High Temperature Pipeline Coatings - Field Joint Challenges in Remote Construction

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ABSTRACT

Industry watchers see global trends in pipeline technology and pipeline coatings are in part dictated by where the oil and gas reserves are located. These reserves are becoming increasingly difficult to find. Producers are looking further afield and often find the reserves are much deeper than in the past. Associated with this, the resources tend to flow under high temperatures and pressures. The pipelines may also need to be constructed in remote and harsh environments. This paper examines some of these trends and provides case histories of several high temperature projects constructed in the remote and harsh environments.

1. INTRODUCTION

High performance pipeline corrosion protection coatings have been developed to meet the demanding requirements of current pipeline engineers. A variety of pipeline-coating technologies are available, and selection has evolved along geographical lines.

In North America, fusion bonded epoxy (FBE), and 2-layer polyethylene (2LPE) have been the dominant coatings, although accelerating acceptance of multi-layer coatings is being noted. In Europe, Asia, Middle East and South America, multi-layer polyolefin coatings such as 3-layer polyethylene (3LPE) and 3-layer polypropylene (3LPP) tend to be favoured. Also, newer technologies such as composite coatings (HPCC) and multi-layer, insulated systems are gaining attention[1, 2.] The table below examines commonly available coatings and their typical maximum operating temperatures.

High Temperature Coatings

Coating Type	Maximum Operating Temperature†
Fusion Bonded Epoxy (FBE)	85 - 90ºC
2-Layer Polyethylene (2LPE)	60ºC
3-Layer Polyethylene (3LPE)	85 - 90ºC
3-Layer Polypropylene (3LPP)	110 - 140ºC
Composite Coatings (HPCC)	85ºC

† - Data gathered from pipe coating companies' published literature. Speciality grades of raw materials may be rated higher.

Coating decisions are generally based on the owner or engineering company preferences, but pipeline construction and operating conditions need consideration[3]. Pipe is often sourced and coated a long distance from its ultimate destination. On recent large projects in the Caspian region and in Africa, most of the pipe coating was applied in the Far East and transported by ship then truck to remote locations.

With shipping and handling over long distances, coating damage is a real concern. The robust nature of 3LPE and 3LPP coatings, compared to FBE, generally results in less handling damage. The author recently visited a project where substantial damage to the FBE coated pipe had occurred during shipment from the Asian pipecoating facility to an Eastern European construction site.

Once the coated pipe is delivered to the right-of-way and pipeline welding begins, then application of the field joint corrosion protection commences. There are several technologies available, each facing its own challenges relative to installation and long term performance. Under especially harsh environmental or geographical conditions, these challenges are magnified.

Unlike pipeline coatings which are applied under well controlled factory conditions, field applied joint protection coatings are applied under unpredictable conditions, whether frozen tundra, a sand-swept desert, mountainous regions or rainforest. The resulting field joint is expected to provide corrosion protection performance and quality consistent with plant applied coatings.

This article examines pipeline construction in three distinct geographical regions. The pipeline specification and operating conditions vary for each. However, a few key elements are common to all geographical and environmental regions.

2. FIELD INSTALLATION CHALLENGES

Construction practises vary by temperature. When temperatures dip below -40ºC, it is difficult to work. At some point the project must cease until temperatures increase to a point where people and equipment can function. Conversely, when daytime temperatures exceed +45ºC with high intensity sun, the health risk to workers is a concern.

Temperature fluctuations are common in construction conditions. Daytime high temperatures with full sun focused on the coated pipe can substantially elevate the pipeline temperature. This phenomenon is particularly prevalent in hot climates but also in cold climates where the dark surfaces of many types of pipeline coatings will absorb solar radiation. Overnight lows will then create significant steel temperature swings that can have adverse effects on brittle coatings as the pipeline expands and contracts.

Different types of field applied joint protection materials require a variety of installation equipment. Usually, blasting or other surface preparation equipment will be required, along with equipment to preheat the cutback area and possibly post-heat. For example, post-heating may be required to facilitate curing of applied materials such as two-component liquids. The most efficient and reliable method of supplying heat is through electrical induction. High frequency induction generators and coils are commonly available for pipeline construction and a relatively small investment, through monthly rental or purchasing of the equipment, enhances productivity greatly.

Product selection relative to the coating type and project specification is critical when working in extreme environments.

