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Corrosion of Building Assets – Problems and Prevention

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Summary
Corrosion of building services is sometimes attributed to cost-cutting by the building owner, the constructor, or the building services designer. Lack of proper maintenance is another contributing factor to building corrosion problems. Inadequate weather tightness of the cladding on a building that results in the ingress of water into a building envelope can also contribute to corrosion of building assets. In recent years higher incidences of corrosion in building water piping systems have occurred. Water pipework corrosion experienced in institutional buildings can sometimes be attributed to lower water quality contained in the supply pipework. Lack of a proper water management protocol and incorrect water piping commissioning practices in new buildings have resulted in initiation of microbiological influenced corrosion (MIC) in water supply lines.

Another issue that needs to be addressed is the practice of building service engineers to specify dissimilar metal contacts in heating, ventilation and air conditioning systems (HVAC) water systems. The performance of some HVAC equipment can be compromised from new by the use of dissimilar metal contacts that increase the risk of galvanic corrosion in the plant. Many building owners are unaware that appropriate corrosion prevention measures, such as using more stainless steel, are more cost-effective than replacing building service equipment that has failed due to corrosion. Case studies are presented on corrosion of building assets including HVAC equipment, water piping and building claddings. An outline is given of good industry practices to avoid known types of corrosion encountered in building services.

1. Introduction

Corrosion of plant and equipment that comprises building services is not unlike an asset assassin because the result of serious corrosion in buildings can be devastating for owners. Corrosion of any key building asset including heating, ventilation and air conditioning equipment (HVAC), presents the most potentially damaging loss to a building next to the threat of fire. Insurance claims and litigation that can ensue from corrosion of building assets can ramp up the cost of a corrosion failure for the owner. Corrosion-damaged air conditioning coils and heating plant cannot process air and heat efficiently as intended by the building designers. This introduces operational issues including increased power usage and increased maintenance costs as the building services have to work harder. Factors such as these can also result in problems for building occupants such as lower comfort levels which affect productivity at work.

The effect of corrosion of building services in buildings is to greatly increase costs with possible loss of commercial income for the building owners. Some owners are prepared to ignore the risk that a *corrosion tax* would apply to their building assets if corrosion occurs. Failure to consider the potential for corrosion during the design of building services will eventually increase costs, introduce safety hazards and may also have an environmental impact. It is surprising to note the low priority given by some building owners, architects, designers, constructors and maintenance engineers to corrosion prevention on assets such as HVAC plant, water piping systems and building claddings. The situation can sometimes be accounted for by lack of awareness of the damaging effects that corrosion can have on critical building plant and the serious consequences of an asset failure.

The corrosion of building services and other equipment within a building envelope can have far reaching consequences [1]. Corrosion damage to building services impinges upon the following areas of the building structure:

- The structural soundness of the building and building service equipment may be severely affected.
- If a metal component is embedded in another building material, corrosion products can expand and cause distortion or cracking of the other material with serious consequences.
- Failure of the material due to corrosion may lead to entry of water into the building envelope causing hidden corrosion of structural elements.
- Unsightly corroded surfaces may be produced with visible weeping of red rust, which downgrades the building aesthetics.
- Manufacturing defects or design deficiencies may produce localised corrosion such as crevice corrosion, which may lead to corrosion-induced cracking of structural building elements.

The pre-eminent global organisation for building services design is the *American Society of Heating, Refrigerating and Air Conditioning Engineers* (ASHRAE), founded in the USA in 1894. This organisation publishes the ASHRAE Handbook [2], an internationally recognised resource for HVAC and refrigeration engineering. ASHRAE is a global leader in the production of Codes and Standards for building services design. The standards are often referenced in building codes used by architects and engineers in many regions, including Australasia. However, it is unfortunate that the ASHRAE Handbook devotes little space to addressing potential corrosion issues that can occur in poor building services design.

