PUMP EFFICIENCY MONITORING AND MANAGEMENT AT MELBOURNE WATER

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ABSTRACT

Melbourne Water is one of the largest users of energy in Victoria spending about $14.1M in 2003/04. Melbourne Water's aim is to minimise imported energy costs and associated greenhouse gas emissions by maximising its capacity to generate renewable energy and by ensuring that major energy consuming components are being operated and maintained in a manner that minimises energy consumption. The latter includes pumping stations, which account for 60% of Melbourne Water's energy consumption.

In March 2005, the Sustainable Energy Authority Victoria (SEAV) formed a partnership with Melbourne Water under the Business Energy Innovation Initiative to undertake a pump efficiency study.

When fully implemented the outcomes from the study are expected to yield energy savings in the order of 2% to 4%, which equates to approximately 3,470 to 6,940 MWh with a commensurate cost saving of $109,000 to $218,000 per annum. This also results in a reduction in greenhouse pollution of approximately 2,500 to 5,000 tonnes per annum or the equivalent to removing 575 to 1,150 average cars from Victorian roads each year.

KEY WORDS

Pump efficiency, greenhouse pollution, energy savings, flowmeter calibration

1.0 INTRODUCTION

Melbourne Water is one of the largest users of energy in Victoria spending about $14.1M in 2003/04. Melbourne Water's aim is to minimise imported energy costs and associated greenhouse gas emissions by maximising its capacity to generate renewable energy and by ensuring that major energy consuming components are being operated and maintained in a manner that minimises energy consumption. The latter includes pumping stations, which account for 60% of Melbourne Water's energy consumption.

In March 2005, the Sustainable Energy Authority Victoria (SEAV) formed a partnership with Melbourne Water under the Business Energy Innovation Initiative. The Authority established the Business Energy Innovation Initiative in November 2003 to assist Victorian businesses increase productivity using innovative sustainable energy options.

Under the initiative, Melbourne Water engaged a consultant to conduct real-time efficiency monitoring using the thermodynamic measuring principles. The technology was applied at four of Melbourne Water's major pumping stations where individual pumpsets were monitored.

Information about each individual pump and pump station operation was analysed and recommendations made regarding the following:

- Pump condition and opportunities for energy reduction through pump overhauls
- Pumping Station operation and opportunities for energy reduction through revised pumping regimes.

When fully implemented the outcomes from the study are expected to yield energy savings in the order of 2% to 4%, which equates to approximately 3,470 to 6,940 MWh with a commensurate cost saving of $109,000 to $218,000 per annum. This also results in a reduction in greenhouse pollution of approximately 2,500 to 5,000 tonnes per annum or the equivalent to removing 575 to 1,150 average cars from Victorian roads each year.

2.0 DISCUSSION

2.1 Project background

In March 2005, Melbourne Water engaged the consulting firm Advanced Energy Monitoring Systems Ltd (AEMS) to conduct efficiency testing of four of its largest pumping stations. Three of these were the sewerage pumping stations located at Brooklyn, Eastern Treatment Plant at Carrum and Hoppers Crossing and the fourth was a water pumping station located at Yering Gorge.

The consultant was instructed to undertake the following works:

- Test and report on performance of each pump
- Undertake a calibration check on the flow meter on each pump.
- Undertake an analysis of the performance of each station using the data available from the existing SCADA system and produce an optimised pumping schedule for each station.
- Determine pump condition and opportunities for energy reduction by pump refurbishment.
- Produce a comprehensive report that includes plant condition, efficiency, mode of plant operation and opportunities for energy reduction through revised operating schedules.
- Train Melbourne Water staff in system testing, analysis and system optimisation.

The outcomes of the study are to be reported to the Melbourne Water Energy and Greenhouse Steering Committee and the Sustainable Energy Authority to determine the potential for implementation amongst other Melbourne Water pump stations and the potential broader application for the Victorian Water Industry.

It is estimated that if the implementation of the study recommendations lead to 4% pump efficiency gains across the Victorian Water Industry then power cost savings of up to $1 million per annum could be realised. This would also result in a significant reduction in greenhouse pollution of up to 23,000 tonnes per annum or the equivalent to removing 5,350 average cars from Victorian roads each year.

