Internal corrosion[4] in steam heating systems occurs principally in the condensate return pipes and is nearly always caused by oxygen or carbon dioxide, or both, in solution in the condensate. Oxygen may enter the heating system with the steam, owing to its presence in the boiler-feed water, or it may enter as air through small leaks, particularly in systems which operate at sub-atmospheric pressures. When a steam heating system is operated intermittently, air rushes in during each shutdown period and oxygen is absorbed by the condensate which clings to the interior surfaces of the pipes and radiators. The rate of corrosion depends upon the amounts of oxygen and carbon dioxide present in solution, upon the operating temperature, and upon the length of time that the pipe surfaces are in contact with gas-laden condensate.

Another possible cause of corrosion is a flow of electric current sometimes resulting from faulty electrical circuits which should be corrected. Electrolytic corrosion also may occur because of the presence of two dissimilar metals, such as brass and iron, but the condensate in practically all steam heating systems is such a weak electrolyte that this cause of corrosion is very infrequent.

If trouble is experienced from corrosion, oxygen should be eliminated from the feed water by proper deaeration with commercial apparatus. The elimination of the oxygen due to air leakage is more difficult because of the multitude of small leaks which exist around valve stems and in pipe joints. In vacuum systems, however, an attempt should be made to minimize such leakage.

Carbon dioxide in varying amounts is contained in steam produced from the majority of water supplies. It is formed from the breaking down of carbonates and bicarbonates which are present in nearly all natural waters. It can be partly removed by chemical treatment and deaeration, but there is no simple method whereby it can be entirely eliminated.

These gases cause corrosion only when in solution in the condensate; when they are mixed with dry steam their corrosive effect is negligible. The amount of gas in solution depends upon the partial pressure of that gas in the atmosphere above the surface of the solution, in accordance with the well known physical law of Henry and Dalton[5]. The correct application of this law, however, requires equilibrium conditions which do not always exist under the flow conditions prevailing in a heating system.

There is a distinction between corrosion in heating systems proper and in the condensate discharge lines from other apparatus using steam at relatively high rates, particularly at the times of the cycle when the steam consumption is at its heaviest. In such equipment the gases tend to accumulate in the steam space and to become dissolved in the condensate in high concentrations, thus greatly increasing the possibilities of corrosion. The condensate will more nearly approach in composition the composition of the steam than will the normal condensate from apparatus such as room radiators, and will, therefore, normally include in solution more contaminants. It is possible that careful venting of such equipment would reduce the amount of contaminants dissolved in the

[4]New Light on Heating System Corrosion, by J. H. Walker (*Heating and Ventilating*, May, 1933). A.S.H.V.E. Research Report No. 983—Corrosion Studies in Steam Heating Systems, by R. R. Seeber, F. A. Rohrman and G. E. Smedberg, (A.S.H.V.E. Transactions, Vol. 40, 1934, p. 253). A.S.H.V.E. Research Report No. 1037—Corrosion Studies in Steam Heating Systems, by R. R. Seeber, F. A. Rohrman and G. E. Smedberg, (A.S.H.V.E. Transactions, Vol. 42, 1936, p. 263). A.S.H.V.E. Research Report No. 1071—Corrosion Studies in Steam Heating Systems, by R. R. Seeber and Margaret R. Holley (A.S.H.V.E. Transactions, Vol. 43, 1937, p. 461). Corrosion in Steam Heating Systems, by L. F. Collins and E. L. Henderson. (*Heating, Piping and Air Conditioning*, September, 1939 to May, 1940).

[5]Some Fundamental Considerations of Corrosion in Steam and Condensate Lines, by R. E. Hall and A. R. Mumford (A.S.H.V.E. Transactions, Vol. 38, 1932, p. 121).

condensate, thus giving less corrosion. There is evidence that the partial pressures of the gases and the possibility of corrosion are much lower in heating systems than in high usage equipment. Hence, corrosion observed in the condensate discharge lines from high usage equipment does not necessarily indicate that equally serious corrosion is taking place in the heating system.

The seriousness of corrosive conditions is best determined by actual measurement rather than by inference from isolated instances of pipe failures. The *National District Heating Association* has perfected a corrosion tester for measuring the inherent corrosiveness of existing conditions. This corrosion tester consists of a frame supporting three coils of wire which are carefully weighed. After the tester has been inserted in the pipe line for a definite length of time, the loss of weight of the coils, referred to an established scale, indicates the relative corrosivensss of the condensate. Accompanying such corrosion measurements, a careful chemical analysis should be made of the condensate, and the findings will serve as a basis for an intelligent study of the problem[6].

There are some indications that after a condensate containing carbon dioxide has dissolved some iron and thereby raised its *pH* value, its corrosive action is greatly reduced and the solution will remain comparatively inactive until admission of oxygen permits the precipitation of the dissolved iron as ferric oxide. The *pH* value of the condensate may be buffered to a fairly high value by the solution of iron and not correspond to the *pH* value to be expected in the unbuffered solution containing the same amount of carbon dioxide.

Although inhibitors of various types have had considerable trial and experimentation and successes have been reported, they require further study. Among these inhibitors are oil, sodium silicate, sodium hydroxide, tannin, and various other organic compounds, some of which release ammonia gas. The possible toxic effects, particularly if the steam is used for contact cooking of food, should not be overlooked.

In view of the fact that corrosion is most frequently found in the return lines from special equipment, which constitute a relatively small part of the total piping in a building, a simple solution of the corrosion problem may be to use non-corroding materials in those certain portions of the piping system, since the higher cost will usually be an unappreciable portion of the total. Brass and copper are undoubtedly less subject to this type of corrosion than the ferrous metals, and considerable attention is now being given to corrosion-resistant linings for ferrous pipe. Cast-iron pipe, sometimes alloyed with other metals, also deserves consideration.

Eighteen ferrous and non-ferrous metals and alloys were recently tested in a large air conditioning installation[7]. Observations were made in the wash water of the dehumidifier and in the air stream beyond the eliminator plates. The corrosion rates of all metals and alloys utilizing a dichromated-treated wash water were extremely low. Localized attack in the form of pitting was found to occur on steel in crevices or under solid accumulations. Just beyond the dehumidifier eliminator plates corrosive conditions were observed to be particularly severe and in such locations non-ferrous metals and alloys and stainless steels were most resistant. Alloy steels were found to be superior to mild steel.

[6]A Method of Measuring Corrosiveness, by J. H. Walker, *Proceedings, American Society for Testing Materials*, 1940.

[7]A.S.H.V.E. Research Paper—Corrosion Tests in a Water-Recirculating Air Conditioning System, by W. Z. Friend (A.S.H.V.E. Transactions, Vol. 48, 1942, p. 233).