Maximizing Membrane Water Treatment Plant Performance

Nadine Barnes and Marc Larson

Miramar, located in southeast Florida, is experiencing significant population growth. To provide a high quality drinking water to its expanding population, the city contracted with Montgomery Watson Americas to design and construct a state-of-the-art membrane softening water treatment plant. Through Montgomery Watson the city contracted JMM Operational Services, Inc., to provide warranty startup services for an initial six-month period. Major components of JMM's scope of services included the development and implementation of an operations and maintenance optimization program. The comprehensive program included:

- Energy Management and Conservation
- Chemical Conservation
- Staff Training and Utilization
- Computerized Maintenance Management System (CMMS)

Because of various construction delays, the facility did not begin water production until three months into the operations contract. Although there was minimal operation time in which to implement the optimization strategies, a baseline program was developed for future application. The purpose of this article is to illustrate the basic concepts for any facility optimization plan and outline the highlights for Miramar's West Membrane Water Treatment Facility project.

Energy Management and Conservation

Because of the rising cost of power and the high energy requirements of membrane treatment, a power conservation plan is an excellent way to reduce operating costs. To develop such a plan, a review of the following is required:

- Utility Rate Structures
- Curtailment Programs
- Current Usage (demand and total KWH)
- Facility Operating Requirements

Utility Rate Structures: Researching the power company's rate structures with the account's representative identifies potential schedules at lower electrical costs. Several options are normally available, such as peak shaving or curtailment programs to reduce the power company's billing demand charges during peak cycles.

After identifying available options, a monitoring plan for all power intensive treatment processes is developed to determine amperage draw and hours of operation per month. Graphing these parameters will illustrate demand trends. By comparing the peaks to the power company's peak demand cycles, a determination of the optimum times for energy cost reduction are evident. The operations plan is modified to correspond with the lower rate cycles while maintaining production levels.

Other possible areas of investigation should include the use of auxiliary power supply during peak demand cycles and reduction of plant lighting and air conditioning requirements. Charting actual power consumption versus treated water produced is a method to identify any existing area of improvement and benchmark future use.

Curtailment Programs: A facility equipped with emergency generators may be able to contract with its utility company for curtailments or interruptible service riders. These riders are an additional contract agreement with the power company to drop or "shed" load from the facility demand by engaging the emergency generators for power requirements. A contract term of three years is typical. Considerable savings can be achieved if the generator operating costs and production rates are adequately matched. Conversely, significant cost penalties will be applied if the facility is unable to meet the contractual terms.

Facility Operating Requirements: A strong operating strategy must be developed for the implementation of an energy conservation plan. Elements of the strategy should include modification of time of use of power-intensive process components, such as filter backwash, membrane water treatment, high service distribution pumping, raw water pumping, etc. Operations management should review the current operational modes from a cost-benefits analysis perspective to evaluate the success of a modified operations strategy.

Current Usage (demand and total KWH): Once a baseline range for energy demand and total kilowatt usage have been determined, operators must monitor daily usage and forecast production rates versus demand and billing charges. This trend analysis enables the operator to determine positive or negative changes in the energy conservation plan.

Chemical Conservation Plan

A chemical conservation program is an excellent way to realize a tremendous savings in production cost. Although requiring an initial amount of time and diligence on the part of the operations staff, future benefits are well worth the effort. To begin the development of a chemical conservation plan, the following operations elements should be reviewed:

- Chemical Dosages
- Bench Testing
- Pump Calibration
- Trending Analysis
- Cooperative Agreements

Chemical Dosages: Determination of the optimum chemical dosage to meet regulatory requirements is the primary goal of this task. New facility dosage rates are developed during the design phase and can be applied during startup scenarios. If time permits, stoichiometric calculations and bench testing are preferred methods for determining chemical dosage amounts. The focus is to determine *which* chemicals at *what* range provide the *best* performance. Once a dosage range is established, the product results qualify the exercise findings. The operator must maintain adequate operational data for continual improvement in the dosage rates. Comparison through bench tests of alternate chemical products or different grades of the same chemical is another means of costs savings.

