are expensive.[33] Concrete linings for steel bunkers have also been effectively employed.[34]

The use of high chromium steels is not always a sure cure, especially with coals treated with dust allaying agents high in chlorides.

Flues, Stacks, and Fire-side of Boilers

The surfaces of flues and boilers contacting the products of combustion, seldom experience corrosive attack when the equipment is in operation. Breechings, smoke hoods and canopies in contact with flue gas may, however, be subject to attack during the warming-up period of an appliance, or when the rate of operation is so low that the temperature of the flue gas is below the dew-point. It is common practice to use cast-iron or acid resistant vitreous enameled steel in flue gas connections to appliances, to prolong the life of these parts. The shut-down period, when condensation of moisture occurs on the metal surfaces, is usually the time when most damage is done.[35] In those sections of the stacks where flue gas temperature drops below the dew-point, corrosion is inevitable during operation.

It is clear that where long shut-down periods are anticipated, a practical method for mitigating corrosion is to clean the surface thoroughly and to provide adequate clean, dry air circulation to prevent condensation. (See also Care of Idle Heating Boilers, Chapter 16).

Protective coatings with organic binders are destroyed rather rapidly above 400 F because of the decomposition of the organic materials. The surfaces of metals, whose temperature does not exceed 400 F, may be protected by periodically applying paints such as those specified in the following paragraphs entitled Air Ducts.

Air Ducts

The most practical method for protecting air duct surfaces made of steel from atmospheric corrosion, is to apply protective paints. One of the most effective protective coatings is red lead paint.

Three coats of paint should be applied, of which the first two coats should be rust inhibitive paint such as red lead paint, with the second coat tinted to a light brown color with carbon black, and the finishing coat may be red lead paint tinted to a black or brown color, black paint made according to Federal Specification TT-P-61, red iron oxide paint conforming to Federal Specification TT-P-31, or white or light tinted paint made according to Federal Specification TT-P-40.

Another paint which has had some use for priming iron and steel is zinc chromate paint.

Under some conditions, a chlorinated rubber base paint made according to Federal Specification TT-P-91 may be used for the finishing coat, particularly where the presence of highly corrosive gases or contact with strong alkaline water would injure the standard paints. Rubber base paints should be used only for the finishing coat over regular priming and second coats.

BURIED PIPE LINES

Lines that are cold and in intimate contact with the earth are corroded from the same causes as in mineral waters, but pitting is usually more intense due to variations in concentration of salts and oxygen in solution, acidity, drainage, and presence of solid materials (such as cinder) in contact with metal pipe. Galvanic currents, induced by contact of certain dissolved constituents in the soil, often act over a large area, and accelerate corrosion where they leave the pipe line.

Certain bacteria that thrive in the absence of oxygen have the power to obtain hydrogen and dissociate sulphates in the soil, with a resultant production of hydrogen sulfide which attacks the iron to form iron sulphide.

Stray electric currents from electric power generating stations sometimes find their way into buried steel structures, and do damage in proportion to the current density where the current leaves the metal to enter the ground.

Pipe Materials

Some underground corrosive environments found in the air conditioning and heating industries require special materials. The selection of such materials must be based upon an economic evaluation, as the use of expensive first cost materials is not wise if the life of lower cost materials is adequate. On the other hand, a material low in cost and corrosion resistance should be avoided if it leads to costly shut-downs, repairs, and early replacements. Underground piping materials should be selected for their ability to resist exterior as well as interior corrosion, and careful evaluation of the soil and water should be made.

Underground corrosion of metals is particularly difficult to predict. There are many different types of soils varying in composition and in ability to corrode both ferrous and non-ferrous metals. Where excessively corrosive soils are encountered, special materials may be necessary, but generally the commonly used ferrous materials have proved to be the most economical. Copper and many of its various alloys are also used advantageously, but their use is more restricted to selected localities. It has been found that soils with high content of organic matter or alkaline soils in which the ratio of chlorides and carbonates to sulphates is high, may be corrosive to copper.[36] Copper or the commonly used ferrous metals should not be embedded directly in cinders or in tidal marshes, as they may be unduly attacked by sulphur compounds. It is also wise to avoid the embedding of any pipe materials in soils where unusually high salt contents are known to exist.

Galvanized wrought-iron pipe and steel will resist underground corrosion quite satisfactorily, particularly if the galvanized coating is 3 oz per square foot or more. The National Bureau of Standards found in recent tests that where an underground piping material contains 3 oz of galvanizing per square foot or more, the life of the pipe materially increased. The zinc used for galvanized coating is on the electrochemical protective side of the iron; and the zinc as it corrodes is changed to zinc compounds before the underlying base metal is attacked. This fact and the mechanical protection provided by the zinc coating account for the protection afforded by the galvanized coating. Once the galvanized coating has been destroyed, the base metal must then retard the corrosive attack, and the rate of attack depends upon the composition of such base metals. Lead-coated pipe[37] has had a limited application for underground service. It has been found that it corrodes chiefly in soils deficient in oxygen or containing cinders.

Protective Coating

Protective coatings for buried pipe lines are in a class by themselves because of the unusual service conditions, and because it is not possible to maintain them by recoating when necessary. Buried steel pipe lines have been protected against corrosion with considerable success by the use of