Two-component liquid epoxies simply stop curing at low temperatures. Additionally, as the cure time is protracted a reduction in performance properties may occur. At high ambient temperatures, reaction-cured coatings may cure too quickly or have short and impractical pot lives. Humidity levels have limited affect on epoxy materials but polyurethane materials can face dramatically altered cure rates and physical property variations with humidity changes. This occurs due to the reaction between the moisture and the isocyanates in the curing mechanism.

Fusion bonded epoxy powders kept on a right-of-way need to be properly stored to protect against humidity and temperature extremes, which can affect the reactivity of the powders during installation.

Sheet and plastic / adhesive composite materials such as heat-shrinkable sleeves or field applied tape systems also need to be chosen and handled in as prescribed by the manufacturer. This can be accommodated through product selection and ensuring correct storage conditions.

Job site storage needs to be taken into account for the selected coating technology and ambient conditions. The use of preconditioning (cooling or heating) for the materials prior to use may be required.

3. CASE STUDIES

Three region types were chosen to highlight extremes in environmental and geographic challenges. The experiences of these regional projects can be applied to projects almost anywhere in the world.

3.1. Desert

This case study covers a Middle Eastern pipeline project that involved a series of high temperature flow lines from well heads to a processing station and the associated large diameter transmission line that transported the gas and condensates to the nearest port, some 517km away. The flow lines were designed to operate at 110ºC and were coated with 3LPP. Polypropylene-based heat shrinkable sleeves were selected as the field joint system. The transmission line was coated with 3LPE and 3-layer polyethylene heat-shrinkable sleeves were used for the joints.

During construction, this project was sunny, hot and dusty with low relative humidity and ambient temperatures ranging from 35 to 45ºC. Pipe surface temperatures exceeded 65ºC at mid-day.

The pipeline was constructed by an international contractor, but with limited pipeline construction experience, which created some training opportunities. Equipment requirements included blast equipment, diesel induction generators and coils, standard heat-shrinkable sleeve installation tools and tents for protection.

The owner, specifier, main contractors and subcontractors represented five nationalities, with administration, construction, inspection and others representing many more. This created challenges in original specification interpretation, ongoing construction communication and follow up. To this end, it was important to maintain clarity in communication, maintain records, have all parties agree on details in writing and have each participant sign a copy of the meeting's minutes.

In order to maintain flow of materials and resources to the pipeline, the remoteness of operations required strong logistics and logistical support from a main office away from the pipeline.

In high ambient temperatures and day/night temperature swings, the pipeline “jumped-off” the supports due to thermal expansion. The use of sandbags to support the pipe, rather than wood blocking, limited the damage to the coating.

Sandstorms contaminated the joint materials during installation or buried the pipeline overnight. Chlorides present in the sand can then contaminate the cutback. Correct surface preparation and pre-cleaning prior to blasting and the use of blast media that do not contain chlorides was particularly important.

Like many pipeline construction projects in remote areas, low cost local labour with limited experience was employed. A strong ongoing training and quality control program including holiday and peel adhesion testing was instituted to ensure proper and consistent installation.

The field joint system was supplied as a complete kit. This took away many of the challenges of bringing parts together and allowed the prime pipeline contractor to install the system. Alternatively, sub-contract "expat" labour brought in from great distances for long periods of time would have been a considerably more expensive option.

Planning, persistence, and communication (satellite telephones and the Internet) played a significant role in responding to the contractor's questions. Field service people from various countries were enlisted for initial training, and then for follow up inspection and training.

Desert Photographs

Sandstorm on the Right-of-Way

Partially Buried Cutback

Thermal Movement

Protective Tent

Coating Damage due to Movement

Finished Polypropylene Sleeve

3.2. Rainforest

This project was in the tropical environment of the Equatorial Amazonian Rainforest and consisted of a high temperature trunk line from a major oil field to the oil company's in-country base of operations.

The pipeline was designed to operate at 90ºC and the coating was FBE, chosen based on North American specifier preferences. This was uncommon because 3LPE is the prevalent coating choice in South America. High temperature, polyethylene based heat-shrinkable sleeves were chosen as the field joint protection system based on notable experience with an earlier phase of this project.

The climate was hot and humid with temperatures ranging from 35 to 47ºC and with daily showers being the norm. Flat terrain with dense vegetation, combined with the environment in question, created difficult working conditions.