Pump Calibration: Determination of the *actual* chemical feed rates is required to optimize actual feed dosage rates. We recommend that this exercise be completed on an annual basis and/or following major maintenance of the equipment component. Drawdown tests using calibration columns on the feed pumps should be performed on a routine basis. Pump curves illustrate pump output rates versus chemical feed rates. The curves are posted for operators to determine actual chemical dosage rates. As an ongoing process, this will ensure that feed rates remain at optimal levels and that long term savings on chemical costs are realized.

Cooperative Agreements: Cooperative agreements among surrounding facilities and/or municipal agencies for purchase of chemicals in higher quantities can result in lower unit costs.

Trending Analysis: Trending of the chemical usage and comparison with the amount of water treated will determine a constant chemical feed rate for benchmarking these data with the finished water analysis. Benchmarking these data with finished water quality will assist in the definition of other modifications to the chemical dosages.

Staff Training and Utilization

Proper staffing levels for a facility are based on the functionality of each position. Considerations must include customer service and production needs, maintenance, and sampling requirements. With proper staffing, a reduction in overtime and associated labor costs can be achieved. Methods for accomplishing this goal include:

- Operator Training
- Cross Training
- Certification
- Shift Utilization

Operator Training: A managed operator training program, whether in-house or from outside sources, is mandatory for completion of an optimization plan. A well-trained staff member is a productive and efficient worker seeking new ways to complete a task in a more cost-effective manner. Cross training of staff is an effective way to optimize available staff time while reducing overtime. Cross training also gives an employee a greater knowledge of the entire treatment process.

Shift Utilization: Economies are achieved by modifications to the shift schedule through operation during off-peak energy periods, performing maintenance during low production needs periods, and operating with swing shift concepts.

Computerized Maintenance Management Systems

Facility maintenance is often overlooked as an area for optimization. With a well-designed and implemented maintenance program, minimized maintenance costs and equipment down time will be achieved. A balanced program will include:

- Predictive Maintenance Audits
- Computerized Maintenance Management Systems
- Equipment Numbering
- Work Order Request
- Scheduled Preventive Maintenance Work Order
- Reporting
- Cost analysis
- Resource Allocation
- Inventory Control

Predictive Maintenance Audits: A maintenance audit by a reputable maintenance audit contractor for thermographic, vibration, and oil analyses on all equipment provides baseline documentation of equipment condition for future benchmarking activities. An annual recheck of these parameters allows prediction of equipment failure and reduction of repairs and equipment down time. Payback is easily realized through cost savings from equipment repair, associated labor, and/or downtime.

Computerized Maintenance Management Systems: A typical CMMS program identifies all plant equipment (which allows for easy tracking of the preventive maintenance of the equipment), repair costs, downtime, equipment and parts inventories, and several other parameters. A manager can plan inside or outside resources to complete preventive maintenance tasks on the equipment in a timely manner. Corrective maintenance events, tracked according to equipment number, provide additional information for tracking reoccurring failure of specific components. Established inventory levels of spare parts, lubricants, and equipment minimize the daily activity of developing a bill of materials for each maintenance event. Report features document employee productivity levels, costs per maintenance event, type of event, and data for future benchmarking comparisons.

Summary of Project Results

Energy Management: JMM developed a monitoring plan for major equipment to document the amperage draw of each equipment component. Additionally, the effect of maintenance activities on the equipment components and their respective amperage draw is documented and utilized as one of the criteria for monitoring the effectiveness of the facility maintenance. The facility and wellfield power usage were tracked closely and compared to the power company's demand cycles to determine if the power load can be redistributed to off-peak hours. Florida Power and Light's curtailment program was investigated but was unavailable at that time. We assessed large non-essential power uses, such as excess lighting and overuse of air conditioning.

In accordance with the DEP rule mandating four hours per month of auxiliary power equipment operation, the emergency generator is operated during the highest peak demand cycle to alleviate the cost of operation.

The operating cost for air conditioning and lighting was evaluated to determine the minimal safe amount of lighting and air conditioning use. After evaluation, these changes were placed into effect to lower the operating cost for the facility.

Chemical Conservation: We determined the optimum dosages of treatment chemicals by testing the feed, product water, and concentrate streams to define minimal effective doses. Additionally, we worked closely with the manufacturer's representatives for the membrane elements, odor control towers, and scale inhibitor chemical systems to obtain their input and recommendations.

