PAPER 6

Recognising the risks from increasing use of electronics *in the field of municipal water and wastewater engineering*

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ABSTRACT

Water and wastewater projects increasingly utilise electronics to control a growing multitude of functions, whether the aim is to optimise processes, or to provide additional safety features for the protection of personnel and environment, or to improve the life span of plant and equipment. Electronics have become prevalent in all but the simplest of processes.

Traditionally, water projects required mainly civil engineering skills and competencies in water or wastewater process design, civil and structural know-how, some knowledge of mechanical and electrical engineering and project management skills.

Electronic engineering – also referred to as Control & Instrumentation or 'ECI' (Electrical and Control & Instrumentation) – brings many new opportunities but also less obvious challenges to traditional water and wastewater infrastructure projects. Risks can go undetected when working on sites with severe space limitations, younger designers that have not yet been involved with HAZOP studies and the like, understanding the interrelationships between all other disciplines but especially electrical and electronic engineering, poor scope definition, late design changes, reduced budgets for capex and opex and dispersed design teams.

In addition there are newer challenges that include increasing cost of electricity and the need for smart systems, 3D modelling, drone based survey and terrestrial laser scanning for generating 3D models, ICT systems and support, and increasingly complex Regulations.

The list of new skills required is accelerating at a rapid pace, and the risk of making fundamental errors, potentially "Classic Failures", is increasing if clients and designers become captured by the features and benefits of electonic wizardry, but lose sight of the potential pitfalls.

Some risks may be 'old hat' to experienced civil engineers but, where less experienced design teams are not led by suitably experienced practitioners, they could easily cause Classic Failures that can be defined as "*ignorance or disregard of basic engineering principles, or the disbelief that a certain event can occur despite what physics and mathematics predicts can and will happen*".

This paper outlines some of the risks that the lead engineer, usually a civil engineer, must be aware of in order to identify the risks that are associated with increasing electronic control and automation, and suggests some approaches on how to reduce or manage the risks.

INTRODUCTION

Most water and wastewater treatment plants and pump stations that are over about 20 years old were controlled by electromechanical plant that used timers, relays and switches for automation of the processes. The wires and connections were such that electricians typically used screwdrivers and spanners to make electrical connections. Corrosion of steel components such as MCC cabinets has always been an issue, but copper was considered an inert material and not needing much attention once it had been installed.

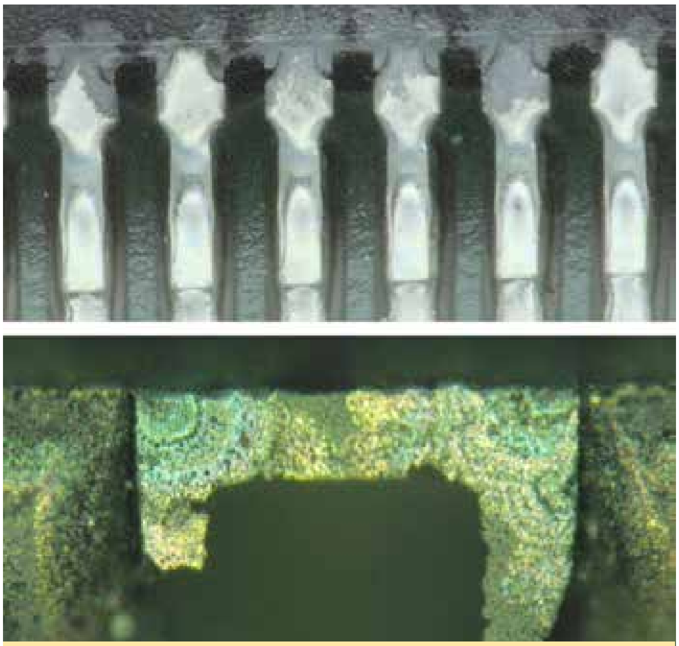

FIGURE 1: Example of a common microclimate: Cracks between plastic remainders and copper pins in combination with a low amount of H_2S and relative humidity > 60% that led to creeping corrosion

Civil engineers who specialise in water and wastewater projects need many skills including process design, hydraulic, structural and geotechnical engineering, as well as a working knowledge of mechanical and electrical engineering. Robust and reliable installations were developed with this set of traditional engineering skills.