In order to avoid building services corrosion problems the ASHRAE handbook generally specifies the use of appropriate materials selection (standard engineering materials) and using water treatment with corrosion inhibitors in building water systems. However, this approach ignores the likelihood that if a water treatment program is poorly managed or neglected then corrosion is often inevitable. A corrosion problem may be inadvertently *designed* into the building system and avoidance relies totally upon proper maintenance to ensure good corrosion control is operational. There are many building water piping designs that include the connection of dissimilar metals which introduces galvanic corrosion issues. Astute building system designers are aware of the potential for galvanic corrosion and they recognise the threats that inadequate corrosion control may impose on the building services. Nevertheless, circumstances still arise that contribute to unexpected building asset corrosion problems.

Many publications outline corrosion problems that are encountered in buildings and which inflict damage on building services [3-9]. Some case studies have been chosen to illustrate building services corrosion problems. A number of the corrosion failures outlined are due to poor design - these are often *corrosion blunders*. Some corrosion failures are due to poor plant maintenance and others are associated with the ingress of water into a building envelope.

2. Case studies on Corrosion of Building Assets

2.1 Hot Water Heating Plant Corrosion

A hospital for the elderly had installed an underfloor heating system to provide low pressure hot water to heat wall radiator panels in the residents' rooms. After several years in service, corrosion occurred in the radiators that resulted in leaks developing in the wall-mounted radiator panels *(Figure 1)*. A dismantled aluminium alloy radiator showed an extensive build-up of corrosion products inside the panel heater *(Figure 2)*. The hot water system comprised an interconnected underfloor network of copper tubing, steel fittings, copper alloy fittings, and polyethylene plastic pipework (PEX). The water supply was chemically treated with a corrosion inhibitor but the hospital water treatment had unfortunately been neglected after commissioning.

The presence of copper tubing and copper alloy fittings in the hot water heating system gave rise to mobile copper (ions) in the hot water tubes that initiated galvanic corrosion on bare aluminium alloy and carbon steel studs inside the radiator panels. The panel heater design that involved contact between aluminium alloy bodies and steel studs in the hot water had exacerbated the galvanic corrosion process.

The underfloor heating system was vulnerable to internal corrosion because the water supply corrosion inhibitor treatment program had been neglected. After chemical clean of the tubing was carried out an appropriate water treatment regime was reinstated to prevent further internal corrosion of the hot water system and the radiators. Wherever practicable, it is best to avoid incompatible bimetallic couples in heating plant employing water as the heat transfer medium [4,9]. If this basic corrosion control requirement cannot be achieved and dissimilar metals are incorporated into a heating water system in an institutional building then water treatment with corrosion inhibitors must be employed and the treatment program must be routinely monitored for efficiency.

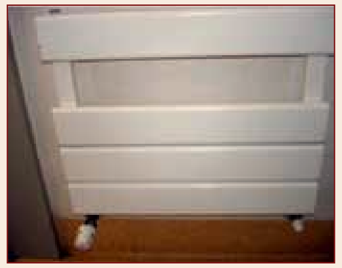

Figure 1. Hot water panel heater leaked due to a design comprising aluminium panels joined internally with steel studs.

Figure 2. Corrosion product inside aluminium heater panel. Corrosion is due to galvanic corrosion.

2.2 Accelerated Corrosion of Copper Piping in a High Rise Building

Accelerated corrosion of 100mm copper plumbing piping carrying waste water to underground sumps was an ongoing problem in the basement area of a high-rise building. The sumps were constructed of concrete for containment of the wastewater and stormwater. The copper piping carried waste fluids containing waste water, sewage, cleaning chemical residues and stormwater. Leaks due to localised corrosion had developed in the copper piping which required the copper pipes to be frequently repaired by a plumber. However, the copper pipe corrosion continued unabated even after plumbing repairs had been carried out.

