THE LAST 5% - IMPACTS ON PLANT OPERABILITY

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ABSTRACT

One of the single biggest factors that impacts plant operability is infrastructure and equipment that has not been installed and commissioned correctly. During the project lifecycle, from concept to handover, the level of attention to detail varies from stage to stage. The last 5% of a project requires a significant amount of time and effort to complete, however, it is often under-resourced due to time constraints, budget pressure or issues relating to the client/contractor relationship. Critical steps during the last 5% include verification of the PLC/SCADA interaction, testing over the full design envelope, sequence control, plant documentation (as built) and baseline operating data. Often issues related to poor execution of the last 5% are not realised until the plant has been in operation for 1 – 2 years. This paper investigates a number of real life scenarios, lessons learnt and steps to ensure that installation / commissioning is completed in a way that enhances the long term operation of the infrastructure.

1.0 INTRODUCTION

Permeate Partners is a specialist consultancy company involved with the design, approval, procurement, construction and operation of water treatment facilities across Australia. Whilst our preference is to support projects from concept to operation we are often engaged by Clients to investigate issues with existing infrastructure. More often than not, these problems relate to poor execution during the final phases of project delivery. Issues range from incorrect transmitter scaling to major commissioning faults, all of which can have a fundamental impact on the operation and performance of the plant. Depending on the infrastructure configuration/type these issues may also jeopardise equipment warranties. This paper explores real life situations where faults that should have been identified during the final stages of the project, have surfaced over the first 12 - 24 months of operation. It also aims to provide recommendations to Clients on how issues with the last 5% might be mitigated.

2.0 WHAT IS THE LAST 5%?

There are a number of key areas which may cause problems with plant operation if not completed correctly and thoroughly at the end of the project. In order to explain how these problems have affected plant performance, actual cases have been presented as examples. The cases have been separated into the following key areas including:

1. PLC / SCADA
2. Sequence control
3. Documentation
4. Baseline operating data
5. Compliance and environment

This paper will identify what went wrong and what was done to rectify the issue. It also details the affect that these particular problems had on plant performance, equipment warranty, operational costs and efficiency. Through resolving the various issues presented in this paper, Clients were able to reduce their plant running costs through reduced operator interaction and improve product water quality.

2.1 PLC/SCADA

The PLC and SCADA system is the heart of any water treatment plant. Errors in these systems can cause a range of issues from excessive chemical use to damaged equipment, non-compliance in treated water quality and in some cases, pose significant health and safety risks to the surrounding environment and personnel. This section investigates four separate cases that have been identified on sites across Australia.

Set points and their respective design limits are integral in protecting equipment from operating outside its design criteria. If any process parameter exceeds the operational design limit of the respective piece of equipment, then a warning should be generated on the SCADA. If the values continue to exceed the design limits, typically the plant will alarm and shutdown to protect the equipment. Permeate Partners attended a site in Victoria to investigate the poor performance of their Reverse Osmosis unit (RO). When reviewing the key performance data it was identified that the RO was running with a differential pressure of 10bar across two stages. Whilst there was an alarm setup in the PLC, it had been set to 12 bar to enable the unit to run. This resulted in the unit continuing to run despite significant solids ingress into the machine. Figure 1 is the lead element on the first stage of the RO.

__Figure 1:__ ***Solids Ingress into the RO***

Despite the controls being in place, the set point was set outside of the design limits. Notwithstanding the fact that there were other issues present at the plant, the set point should never have been able to be set outside the design envelope. As a result of this failure, the client needed to replace the entire set of membranes at a cost of approximately $40,000.

In order for membrane plants to operate effectively in waste water applications, membranes are cleaned periodically with sodium hypochlorite and citric acid. Membrane suppliers specify set chemical concentrations for membrane cleaning and they form part of the membrane warranty. Permeate Partners provided technical assistance in the installation and commissioning of a Membrane Bio-reactor (MBR) waste water treatment plant (WWTP) located in Western Australia. When reviewing the chemical dose rates it was found that the dosing pump was delivering only 30% of the required chemical. Although the SCADA was displaying the correct dose rate (approximately 95L/hr) the pump was only capable of delivering 30 L/hr. This resulted in the poor performance of chemical cleans and non-compliance of the membrane manufactures warranty.

After a detailed review and discussion with the Contractor it was determined that the pump was severely undersized, subsequently the pump was replaced with a unit capable of delivering 150L/hr. This simple check avoided the potential breach of the membrane supplier's guidelines / warranty and had the potential to affect plant performance.