A calibration schedule for the plant instrumentation and chemical feed systems was developed to ensure correct dosing of the chemicals. The calibration procedure utilizes the calibration cylinders installed on each chemical feed pump inlet line from the day tank, and drawdown tests performed on a weekly basis to determine actual feed rates.

Miramar entered into a cooperative agreement with surrounding cities to purchase bulk treatment chemicals in higher quantities and lower cost. Although bulk purchasing is a means of cost reductions, loss of reactive strength over time must be monitored closely. At Miramar, the main concern was sodium hypochlorite, a disinfection chemical, which tends to lose reactive strength. Only a minimal quantity of such a product should be maintained in stock.

Bench testing of the product water continues to determine the optimal dosage of corrosion inhibitor to the distribution system. The results of these tests will indicate the correct utilization dosage to prevent damage to the distribution system and reduce lead and copper in consumers' homes.

Staff Training and Utilization: The plant is normally operated only eight hours per day. We recommended plant operation during the lower power cost cycle, the overnight hours, with the remainder of the staff on-site during the day for receiving deliveries, maintenance, instrumentation calibration, and laboratory sampling and testing. During JMM's tenure, one operator was assigned to an overlapping schedule to increase production, while eliminating the need for overtime.

Cross training of the instrumentation technician as an operator, after the individual obtains a water treatment plant operator's license, gives the staff additional flexibility.

Maintenance Management Systems: JMM contracted with a maintenance audit contractor to conduct thermographic, vibration, and oil analysis on major plant equipment to establish baseline conditions. As the facility equipment matures, this information will be valuable in determining the effectiveness of the plant maintenance program. During the contractor's evaluation, several loose connections were discovered in the motor control centers and breaker boxes. The maintenance audit also revealed several equipment items operating inefficiently or with high vibration problems. The problems were rectified with minor repairs saving down time and higher repair costs had the equipment been operated to failure status. We recommended a maintenance audit be conducted on an annual basis as part of the facility maintenance schedule.

We installed a computerized maintenance management program to include all plant equipment designated by a unique equipment number in a database program. This system allows for easy record keeping and retrieval of archived information. The program contains all maintenance and calibration activities recommended by the manufacturers for each item of equipment, and generates maintenance work orders automatically for scheduled preventive maintenance events.

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Public Contract Operations: An Alternative to Privatization

Marc J. Rogoff

Privatization of public utility operations—it is the focus of recent professional conferences within the last few years, heard from the lips of aspiring candidates for public office, and even highlighted in features found on CNN news and stories published in *USA Today*.

Privatization means different things to different players in the current public utility scene in Florida. Hallway gossip heard around the water coolers in local government suggests that most public employees are quite fearful that privatization will wipe away their public agency jobs. Politicians see privatization as a way of balancing city and county budgets by using more efficient private companies in an era where there is strong taxpayer resistance to higher property taxes and utility rates. Professional utility managers see privatization as a way to benchmark their operations and enable them to reinvent government by infusing private business techniques into local government.

Typically, calls for privatization come with the election of a new board or council whose new members are convinced that private business can run public utility systems more efficiently and at a lower cost to the ratepayers. Calls for privatization can also come with an unsolicited proposal by private enterprise to take over public utility operations. There has even been a suggestion by the mayor of Indianapolis that the "yellow pages test" should be applied to most local government operations. That is, if one can find a vendor in the local telephone pages providing a similar service, it should be bid and turned over to private business. However, in my opinion, the jury is still out as to whether private enterprise can handle all of the traditional functions of government more efficiently and at lower cost.

While not discounting that there are instances where privatization can provide a clear match for the needs of local government, an approach called "Public Contract Operations" (PCO), increasingly appears to be a middle ground for political decision-makers unwilling to surrender leadership to the private sector, while at the same time unwilling to allow public agencies to continue business as usual. The PCO approach is one that empowers local government employees by providing critical performance incentives needed for overall success, while at the same time providing for essential plant reinvestment. A recent case study illustrates the elements of the PCO approach.

The CMUD Story

Early in 1995, a firm specializing in private contract operations made an unsolicited offer to the Charlotte, North Carolina city council to purchase and operate a 40-MGD wastewater treatment plant. While the city rejected the unsolicited offer, the council instructed the Charlotte-Mecklenburg County Utility Department (CMUD) to proceed with a plan to allow contract operations in its seven treatment plant system.

