environmental conditions and hazards:

RTP has the capability to withstand external load up to 20% deformation. Hence it can resist external crash and impact. The installed solution has fewer connections that greatly reduce the possibility to joint leaks

#### Ease of installation:

The light weight and flexibility make it easy to be transported and deployed, and allows it to be laid in areas with difficult access such as mountainous and soft-soil locations. The laid flow line can be left open to the air with no necessity to bury or reinforce in crossings. The finished product is mechanically strong and can allow for the movement of heavy vehicles and trucks when laid across the roads.

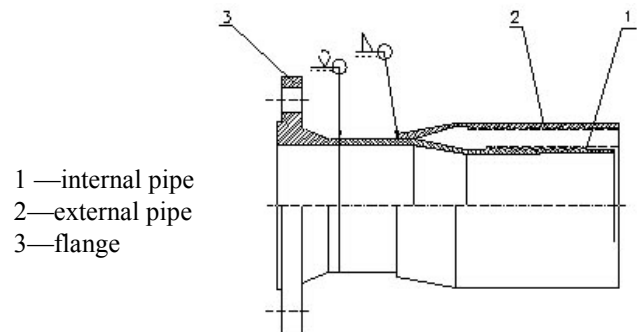
#### Ease of re-routing:

When a piece of RTP is required to be re-routed and length to be readjusted, operators just need to cut off the required section and replace it with electro fusion or flange connection.

### 5.3 RTP Connections

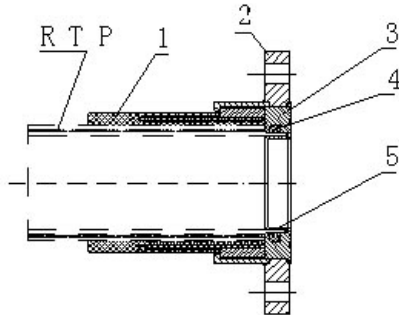
Experience gained by the industry in hooking up fiber glass system has been adopted by the RTP industry

**Swaging joints:** to connect RTP to pipe system  
Connected to RTP through swaging machine, the swaging joint has a simple structure, easy operation, high reliability and tough pressure resistance.



### Electro fusion joints: to connect RTP to pipe system

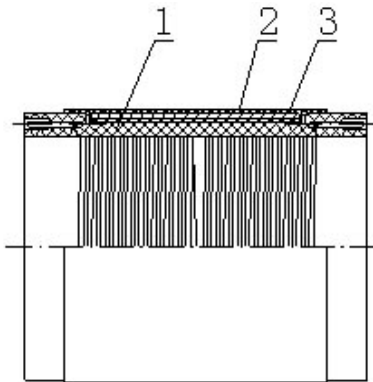
An electro fusion sleeve with glass fiber reinforcement and flange. The connecting part is made of the same material as RTP cover, which is integrated to RTP by electro fusion. It can withstand high pressure with high reliability.



- 1—Electro fusion Sleeve
- 2—Integrated Flange
- 3—Sealing Base
- 4—Seal
- 5—Inner Sleeve

### Inline coupler: to connect RTP to RTP

A reinforced electro fusion pipe made by same material as the RTP cover connects two RTP ends together through electro fusion. It can withstand high pressure with high reliability.



- 1—Electro fusion Sleeve
- 2—Glass Reinforcement
- 3—Cover Highlight

## 6.0 Economics and Life Cycle cost analysis

ISO 15663: “Petroleum and natural gas industries – life-cycle costing” emphasizes the need for taking a calculative approach to decision making with a long term perspective than short term factors.