The design and construction of the building services piping system for draining waste water into the sumps had contributed to *erosion-corrosion* damage inside the copper piping. Additional problems included copper pipe encapsulated into concrete, dissimilar metal contact between copper pipe and steel valves (Figures 3,4), bifurcated joints showing erosion-corrosion due to turbulent flow, and poorly brazed copper elbows. The repair of leaking copper pipes by brazing had produced a harmful microstructure in localised areas of the copper piping which contributed to localised internal corrosion on the copper piping.

The failures of the copper drainage pipework could not be avoided because the aggressive fluid inside the copper drainage pipes was not able to be changed. Total replacement of the copper piping was necessary using a corrosion-resistant polymer (ABS). It was important that the corrosive nature of the waste fluids in the drainage lines be taken into account during the design stage of the waste water piping system, but this design aspect had been overlooked.

Figure 3. Corrosion at badly designed valve-pipe joint in water piping of high-rise building.

2.3 Microbiologically Influenced Corrosion (MIC) in Water Supply Piping

Commercial buildings contain different water supply systems that include potable water, hot water, fire water and cooling water. Water systems utilise pipework and other ancillary equipment made of various materials. Often the control of corrosion in water supply piping does not receive the detailed attention that it requires by plumbing designers to ensure that the water supply system will give uninterrupted service for long periods of time.

The water piping network for a large air conditioning (AC) plant for airport buildings providing cooled air into the busy complex was constructed from black steel with no internal corrosion protection. The water source for the buildings was a bore supply delivered through steel pipework and then re-injected back into the aquifer. There was no chemical water treatment provided for the once-through AC cooling water supply at the airport buildings. During winter the AC system was switched off and untreated cooling water lay in the steel pipework which was unfortunately not drained during shutdown. After several year's service the steel pipework leaked and escaping water caused severe damage to retail businesses in the airport building.

Examination showed that the pipework leaks were due to internal pitting corrosion which caused perforations in the black steel piping. The pitting corrosion was determined to be due to MIC on the internal walls of the steel water pipes. Microbiological examination showed that a sulphate-reducing bacteria (SRB) strain had colonised the inside of the steel water pipes. SRB were introduced into the cooling pipework circuit via the ground source water supply which was not treated with a biocide. Hundreds of metres

Figure 4. Severe galvanic corrosion of the steel at valve-copper piping joint.

of corrosion-damaged steel piping was replaced with ABS plastic piping at a very high cost *(Figure 5)*, and legal action ensued. Similar MIC issues have arisen in building fire water piping and in galvanised steel potable water piping in commercial buildings [8-10]. Conventional copper tubing used for potable water supply in plumbing systems within institutional buildings is also known to be susceptible to MIC attack under certain circumstances [11].

Figure 5. Steel piping failed in once-through AC water circuit at airport complex due to MIC.

2.4 HVAC Equipment Exposed to Marine Environments

Commercial buildings are exposed to the atmosphere and the rate of corrosion of any exposed metals depends on the alloy type, exposure to rain, ambient temperature, degree of atmospheric pollution (e.g. *marine aerosol*) and the extent of exposure to a prevailing wind. Some undesirable details in building construction permit rain water ingress into a building envelope and the rain water can initiate corrosion of inadequately protected HVAC plant exposed to the environment.

Figures 6-8 show the result of corrosion damage that occurred in the plant room of a prestige high-rise apartment building located near the sea. The plant room was located on the top level of the 40 storey building under an aluminium-slat dome structure through which rain water, marine aerosol and birds gained easy access. The exposed plant area which included HVAC equipment was not well maintained and the design of some of the plant and pipework ensured that galvanic and general corrosion on some metallic components occurred.

