SYDNEY START UP AND OPERATIONAL EXPERIENCE

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Abstract

The commissioning of the DWEER™ energy recovery system at the Kurnell desalination plant near Sydney required only limited on-site Calder supervision. The limited time spent on site by Calder engineers illustrates the ease of startup and the robust operation of the DWEER. Once the controls were calibrated, the DWEERs handled just about any conditions experienced during commissioning without the need for intervention from a Calder engineer.

Remote access allows Calder service engineers to evaluate operating parameters and system performance, make adjustments as needed and provide guidance to the operators online. This capability saves time and money while improving customer service. The paper will highlight examples of operating experiences.

I. INTRODUCTION

The Sydney Desalination Plant is located in the Kurnell industrial estate area, a suburb in southern Sydney in the state of New South Wales, Australia. The plant is a potable water supply project and a subsidiary fully owned by Sydney's state owned corporation Sydney Water. The plant was constructed by Bluewater Joint Venture, a conglomeration of Veolia Water Australia Pty Ltd and John Holland Pty Ltd.

The project was announced when Sydney dam levels dropped to 34% in February 2007. Since January 28, 2010 the plant is fully operational and produces 250,000 m3/d (62.5 MGD) for 1.5 million people in Australia's largest city. The project was delivered on time and $60 million under the total approved budget of $1.896 billion. Part of the Kurnell's desalination plant costs was the construction of a wind farm to offset the operational energy usage by 100% renewable energy, as well as intake- and outlet-tunnels to the Tasman Sea and a 18km product water pipeline underneath Botany Bay. All infrastructurewas designed and constructed to handle the ultimate capacity of 500,000 m3/d (125 MGD) in case of future expansions.

Figure 1: The Sydney Plant (Courtesy of Sydney Water)

Figure 2: Location of the Sydney Plant

It is the goal of Calder GmbH, a Flowserve Company, to continuously improve the design of the DWEER SWRO energy recovery product. This paper demonstrates how experience gained during the commissioning of several large SWRO plants over the last couple of years have helped to gain important knowledge and resulted in simplified commissioning and start up procedures. Also, the lessons learned from the commissioning of the Sydney SWRO plant will be discussed on the following pages.

II. Individual feed pump system

The plant capacity of 250'000m3/d (62.5 MGD) is divided into a 12+1 train design, meaning at full production each of the 12 operating trains has a capacity of roughly 20,835m3/d (5 MGD). The energy recovery system consists of 5 DWEER units in parallel next to each train, and a total of 65 DWEER units are installed. The DWEERs are grouped into racks of 10 units, 5 of which serve the membrane skid on the left and the other 5 serve the membrane skid on the right of DWEER rack.

Figure 3: DWEER rack in Sydney, designed to handle 2 Sydney trains or a max. capacity of 41,640 m3/d (10 MGD).

The plant design includes an individual feed pump system, which means that not only is the feed of the ERS independent from the feed of the high pressure pumps, but also that each train is completely individual, enhancing an independent feed system. Such design maximizes the plant’s flexibility while keeping efficiencies of different equipments such as pumps at a high level due to the large size of each train. This design proves to be advantageous especially at Sydney, where expected production capacities vary greatly due to unpredictable external circumstances such as rain fall and future dam levels.

A projection showing the normal design operating conditions under full load of Sydney’s desalination plant from an energy recovery point of view is given in figure 4 below:

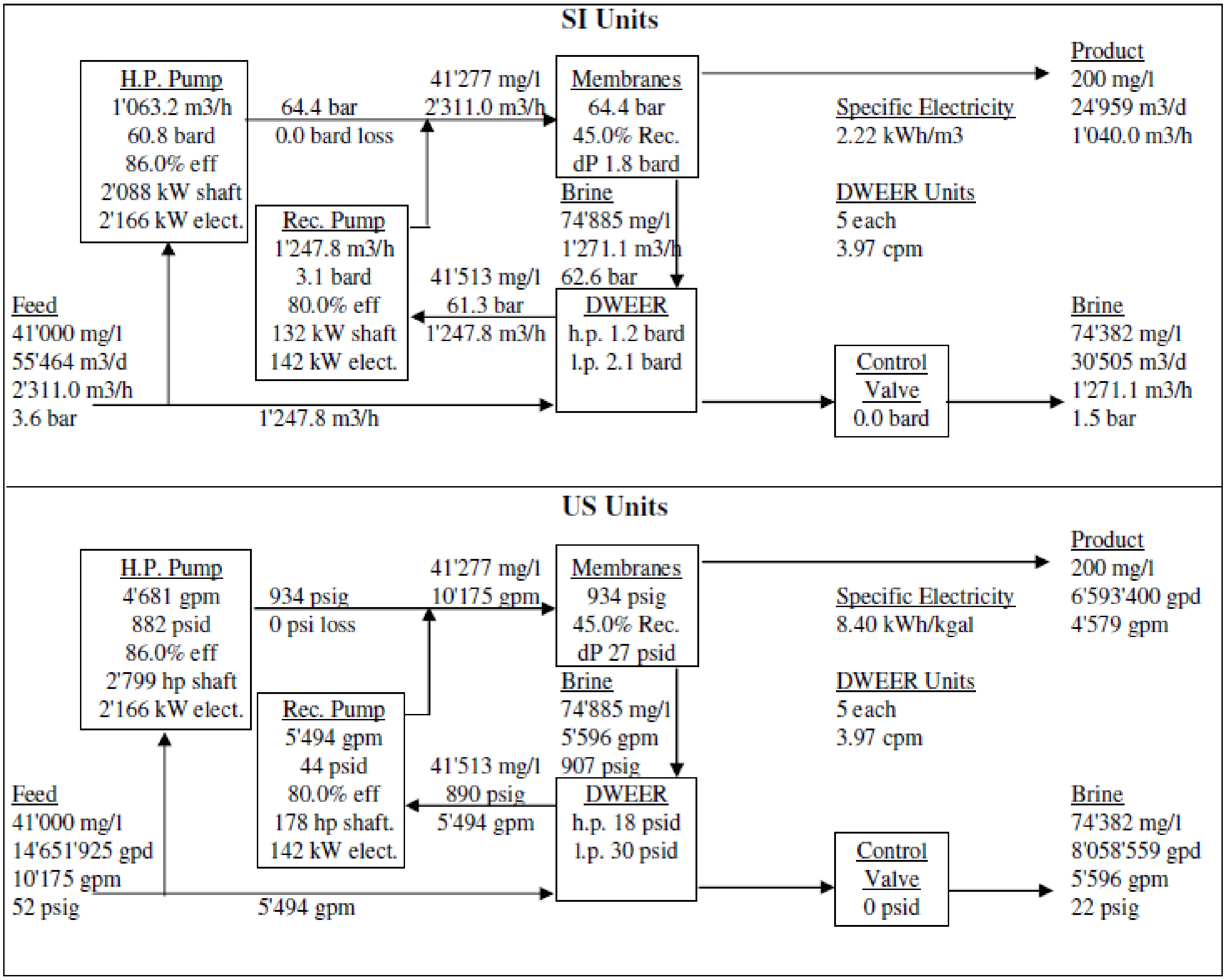


Figure 4: Train projection for Sydney Normal Operation Design Condition, Calder 2008

The chosen design with its combination of maximized flexibility through totally individual trains and large train sizes offers a number of advantages with regards to efficiency and commissioning from an energy recovery point of view, which shall be discussed.

2.1 No interaction between trains

Due to the separation of the feed system for each train there is no hydraulic interaction of any kind between the single trains. This has been proven to be especially advantageous during commissioning, as each train could be commissioned whenever it was ready and it did not rely on any other trains or equipment.