In general, decisions are taken in Oil companies based on four levels of analysis:

Level 1: the initial cost of the equipment X

Level 2: the total cost of the installed equipment including commissioning, protective systems to be built around the equipment

Level 3: the long term life cycle cost of the equipment, the

replacement or repair frequency

Level 4: the impact of loss of revenue or deferment of revenue from the repair or replacement

Examples shared in this paper shall address cases from Level 2 upwards

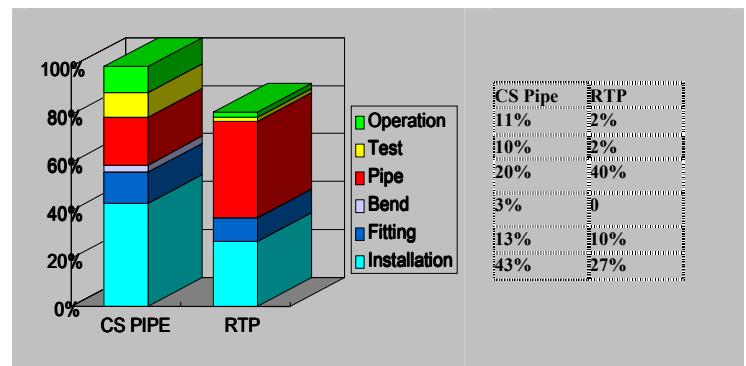
### Level 2 example: Total cost of installed facility + year 1 Operations costs

Consider the case of a flow line installation – two alternatives considered for the application; say the RTP and Carbon steel

In this example, the procurement cost of the RTP is exactly double the price of the Carbon steel tubing. Decision making based on Level 1 would eliminate the RTP for this application. Level 2 analysis looks at the total cost of the installation which is graphically depicted in the following section.

The RTP takes lesser time to install, requires lesser manpower to reel out and eliminates welding costs. In additional the bending capability of the RTP allows for elimination of procurement costs of bends and expansion loops etc.

The situation turns even more favorable for RTP if the Carbon steel needs to be protected by external and internal coatings of epoxy and additionally fortified with cathodic protection.



Source: Veeker - Germany

### Level 3 example: Life cycle cost of the installation

Consider four alternatives for downhole tubing, a water injection system, which is anticipated to have more than 50 ppb of Oxygen laden with chlorides.

13 CR is eliminated for this application; customer has a choice to use:

L 80 tubing which will last for say 3 years or

L 80 + Corrosion inhibitors which will last for say 5 years or

L 80 lined with GRE that will last a minimum of 20 years or

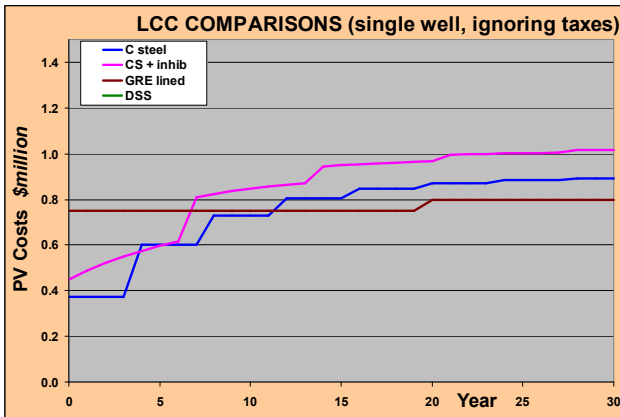
Duplex Stainless steel which will last for 30 years

Indexing the cost factor of L 80 tubing as 1 (\$375 K), the L 80 + corrosion inhibitor as 1.2, GRE lined L 80 as 2 and Duplex stainless steel as 10, a life cycle cost is worked out and plotted in graph below. Rig cost is assumed at \$ 2,000 per day and

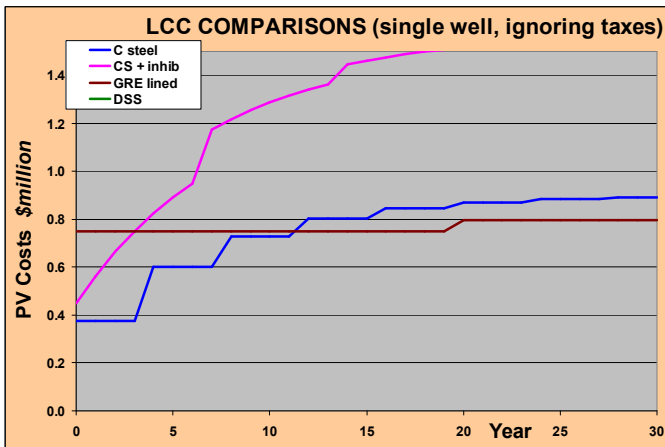
shut-in duration is applied uniformly on all cases as 30 days. For the option of L 80 + inhibitor injection the inhibitor chemicals are assumed to be costing \$ 600 per barrel and a 20 ppm is the chemical injection target

