little as 60 ppm of a mixture of polyphosphate and chromate. Close control over *pH* is a requirement for good corrosion control by this process.

Sodium nitrite has not had widespread use as a corrosion inhibitor in open recirculating systems. It has been reported that difficulty may be encountered in maintaining effective concentrations. Considerable field experience is needed to further qualify this inhibitor.

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 The age old assumption that closed systems are closed is no longer valid.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]

Refrigerating Systems

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

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[23] 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. 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 sulphur dioxide is used, more than 50 ppm (0.005 percent) of water will cause appreciable corrosion of virtually all the common materials.

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

Minimizing Steam Condensate Corrosion

There are four expedients that may be utilized to minimize corrosion in steam condensate systems: (1) treatment of the boiler feedwater so as to eliminate deleterious gases entrained with the steam, (2) design of the condensing equipment to minimize dissolution in the condensate of the deleterious gases entrained with the steam, (3) chemical treatment of the condensate, (4) use of resistant metals.

Boiler Feedwater Treatment. Elimination of oxygen from boiler feedwater and, therefore, from the steam developed, can be accomplished either mechanically or chemically. In some steam generating stations, both expedients are employed.

Tests[24] have indicated that in small low-pressure heating boilers, where the boiler input contains less than about 50 ppm of carbonate hardness, the CO_2 in the steam can be controlled by adding calcium hydroxide to the boiler. In Fig. 6 are shown the equilibria conditions proposed for boilers operating at pressures up to about 5 psi gage. This expedient may *not* be used in higher pressure boilers, because of the possibilities of scale and sludge formations. In the latter, the only method used to date for treating the feedwater consists of removing the alkaline earth salts, *i.e.*, softening, and subsequent acidulation followed by deaeration at temperatures near the atmospheric boiling point of water.[25]