However, electronic components in the form of PLCs (programmable logic controllers – essentially computers) gradually replaced the older traditional equipment to control a multitude of processes such as optimisation of water or effluent quality, minimisation of electrical energy, or providing safety features for the protection of personnel, plant and equipment, and environmental concerns. Electronics have become prevalent in all but the simplest of processes.

There is no doubt that electrical and control & instrumentation or 'ECI' provides many new opportunities and positive advantages for water and wastewater infrsastructure. However, ECI has brought with it many less obvious challenges, and the risks are often overlooked.

Risks can go unrecognised when projects are constrained due to insufficient space on sites, or architects' unrealistic demands, or insufficient budget. More experienced engineers take their own experience for granted, and they sometimes assume that their juniors will attend to the detail required to prevent 'obvious' failures. Sadly the downward pressure on designers' fees has made it commonplace to delegate increasingly complex design tasks to younger designers, without sufficient oversight, before they have learned about attention to detail, workplace hazards and operability issues.

This paper focusses on the potential risks that the lead design engineer, usually a civil engineer, must be aware of so that he or she can make conscious and informed decisions when considering the electrical and electronic engineering components on water and wastewater projects.

RISKS THAT ARE SPECIFIC TO ELECTRONICS

The risks that affect electrical and electronic systems include lightning strikes, power outages and surges, incorrectly installed cables in close proximity to MV or HV cables, lack of operator competence, hydrogen sulphide emissions in wastewater systems, and in some instances, commissioning not properly executed and documented.

The exposed parts of electronic connections and junctions operate at low voltages (< 24 volts) and typically carry low currents, commonly 4 to 20 mA. The crosssectional areas of copper wires for electronic components can be very small, where single core wires are as small as 0.32 mm diameter or even smaller. Copper tracks on PC board slots are very thin, typically in the order of 35 µm (35 microns).

Open circuits can occur in a matter of weeks due to the corrosive effect of fugitive gases such as hydrogen sulphide and chlorine on thin copper wires or PC board tracks and contacts, so the effects of copper corrosion can be devastating.

Silver coated wires and components are equally prone to the corrosive effects of hydrogen sulphide, as they can form dendrites that grow like microscopic trees and can cause short circuits between adjacent electrical pathways.

Electronic technicians are needed to repair or replace the failed components. If the operating environment has not been designed or managed properly, the costs for electronic replacement parts, highly skilled labour and operational down-time can affect the entire viability of the infrastructure.

Electrical and electronic installations are subject to many other risks, but none are as subtle nor as deveastating as the effects of gaseous and airborne chemicals.

APPROACHES TO REDUCE RISK

Several levels of protection should always be considered, since it is well-known that failures are seldom due to a single cause. Following is a selection of recommendations that should always be considered in the conceptual and preliminary design stages of water and wastewater infrastructure projects where electrical and electronic control components are to be installed.

Prevent water, sewage or process chemicals making direct contact with components

- Locate the MCC and the PLC enclosures well away from any high-pressure pipework or pumping components where a leak can spray water or chemicals directly onto the MCC or PLC (This risk should be obvious to an experienced designer, yet there are many installations where it is hard to believe that such a fundamental mistake could have been made)
- Free water from the condenser coils of air conditioners must be captured in enclosed drip trays, and provided with adequately sized pipes so that free water can never drip or be blown onto electrical and electronic components.

Prevent harmful gases from getting in contact with the electronic components

- The corrosive effects of gases such as hydrogen sulphide are devastating when they come into contact with copper and silver components in electronic equipment
- This source of damage is not always obvious because the corrosive effects are not generally understood or appreciated; that is, until an installation suffers significant damage and operations are compromised

