Petroleum Underground Pipelines Protective Coating

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Introduction

The general conception of a paint is of a cold-applied material containing thinners which evaporate to leave a higher molecular-weight base protective, of 25-50µm thickness per coat. For buried or submerged structures, where maintenance is difficult or even impossible and a degree of physical protection is also necessary, such thin protective paint barriers between metal and the corrosive electrolyte environments of soil or water are usually quite inadequate. In dealing with underground structures, therefore, the thicker protective's needed are regarded as coatings rather than as paint finishes. Since petroleum pipelines provide the greatest area of metal surfaces to be protected below ground, a detailed discussion of the protection given to them would appear to be the best means of dealing with coatings for underground use. Improvements are continually being made in the quality of coating materials and their application, but it is still difficult to produce at economic cost a permanent coating for a buried pipeline. The disruptive effects of handling, construction, penetration by rocks, soil stress, material ageing, etc. inevitably result in areas of bare metal being exposed to corrosive soil electrolyte at isolated locations, with ultimate pitting or holing of the metal. The combination of coating with cathodic protection shows the greatest economic advantage. Many types of coating are used, from thick concrete to thin paint films, and each has its own particular suitability, but the majority of pipelines throughout the world today are coated with hot-applied coal tar or petroleum asphalt-base-filled pipeline enamels. In the special case of pipelines operating at relatively high temperatures such as for the transmission of heavy fuel oil at up to 85°C, heat insulation and electrical insulation are provided by up to 50mm of foam-expanded polyurethane. As a further insurance against penetration of water, and to prevent mechanical damage, outer coatings of polyethylene (5mm), butyl laminate tape (0.8 mm) or coal-tar enamel reinforced with glass fiber (2.5 mm) have been used.

Properties Required of Buried Coatings.

The aim in applying a coating to a buried metal such as a pipeline is to prevent electrical contact with an electrolyte such as soil and/or water. The characteristics required are as follows:

1. **Ease of application.** It must be possible to apply the coating in the factory or in the field at a reasonable rate and to handle the pipe reasonably quickly after the coating has been applied without damaging the coating.
2. **Good adhesion to the metal.** The coating must have an excellent bond to steel. Priming systems are frequently used to assist adhesion.
3. **Resistance to impact.** The coating must be able to resist impacts without cracking.
4. **Flexibility.** The coating must be flexible enough to withstand such deformation as occurs in bending, testing or laying, as well as any expansion or contraction due to
changes in temperature. It must not develop cracks during cooling after application or curing.

5. **Resistance to soil stress.** The coatings are often subject to very high stresses, due, for instance, to the contraction of clay soil in dry weather, and they must be able to resist such stresses without damage.

6. **Resistance to flow.** The coating should show no tendency to flow from the pipe under prevailing climatic conditions. It must not melt or sag in the sun and it must have sufficient resistance not to be displaced from the underside of large-diameter pipes.

7. **Water resistance.** Coatings must show a negligible absorption of water and must be highly impermeable to water or water-vapor transmission.

8. **High electrical resistance.** The coating must be an electrical insulator and must not contain any conducting material.

9. **Chemical and physical stability.** The coating must not develop ageing effects, e.g. denaturing due to absorption of the lower-molecular weight constituents, or hardening with resultant cracking from any cause including oxidation. It should be stable at operating temperatures.

10. **Resistance to bacteria.** The coating must be resistant to the action of soil bacteria.

11. **Resistance to marine organisms.** In the case of submarine lines, the coating should not be easily penetrated by marine life, e.g. mussels, borers, barnacles, etc. These characteristics cover the general ideal for a pipeline coating, but obviously modified conditions may impose requirements which are more, or less stringent; this of course also applies to other types of buried structures.

**Preparation of Metal Surface**

Before applying a protective coating it is essential to ensure that the surface is free from rust, mill scale, moisture, loose dust, or any other incompatible material which might prevent the electrically non-conducting coating from bonding properly with the metal surface or which might produce defects in the continuous film.

The following cleaning methods are available and each may have a particular advantage in given circumstances:

(a) **Mechanical cleaning.** Hand or mechanical wire brushing, impacting or abrading are methods suitable for hot applied coatings, for repairs to damaged areas or for relatively small or inaccessible areas.

(b) **Blast cleaning.** Air-blast or centrifugally-impacted sand, shot or grit are appropriate for thin-film multi coat systems or for continuous factory production. Several visual standards are available

(c) **Pickling.** Dipping in inhibited hydrochloric or sulfuric acid is commonly used in factory production, particularly in conjunction with hot phosphoric acid dipping.

(d) **Flame cleaning.** This is appropriate only for field repair work where a dry or warm surface can be obtained only by flame application and must be preceded usually by mechanical cleaning.