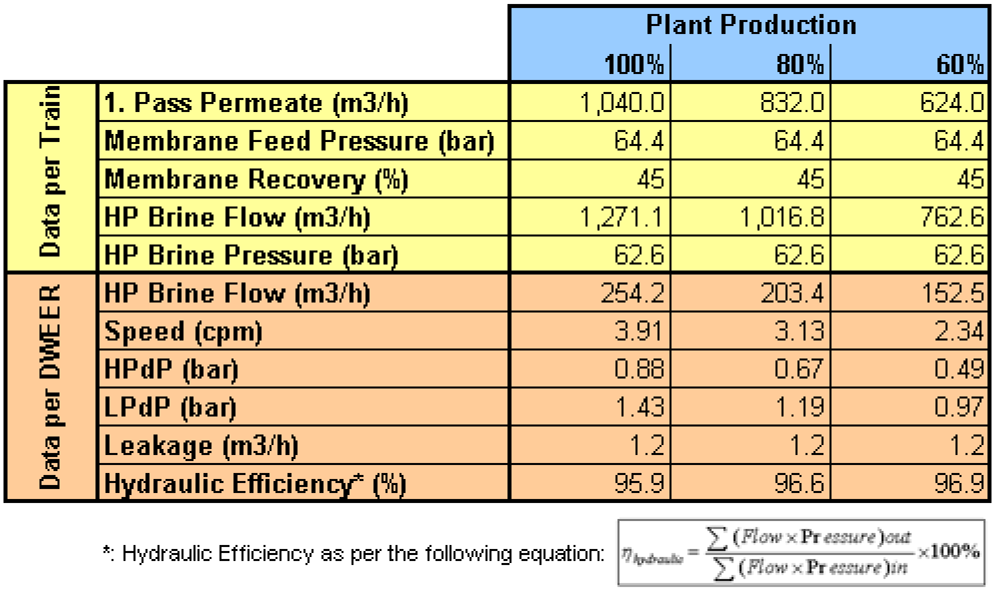
During operation, whenever the rainfall increases and less production is required, or in case of unplanned shutdown of equipment, full individuality proves to be a big advantage – especially when the design includes a stand-by train as it does for Sydney.

2.2 *Full flexibility*

Besides the flexibility to handle fluctuating operating conditions and taking single trains off-line for maintenance reasons, flexibility also is increased with regard to operating conditions of single trains without influencing the operating conditions of other trains. In case of a lower required plant output, the options are increased as there is a choice between continuous production with the same number of trains at changed operating conditions and increased overall efficiencies due to lower velocities, or the complete shut down of single trains and production with a reduced number of trains.

The first option only makes sense in plants designed with a focus on optimized energy consumption as is the case for Sydney, where pumps are equipped with VFD's and the energy recovery system (ERS) also guarantees possibilities for a certain flexibility in regards to flow-rates and pressure values. In the specific case of Sydney however, the energy recovery system controls adjust the operating speeds automatically by changing the number of cycles per minute in the LinX™ valve. As less flow means less hydraulic velocity and reduced differential pressures, the efficiency of the energy recovery system in Sydney is actively controlled to be maximized.

Table 1 illustrates this concept for ERS efficiency and possible power savings, by comparing the differences in the projected ERS performance between 100%, 80% and 60% of plant production while keeping all 12 trains in operation instead of shutting some down (Note: the following table compares only the performance and efficiencies of the ERS. Changing efficiencies and power requirements of other equipment, such as the pumps, is not considered):



		Plant Production		
		100%	80%	60%
Data per Train	1. Pass Permeate (m3/h)	1,040.0	832.0	624.0
	Membrane Feed Pressure (bar)	64.4	64.4	64.4
	Membrane Recovery (%)	45	45	45
	HP Brine Flow (m3/h)	1,271.1	1,016.8	762.6
	HP Brine Pressure (bar)	62.6	62.6	62.6
Data per DWEER	HP Brine Flow (m3/h)	254.2	203.4	152.5
	Speed (cpm)	3.91	3.13	2.34
	HPdP (bar)	0.88	0.67	0.49
	LPdP (bar)	1.43	1.19	0.97
	Leakage (m3/h)	1.2	1.2	1.2
	Hydraulic Efficiency* (%)	95.9	96.6	96.9

*: Hydraulic Efficiency as per the following equation:

$$\eta_{hydraulic} = \frac{\sum(Flow \times Pressure)out}{\sum(Flow \times Pressure)in} \times 100\%$$