The extensive corrosion damage was predominantly caused by the ingress of *marine aerosol* through the open dome cladding. Deposits of corrosive sea salt and bird guano had contributed to premature corrosion occurring on a variety of plant surfaces. Water escaping from AC chiller units had also caused corrosion on the galvanised steel chiller cladding. Corrosion protection for the various structures was provided by poor paint coatings which in many cases had failed after only ten years in service. Galvanised steel components performed better, but some galvanised steel fixings had undergone severe surface corrosion. Copper piping faired well. However, due to dissimilar metals contact at steel flanges, galvanic corrosion had occurred on the steel *(Figure 7)*. Dissimilar metal corrosion also occurred on steel pipes where stainless steel fittings had been welded to the carbon steel pipework. Little maintenance had been carried out to mitigate the corrosive effects of the marine aerosol on the plant materials located inside the building plant room.

The corrosion damage due to windborne sea salt on bare copper fin-fan coils of a large AC condenser unit exposed to the atmosphere 56 levels up on a tower structure located in a marine environment is illustrated in *Figure 9*. The copper fins had undergone surface corrosion damage to an extent that the copper fins had become useless for heat transfer. The copper fins on the coils had not been given adequate protective coating during manufacture. A high quality protective coating on the copper fins is essential to mitigate the effect of a severely corrosive environment.

Figure 6. Steel coils for vibration damping of chiller in plant room of high-rise building. Corrosion due to ingress of marine aerosol into building

Figure 7. Corrosion due to dissimilar metals: copper pipe-steel flange-SS valve in water system.

2.5 Thermogalvanic Corrosion on an AC Condenser Coil

Corrosion occurred on several condenser units of air conditioning (AC) plant at the premises of a manufacturing company. Corrosion developed on the surfaces of copper tubes on a condenser coil at the end plate which resulted in perforation of the copper tubes and loss of refrigerant gas from the AC unit resulting in plant failure *(Figure 9)*.

Immediately adjacent to the AC plant room was an 11 KV electrical cable protruding through the wall and a question arose regarding the possibility that induced DC current in the affected condenser unit had introduced *stray current corrosion*. A stray current survey in the plant room showed there was no evidence that stray current corrosion had contributed to the corrosion on the copper tubes and end plates of the AC condenser.

There was some galvanic corrosion occurring on the condenser end plates due to dissimilar metal contact between the copper tubes and galvanised steel in the bulkhead environment. The dissimilar metal corrosion was exacerbated by the presence of moisture and grime in the vicinity. The lack of adequate corrosion protection, namely a good organic coating on the end plate metal components, exacerbated the rate of the corrosion. There was also turbulent air flow occurring in the condenser area which contributed to the presence of *wet* and *dry* areas adjacent to each other on the end plate. Where *wetness* was present on the copper and galvanised steel components at the condenser end plate corrosion on the copper coils and on the galvanised steel was higher.

The probable cause of the corrosion on the copper condenser coils was *thermogalvanic corrosion*. It is not possible to design AC condenser coils with completely isothermal surfaces. Condensers can have temperature differentials along the same metal surface in the presence of an electrolyte. Temperature differences give rise to electrode potential differences that generate small DC current on metal components and corrosion occurs in the *hotter* zone. Depending upon the environment localised corrosion on metals may accelerate or decelerate. The driving force for *thermogalvanic corrosion* is small and if the resistance of an electrolyte is low the corrosion is confined to small areas causing pitting corrosion at the edge of the hotter zone. Thermogalvanic corrosion is usually a dormant condition that can accelerate localised corrosion on a passive metal such as copper if the environment alters.

Figure 8. Failure of paint coatings on steel piping and fittings in building services plant room.

Figure 9. Corrosion of copper air-cooled fin-fan units of large condenser units on high-rise tower situated in a severe marine environment.

2.6 Corrosion in Heat Pumps and Air Conditioning Units
Over the past decade the installation of heat pumps and small air conditioners in residential and commercial buildings has increased rapidly around the world. A modern inverter heat pump provides air conditioning in summer and heating in winter. A heat pump works by extracting heat from the air outside a house and bringing it indoors and therefore is it is like a refrigerator in reverse. By cooling a room it extracts heat and releases the heat externally. Thus heat pumps are heat exchangers and the source of the heat can even include a geothermal hot water supply.