In order to prevent solids build up in the membrane tank during operation of an MBR, the feed rate to any given membrane system is typically 4-5 times the permeate production rate of the membrane cell. Feed rates below this level can lead to excessive concentration of solids in the membrane tank, leading to the potential breach of the allowable solids filtration limit set by the membrane manufacturers. Permeate Partners attended a MBR WWTP in Victoria to investigate issues with high trans-membrane pressures (TMP's). A review was conducted on the system and it was identified that although the recirculation ratio on the SCADA was set to 4:1, it was not mapped to the correct tag in the PLC that controlled the membrane feed rate. The hard coded set point for the recirculation rate was set to 2:1 leading to excessive solids build up in the membrane tank, sludging of the membranes and a subsequent breach of the membrane warranty. This issue was only identified after the plant had been in operation for 18 months as the effect was not immediately apparent on the new membranes. After some time, the eventual solids build up deteriorated the membrane condition and led to the failure of three membrane cassettes. Figure 2 is an indication of the level of sludging between the membrane panels.

<u>Figure 2:</u> ***Sludged Membrane Cassettes***

In addition to this issue, the TMP alarm that would usually protect the membrane cassettes was not tested correctly and included a 5 minute delay. This resulted in the membranes never tripping on high TMP and they subsequently ran outside of the membrane manufactures design guidelines. As a result the client was forced to replace 3 of the membrane cassettes at the cost of nearly $95,000. This major fault could have been avoided if two simple tags had been mapped correctly and checked during commissioning.

2.2 Sequence Control

Aeration is one of the largest users of power in wastewater treatment. In order to maximise plant efficiency, aeration should only be used as required by the treatment plant. Permeate Partners attended a site in North Queensland where the Client was concerned about the amount of power the site was using per kL of recycled water. A review of the facility identified that the membrane blowers were running 24 hours per day despite only required in some instances to run for 8 – 10 hours.

With the membrane blowers being one of the largest consumers of power onsite, a simple standby aeration control philosophy was implemented to limit blower run time to the operational requirements of the plant. This reduction in blower run time resulted in an annual saving of approximately $30,000/annum. Figure 3 below illustrates the power consumption before/after the changes.

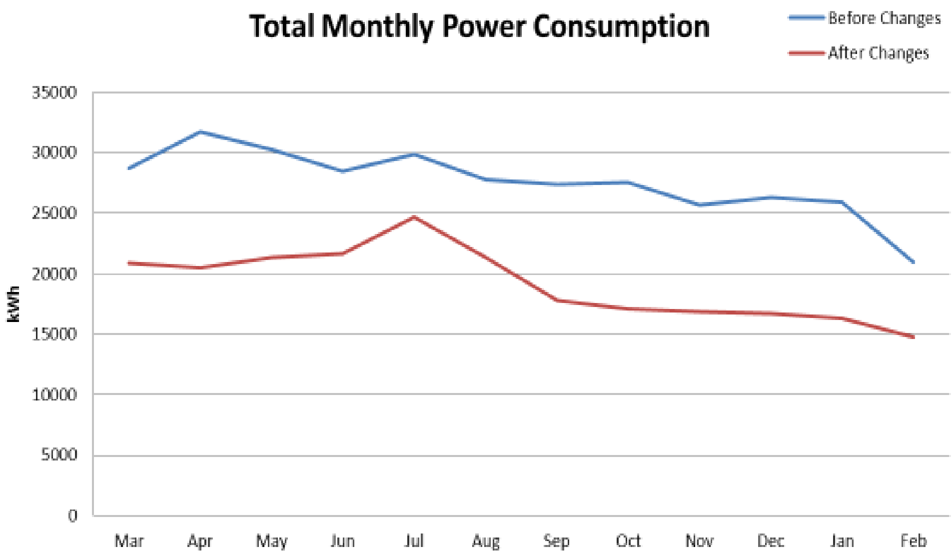

Figure 3: *Power Reduction after Control Changes Implemented*

Again a relatively simple change that should have been identified during the commissioning stage resulted in a substantial increase in the running costs for the plant.

On another site, Permeate Partners was requested to review the plant operation after commissioning and performance testing had been completed by the Contractor. A number of issues were identified, of which one was related to the plant set points. The plant was designed with double protection before the RO, with both a free chlorine analyser as well as an ORP instrument to protect against membrane exposure to free chlorine. However, both were incorrectly configured, with the free chlorine alarm set at 2 ppm and the ORP instrument incorrectly installed. Ultimately the RO membranes had to be replaced at a cost of approximately $100,000 due to poor performance as a result of free chlorine exposure.

2.3 Documentation

Documentation is a critical part of the plant construction package as it provides a reference for operators to utilise for training, optimisation and fault finding / rectification. Errors and / or incomplete documentation can lead to damage of plant equipment and pose a safety risk to personnel working on the plant.

As mentioned previously in Section 2.1, chemical cleaning is an integral part of membrane plant operation. The level of automation varies from plant to plant depending on capacity and design requirements. Permeate Partners was asked to conduct a review of a membrane plant in Victoria as it was experiencing issues with high TMP's. After completing a clean onsite with the documentation provided to the Client, it was identified that the procedure contained numerous errors. This resulted in insufficient chemical being sent to the membranes, poor cleaning results and increased downtime due to high TMP's.

