PCI Paint & Coatings Industry

Coal Tar Enamel

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During the last hundred years, coal tar enamel (CTE) coatings have been used on more in-service pipelines than any other coating in the world. Millions of miles of steel pipeline have benefited from the corrosion protection offered by CTE. How, after a century of use, can CTE stand up to natural enemies like root growth, soil bacteria, moisture, salts, acids and extreme temperatures? How, after newer and more attractive systems were developed, has CTE remained one of the most popular and most efficient corrosion protection systems? Because it was designed to endure both the elements and the test of time.

Steel pipelines are the safest and most cost-effective method of transport for large volumes of gas, oil, water and other liquids or slurries. Because steel corrodes when in the presence of oxygen (air) and moisture, it will react and revert to its natural state — rust. If a pipeline corrodes it may leak or burst, having dangerous, expensive or even disastrous results. Corrosion is prevented by creating a barrier between oxygen and moisture and its victim, the steel. CTE provides one of the most effective corrosion protective barriers.

Key Technical Developments

The good film-forming and waterproof properties of coal tar products have been known for centuries, but it has only been during the last century that they have been refined enough to provide pipeline coatings.

Initially, the coatings were simple mixtures of crude pitches and solvents. They were brittle at low temperatures and soft and sticky at warm temperatures, which limited their use. However, rapid improvements have recently been made. Coal tar liquors were obtained from high-temperature coke ovens and refined to give stable soft pitches that were used as the basis for CTE. Special powdered coals were dispersed at high temperatures in these soft pitches and with heavy coal tar flux oils to make a plasticized product called modulate. The result was a lowering of the brittle point and a large increase in the softening point of the product. The addition of only 1% coal can increase the softening point by 3–5° C. The ratios of these reactants were selected to produce the required softening point (usually 90–130° C) and penetration figures (usually between 5 and 30).

The next development was the addition of inert fillers such as powdered talc or slate. These improved the flexibility, impact resistance and strength, and reduced the cold flow. Unlike coal, these fillers had only a marginal effect upon the softening point and penetration figures.

The modern process plant incorporates all these developments. The coal tar pitches and oils are more reliable and stable, the coal is specially selected, and the inert fillers are finely ground to meet modern requirements. The process times and temperatures are crucial, and were adjusted to meet the present tight standards.

The introduction of glass fiber innerwraps within and the application of outerwraps fused onto the surface of the coating further improved the mechanical strength of the system. They provided extra protection against soil stresses and impact damage during handling and installation.

Offshore oil and gas discoveries, particularly in the United Kingdom sector of the North Sea saw the introduction of concrete weight coatings on top of the corrosion coats. CTE proved to be an excellent choice of coating as it provided a good surface onto which the concrete could adhere.

At the same time, several developments have been made in the primers used with the enamel. Initially, the primer was a simple solution of pitch or modulate in naphtha or similar solvents. This was slow drying, and was replaced by a quick-drying synthetic primer around 1960. The synthetic primer was based on chlorinated rubber and enabled the coating applicators to install fast conveying factory systems. The most recent development by Reilly Industries is the EP-10 epoxy primer. This provides an extra strong bond that improves the high temperature capability of the enamel.

EP-10 Epoxy Primer System

EP-10 is an epoxy primer that is applied immediately prior to the enamel flood coat. It provides an enhanced chemical and mechanical bond, and the synergy between the epoxy and enamel creates outstanding resistance to cathodic disbondment at elevated temperatures as high as 240°F (115°C), and improved adhesion at all temperatures. In addition, the low VOC level meets all the current requirements in environmentally stringent areas like California. This development will lead to longer service life and improved performance at temperatures up to 240°F, and the extra adhesion will give better mechanical protection from soil stresses and handling damage.

Standards

Pipelines are expensive. Whether underground or undersea, excavation and repair are very costly. Protective coatings are crucial in these applications, and must be applied according to the highest standards. The efficiency of the coating depends upon many factors — the design of the coating, surface preparation, application, inspection, and handling and installation. All these aspects should be monitored by suitable technical standards and codes of practice.

In the past, coatings have been hand applied in the field by the “granny ragging” method. Surface preparation consisted of mechanical scrapers and wire brushes rather than the grit-blasting used today. Inspections were poor or nonexistent, leading to faulty and uneven coating thickness. The quality of enamel was inconsistent and misused, and the pipes were lowered into the ditch before the coating had cooled. Numerous examples of bad practice and inconsistencies needed to be eliminated. However, despite the poor application conditions, there are many examples throughout the world of pipelines coated over 40 years ago that are still in operation today.

On April 25, 1940, the first standards were introduced by the American Water Works Association, designated 7A.5 and 7A.6. There have been 12 revisions at regular intervals to obtain the latest edition AWWA C203-97. The British Standard BS4164 was first published in 1967 and has been regularly updated to the last issue in 1987.