Table 1: Different plant production ratios and effect on ERS performance

2.3 *Single train optimizations*

Full separation of the trains further allows for single train optimizations. As there is no reliance on other train's equipment there is no need to consider any compromises. With regard to energy recovery devices this means increased efficiencies for each train by individual optimization of operating speed and equipment utilization. Other possibilities with impact on efficiency and specific energy consumption include train individual adjustments of ERD back-pressure to optimize the flow balance between single devices and, therefore, mixing and overflush or underflush values. Combined with other equipment optimized for energy usage such as VFD controlled pumps, each train may operate at its own best efficiency point according to the overall production requirements.

2.4 Future optimizations

Looking forward to possible future optimizations and tests, the split into various small sub-processes by full separation of single trains has proven to be advantageous. Before a certain modification is applied to the entire plant, its different options may be tested and evaluated by module or a single train without any consequences for the commercial operation.

III. Reduced commissioning time

As Australia is a very remote location for a Swiss based company, reduction of commissioning time and site visits resulted in considerable cost savings to both the operator as well as the supplier. Excluding certain small adjustments and corrective actions after first start-ups, Calder has only spent a total of 30 days on site for installation supervision and commissioning support including a few days for performance testing, which is not much considering the plant size, an overall project time exceeding 2 years and time for full plant commissioning of more than one month.

Again, the individualization and full separation into independent trains have contributed a lot to this achievement. For both the installation and commissioning, this allowed Calder to train the plant personnel on only 2 trains while the remainder could be accomplished without the need of on-site assistance. In addition, the commissioning of the first trains could have been done and operator's personnel trained while other trains still were under construction. Then the same procedures could be modeled and applied to the other trains when they were ready, another great time savings as a result of the chosen plant design. Of course, this is not an exclusive advantage for the energy recovery equipment, but applies to any other equipment and subsystem.

Furthermore, the energy recovery system in Sydney is capable of remote control access. This means that Calder service engineers can have access (controlled and authorized by the operator) to the current operating conditions of the equipment at any time and from anywhere, and make adjustments as needed. This guarantees the ability to support the customer 24/7 for any operational issues.

IV. DWEER efficiency

In January 2010, the performance tests for the plant took place under normal design operating conditions as shown in figure 4. Each single DWEER was handling 255m3/h at 62.6 bar (1122 gpm at 918 psi). The DWEER energy recovery system exceeded expectations by contributing to the overall plant efficiency, which came in about 30% under the contracted maximum sum of system losses. Figure 5 shows the total power targets of the losses as contracted compared with the actual values per train as measured and approved during the performance tests. The losses for the actual values as shown in figure 5 are averaged actual measurements taken during the performance test for each of the 13 trains:

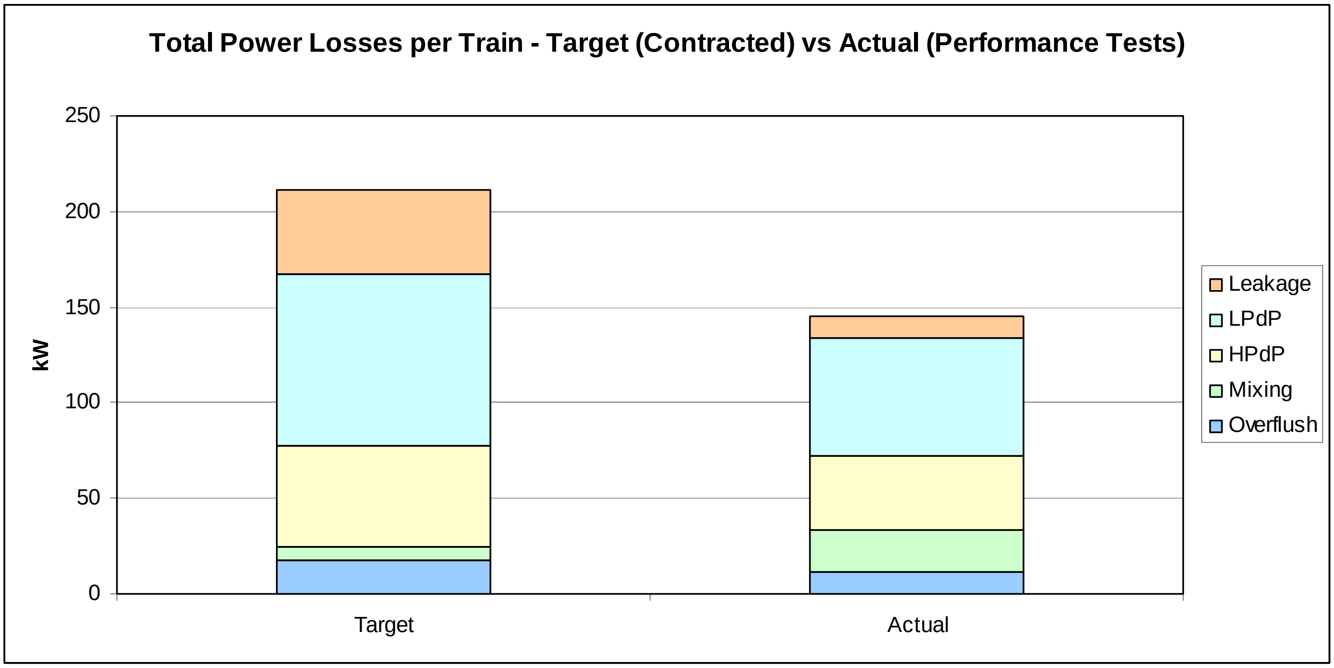


Figure 5: Target (contracted) and actual power losses of the DWEER ERD in Sydney

The main reasons for this excellent result are the differential pressures and leakage values, where the actual system far exceeds the expectations. This was the first time Calder installed a *quint DWEER system*, meaning 5 DWEERs in parallel to serve one fully individualized train. The five units in parallel proved to be a great advantage due to flow distribution and balance in case of slight changes in operating conditions, resulting in reduced differential pressure values over the ERS.

As a result of experience with other projects such as the relatively nearby Gold Coast Tugun plant, Calder introduced some product modifications and improvements on the LinX valve during the manufacturing of the DWEERs for the Sydney project. Since Calder could demonstrate the benefits of these design modifications, resulting in significantly reduced differential pressures (through optimized flow paths) and reduced leakage rates (closer tolerances for the LinX valve internals and introduction of the LinX piston nose design), all of these enhancements were approved for use for the project.

The only area where the DWEER system did not meet the requested values has been mixing. The main reason for that is the design of the inlet to each of the quint DWEER systems, which includes a 90% elbow quite near the hp brine inlet of each energy recovery device. This may lead to an unbalance in the flow distribution between the two vessels of one DWEER device, resulting in a possible underflush situation of certain vessels due to differences in the flow path and therefore, vessel piston velocities within one DWEER as shown in figure 6:

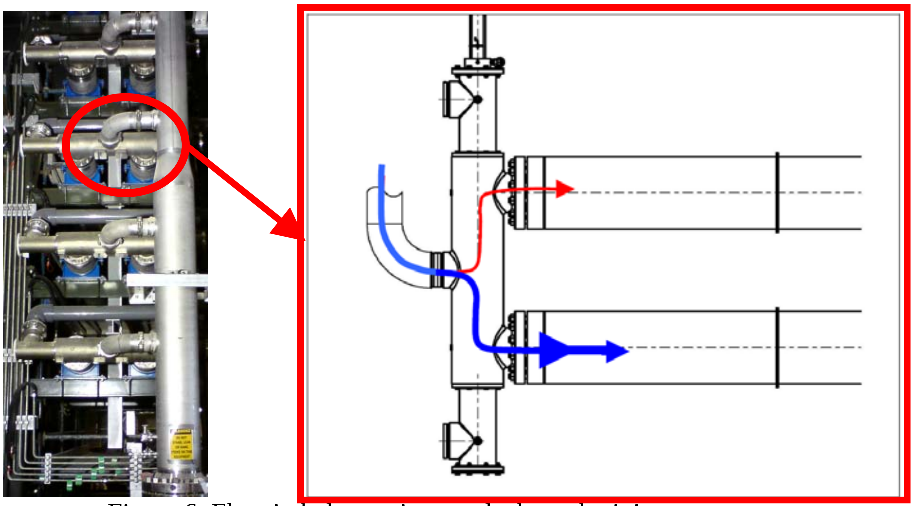


Figure 6: Flow imbalances in vessels through piping asymmetry

This situation is a case of underflush rather than mixing, but the effect remains the same. The result is an increased TDS within the hp feed flow exiting the energy recovery system. However, as already explained above, this loss is more than compensated by the superior overall system performance. Also, it should be noted that the overflush value during the performance test was about 1% lower than contracted (2% actual vs 3% target), which has an additional effect of increasing salinity on the feed side of the device.

While the overall power losses of the system have been discussed in figure 5 above, the following chart (figure 7) shows the additional power requirements (mixing) and power savings (other losses) of each of the contracted performance values per train. Again, the actual values shown represent averaged measured values during performance tests:

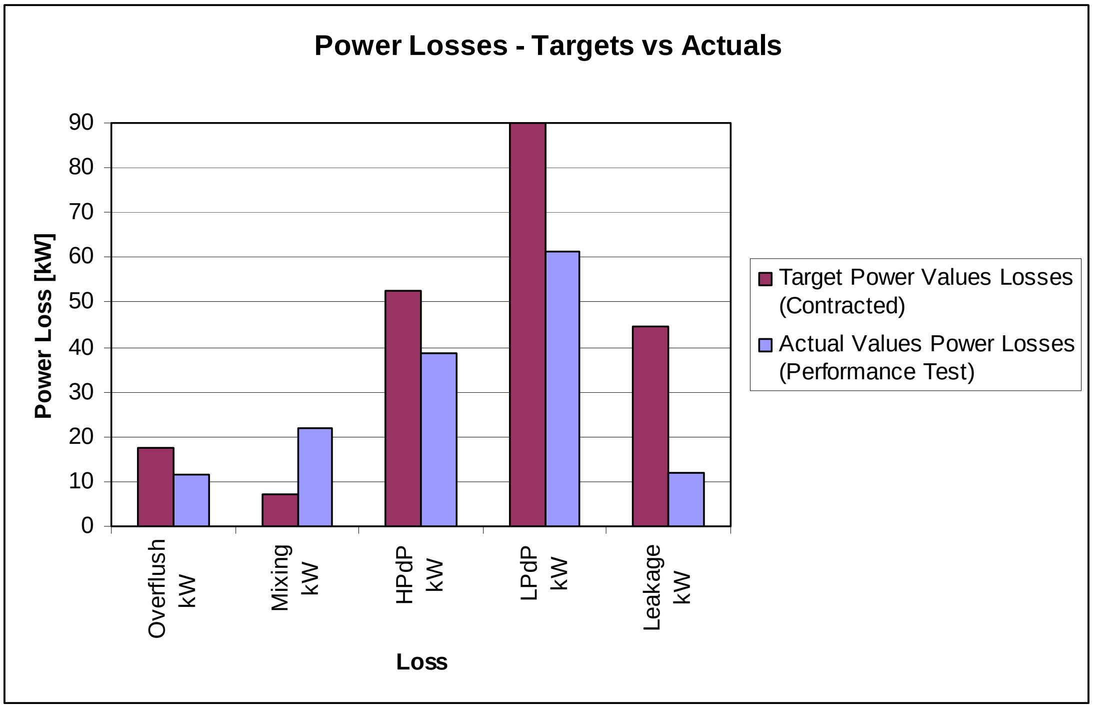


Figure 7: Power requirements and savings per train for single contracted system losses

In terms of hydraulic efficiency (defined as per the equation shown in figure 8 below), the DWEER system in Sydney exceeded the target value of 93.4% by 2.5%, resulting in the actual (performance test) value of 95.9%.

$$\eta_{hydraulic} = \frac{\sum (Flow \times \Pr essure)out}{\sum (Flow \times \Pr essure)in} \times 100\%$$

Figure 8: Equation for hydraulic efficiency

V. Lessons learned and future areas of efficiency gains

The general experiences in Sydney from an energy recovery point of view were and are positive. This was the first time a quint DWEER system was installed, and the plant had some other design features such as the discussed train separation.