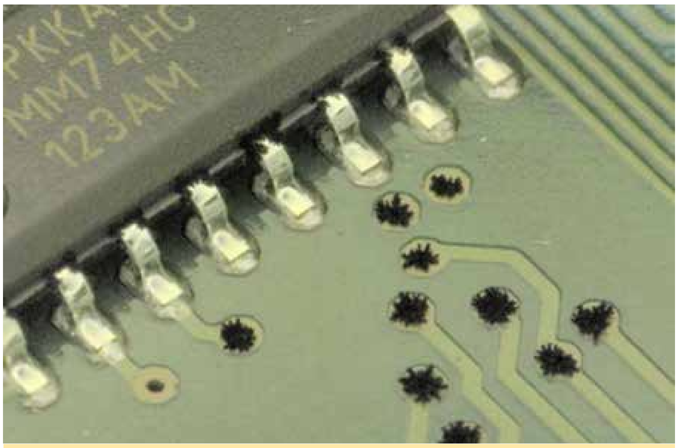

FIGURE 2: Products of dry corrosion emerging from gaps and plated through holes

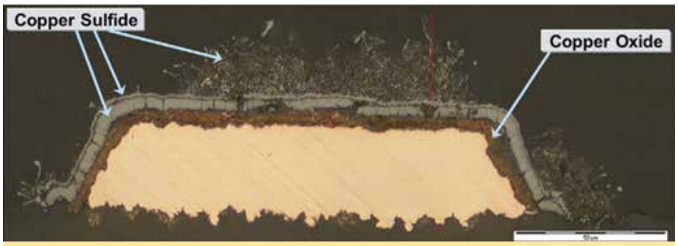

FIGURE 3: Silver sulphide (AgS) needle shaped crystals, providing evidence of a "short circuit" failure

FIGURE 4: Cross section of a corroded copper track after mixed gas test (H_2S (2.11 ppm) + SO_2 (10 ppm) + Cl_2 (0.1 ppm), 21 days) showing the build-up of corrosion

Reduce H_2S emissions

- Hydrogen sulphide (H_2S) and other harmful gases are released by orders of magnitude higher under highly turbulent conditions when energy is released at sharp bends, hydraulic jumps and cascades, as compared to when flow regime is laminar or when the water surface is not broken
- Cascading or plunging sewage and hydraulic jumps must be avoided
- Incoming sewer velocities at pump stations and sewage treatment works should be minimised by designing the incoming sewers with flat grades, appropriately large diameters and sufficiently long approach lengths

Scrub off-gases to reduce fugitive gas concentrations

- Several types of scrubbers are available, all with their own advantages and disadvantages
- Scrubbing is often used primarily for odour control in built-up environments because the rotten egg odour of hydrogen sulphide raises intense public displeasure, and the problem demands immediate and urgent attention

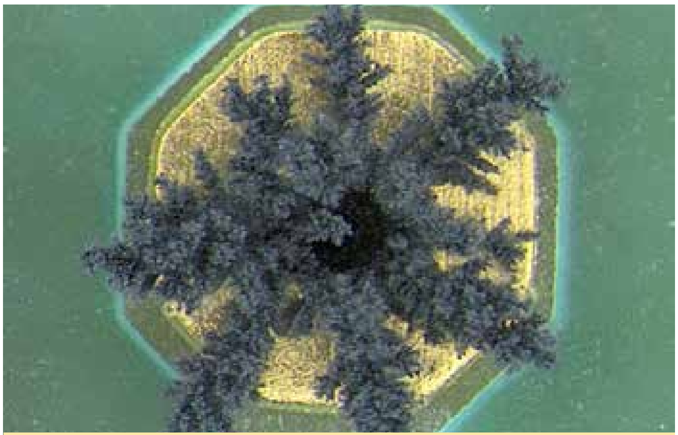

FIGURE 5: Dry copper sulphide crystals emerging from a plated through-hole; no dendrite, no creeping

