be protective. Calcium carbonate scale in hard waters represents such an example. Or, temperature may affect the nature of the corrosion product, which may be relatively stable and protective in certain temperature ranges, and unstable and nonprotective in other temperature ranges. Zinc in distilled water represents such a case, the corrosion product being nonprotective in the range of about 140 to 190 F, but reasonably protective at other temperatures. Thus, the effect of temperature on a particular system is difficult to predict without specific knowledge of the characteristics of the metals involved and the constituents of the media.

Pressure

As is the case with temperature, it is difficult to predict the *effects of pressure on corrosion. Where dissolved gases* such as oxygen and carbon dioxide may affect corrosion rate, pressure on the system may increase their solubility and thus increase corrosion. Similarly a vacuum on the system will reduce dissolved gas solubility and thus reduce corrosion.

In a heated system pressure may raise the boiling point of the media, and thereby affect corrosion rate through the effects of temperature.

It is seldom possible or practical to control corrosion of a metallic system simply by means of pressure control.

Velocity

The effects of velocity of flow of the media in a system will depend upon the characteristics of the particular metal or *alloy. In media where* oxygen increases corrosion rate, for example iron or steel in water, velocity of flow can increase corrosion rate by making more oxygen available to the metal surface for reaction. Under the same circumstances, alloys dependent upon thin oxide films for corrosion resistance may have such films enhanced due to velocity, and remain quite resistant up to very high velocities. Such is frequently the case with stainless steels.

For metal systems in which corrosion products retard corrosion by acting as a physical barrier, velocity of media flow may sweep away these products and, therefore, permit corrosion to proceed at its initial rate. In specific media, and for a specific metal, there may be a critical velocity below which the corrosion product film is adherent and protective.

Turbulent media flow may cause uneven attack, involving localized erosion as well as corrosion. Such attack is referred to as *erosion-corrosion*, and may occur in piping systems at sharp bends if the designed flow velocity is rather high.

Very high velocity may lead to localized cavitation, a damage mechanism involving bubble formation and collapse which literally *tears out* particles of metal. Such attack may occur in pump impellers and mixer propeller blades.

For more information on the effects of velocity, refer to Copson.[10]

PREVENTIVE AND PROTECTIVE MEASURES

Materials Selection

In theory, it is possible to construct almost any piece of equipment for a heating or air-conditioning system with materials which will not corrode to any significant degree under service conditions. However, this is rarely possible because of economic and physical limitations. For example, silver is a corrosion-resistant metal with excellent heat transfer properties, but it is much too expensive for common use in condenser tubes. Many plastics resist the chemical action of flue gases but they are not used for fireside service because they melt or burn at flue gas temperatures.

When selecting materials for the construction of a given piece of equipment, it is necessary to consider the corrosion resistance of each proposed metal or other material to the service environment, the nature of the corrosion products which may be formed, and their effects upon the functioning of the equipment, the suitability of the materials to handling by standard fabrication methods, and the effects of design and *fabrication limitations upon tendencies toward local* corrosion (as discussed in the preceding section). The overall economic balance during the projected life of the equipment should also be considered. For example, it may be less expensive in the long run to pay more for a corrosion resistant material and avoid the need for regular painting or other corrosion control measures, than to use a less expensive material and be required to *carry out a regular corrosion control* maintenance program throughout the life of the equipment.

Other considerations include selection of materials used during fabrication and the methods of fabrication to be employed. Acid fluxes, for example, if not properly removed from a piece of equipment, can aggravate localized corrosion after the product goes into service.

Both metallic and nonmetallic materials of construction are utilized in heating, refrigerating, and air-conditioning equipment. Ferrous metals are widely used and include cast iron and cast steel, wrought iron, mild steel, and many alloy steels, including the so-called stainless steels. The less corrosion resistant forms of ferrous metals may be protected in many ways including galvanizing and other forms of zinc coating, cadmium plating or other types of plating, painting, and plastic dip-coating.

Copper and a variety of copper-base alloys, including brasses, bronzes, and cupronickel, are widely used for condenser tubing and other applications requiring greater corrosion resistance. Aluminum and its alloys are also used under suitable environmental conditions.

Nonmetallic materials of construction include wood and concrete (frequently used for cooling tower construction), rubber, plastics, fiberglass, and fabrics. A variety of protective coatings are also in use.