As a result of the experiences gained during commissioning and after one year of operation, Calder is working with Sydney Water and Veolia Water Systems & Technologies on two additional projects to further increase the plant’s efficiency. The first project focuses on lowering the backpressure of the DWEER system by introducing breathers in the low pressure brine line. The second project involves flow straining elbows to improve the flow balance between the five DWEERs in parallel per train, which is likely to reduce the underflush (mixing) and apparent overflush values.

The entrance angle of hp brine and the resulting salinity increase (mixing) due to flow unbalances between the 2 DWEER vessels has been discussed before. The other enhancement includes a review of the effect of the installation height. It is advantageous to have overall access with enough space for any possible scenario, and it also is a very compact design to arrange the DWEER systems for two trains next to each other with staggered LinX valves as shown in figure 3. But the high rack and header designs in Sydney may also result in certain disadvantages with regard to back pressure requirements of the energy recovery system. The DWEER, since it is not a high speed rotating but a low speed reciprocating device, generally does not risk cavitation. With an optimized system design and symmetric piping layout it has proven to be able to operate at atmospheric lp brine pressure values in various installations. But a minimum backpressure is required for discharging the brine properly, as is also the case in Sydney.

This backpressure (lp brine pressure) is considered a loss in SWRO energy recovery because the required ERS lp feed pressure basically is the sum of system differential pressures (energy recovery system and piping losses) plus required ERS backpressure for brine disposal. Therefore, further pressure reductions of the lp brine stream to the minimum required pressure level for brine evacuation obviously will directly result in reduced specific power consumptions. Overall operating experience at the Kurnell plant indicate a potential additional power savings of 30kW per train (averaged) in the lp ERS feed line can be expected. This would result in more than 350kW for the entire plant under full production. The first tests incorporating breather devices on the lp brine stream have been done on a single train and proved effective.

Other lessons Calder has learned with this first installation of its kind and actions resulting thereof include internal optimizations in product and installation documentations. This was the first time a quint DWEER system was installed combined with an enhanced LinX™ valve and other efficiency optimizing design modifications. As a result, some startup problems occurred during the first operating hours, requiring corrective actions. These corrections have not been discussed in detail as they relate to product improvements that occur with all new product releases. Calder ensured that support was available to the Sydney site throughout the startup and that any modifications were completed in a manner that had little or no effect on the production or the reliability of the equipment. The design modifications are now included as standard on new projects.

VI. Conclusions

The Sydney desalination plant produces about 15% of Sydney's current overall water needs and has proven reliable. The commercial operation meets the requested flexibility and exceeds expectations for overall and specific energy consumptions. The design of splitting the overall production into a number of fully separated trains basically operating like small plants themselves, offers distinct advantages such as testing possible process modifications. Also, it has proven to be a flexible solution in regard to expected fluctuations in production and operating conditions, and to be an advantage to increased overall process efficiency by optimizing each train individually without reliance on the "worst" performer within the process chain.

An especially interesting aspect of this plant design of 250,000 m3/d (62.5 MGD), is that it allows for high production flexibility by splitting production into 12 trains while still having large train sizes exceeding 20'000 m3/d and, therefore, maintaining high pump efficiencies. Adding a stand-by train further avoids any reduction of production in case of scheduled maintenance or any unforeseen event. Train individualization again is a great advantage when switching production between single trains.

The DWEERs proved to be robust during the startup phase. The flexible operating speed allows the ERS to follow plant capacity and maximize efficiency. Remote access allows 24/7 support of the equipment without having to wait for a service engineer to travel to the site. Design enhancements of component parts were incorporated during manufacturing and proved successful. Additional installation enhancements will result in further energy savings for the plant. The relationship with Bluewater Joint Venture proved successful for all parties.