2.2 Test method

AEMS is a United Kingdom based company that has developed the field application of the thermodynamic method of pump efficiency testing and from that system monitoring and optimisation.

Traditionally, pump efficiency is determined by dividing the hydraulic power produced by the pump (water power **ρgH Q**, where **ρ**is water density, **H** is pressure and **Q** is flow) by the shaft power supplied to the pump. Normally, pressure is readily measured but it is often difficult to accurately measure flow.

2.3 The Yatesmeter System

The testing method developed by AEMS is called the Yatesmeter system. It employs the thermodynamic method as detailed in ISO 5198 –1987 and the Code of Practice for Pump Efficiency Testing by the Direct Thermodynamic Method June 1995 by The Pump Centre, UK.

The method involves insertion of temperature probes and connection of pressure transducers on both the suction and delivery sides of the pump to measure the differential water temperature and pressure.

The energy lost due to the inefficiency of the pump is measured by the differential head and differential temperature across the pump. Neither the flow rate nor power absorbed by the pump needs to be measured.

Where the shaft power absorbed by the pump can be determined, the flow rate may be calculated from the power absorbed, the differential head and the measured efficiency.

The Yatesmeter equipment consists of the following:

- Yatesmeter – an electronic unit that converts instrument signals to pump efficiency and flow and transmits the data to the laptop computer (refer Figure 1).

- Laptop computer - for control of the Yatesmeter and data logging (refer Figure 2).

Figure 1: ***Yatesmeter***

Figure 2: ***Yatesmeter & Laptop***

- Power monitor
- Strobe for rotational speed measurement
- Temperature probes (refer to Figure 3)
- Pressure Transducers (refer to Figure 3)

Figure 3: ***Temperature probe & pressure transducer installations***

2.4 Tappings and instrument installation

The Yatesmeter requires access to the suction and discharge of the pump under test. For a dry well configuration, two ½ inch BSP tappings, as shown in Figure 4, are required, one in the suction of the pump and one in the discharge of the pump. The tappings are installed 2 pipe diameters away from the flanges of the pump (refer to Figure 4 & 5).