(e) **Pipeline travelling machine.** For long runs on continuously-welded pipelines, a machine with rotary wire brushes and/or impact tools and cutting knives may be used to prepare the surface. It is desirable to apply the primer or coating immediately after the cleaning operation.
The preparation of the metal surface to receive the protective coating is of prime importance since a coating which is not bonded to the metal surface can allow electrolytes to contact the metal, with resultant corrosion. If water films develop between the metal and the electrically non-conductive coating, cathodic protection becomes ineffective.

**Coal Tar and Petroleum Asphalt Coatings**

**Coal tar:** is a brown or black liquid of high viscosity, which smells of naphthalene and aromatic hydrocarbons. Coal tar is among the by-products when coal is carbonized to make coke or gasified to make coal gas. Coal tars are complex and variable mixtures of phenols, polycyclic aromatic hydrocarbons (PAHs), and heterocyclic compounds, about 200 substances in all. Coal Tar Products, which offers good adhesion to substrates such as steel and aluminum. These are easy to use and offer corrosion resistance, suitable for a wide range of climatic conditions and ensures that pipelines are shielded from all elements of nature.

![Fig.(1) Types of coal tar products.](image_url)
Asphalt: is a heavy, dark brown to black mineral substance, one of several mixtures of hydrocarbons called bitumen. Asphalt is a strong, versatile weather and chemical-resistant binding material which adapts itself to a variety of uses.

Asphalt is one of the world's oldest engineering materials, having been used since the beginning of civilization. Around 6000 B.C. the Sumerians had a thriving shipbuilding industry that produced and used asphalt for caulking and waterproofing. As early as 2600 B.C. the Egyptians were using asphalt as a waterproofing material and also to impregnate the wrappings of mummies as a preservative. Ancient civilizations widely used asphalt as a mortar for building and paving blocks used in temples, irrigation systems, reservoirs, and highways.

Coal Tar and Petroleum Asphalt Enamels
The majority of pipelines today are coated with hot-applied plasticised coal tar or petroleum asphalt enamels. Both coal-tar pitch and petroleum asphalt have been used as protective with and without filling materials. When filled they are termed enamels or mastics. Straight and filled enamels Fillers are normally added up to a maximum of about 30% weight (calculated on the mixture) which is equivalent to about 15 to 20% by volume. A filled coal-tar pitch has a higher softening temperature than the unfilled material, which results in a reduced tendency to flow. This fact is important in tropical countries or if a pipe is to operate at a somewhat elevated temperature. Resistance to impact and abrasion of a coating is improved by the filler. The viscosity of the pipe coating is also increased; this entails a higher application temperature (193-249°C).

A satisfactory filler must have the following characteristics:
1. Low water absorption. In this respect certain fine clays are unsuitable.
2. Ability to be readily wetted by the enamel.
3. Finely-ground composition, particles preferably of laminar shape to prevent settling when the enamel is molten.
4. Relatively low specific gravity, so that there is the minimum tendency for the filler to settle-out in the melting kettle.

In present-day practice the materials which are commonly used and which satisfy most closely these requirements are talc, pumice powder, micro asbestos and slate powders. It must be appreciated that there is an optimum percentage of filler which
imparts to a coating the required melting point and toughness; beyond this point application, becomes more difficult and water tightness may be impaired. Petroleum asphalt or coal-tar pitch as coatings The question of whether coal-tar pitch or petroleum asphalt is the more suitable for the coating of underground pipelines has raised a good deal of controversy. Asphalt and pitch are both waterproof materials, and they resemble one another in physical type. In the right circumstances both can be very effective in preventing the access of water to buried or submerged steel surfaces. Petroleum asphalts are manufactured in two general types: 

(a) a straight residue from distillation, which can be of the hard, high-melting type, and

(b) so-called ‘blown’ grades which are prepared by partially oxidizing the asphalt base by blowing in air.

The general difference between the two grades is that ‘blown’ asphalt has a higher softening point than straight asphalt of the same penetration. In assessing a pipeline coating the softening point is of considerable importance, since it determines the tendency to flow, and a certain minimum softening point is therefore necessary. A ‘blown’ asphalt has the advantage over straight material of the same softening point in that it has a better resistance to impact, since it is of a more rubbery nature. For this reason most petroleum asphalt coatings are based on the ‘blown’ variety. So far as coal tar is concerned, it was formerly the custom to use the straight residual pitch, but nowadays shock resistance is improved by a so-called plasticising process. The differences between asphalt and coal tar in relation to their application as pipeline coatings require comment.

1. It is often claimed that a coal-tar-base coating absorbs less water than an asphalt coating and there is evidence in practice to support this claim, but some asphalt enamels in practice have been as good as the best coal-tar enamels.

2. Coal-tar enamels are claimed to have better adherence than the asphaltic enamels to clean metal, probably because of the presence of polar compounds, but little difference can be noted in practice under proper pipelining conditions.

3. The asphaltic enamels are easier to apply since they do not produce so much obnoxious fume and are usually applied at slightly lower temperatures.

Fig.(3) Coated pipes with coal tar.

Fig.(4) Coated pipes with Petroleum asphalt and coal tar.