Impetus for this plan had nothing to do with inefficiencies and high costs. CMUD facilities have an enviable track record of reliable service, regulatory compliance, avoidance of fines, and providing water and wastewater rates among the lowest on the Atlantic coast. Nevertheless, in 1996 the city council issued a request for proposals (RFP) for contract operations and maintenance services for two of its seven treatment plants: the 15-MGD Irwin Creek Wastewater Treatment Plant and the 20-MGD Vest Water Treatment Plant. The RFP established stringent requirements for the winning bidder by requiring that operating efficiencies be increased while maintaining all existing customer benefits. Fair treatment of staff also remained a priority.

CMUD Employee's Bid

The challenge for the CMUD response team was to meet all of the RFP requirements by making the most of privatization techniques, but without surrendering leadership to the private sector. Prior to the release of the RFP, CMUD staff obtained approval from the city council to compete with private operators for operation of the two facilities. CMUD staff, which had formed the entity "CMUD Contract Operations" (later to be called CM-ConOp), hired HDR Engineering, Inc., to assist with the bid preparation. So one group of CMUD employees was responsible for preparing the RFP and evaluating responses, while a second group was preparing a response in competition with private operators.

In April 1996 the CM-ConOp submitted bids to operate the plants under the terms and conditions stated in the RFP. The city also received bids from six private companies and/or joint ventures to operate these facilities. Analysis of the price proposals contained in the bids indicated that the CM-ConOp combined bid was the lowest cost bid with a first year proposed annual fee that was over $350,000 lower than the nearest competitor.

Public Contract Operation

In helping CM-ConOp develop, submit, and win the bid, HDR developed an entirely new approach to providing local government utility services, one that we term "Public Contract Operations," or PCO for short. PCO involves the delivery of services by a public agency to a city or county government through the development and execution of a public "contract." The contract is actually a memorandum of understanding agreed to jointly by the local government and the governmental operating agency. The memorandum of understanding contained all the terms and conditions that the local government would include in a service contract with a private company. In the CMUD case, it was similar to the draft services agreement included by the city in the RFP.

Key elements of the CM-ConOp bid include the following:

- *Provision of Cost and performance Guarantees*—CM-ConOp agreed to provide the same level of performance as would have been required by the city and the private contractors. The costs to the city for the delivery of these services by CM-ConOp will be fixed for the three-year contract term, as per the terms and condition required in the RFP and included in the memorandum of understanding. A portion of any savings achieved by CM-ConOp in operating the plants at a cost that is lower than the annual fee will be set aside to "guarantee" the coverage of cost overruns in the remaining years of the contract.
- *Reliance on Plant Automation*—Similar to private contract operators, CM-ConOp chose to minimize staffing at the plants by increasing the use of automation. Operators will be provided with state-of-the-art automation systems to enable remote monitoring and/or control of pumps, valves, blowers and similar equipment.
- *Development of New Job Classifications and Responsibilities*—To operate the plants under contract, CM-ConOp chose to develop a new classification of plant operator: a public contract operator. All operators will be fully cross-trained and will perform maintenance as well as operational responsibilities. Operators will be empowered to make on-the-spot decisions to enhance plant performance and minimize operational costs.
- *Institution of Performance Incentives*—The CM-ConOp operators will receive a direct share of any savings that result from the actual plant operating cost being less than the annual fee.
- *Plant Reinvestment*—A portion of the CM-ConOp fee will be used to pay for plant capital efficiency improvements, which will be made outside of the capital improvements plant process traditionally used by CMUD to finance capital projects.

What Can Be Learned by Florida Utility System Operators

As illustrated in the CMUD case, service delivery through PCO enables communities to receive the best elements of both the private sector and the public sector approaches. PCO melds the performance incentives and automation investments of the private sector with the public goals and policies of the public sector.

PCO, unlike its private counterpart, allows for public policies and service objectives to continue to guide the overall operation of water and wastewater utility systems. The plants and their employees continue as public sector employees. The plant management and staff are under direct control of city or county government and are generally long-standing residents of the local community. Important from our viewpoint, public goods and policies are not superseded by incentives to maximize short-term profits. Plant cost savings are fully reinvested back into the local community.

The favorable outcome for CM-ConOp is an example of taking on the privatization challenge and giving the public the most effective environmental health protection at the best possible cost. Our opinion is that the CM-ConOp approach is likely to alter the way communities across Florida provide municipal services far into the future.