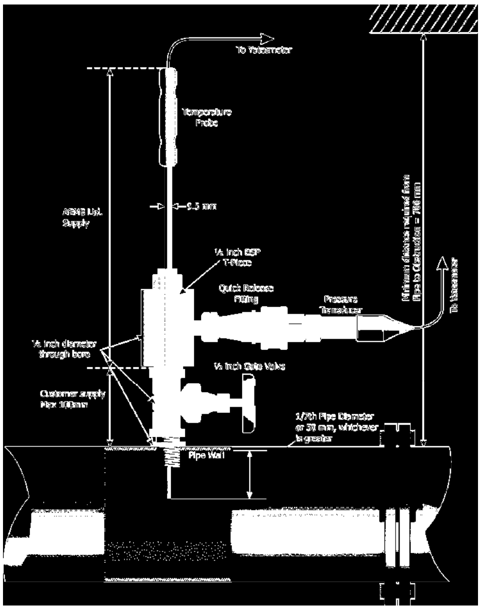

Figure 4: ***Standard Tapping Arrangement***

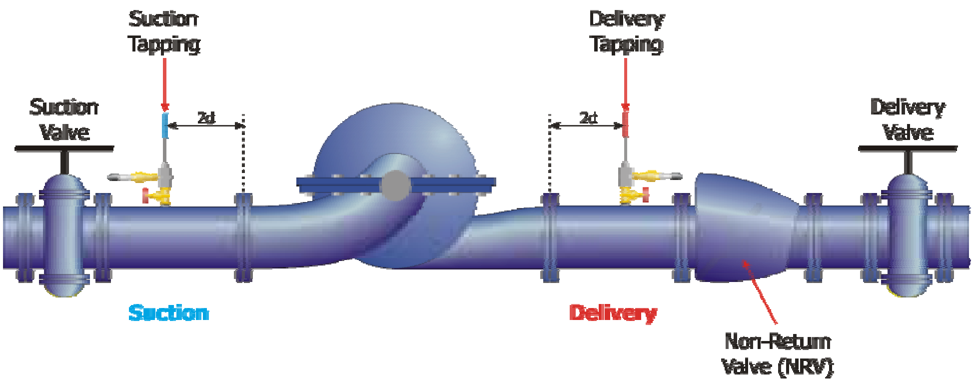

Figure 5: ***Typical Tapping Arrangement***

2.5 Accuracy of the method

The accuracy with which the efficiency of a pump can be measured by this method is determined by the accuracy of the differential pressure and differential temperature measurements. These are affected by the limitations of the measuring equipment and by the measuring conditions at the inlet and outlet sections of the pump. Intuitively, most people focus on the accuracy of the measurement of the differential temperature. The accuracy of the method increases with the differential head. The ISO standard states that the method can only be used for pump total heads in excess of 100 metres.

AEMS state that is has developed the system so that it can be used when differential heads are as low as 10 metres. The temperature probes do not measure absolute temperature accurately but are calibrated in pairs to read the differential temperature accurately to one milli-Kelvin (one thousandths of a degree Celsius).

As well as taking test point measurements as accurately as possible, the system utilises multiple sampling to produce an averaged reading (typically at one second intervals for ten seconds) and then take 8 or more readings at 15 to 30 second intervals. This averaging of multiple readings is used to smooth out the temperature differential fluctuations occurring and average the instrument variability.

Direct measurement of the inefficiency of the pump results in a greater accuracy of the calculated efficiency. For example with a pump operating at 80% efficiency (20% inefficiency), a 4% measurement inaccuracy of the inefficiency measurement results in a 1% efficiency inaccuracy.

2.6 Flowmeter calibration

Determination of the flow requires accurate measurement of shaft power input to the pump. This can be done either directly by measurement of shaft speed and torque or indirectly by subtracting various electrical and mechanical losses from the measured electrical power input to the driving motor.

The Yatesmeter system employs the indirect method. On medium voltage systems power monitoring equipment is attached to the starter panel and a data lead run from the power monitor to the Yatesmeter. On high voltage systems either the station instrumentation is used and the power reading entered manually or a monitor is attached in series with the installed metering equipment and a data lead run to the Yatesmeter.

The method to ascertain the electrical and mechanical losses of the motor drive is proprietary intellectual property retained by AEMS. Calculations of losses in motors running at both asynchronous speed and controlled by rotor current control are based on empirical results from extensive testing. This is a potential source of significant error.

The results from the work in some cases indicated very good agreement between the installed flow meter and the test result and in other cases considerable and consistent disagreement.

2.7 Station operation optimisation

As well as basic pump testing AEMS also undertakes pump station system monitoring analysis. This is done by either installing Yatesmeter testing equipment on all pumps in the station for a period of time, typically one week, or, as in Melbourne Water's case, by analysis of data from the existing Melbourne Water SCADA system.

System monitoring analysis compares the actual combined station pumping efficiency or pumping cost to that which could be achieved if the optimum combination of pumps and operating speeds were used.

The three sewer pump stations that were tested are generally required to operate in a follow the flow mode where the pumping rate matches the inflow rate.

Scheduling of pump operations and pump start and stop transition points when flows are increasing or decreasing can significantly affect the station efficiency. This is because the variable speed pumps used to match the inflow rate run more efficiently at higher flows. If the pump start and stop transition points can be managed to enable the variable speed pumps to mostly run at higher speeds, and the more efficient fixed speed pumps to be run instead of variable speed pumps, then the combined station efficiency will be improved.

2.8 Testing undertaken

Testing was done on 23 of the 28 pumps available. Some of the pumps were unavailable at the time due to maintenance works (refer to Table 1).

