water systems, such as cooling towers and evaporative condensers, proper feeding equipment must be used. Shock-feeding of chemicals for control of scale and corrosion will usually be ineffective. Since there is normally a continuous water loss due to drift and bleed-off from the system, a uniform rate of chemical feeding should be used so as to replenish chemicals lost from the system. By use of proportional feeding equipment, a constant concentration of water treatment chemicals will be maintained at all times. This will provide optimum results and give maximum economy.

Closed Recirculating Systems

The term Closed Recirculating System is in reality a misnomer. Except for relatively small systems, most closed systems are open because they most usually require make-up water. Recently, tests conducted on 84 closed systems indicated that more than 50 percent of the systems had one or more water changes per month because of leakage. Weekly water changes were found in more than 10 percent of the systems.[21] Continuous make-up, of course, replenishes oxygen in the system, thus promoting corrosion. It is imperative, therefore, that corrosion control be provided for most closed systems. The age old assumption that closed systems are closed is no longer valid.

Corrosion control is usually accomplished by (1) mechanical or chemical deaeration or (2) use of corrosion inhibitors such as chromates and nitrites.

The use of polyphosphates is not generally recommended for closed systems because they will revert to ineffective orthophosphates unless there is a large replacement of water containing polyphosphate.

Higher concentrations of chromate are usually maintained in closed systems as compared with open systems. This is primarily due to the fact that, since water losses are usually small, the cost of maintaining excess chromate as a safety factor is small.

TREATING CHEMICALS

Whenever chemicals are used to control scale, corrosion, algae, and slime, competent advice from a water chemist is desirable. Often factors considered irrelevant to the layman, will be of much importance in securing effective treatment. Very often troubles are created through improper use of chemicals and are more serious than if they were not used.[22]

An investigation[23] of so-called miracle water conditioners which claim to completely control scale and corrosion problems, without resorting to accepted chemical practice, has indicated that such water conditioners have no significant effect upon the problems of scale and corrosion.

Water Treatment Program

A water treatment program, in specification form, has been suggested by Keville and Scicchitano.[24]

REFRIGERATING SYSTEMS

Corrosion in refrigerating systems is confined to surfaces in contact with brines or those in contact with refrigerant.

Brines. Refrigerating brines usually are comprised of sodium chloride, calcium chloride, or calcium and magnesium chlorides. The corrosivity of dilute brines is higher than their more concentrated solutions. The corrosivity of sodium brines, other conditions being fixed, is about 1.5 times greater than brines of the alkaline earth metals.

Brines are excellent electrolytes. Contact of dissimilar metals of wide potential differences, when in contact with brines, results in rapid corrosion by galvanic action.

Table 6 . . . . Quantities of Sodium Dichromate to be Added to Maintain Initial Concentration

Specific Gravity of Brine to be Strengthened	Lb Sodium Dichromate per 100 Lb $CaCl_2$ Added
1.16	0.695
1.18	0.621
1.20	0.556
1.22	0.502
1.24	0.455
	Lb of Sodium Dichromate per 100 Lb NaCl Added
1.12	1.79
1.14	1.47
1.16	1.32
1.175	1.18

The leakage of air, acid refrigerants, or both, accelerates the corrosivity of brines. Ammonia precipitates calcium and magnesium salts, thus clogging the system at restricted points.

The addition of caustic soda and sodium dichromate to brine solutions to inhibit corrosion of iron, is a more or less general practice. Sodium silicate and sodium phosphate are also used at times, but tests indicate they are not as effective as is sodium dichromate. It has been suggested[25] that 125 lb of sodium bichromate per 1000 cubic feet of calcium chloride brine, and 200 lb per 1000 cubic feet of sodium chloride brine, be added to inhibit brines; that when salt or calcium chloride is added to "strengthen" brine, sodium dichromate also be added in the amounts shown in Table 6.

Refrigerants.[26] The common refrigerants, except those of the hydrocarbon type, will attack the common metals and alloys if *moisture is present*. Even a very small amount of water may cause severe corrosion with certain refrigerants. The amount required need only be sufficient to produce a water film on the metal surface.