Water that forms from air passing over a cold condenser surface inside a heat pump cabinet must be drained to an external sump. However, if the water does not drain freely and moisture condenses on the bottom of the heat pump cabinet, hidden internal corrosion of the casing can ensue and failure of the heat pump may result *(Figure 10)*.

Internal corrosion of heat pumps and air conditioners can occur when a building fitted with the appliance is located near the coast or in geothermal area, for example Rotorua in New Zealand. The corrosive environment created by water ponding on the cabinet bottom is worse if pollutants such as sea salt or geothermal hydrogen sulphide (H_2S) are carried inside the heat pump by the air intake. Failures of heat pumps due to corrosion have been recorded in these locations after only five years in service. The heat pump manufacturers often will not accept liability for the appliance failures resulting from internal corrosion.

Manufacturers, installers and owners need to be more aware that heat pump are usually contained in steel cabinets with a basic coating (paint or powder coating) for corrosion protection. The internal steel surface of a the cabinet is often susceptible to surface corrosion. The corrosion problem can occur inside small units installed externally on walls and roofs of buildings located in corrosive enviroments. Heat pumps used to heat swimming pools employing salt water chlorinators may also be susceptible to internal corrosion damage.

2.7 Claddings, Water Ingress and Building Corrosion
The purpose of a building cladding is to ensure that a building looks attractive and to ensure that the building envelope is watertight. It is possible that poor construction detail and the use of some materials for claddings may permit rain water to enter the building envelope. If the cladding is not watertight it is likely that hidden metal fixings within wall cavities will corrode and possibly even fail. Water can be retained in crevices on metal surfaces or between a metal and some other material, resulting in unseen corrosion damage. Water may also drip onto a metallic surface carrying dissolved contaminants such as alkalies or salts which are corrosive to metallic fixings in the building walls. Thus, the integrity of a building cladding is critical to the durability of the materials used in construction of the building.

Figure 12 shows the condition of a proprietary coated steel cladding material on a building after only 15 years in service. The external corrosion is due to poor cladding design resulting in crevice corrosion and ingress of rain water. The steel cladding panels had undergone crevice corrosion in areas where rain water containing aggressive marine salts had been trapped in joint locations causing serious degradation of the cladding. The corrosion damage observed was superficial in some areas but extensive in others, including locations where cladding perforations had occurred. The entire building had to be reclad after 15 years. Similar cladding failures have been reported involving corrosion of proprietary aluminium composite panel claddings on high-rise buildings that suffered leakages. In most cases the cause of water ingress into the internal wall cavities was poor cladding detail and poor installation of the cladding material on the building façade.

Figure 10. Thermogalvanic corrosion on copper tubes at end plate of condenser unit. Galvanic corrosion on galvanised steel.

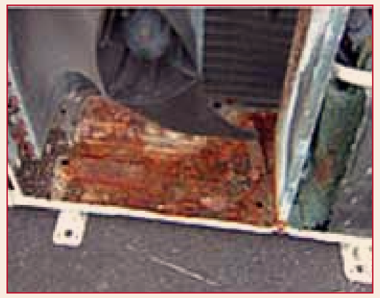

Figure 11. Corrosion inside poorly protected steel cabinet of a heat pump. Condensed water inside cabinet supports corrosion.

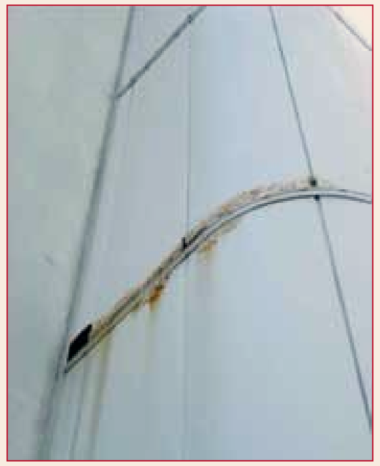

Figure 12. Failure of proprietary cladding showing corrosion distress at seams resulting in water leakage.