Materials of construction (metallic or nonmetallic) frequently used for components of air-conditioning and refrigeration equipment are summarized in Table 2.[11]

Protective Coatings

Surface Preparation. One of the most important factors in corrosion control is the condition of the substrate prior to coating. For this reason, surface preparation should be considered with great care.

The environment in which the system components will eventually operate, will largely determine the type of coating needed. Each coating has a particular tolerance for surface contamination which will determine the degree of surface preparation necessary. Coatings which require the removal of all contaminants are not necessary in some environmental conditions.

The presence of rust and mill scale often presents a problem in surface preparation. Mill scale is a source of trouble because it does not have the same coefficient of expansion as the steel and, as a result, it may become cracked and loosened during fabrication and shipping or during expansion and contraction of the metal. As a result, moisture and contaminants may gain access to exposed areas and cause corrosion.

Surface preparation is generally divided into two types, mechanical and chemical.

Mechanical cleaning methods are generally described as follows, and are more effective in descending order of listing.

Table 2 .... Composite Reference of Suitable Materials for Equipment Components[a,b]

Equipment	Casings and Supports			Grids, Fill, and Eliminators			Pipes			Ducts			Heat Transfer Surfaces			Valves and Pumps			Fans		
Cooling Towers			G					C	G								C			C	G
	O	P			P			P													P_c
	S	SS	W		SS	W	S									S				SS	
Evaporative Condensers		C	G		C	G		C	G		C	G		C	G		C				G
	O	P	P_c		P			P		O		P_c			P_c						P_c
	S	SS	W		SS		S							SS		S			S		
Cooling Coils (condensation)	A	C	G					C	G				A	C	G		C				
		P	P_c					P							P_c						
	S	SS	W				S	SS						SS		S	SS				
Air Washers	A	C	G			G		C	G		C			C	G		C				G
	O	P	P_c		P			P		O		P_c			P_c						P_c
	S	SS	W		SS		S	SS			SS			SS		S				SS	
Room Air-Conditioners (condensers and evaporators)	A	C	G	A	C	G	A	C	G				A	C	G		C		A	C	G
	O	P	P_c	O	P	P_c		P							P_c		P			P	P_c
	S	SS	W		SS	W		SS						SS		S	SS			SS	
Air-Cooled Condensers	A	C	G	A	C	G	A	C	G	A	C	G	A	C	G	A	C		A	C	G
	O	P	P_c	O	P			P		O		P_c			P_c						P_c
	S	SS	W	S	SS	W	S	SS		S	SS	W	S	SS		S	SS		S	SS	
Heating Coils	A	C	G	A	C	G	A	C	G				A	C	G	A	C				
	O	P*	P_c	O	P*	P_c									P_c						
	S	SS	W	S	SS		S	SS					S	SS		S					
Ducts										A	C	G									
										O											
										S	SS	W									
Fans																			A	C	G
																				P	P_c
																			S	SS	

* Below 150 F.
[a] Based on data from Reference 11.
[b] Metallic or Non-metallic materials used are classified as follows:
A = Aluminum; O = Organic Finishes; S = Steel; C = Copper and Alloys; P = Plastic; SS = Stainless Steel; G = Galvanized Steel; P_c = Plated Coating; W = Wood

1. *Hand cleaning* is one of the oldest and most commonly used methods of cleaning, accomplished by use of a wire brush, scraper, or chipping hammer.

2. *Power tool cleaning* is done with rotary wire brushes, descalers, and rotary scalers.

3. *Flame cleaning* utilizes a torch which is played on the steel to take advantage of the difference in the rate of expansion between the base metal and the mill scale. An advantage of this type of cleaning, in some cases, is that the steel can be painted while it is still warm, thereby eliminating for all practical purposes, the problem of adsorbed moisture.

4. *Blast cleaning* involves abrading surfaces with high velocity impact of abrasive particles.

Chemical Cleaning. Many types of chemical surface preparations are available, and selection depends on the type and degree of contamination. A brief description of each follows.

1. *Solvent wiping and vapor degreasing* is the least effective of all types of chemical surface preparation, but it is still one of the most widely used. In solvent wiping, the surface is wiped with a suitable solvent such as naphtha or toluol.

In vapor degreasing, the item to be cleaned is exposed to the solvent in its vapor phase. The solvent condenses on the metal surface and washes off the contaminant. This method is more satisfactory than wiping, because it can clean irregular surfaces better, and solvent contamination is not a factor. Solvent wiping