

carbon dioxide. In rare instances, hydrogen sulphide, sulphur dioxide, or ammonia are present.

In most steam condensing equipment^{7, 8}, the non-condensable gases entrained with steam accumulate so that the amount present in the vapor space is several hundred times higher than in the incoming steam and, the amount dissolved in the condensate may therefore approach, or even exceed for short periods, the amount entrained by the steam.

CAUSES AND PREVENTION OF SCALES AND SLUDGES

Scales may be formed on surfaces of equipment in contact with water, and sludges in the body of the water, by the separation from the water of dissolved or suspended solids. According to the nature of a particular piece of equipment and the method of its operation such separation may be promoted by one or more than one, of several factors:

- The concentration of solids may be increased by the evaporation of water.
- The dissolved solids may be rendered less soluble in the water by changes in temperature.
- Conditions may favor the decomposition of unstable compounds with the formation of less soluble compounds.

TABLE 5. DATA TYPIFYING THE DELETERIOUS GAS CONTENT OF DIFFERENT ATMOSPHERES.

Name of Gas	Chemical Formula	Air				FLUE GASES					
		RURAL		METROPOLITAN		BITUM. COAL		FUEL OILS		NATURAL GAS	
		% by Volume	Partial Pressure psia	% by Volume	Partial Pressure psia	% by Volume	Partial Pressure psia	% by Volume	Partial Pressure psia	% by Volume	Partial Pressure psia
Oxygen.....	O ₂	21	3.143	21	3.143	2	0.299	7	1.048	10	1.497
Carbon Dioxide	CO ₂	0.03	0.004	0.06	0.009	15	2.245	13	1.946	10	1.497
Sulphur Dioxide	SO ₂	None	None	0.003	0.004	0.07	0.010	0.03	0.004	0.0001	0.0015

Figs. 2 and 3 show that the solubilities of both calcium carbonate and calcium sulphate decrease with the rising temperature within a moderate range of temperatures. Surfaces transferring heat into water, such as condensers and coolers, are more susceptible to scale and sludge formation than are the cold parts of the same system using the same water.

The most common of the unstable soluble salts are the bicarbonates of calcium, magnesium, and occasionally iron. Under conditions favoring the removal of carbon dioxide, as when the water is strongly aerated or when it is boiled, the bicarbonates are readily converted to the relatively insoluble carbonates (or, in the case of iron in the presence of oxygen, ferric hydroxide or oxide may be formed). Conversely, carbonates are readily converted to the more soluble bicarbonate by the addition of carbon dioxide or other acidic materials. This explains the increase in the apparent solubility of calcium carbonate at decreasing pH values (increasing concentration of hydrogen ion) shown in Fig. 2, the carbonate really going into solution largely as bicarbonate.

It is sometimes desired to evaluate the tendency in a particular water toward the separation of calcium carbonate, which may be desirable as a means of establishing a corrosion-resistant film on metal surfaces, or in

other circumstances may be undesirable because of the impedance of the calcium carbonate film to heat transfer. This tendency is indicated approximately by the Langelier Index⁹, which is obtained by subtracting the actual pH of a particular water from the pH at which it is estimated precipitation of calcium carbonate would just begin. This estimate may be made by the use of Fig. 4.

There are various expedients which may be employed for avoiding or mitigating difficulties due to scales:

- The water may be treated before use to remove elements such as calcium, magnesium, and iron, which form relatively insoluble compounds. In the various softening processes this removal of these elements is accompanied by the addition of other elements, particularly sodium, the compounds of which are relatively soluble.

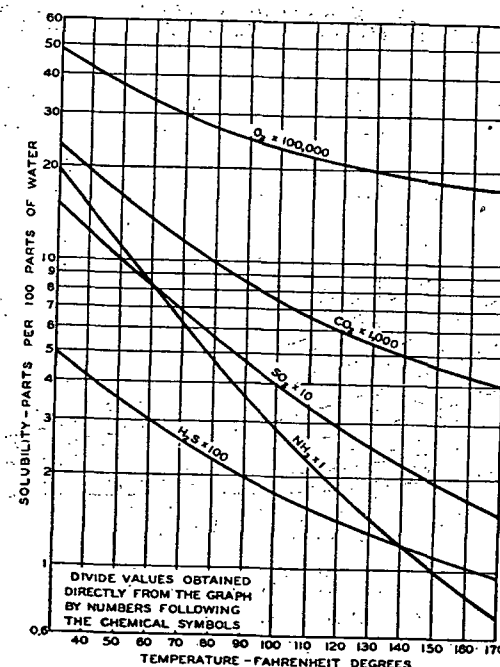


FIG. 1. SOLUBILITY OF GASES AT PARTIAL PRESSURE OF 1 PSI

- The water may be treated within the equipment to promote the separation of dissolved solids as sludges, rather than as scale which is in most cases more objectionable.
- The increase in total solids due to the evaporation of water may be controlled by the displacement, continuously or intermittently, of some of the used water by fresh supply.
- Substances, such as the polyphosphates, having the property of inhibiting the precipitation of calcium carbonate from solutions supersaturated with it, may be added.
- The pH of the water may be lowered (hydrogen ion concentration raised) to reduce the tendency for precipitation of carbonate. This is permissible only to such an extent as will not cause a serious increase in rate of corrosion.

The choice of the best expedient must be made for each type of equipment and will be affected by local considerations.