3. Discussion
It is well known that corrosion control begins during the design stage of a building project. Good corrosion control requires the awareness and co-operation of an entire design team, including the engineers and designers not only in each discipline but in overall project management. A very important part of the project is the post-fabrication cleaning and maintenance of the building, including the HVAC plant and water piping. Adequate means must be planned and implemented for collecting, reporting and recording any corrosion information that arises from operational situations once the building project is completed.

Although dissimilar metals are used in heating and air conditioning systems it does not necessarily mean that a galvanic corrosion failure will occur. Sometimes dielectric isolators are used to avoid galvanic corrosion issues but installation of these fittings can be troublesome. Engineers and owners should recognise that using dielectric isolators is not a substitute for employing proper water chemistry control and that well-managed water treatment can eliminate the need for diectric isolator fittings, as well as ensuring a long service life for HVAC piping.

In recent years *microbiologically influenced corrosion* (MIC) has emerged as a cause of corrosion issues in water piping resulting in failures of pipework in building water systems. In the past decade there have been many cases of MIC in water supply piping reported, some of which have resulted in serious consequences for building owners. The upsurge of MIC problems in building water systems has been thoroughly investigated [11] and some studies indicate that the increase of microbial corrosion problems in building piping is associated with plumbing design and commissioning practices for water systems. Another likely factor is deterioration in the quality of water used in some buildings.

During plumbing system commissioning in a new building, pipework pressure testing using the local water supply is carried out. Afterwards supply water sometimes remains stagnant in the piping for several months. During this time it is possible for *biofilms* to develop inside the water piping, be it steel, copper or stainless steel. After some years, bacteria strains that support corrosion of metals (e.g. sulphate-reducing bacteria) may initiate MIC that results in localised corrosion attack inside the metal piping. Multiple random water leaks in piping may ensue which can cause serious damage inside the building envelope.

In order to mitigate corrosion in building services the following industry practices are recommended:

- Externally located AC condenser units with copper or aluminium fins should be washed frequently with fresh water to ensure that deposited salts and grime are removed from metal surfaces which are susceptible to atmospheric corrosion.
- If metal surfaces are not well protected with good paint coatings then additional protection against corrosion should be applied to metal surfaces; for example, corrosion prevention compounds (CPC) can be used.
- Corrosion occurs preferentially at *hot spots* in heating plant and in heat exchangers. As much as it is possible there should be few *hot spots* on the end-plates of the AC condenser units in order to avoid thermogalvanic corrosion.
- Consideration should be given to coating fin-fan condensers with a good quality coating to insulate any dissimilar metal contacts, particularly if a damp environment prevails. A good coating requirement also applies to the internal cabinet surfaces of heat pumps and air conditioners.
- A detailed understanding of water treatment requirements in a building, based upon the water make-up quality, equipment design, construction materials, and operational practices, is essential to ensure building service plant reliability.
- Effective water treatment servicing and monitoring programs designed to minimise corrosion, deposition, and microbial problems can have a positive impact on system performance, which is critical for cost-effective operation of HVAC plant.

In recent years there has been a trend for building design engineers to employ stainless steels in HVAC applications. Stainless steel has sometimes been chosen in applications where it is known that corrosion would occur in a water system, such as once-through piping in water cooling circuits of AC systems [12,13]. *Life cycle costing* of engineering materials demonstrates that in some water piping applications the use of stainless steel provides a much longer life, compared to traditional engineering materials such as steel or galvanised steel used in conjunction with water treatment. The high cost of the water treatment involved and the ongoing maintenance costs if a water cooling system suffers internal corrosion are often outweighed by the higher capital cost of employing stainless steel from the start of an HVAC project.