The costs are discounted by a factor of 15% annually to convert the future costs to today's value.

For a 10,000 bpd water injection well, the life cycle costs compare as follows:



For a 30,000 bpd injection well, the sensitivity is reflected in one solution – the L 80 + Corrosion inhibitor injection. The costs of other solution remained the same



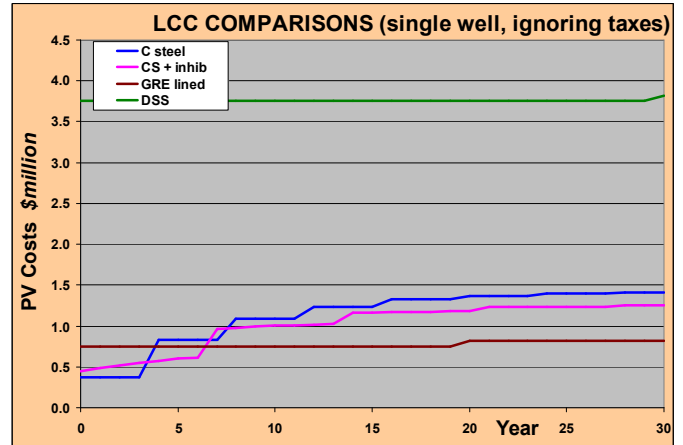
In Level 3 example, where no value is assigned for the water injection done in the field, the CS + GRE solution becomes attractive after about 12 years, which is merit worthy considering the objective life of the well to be 20 years atleast

**Level 4 example: Life cycle cost of the installation with value assigned for the water injected**

This example considers a value for the water injected, which could be justified based on environmental and reservoir management reasons. Many Environmental agencies with back up of respective Governments stipulate that produced water is reinjected back to the ground and levy stiff penalties. This could be as high as \$ 10/barrel of water. Water injection

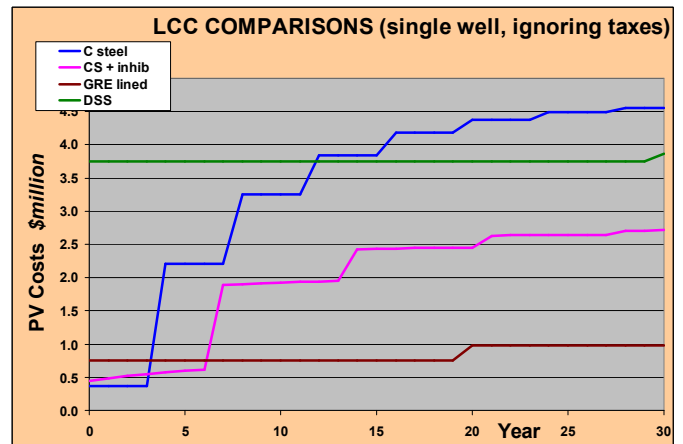
in reservoirs which require pressure sustenance, when suspended for a few days has an indirect impact on the oil production. Every barrel of water injection missed can be associated with every barrel of loss of liquid from the well

A nominal value of \$ 1/barrel has been assigned in the Level 3 example in previous section; even for a 10,000 bpd water injection well, the decisions change.



The Cost of L 80 +GRE is recovered by the 4<sup>th</sup> year, when compared with just the price of L 80 pipe.

