

For new subsurface structures, it is therefore good practice to include corrosion control measures in the design. Such corrosion control measures must be selected and adapted to meet the specific conditions in which the structure will exist. A corrosion survey of some form is usually necessary before corrosion control measures can be designed for underground structures.<sup>22</sup>

### Protective Coatings—Electrically Insulating

Protective coatings are applied to underground structures to isolate them from the soil environment and to insulate them from electrical effects. Such coating materials must possess long term qualities of high electrical resistance, inertness to the environment, low water absorption, high resistance to deformation by soil pressures and the temperatures at which they are operated, and good adhesion. Most coatings require reinforcing, shielding, or both, to resist soil stresses. The performance of all coating systems, even those of the best material specifications, are dependent upon the metal surface preparation, application procedure and conditions, backfilling and the physical, chemical, biological, and electrical stresses that occur in service.

The coatings most commonly used on underground structures include the following:

1. Hot-applied coal tar enamel.
2. Hot-applied petroleum base coatings, such as asphalt enamels and waxes.
3. Polyethylene or polyvinyl (tapes and extruded polyethylene).
4. Coal tar epoxy resin.
5. Cold-applied bituminous and asphalt emulsions, cutback solvents, grases, etc.

The performance of the cold-applied coatings is generally found to be the least effective.

Each of the coatings is formulated by its manufacturers for specific application and service conditions.

The Technical Practices Committees of the NACE have prepared statements on minimum requirements for coal tar coatings,<sup>23</sup> asphalt-type protective coatings,<sup>24</sup> and prefabricated plastic films.<sup>25</sup>

### Cathodic Protection

Although cathodic protection can be applied to bare structures underground, it is most widely used to provide corrosion control for exposed metal at the coating flaws (holidays) which inevitably occur on the coating during and after installation. The rate of metal penetration at coating flaws is often greater than that on bare surfaces.

The cathodic protection of underground pipelines and tanks can be accomplished by either galvanic anodes (magnesium or zinc) or impressed current systems. Impressed current may be applied from anodes distributed alongside the structure, from remote anodes, or from deep well anodes.

The method used depends upon the economics and the site conditions affecting the cathodic protection design requirements.

Full cathodic protection is achieved when the current applied to the structure is an amount sufficient to prevent current flow into the soil from any and all points on the surface of the structure.

Specifically, this protective current must be applied to the structure in an amount sufficient to maintain its external surface, at every point, negative by at least 0.85 volts to a copper-saturated copper sulfate half cell in the immediate proximity thereof.<sup>26</sup>

### Types of Soils

The corrosivity of a soil is affected by its porosity (aeration), electrical resistivity, dissolved salts (depolarizers and inhibitors), moisture, and acidity or alkalinity. Although corrosion rates and characteristics cannot be exactly related to the individual factor, the attack on a metallic structure buried in nonuniform soil will generally be greatest on those surfaces in contact with the least porous (air-free), least resistive, most saline, most moist, or the most acidic soil.

The National Bureau of Standards has compiled the most extensive data<sup>27</sup> on a series of field tests on various metals and coatings in many typical soils throughout the United States. These studies, begun in 1910 and continued until 1955, are the most important source of information on soil corrosion available.

### Bacterial

High rates of corrosion in some air-free environments have been found to be associated with the presence of sulphate reducing bacteria (spirovibrio desulfuricans). The role of these bacteria in the corrosion process is being vigorously studied.<sup>28</sup> Tests on bacterial growth have shown some coating materials are susceptible to biological attack.

Bacterial activity should not be considered a special and new form of corrosion. The conventional use of well applied coatings, and cathodic protection will control corrosion on underground metallic structures in the presence of these bacteria. Coatings which disbond, allowing water and corrodent to reach the metal surface, will shield the exposed metal from the effects of applied cathodic protection.

### NACE and National Bureau of Standards References

Most of the significant papers presented at meetings of the National Association of Corrosion Engineers, which are pertinent to underground corrosion and protection are published in its journals, *Corrosion* and *Materials Protection*. Specific recommendations (minimum requirements) for underground pipeline corrosion control are developed by Technical Practice Committee T-2.