In addition to this, the chlorine solution destined for MBR membrane cleaning was entering the RO feed tank where it was then passed through to the RO. Although the RO was fitted with ORP protection (SMBS dosing), it was never designed to protect the machine from high chlorine concentration solutions (up to 2000ppm). This resulted in the damage to the RO membranes as the high level of chlorine oxidised the membrane surface. This issue could have been avoided if the correct procedure had been put in place and tested during commissioning.

Plant drawings are another essential part of the documentation required to operate and maintain any water treatment facility. Whilst these documents are sometimes not used in the initial stages of operation, they prove to be a useful resource when completing fault finding exercises.

During the handover of an MBR WWTP in Western Australia, the client was issued with all the as-built documentation from the Contractor. Permeate Partners reviewed the electrical drawings against the actual installation and identified numerous changes that had not been captured in the as-built drawing set. This included discrepancies in isolator locations, wiring runs and other various issues. In the event there is an electrical fault, the site electricians will often refer to these drawings to determine what equipment needs to be isolated to conduct maintenance. Errors in the electrical drawings can lead to the incorrect equipment being isolated resulting in the potential for damage to equipment and injury to personnel. The Contractor was subsequently instructed to complete a detailed review of the entire drawing set and ensure that it matched the site installation.

2.4 Baseline Operating Data & Feed Water Analysis

Baseline operating data provides valuable information whenever trouble-shooting plant performance, especially data collected during the commissioning and performance testing periods. The data also provides a regular check against operational data to confirm plant performance. Over time operational staff may get accustomed to gradual decreases in plant performance, such as TMPs or rejection, and they become the new norm. Taking into consideration there is always ‘ageing’ associated with membrane plant performance, the baseline data provides a check of present performance against design and measuring the actual ‘loss’ in performance. The baseline data also provides a means of evaluating membrane warranty performance and life.

Permeate provides operational support to a 23MLD water treatment facility in NSW which includes three RO trains. The plant was experiencing a rise in differential pressures across the RO membranes. The installation Contractor believed that there was extensive organic fouling within the RO units and suggested a serious of high strength extended chemical cleans that were on the limit of the membrane design. Permeate Partners conducted a series of RO projections on the current feed water and included a deterioration factor in the membrane projection software to accommodate the membrane age. When compared against the initial commissioning data, it was identified that the rise in differential pressures was in fact due to the change in temperature and feed water constituents and the system was operating in line with the projected design pressures. A follow up membrane autopsy confirmed that there was minimal fouling of the RO membranes. Table 1 shown below provides a comparison of the operating data vs projected values.

Table 1: ***Projection Comparison Data***

	Mar-15			Jun-15		
Parameter	**Actual**	**Projected**	**% Deviation**	**Actual**	**Projected**	**% Deviation**
Feed pressure (bar)	10.8	10.8	0.27	14.8	14.7	-0.27
Stage 1 dP	1.6	1.6	4.14	1.8	1.9	-0.52
Stage 2 dP	1.4	1.5	-4.89	1.6	1.7	-8.37

With this information the client was able to forego the extensive cleaning regime suggested by the Contractor and saved approximately $25,000/ additional clean in chemical costs, not to mention a reduced risk of affecting membrane life through high strength chemical cleans.

2.5 Compliance & Verification

Permeate Partners was requested by the Client to review the performance of a UF/RO plant supplied, commissioned and performance tested by the Contractor. There were a number of inconsistent items identified in relation to the contractors commissioning records. The UF permeate turbidity is a critical control point (CCP) to demonstrate compliance with the health performance targets, however, in a review of the system the PLC scaling for the on-line analyser was incorrect. This meant that the PLC was incorrectly reading a lower value than the field instrument. A breach in the CCP would not have been alerted to operators and no corrective action would have taken place. The Contractor checklists noted that the instrument had been signed-off and accepted. The Contractor was subsequently directed to rectify the transmitter scaling to ensure the plant was operated in accordance with the validated conditions.

3.0 CONCLUSION

It is clear that there are number of key aspects of the commissioning / handover phase that need to be addressed to ensure the plant and personnel are protected against operational faults. In order to minimise the risk of these issues Clients should ensure the following tasks are completed prior to handover to operations:

1. Thorough review of the plant SCADA/PLC system to ensure all components of the control system operate as intended. This should include detailed ITP's on each piece of process equipment.
2. Confirm sequence control is operating effectively post commissioning as there is likely to be improvements that can be implanted once the plant is running.
3. Review all plant documentation including but not limited to O&M manual, drawings, operational procedures and control methodology to ensure they reflect as-built / as-commissioned.
4. Capture baseline operating data on start-up and carry out new RO projections for comparison if any changes in feed water occur.
5. Conduct a detailed review of all CCP's in the presence of the Client to demonstrate the plant shuts down if any non-compliant water quality data is produced.
6. Time…time….time; there is always danger at the end of the project to rush these tasks; which is traditionally why we see so many problems today. However time spent at this critical project stage will save substantial time and costs during operation. This is especially important in membrane systems, where start-up problems may results in problems months or years into the future.