Table 1: ***Pumps tested during the study***

Station	**Type**	**Number of Pumps**	**Duty**	**Number Tested**
Brooklyn	Sewerage	8	2200 l/s @ 21.7m	8
Hoppers Crossing	Sewerage	8	5900 l/s @ 34.3m	7
Eastern Treatment Plant Influent	Sewerage	8	3400 l/s @ 13.1m	5
Yering Gorge	Raw Water	4	2890 l/s @ 110m	3

2.9 Testing practicalities

The actual testing of the pumps highlighted a number of practical aspects and limitations, which were:

Test tapping points

Tapping points consisting of a ½ inch (or larger) gate valve approximately 2 diameters each side of the pump are required. Most of Melbourne Water's pumps have existing instrument tapping arms that might have been used but most proved to be either too close or within only one of the discharge volutes. New tapping points at suitable locations were installed on 12 of the 28 pumps.

Power meter installation

In all cases installation and daily relocation of power monitors had to be undertaken by a qualified High Voltage certificated electrician.

Closing of delivery valve

The testing required the throttling of the delivery valve to create the different head and flow conditions required to produce the test points on the characteristic curves. At two stations this required a technician to modify the pump PLC control system inputs so that it did not automatically shutdown the pump.

Ragging of probes

On all the sewerage pumps tested continuous vigilance was required to detect spurious results caused by ragging or fouling of the probes. Ragging is usually indicated by a sudden change in measured differential temperature. Frequent cleaning of the probes was required.

Stability of pump operation

The instability of the pump increases the further away from the best efficiency point (BEP) it is operating. Also the more a pump is worn and inefficient the greater the instability. Consequently the measured parameters become unstable and difficult to measure.

Water temperature influences

It was noted that varying water temperatures had a small effect on the differential temperature measurement and hence the calculated efficiency. The magnitude of the effect was dependant on the rate of temperature change.

Operating head influences

It was noted that the greater the operating head the more stable the readings. The Yering Gorge Pumping Station pumps relatively clean water at a high head. It was observed that test readings were very stable. As a result the testing could be done relatively quickly.

Testing skills

The testing operation requires an experienced and skilled operator to operate the system and to recognise when fouling of the probes occurs and any spurious or inconsistent results that need to be retested.

2.10 Testing results

Preliminary results have highlighted:

- Possible inaccuracies of the installed flow meters. In some cases very good agreement was shown between the installed flow meter and the test result and in other case considerable and consistent disagreement.

- A more detailed examination of the final results may result in rectification works or further work to validate the results. At the Yering Gorge Pump Station it appears that the flow meter errors have resulted in the pump efficiency calculated from the SCADA data being significantly incorrect.

- The efficiency of individual pumps at each of stations varies considerably. Comparison of these results with the maintenance and overhaul history of the pumps and with the SCADA data will be done to see if there is any correlation. If no correlation is found further more critical examination of all aspects of the testing will be required.

- The most inefficient pumps have been identified for overhaul and the potential energy and cost savings to be achieved can now be calculated. In one case, the planned overhaul of a pump was halted after it was revealed to be one of the most efficient pumps in the station.

- Further work as to how the outcomes of the study can be incorporated in to Melbourne Water's existing pump maintenance program is required to ensure the greatest benefits are achieved.

3.0 CONCLUSIONS

Pumping accounts for at least 50% of power consumed by the Victorian Water Industry and more than 60% of Melbourne Water's power consumption. This is both a large expense to the industry as well as being a significant source of greenhouse pollution for the State of Victoria.

Initiatives that can increase the efficiency of pumping stations therefore can have a significant impact on operating costs as well as environmental benefits.

When fully implemented the outcomes from the study are expected to yield in the order of 2% to 4% energy savings, which equates to approximately 3,470 to 6,940 MWh with a commensurate cost saving of $109,000 to $218,000 per annum. This also results in a reduction in greenhouse pollution of approximately 2,500 to 5,000 tonnes per annum or the equivalent to removing 575 to 1,150 average cars from Victorian roads each year.

If the learnings from this study are then taken up across the Victorian Water Industry and lead to a 4% gain in pump efficiency then it is estimated that power cost savings of up to $ 1 million per annum could be realised. This would also result in a significant reduction in greenhouse pollution of up to 23,000 tonnes per annum or the equivalent to removing 5,350 average cars from Victorian roads each year.