densate,[28] 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.

It has been postulated that ammonia,[29] cyclohexylamine,[30] ethylene diamine, and morpholine[31] will retard corrosion of condensate lines. Tests with benzylamine have also been reported.[32] 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

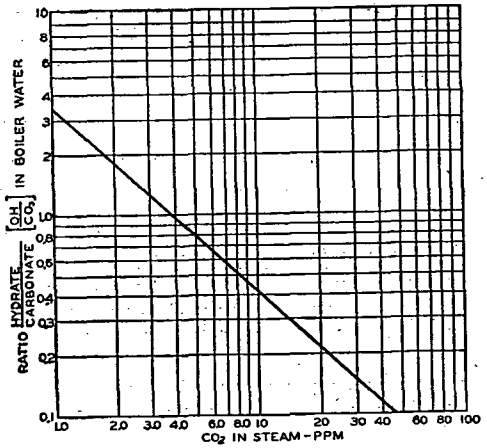

FIG. 6. RELATION OF HYDRATE/CARBONATE CONTENT IN *Hard* BOILER WATER AND CO_2 IN STEAM AT ABOUT 5 PSI OPERATING PRESSURE

(All analytical values are ppm by weight)

too, but tests[33] 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 to which the steam or condensate is put.

Use of Resistant Metals. For economic reasons, the metals known to resist corrosion can seldom be used exclusively for condensate lines in any sizable enterprise. Nevertheless, there may be instances where the use of a limited amount of the more costly, but resistant, materials can be justified. The data in Fig. 7 are the results of tests[34] designed to reflect the corrosion resistance of the more commonly used metals to attack by condensate containing oxygen and CO_2.

In contemplating the use of a resistant metal, as a section of a condensate line, it should be remembered that, if other conditions are *right*, corrosive attack will merely be transferred down stream in the system. Galvanic corrosion resulting from the contact of dissimilar metals in a condensate line seldom occurs. 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 hot condensates.

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

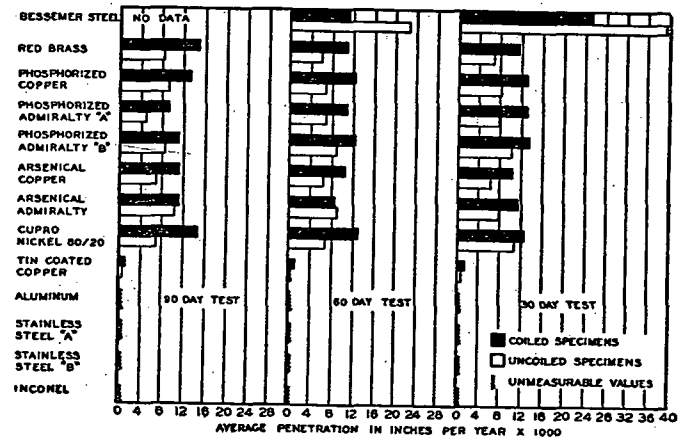

FIG. 7. COMPARATIVE CORROSION RESISTIVITY OF 10 MATERIALS EXPOSED TO CONDENSATE

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 are expensive.[35] Concrete linings for steel bunkers have also been effectively employed.[36]

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.