With the halogenated hydrocarbons, complete elimination of water is much to be desired. Where ammonia is used, copper and its alloys, aluminum and zinc, are attacked especially at elevated temperatures. When sulfur dioxide is used, more than 50 ppm (0.005 percent) of water will cause appreciable corrosion of virtually all the common materials.

USE OF RESISTANT METALS

Steam condensates vary greatly in their ability to corrode metals. The amount of gases that have been dissolved are the determining factors, with oxygen and carbon dioxide, which turns to carbonic acid, being the most common.

Steel, wrought iron, and copper are the metals ordinarily used for pipelines carrying steam condensate. All of these materials have been used with various degrees of success, but under severe corrosive conditions only a few years of service can be anticipated. With the proper metal or alloy carefully selected to suit the existing corrosive conditions, a service life of 15 to 20 years or more is not at all unusual. To obtain a long service life, an analysis must be made of the existing conditions, and if the condensate contains undue amounts of

oxygen, carbon dioxide, and other harmful impurities, mechanical elimination of these gases should be a requirement. Treatment of the boiler water and the condensate itself has also proved to be somewhat effective.

Copper and ferrous metals are attacked by combinations of carbon dioxide and oxygen. When the condensate is being returned to the boiler, any copper corrosion products in the water occasionally present a serious problem. The copper that goes into solution is carried along in the condensate, and upon reaching ferrous materials in the boiler and elsewhere will plate out on the ferrous surfaces and set up galvanic corrosion due to the contact of dissimilar metals.

One of the most successful means of preventing corrosion near the junction point of copper and ferrous piping, or where copper piping is connected to steel tanks or boilers and other ferrous vessels, is to install a *throw-away* section at or near the junction. Since the corroding effect will always be found on the ferrous side of the junction rather than on the copper or copper-alloy side, and the effect is usually localized in the immediate vicinity of the joint, the installation of a ferrous pipe section 8 to 10 in. long will absorb practically all of the corrosion. When this *throw-away* section becomes corroded, it can readily be replaced. It should be noted, however, that in ordinary hot water heating systems this problem of potential corrosion at junctions of dissimilar metals seldom presents itself. Where there is any suspicion in this regard, precaution can be readily and commonly taken by separating the two metals electrically by means of a simple insulating union.

No paint or similar protective coating has thus far proven satisfactory where dissimilar metals are used in the same condensate pipe runs. Tests of cement-lined and vitreous-lined pipe have shown the linings to be readily dissolved by the hot condensates. At condensate temperatures, galvanizing on iron or steel pipe has not proved to have any advantages, and in some cases has been found to be detrimental.

ATMOSPHERIC CORROSION

Most of the problems originated by atmospheric corrosion occur in connection with the fire-side of boilers and furnaces (including their flues and stacks), sewer vents, air ducts, and coal and ash handling equipment. Usually such equipment is fabricated from common types of ferrous metals.

Generally little or no atmospheric corrosion occurs at temperatures higher than the boiling point of water, because at such temperatures little or no condensate is formed. If it does form at the higher temperatures, only negligible amounts of carbon dioxide and oxygen present in the atmosphere, will dissolve in the hot liquid, but sulfur gases may dissolve and cause rapid attack. Oxygen, sulfur dioxide, sulfur trioxide, and carbon dioxide are the deleterious gases most frequently accountable for corrosion in moist atmospheres.

Coal Storage and Handling Equipment

Virtually all coals contain sulfur in the form of pyrite, and some moisture. In storage, the pyrite is likely to be decomposed by oxidation. Moisture dissolves the products of decomposition forming sulfurous and sulfuric acid. The acid solutions vigorously attack the supporting metal.

Rubber linings have been developed for coal chutes and bins to effectively resist corrosion and the abrasive action of the coal, but they are expensive.[27] Concrete linings for steel bunkers have also been effectively employed.[28]

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.[29] 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 35.)

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