HVAC systems where stainless steels such as types 304 and 316 have an established track record in building services include the following applications:

- Fume capture hoods, dampers and exhaust duct work
- Flexible corrugated gas and water piping
- Heat exchangers and dehumidifiers
- Components of pumps and valves

- Cladding for hot water pipework
- Dust collection systems, screens, and filters
- Pressure piping, flanges and bolting
- Components of boilers and water heating systems
- Cooling water pipework for air conditioning systems

The use of stainless steels in the HVAC industries has been steadily increasing and more usage is likely to continue in future. Stainless steels also have many good mechanical properties that are of importance to building service engineers.

In coastal regions or areas where there are aggressive pollutants (e.g. geothermal fields) the buildup of corrosive contaminants can cause perforation failures inside ventilation ducting. This problem is also a concern for indoor heated swimming pool operators and in laboratories. Condensation occurring inside the ducting is a factor in these environments and stainless steel ducting is often selected in order to avoid *dew point corrosion*. Corrosion of ventilation ducting allows poor quality air into ducting which can result in air contamination. Recently there have been concerns about destroying bacteria, dust mites, and moulds present in ventilation systems. In applications where maintenance engineers need to sanitise ventilation system to eliminate the presence of harmful microbes grade 316 SS ducting has been employed. This is because of the corrosion resistance that 316 stainless steel shows against aggressive biocides employed to sanitise ducting systems. High temperature steam cleaning and chemical cleaning can cause internal corrosion in conventional ducting.

In prestige buildings the owners expect that HVAC systems will last as long as the building without need for significant repair or replacement. Examples are government buildings, university buildings, museums and archives. Some organic materials and paint coatings can *outgas*. This is an issue in museums and archives and architects are concerned with air quality and eliminating chemical compounds that outgas into air handling systems. Outgassing can create air flows that may initiate corrosion inside the ventilation ducting. The correct grade of stainless steel is resistant to air handling environments that are employed in these situations. Because stainless steel piping and fittings that are employed are hidden within the building services envelope, HVAC plant using stainless steel plays an important role in maintaining the building integrity and ensuring that water and HVAC systems work efficiently behind the scenes.

4. Conclusions

4.1 Many aspects of corrosion control in the design of building services and plumbing systems are well documented and available to architects, designers and engineers through Codes and Standards. However, some aspects of corrosion protection in the codes are outdated and depend entirely upon application of coatings, and the water treatment for piping being well managed - this does not always happen.

4.2 Failures of plumbing system pipework and HVAC equipment in buildings still occurs. A considerable number of failures reported are due to galvanic corrosion resulting from specification of dissimilar metals connections in water piping systems.

4.3 An increase in failures of water systems due to microbial corrosion may be attributed to the use of poorer quality water in buildings and to inadequate piping system commissioning practices.

4.4 Ingress of a corrosive marine aerosol into HVAC plant areas has increased and this problem is often due to poorly protected building services being openly exposed to corrosive atmospheres.

4.5 Corrosion in heat pumps and air conditioning units for small buildings is an ongoing problem. The corrosion issues encountered are mostly due to inadequate corrosion protection of appliance materials during manufacture. Owners are usually unaware that routine maintenance is necessary to provide a trouble-free life for air handling units installed at locations near the coast and in geothermal areas.

4.6 Stainless steel usage in plumbing systems, HVAC plant and ducting has increased because designers are becoming more aware of corrosion problems occurring in building services. However, stainless steel equipment used in building services must be well fabricated from the correct grade of stainless steel in order to provide a long service life with low maintenance.

4.7 Leakage of rain water into buildings due to external cladding failures has resulted in a number of corrosion issues on hidden metal fixings in wall cavities. Locations with high rainfall are more prone to this corrosion problem in building envelopes.

4.8 Awareness of potential for corrosion issues in the building service industry is slowly improving. However, building service engineers should update their understanding of corrosion control techniques to ensure that corrosion is avoided by good design and proper maintenance.

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