Design of Condensing Equipment. In the design of water heaters and comparable types of condensing equipment,[26] it is possible to shift the accumulation of non-condensable gases to a location away from the condensate level and, subsequently, vent these gases to the atmosphere. Venting an amount of steam equal to about one-half percent of the total steam entering the condenser is the optimum vent rate.

Venting is of little practical value when the CO_2 content of the incoming steam is below about 5 ppm. When the steam contains more than 5 ppm, venting provides a means of producing a condensate containing a minimum of about 3 ppm. However, even as little as 3 ppm of dissolved CO_2 can produce active corrosion if large amounts of condensate are flowing.

Chemical Treatment of Condensate. Condensates containing comparatively large amounts of oil, are practically non-corrosive, due to the protective film provided by the oil. When oil is intentionally added to condensate,[27] inadequate quantities may accelerate rather than decelerate corrosion on those surfaces not covered by the oil. Sodium silicate added to CO_2-bearing condensate has been shown to decrease, but not entirely prevent, corrosive action. It is not known whether the protection afforded by silicate solutions is due to the establishment of a protective film on the metal surface or to neutralization of the CO_2 by the alkali in the silicate solution.

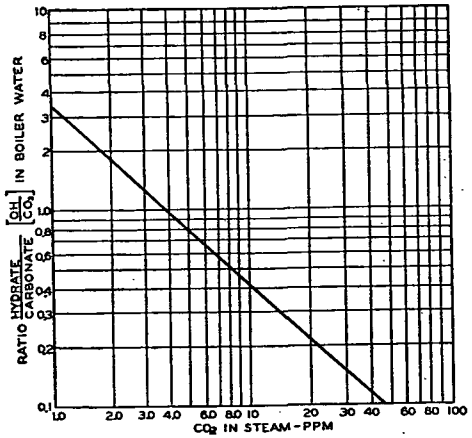

FIG. 6. RELATION OF HYDRATE/CARBONATE CONTENT IN *Hard* BOILER WATER AND CO_2 IN STEAM AT ABOUT 5 PSI OPERATING PRESSURE

(All analytical values are ppm by weight)

It has been postulated that ammonia,[28] cyclohexylamine,[29] ethylene diamine, and morpholine[30] will retard corrosion of condensate lines. Tests with benzylamine have also been reported.[31] Where copper and its alloys are involved, the use of alkaline inhibitors is believed inadvisable. The use of small amounts of sodium hexametaphosphate has been suggested too, but tests[32] indicate that this salt accelerates rather than decelerates, the rate of attack of steel by condensate containing CO_2 and oxygen. Whether chemical treatment of steam or condensate is feasible, must be determined not only upon the basis of the acuteness of corrosion troubles, but also upon the uses made of the steam or condensate.

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 most commonly used materials for carrying steam condensate. All of these materials have had various degrees of success, but under severe corrosive conditions only a few years of service can be anticipated. However, with the proper selection of materials suitable for 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 as well as ferrous metals is attacked by combinations of carbon dioxide and oxygen. When the condensate is being returned to the boiler, any copper corrosion products in the water will 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.

No paint or similar protective coating has thus far proven satisfactory. 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, 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 sulphur gases may dissolve and cause rapid attack. Oxygen, sulphur dioxide, sulphur 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 sulphur 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 sulphurous and sulphuric 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