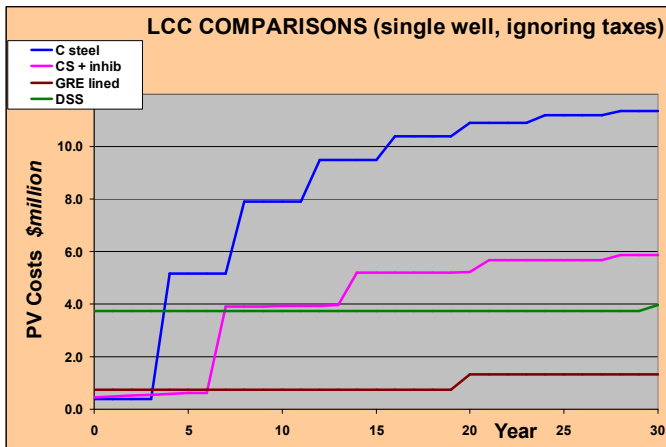
If the value of water assigned is say \$7 to account for penalties to be paid for not meeting injection requirements, interesting results come out



The Duplex stainless steel option, which has a cost index of 10 over the CS, proves to be a better solution that the CS in about 12 years

Level 4 example can also be replayed for Oil with higher value assigned to the oil production lost or deferred – the trend of the curves would be very similar once a value is assigned for the liquid being pumped in for a purpose or being produced for revenue.

Assigning a value of \$ 20 even for the oil, would present a higher magnitude of reference as seen in following page



## 7.0 Conclusion

It would be worthwhile for corrosion engineers, flow line and / or completion engineers to evaluate alternatives that bring in long term benefits to the operation of the facility with limited interruptions

The Life cycle cost approach can be built with specifics of costs applicable to each region and application and Management decisions should be taken rather than limiting to good engineering decision alone

Every operation has a value and the value shall be taken into consideration while carrying out cost comparisons, be it water injection or production wells.

## 8.0 Acknowledgements:

The authors would like to thank the Managements of Aerosun Corporation, Duoline Technologies and Maxtube Limited for granting permission to share pictures and technical information.

The contents of the paper has been written from resources drawn from the above Companies and shall not apply to any similar product, who do not have similar track record and experience

1. The GRE liner referred in the Paper is Duoline 20 which is the brand name of a filament-wound Glass Reinforced Epoxy (GRE) liner manufactured by Duoline Technologies in Odessa, TX, USA. The Company has an 80 million feet track record downhole for water injection and production applications. All the experience quoted in the main paper are based on Duoline 20 and not on the generic application of GRE in tubulars

The GRE lining technology is applied since 1965, used widely in the United States and applied in Europe and Middle East since 1996 with the signing of the licensing agreement with Maxtube Limited, Aberdeen, Scotland. The product is supported by a testimony of 30,000 wells worldwide. Some of the wells installed with Duoline 20 are still in operation for over 30 years.

The specially selected resins in Duoline 20 allow for a maximum operating temperature of 144 deg C, which covers most oilfield applications

Major Oil Companies have also extensively tested DUOLINE for wireline abrasion resistance. Numerous runs were made through 7-inch DUOLINE at a testing facility in the North Sea. DUOLINE 20 was installed in a highly deviated tubing string along with coated tubulars from various manufacturers. A total of 27 slickline runs and 8 braided line runs were made with various tools to diagnose coating/lining failures as they occurred. While instances of catastrophic coating failures were recorded on IPC joint after initial runs, only minor cosmetic damage to the DUOLINE string resulted after all runs were completed.

2. The RTP product description is sourced from Aerosun Corporation from China who manufactures RTP's in their facility near Shanghai, being the only Asian manufacturer to have such a facility, the others in Europe and South America. Aerosun has gone through rigorous testing to meet with industry requirements for the RTP product. These include 10,000 hrs Regression analysis tests as per ASTM D 2992 – 01, Long term strength performance test as per ASTM D 1598, Short term burst test as per ASTM D 1599, Tensile strength test as per ASTM D 2105, Vacuum test as per ISO/DIN 7233.1990 among others. Tests are witnessed by DNV.

## References

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