A statement prepared by this Committee on minimum requirements for corrosion control of underground pipelines<sup>29</sup> reads as follows:

1. Underground steel piping transporting petroleum, gas or related products, where traversing populated areas or existing in such manner as to create a hazard to public safety, should be coated with a protective material of permanent high electrical resistivity. Such coatings, if not so compounded or re-inforced as to resist soil stresses, shall be shielded in such manner as to receive negligible damage from such stresses.
2. Where environment indicates coating, as set out in No. 1, the protective coating should be supplemented by application of adequate cathodic protection of such coated pipe.
3. Where question may arise as to the applicability of these requirements due to existing and long established methods, the problem should be passed to the local electrolysis committee for study and recommendation. It is recommended that such committees be composed of qualified engineers who are cognizant of the overall problem and are free and capable of making objective decisions.

The most comprehensive, long-term study of underground corrosion has been conducted by the National Bureau of Standards. The studies of soil corrosivity, materials, coatings, cathodic protection, stray currents, etc., conducted over a period of 45 years have been published.<sup>27</sup>

### Corrosion and Deposits

#### Insulation Failures

Most thermal insulation does not provide corrosion protection in soils or water. Catastrophic corrosion occurs on hot pipe surfaces when intermittently contacted by water.<sup>30</sup> This corrosion process cannot be controlled by cathodic protection. Insulation, such as fiber glass, magnesia-asbestos, etc., must be kept dry in underground runs through conduits. Notable examples of corrosion have been experienced within a few months after construction on magnesia-asbestos insulated snow melting pipe manifolds extending below the slab into soil.<sup>31</sup>

Natural asphalt materials used for underground pipe heat insulation exhibit some corrosion protective effect. However, they are relatively permeable to water, and repeated heating and cooling initiates attack under the insulation. Similarly, corrosion attack has been experienced at locations of fluctuating water table.

Radiant heat and snow melting pipe embedded in slabs constructed with vermiculite-filled concrete, brick, or concrete block supports, and open expansion joints, have been subject to severe corrosion.<sup>32</sup> Severe corrosion of radiant heating pipe embedded in sand or porous concrete under terrazzo flooring has also been experienced. It is good construction practice, in such heating systems, to avoid severe corrosion problems by using a minimum thickness of 1½ in. of cement-rich concrete to completely surround the piping, a water-proof membrane under the slab, and steel saddle pipe supports. The piping should be coated at expansion joints and pipe should not come in contact with the reinforcing steel. Lightweight or insulating concrete produces local cell activity at the nonuniformities in contact with the piping. The piping should be insulated from all other metallic structures. Magnesium anodes buried in the adjoining soil may be attached to the piping to provide protective effect.

Although cathodic protection has been applied to radiant heating piping,<sup>33</sup> it is not always possible to direct adequate amounts of protective current to corroding surfaces. The best corrosion control measures are those integrated into the original design and construction of the heating system.

#### FIRE-SIDE AND HIGH TEMPERATURE CORROSION

The surfaces of flues and boilers which come into contact with combustion products are seldom corroded while the equipment is in operation. Breachings, smoke hoods, and canopies in contact with flue gas may, however, be subject to attack during warmup periods or when the rate of operation is so low that the temperature of the flue gas is below its dew point. In those sections of stacks in which flue gas temperatures drop below the dew point, corrosion is inevitable during operation.

It is common practice to use case iron or acid-resistant vitreous enamelled steel in flue gas connections to appliances in order to prolong the life of these parts. Protective coatings with organic binders are destroyed rather rapidly above 400 F, because of the decomposition of the organic materials. Metal surfaces with temperatures that do not exceed 400 F may be protected by periodic applications of paints. Protection of stacks and other surfaces which reach higher temperatures may be achieved by the use of other coatings, such as the silicones, that are resistant at the service temperatures.

Fire-side corrosion can be minimized by modification of the firing cycle so as to minimize the number of times that the flue gas temperature drops below its dew point, by specifying low sulfur content fuels, and, in certain types of installations, by the use of fuel oil additives which neutralize the acidic condensates on the fire-side surfaces.

The shut-down period, when condensation of moisture occurs on metal surfaces, is usually the time when the greatest damage is done. When long shut-down periods are anticipated, a practical method for minimizing fire-side corrosion is to clean the surface thoroughly and to provide adequate clean, dry air circulation, in order to prevent condensation. (See also Care of Idle Heating Boilers, Chapter 52.)

### REFRIGERANT SIDE CORROSION

Corrosion problems which develop on the refrigerant side of equipment, and methods for their control, are discussed in Chapters 48, 49, and 50.

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