These two standards have helped to raise the international quality of materials and factory application to their present high levels. AWWA C203, although designed for use in the water industry, is applied worldwide in the oil and gas industries when CTE is specified. BS4164 is a material standard and includes the high temperature grades often required for deep wells.

Chemistry and Properties

The coal tar pitch, which forms the basis for the enamel, consists of polynuclear aromatic hydrocarbons and heterocyclic three- to six-ringed compounds. These stable molecules are formed during coking operations at about 1,300°C. They are packed in planar layers approximately 4.5 Angstrom units apart. During manufacture, the liquid coal tar disrupts the secondary valence forces of the coal and penetrates its plate-like structure as it dissolves. The fillers and coal add flexibility and strength to the product. The strong molecular bonding provides exceptional resistance to water penetration and bacteria. By contrast, the long chain aliphatic bond structure found in petroleum bitumen has lower water resistance and can be degraded by bacteria.

The strong molecular arrangement provides CTE with the characteristics necessary to produce superior pipeline corrosion protection. These can be summarized as follows:

- Water resistant — negligible water absorption and vapor transmission.
- Stable chemical structure — resistant to acid and alkali soils, and good resistance to petroleum products.
- Resistant to cathodic disbonding — most pipelines are protected using impressed current or sacrificial metal anodes; CTE is resistant to the alkaline environment formed at exposed metal surfaces.
- High electrical resistance — even after two years' immersion in water, the electrical resistivity is still 10^{14} ohm cm^3.
- Adhesion — forms a strong permanent bond to the steel surface.
- Resistant to attack by bacteria, marine organisms and root penetration — it forms an impenetrable barrier to tree or shrub roots so microorganisms can find no nutrients and are therefore rejected without causing harm.

Selecting the Correct Grades

The CTE system is made up of four main components: primer, coal tar enamel, glass fiber innerwrap and glass fiber outerwrap. When selecting the enamel and outerwrap grades, it is crucial to consider the performance requirements. Users should consider service temperatures, local ground conditions and seasonal variations when choosing the proper grade.

Primer

Today's pipecoating factories are capable of coating 30 pipes of 40 foot length every hour. This usually reduces the primer choice to one of two options — synthetic type B primer or EP-10 epoxy primers.

Synthetic type B primers are based on chlorinated rubber. They can be applied by spray, brush or roller and dry within 5–15 minutes.

EP-10 epoxy primer is a two-component material. It is applied by multi-component spray equipment to warm pipe (100–140°F). While the primer is still tacky the enamel flood is applied; the heat from the enamel completes the chemical reaction to form the bond.

Both primers are compatible with all different grades of enamel.

CTE Grade

There are four coating grades, all fully compatible with one another but designed for use under different in-service conditions and temperatures (see table).

Each grade is manufactured from the same raw materials and differs only by the ratios used. In general terms, the softer enamels are used at low in-service temperatures and the harder ones at high temperatures. It is important to select the correct grade or grades for each pipeline. High temperature sections, such as after compressor stations, may require a hot line grade whereas the remainder of the line may require the standard Type 1.

Innerwrap

The innerwraps are resin-bonded glass fiber mats with limited elasticity. These reinforcements add mechanical strength to the enamels, which are thermoplastic materials. They strengthen the coating, inhibiting creep and increase the impact resistance. It is recommended that for coating thicknesses below 4 mm one innerwrap is sufficient, but for 4 mm and above two are advisable.

Outerwrap

Outerwraps are CTE-impregnated glass fiber mats. They are porous, allowing the vapors to escape during application and the hot enamel to permeate and fuse the outerwrap to the surface. These glass fiber outerwraps have replaced the old-fashioned and environmentally unacceptable asbestos felts, which were not porous and often entrapped vapors, leading to voids or detached felt.

The selection of the correct grade of outerwrap depends on the mechanical stresses the coated pipe encounters during handling, transport and installation. The effect of soil stress creates a maximum force along the pipeline in the 12 o'clock position, which is proportional to the diameter. For a 1,300 mm diameter pipe, the tensile force is 600 N/50 mm (proportionally less for smaller diameters). Consequently, this would be the required longitudinal strength for the outerwrap. For most projects the standard glass fiber outerwrap in AWWA C203-97 Sec 4.3.4.1 is more than adequate, however for large diameter pipes with high stresses, the stronger woven or lock-welded outerwraps in Sec 4.4.3.4.4 and Sec 4.3.4.5 may be necessary. All grades of CTE and coal tar outerwrap are compatible with one another.

Summary

CTE has an outstanding track record throughout that is unmatched by any other pipe coating material. Technical developments have enabled the system to be applied rapidly and efficiently at costs substantially below competing products. By selection of the correct grades, it is suitable for in-service temperatures between –30°C and +95°C and is effective up to 115°C under concrete weight coat for subsea pipelines. Today’s quality standards for the products and their application will ensure its continued success as a leading corrosion protection coating for steel pipelines.