The contractor had significant experience working in similar environments. With this experience, the contractor was well prepared relative to manpower, equipment and mobilisation. No specialised equipment was used for surface preparation and installation aside from standard heat-shrinkable sleeve installation tools.

As is common for these types of environments, the environmental license was difficult to obtain prior to construction so directional drilling through environmentally sensitive areas was specified. The many small rivers and marsh regions also required concrete weight coated pipe for negative bouancy.

The presence of the dense vegetation and significant wildlife required that workers be cautious to preserve the environment, but also be aware of their surroundings. In the event of a run-in with wildlife, medical staff was available with emergency evacuation on call.

Rain almost every evening in these regions can cause delays in production, and the project bid needed to account for this. The use of heat-shrinkable sleeves, however, was a benefit as they are unaffected by high humidity.

Training by the coating supplier's field engineers was provided at each pipeline spread or when a major crew change occurred. An ongoing quality control program included peel adhesion testing on one joint per 100 and holiday testing on the complete line.

Rainforest Photographs

Rainforest Right-of-Way

Protective Tent

Surface Preparation

Sleeve Wrapping

Sleeve Shrinking

Adhesion Testing

3.3. Cold Climates

The climate conditions are most typical in oil and gas rich regions of northern Canada and Russia. Case study experiences were derived from northern Canada using an HPCC mainline coating system and one in Sakhalin Island, Russia that used a 3LPE mainline coating. The coating decisions were made based on a combination of preferences of the specifying engineers, the desire to try different technologies and the demands of the environment. The Canadian project was part of a study to evaluate the feasibility of X100 and X120 steel for pipeline construction[4].

The construction conditions typically saw temperatures ranging from -35 to -45ºC. The land was snow covered or frozen tundra. On the Russian project, a warm period allowed the tundra to thaw and resulted in extremely muddy conditions.

Each of the projects involved contractors with extensive experience in extreme low temperature construction. Equipment included blast equipment, catalytic gas fired infrared heaters, electrical induction generators and coils, heated busses and standard heat-shrinkable sleeve installation tools.

The extreme cold affects even the most robust equipment. Diesel engines risked not starting if too cold so they were kept running for several days at a time. The equipment required cold start functions and configured for low temperature operation including low temperature synthetic oil, radiator antifreeze fluids and protection of control panels.

Trucks, vans or busses equipped with auxiliary heaters acted as a warm meeting area, a warm place to store some materials and as a workroom for mixing two-component liquid epoxies prior to application under the 3-layer heat-shrinkable sleeve system.

Liquid applied coatings and epoxy primers increase significantly in viscosity when cold. Infrared heaters or induction coils were used for preheating the joint area prior to system installation.

For application of high performance, 3-layer heat-shrinkable sleeve systems induction heating equipment was employed to preheat the cutback area and to force-cure the primer system prior to application of the sleeve. At these low temperatures, the induction heating provided even heat and maintained the heat in the steel longer than torch heating.

Propane fired equipment for preheating and shrinking of heat-shrinkable sleeves may experience freeze up. Adequate handling and storage procedures can minimise these issues.

Ongoing holiday and random cross-cut adhesion testing ensured adequate thickness, and also that adhesion quality was not adversely affected by low temperatures during product installation.

Cold Climate Photographs

Training

Storage & Work Area

Clear Sunny Days

Short Daylight Hours

Induction Preheating

Heat-Shrinking

4. CONCLUSIONS

The common denominators for each of these projects revolves around specification, product selection, contractor experience and preparedness, equipment, training and ongoing inspection.

For the projects that used heat-shrinkable sleeves for the field joint, the type of sleeves chosen for each project was engineered for the design temperature performance under the individual project requirements. The liquid applied coatings used as sleeve primer layer were applied to facilitate proper application and curing in spite of the diverse conditions.

Making specification decisions for construction in remote regions, especially for high operating temperature pipelines, requires a sound knowledge of a number of alternative technologies. Proper specifications need to account for more than just pipeline operating conditions. Well-informed engineers specify based on many levels of compatibility. The field joint technology must be compatible to the mainline system. The field installation technique must be compatible for the construction environment and the contractor’s expertise and equipment. With proper equipment and training, the prime pipeline contractor can effectively apply the products in the field and the client can expect performance in line with their specification requirements.

5. REFERENCES

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