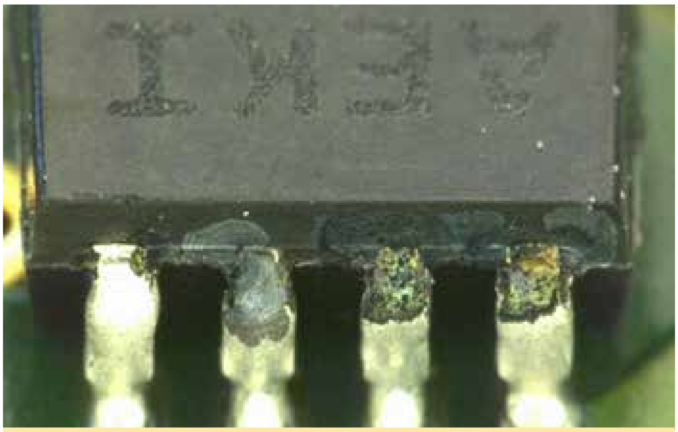

FIGURE 6: Electrical short circuit caused by creeping corrosion between two pins coated with Ni/Pd/Au

- The protection of electronic equipment from fugitive gases can be considered in conjunction with odour control systems, but it requires careful ventilation design as well as other mitigating systems to effectively protect electronic equipment.

Position the PLC and MCC to avoid fugitive gases

- The PLC and MCC should always be positioned as far away, and upwind relative to the prevailing wind direction, from the discharge point of the fugitive gases
- Specifically, MCC and PLC rooms must not have any openings where fugitive gases can pass into the MCC or PLC enclosures directly, such as through cable openings or ventilation ducts.

Proper design of ventilation systems

- Separate ventilation systems should be used for the provision of
  – general fresh air, that is commonly specified as 'changes of air per hour' for areas such as pump rooms and screening chambers, and
  – clean / scrubbed air, where the quality of air should be specified for the PLC and MCC enclosures.
- If general fresh air and clean / scrubbed air systems are to be combined, then special attention must be paid to air flows and pressure balances so that fugitive gases cannot come into contact with electronic control equipment under all operating and fault conditions such as normally closed doors or openings being left open, or strong external winds or storms coming from directions that were not taken into account in the ventilation designs.

Provide clean air for PLC and MCC enclosures

- The PLC and MCC enclosures should use forced ventilation so that the rooms are under positive pressure at all times
- The air should be filtered and scrubbed to specified levels of purity in terms of fugitive gases and particles such that there will be no long-term build-up of contaminants that can cause harm to the electronic components
- Specifications such as ISO 14644-1 can be used to classify and specify the requirements for clean rooms
- Temperature and humidity must be kept relatively constant
- Double door systems with air locks to clean rooms should be provided
- An alarm with corresponding automatic notifications via GSM or similar communication system should be sent to Operations and Management staff for urgent interventions

'Hard wiring' of components

- 'Hard wiring', which essentially comprises of dedicated control wires from the MCC (not PLC) to primary items of plant (e.g. valves and motors), has been specified by experienced and conservative engineers since the advent of PLCs
- Hard wiring allows operators to run the plant when the electronic functions of the PLC have failed; special attention must however be paid by the operator because all electronic protection is suspended when working in manual or remote mode
- Hard wires can be used during cold and dry commissioning to test that physical connections between the MCC and the components (e.g. valves and motors) are working, especially if teething problems are being experienced with the PLC
- The relatively low cost and many advantages of hard wiring cannot be overemphasised
- Less experienced electronic engineers are prone to regard this requirement as "old school" and to argue for not including it in their technical requirements, but lead design engineers must be firm and insist that this is done.

CONCLUSIONS

Some of the approaches to reduce the risk of failure of electronics in water and wastewater environments as described in this paper may seem to be extreme but, if they are taken into account early enough in the design and detailing stages, they do not necessarily add inordinate costs to a project. Net savings will almost always be achieved when life cycle costs are taken into account.

RECOMMENDATIONS

The success and operability of otherwise well designed water and wastewater infrastructure can be ruined if the electronic equipment is not reliable due to one or more shortcomings in the design and / or detailing of a project.

Design engineers, usually civil engineers, therefore need to

- Be aware of the vulnerability of electronic components in water and wastewater environments, and
- Incorporate multiple mitigating and protective features into their designs, and
- Incorporate protective features from the beginning of the conceptual design stage, so as to provide optimal protection, functionality and operability of the electronic components in municipal water and wastewater infrastructure.

REFERENCES

G.Vogel, Creeping corrosion of copper on printed circuit board assemblies, Microelectronics Reliability (2016), http://dx.doi.org/10.1016/j.microrel.2016.07.043