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Waste Strategies

Leonardo D'Angelo

Wasting of sludge is the single most important operation for process control stability of an activated sludge treatment system. It removes a concentrated amount of sludge from one tank, usually a clarifier, to the digester. Once in the digester, the sludge is concentrated by decanting clear liquid back to the head works.

There are several techniques for determining sludge waste rates, ranging from eyesight to complex mathematical formulas.

Eyesight is one of the most important senses operators possess. A thick, dark brown foam in an aerator, for instance, or bulking sludge rising to the surface in either the aerator or clarifier, may indicate an overloaded condition and a need for wasting. On the other hand, a crisp white foam in the aerator or straggler floc in the clarifier reveals under loading and a need to stop wasting.

A "tea" color in the effluent can indicate a need for wasting, while a milky white appearance may call for reduction in wasting.

Some of the formulas for determining target waste rate are common wastewater formulas reversed. One of the most commonly used formulas is for sludge retention time (SRT):

SRT = aeration solids/waste

or, Waste = aeration solids /SRT **[Equation 1]**

Another is the relationship for food to microorganism (F/M) ratio:

F/M = Influent CBOD lb/Aeration MLVSS lb **[Equation 2]**

And still another is the equation for sludge age:

S.A. = (Aeration MLSS X Aeration capacity MGD)/(Influent TSS X Influent Flow) **[Equation 3]**

If the plant has a computer, these formulas can be entered into a spread sheet, which can be programmed to solve for target waste rates by averaging the influent CBOD and TSS, and the aerator and waste MLSS and pounds on a daily basis. Compare all formulas, review and average all the waste formulas and then compare the effluent pH, turbidity, TSS, and/or CBOD against the waste rates. Determine which formula works best for the plant.

The following examples show applications of sludge wasting control to process control:

Example 1

Let's take an example where a plant runs well when the sludge retention time averages around 16 days, the aeration tank MLSS is 2200 mg/l, the influent TSS is 150 mg/l, and the waste MLSS is 12,800 mg/l. The flow into the treatment system is 0.500 MGD and the aeration tank has a capacity of 0.945 MGD. The MLVSS in the aeration tank is 1760 mg/l and the influent CBOD is 150 mg/l.

The solids in the aeration tank, in terms of pounds can be calculated by concentration X 8.34 X flow rate:

2200 mg/l X 8.34 X 0.945 MGD = 17,339 lb/day

Using Equation 1, the sludge needed to be wasted is:

(17339 lb/day)/(16 days) = 1084 lb/day

Or, in terms of sludge flow rate:

(1084 lb/day)/((12800 mg/l) X 8.34) = 0.01 MGD

Example 2

Assume that the aeration tank MLSS from Example 1 is 2600 mg/l rather than the desired 2200 mg/l. The difference of 400 mg/l is equal to (400 mg/l) X 8.34 X 0.945 MGD = 3152 lb/day, which is equal to (3152 lb/day)/(12800 mg/l X 8.34) = 0.030 MGD of waste sludge needed to adjust the aeration tank MLSS to the desired level.

Example 3

Assume that the plant in Examples 1 and 2, which runs well in the summer with the figures given, experiences an increase in flow in the winter to 0.850 MGD and an increase in CBOD to 180 mg/l.

From Equation 2, the desired F/M ratio is (150 mg/l X 8.34 X 0.500 MGD)/(1760 mg/l X 8.34 X 0.945 MGD) = 0.05.

The new F/M ratio is (180 mg/l X 8.34 X 0.850 MGD)/(1760 mg/l X 8.34 X 0.945 MGD) = 0.09.

Since Aeration MLVSS lb = Influent CBOD lb/F/M [from Equation 2]:

Desired aeration MLVSS lb = (180 mg/l X 8.34 X 0.850 MGD)/.05 = 25550 lb.

In terms of milligrams per liter, the desired aeration MLVSS is 25550 lb/(0.945 MGD X 8.34) = 3285 mg/l.

Assuming 80 percent volatility, desired MLSS is 3885 mg/l.

Caution needs to be exercised to maintain adequate dissolved oxygen—a larger biological mass will require a higher oxygen rate (Aeration settings were discussed in the November 1995 issue of the *Florida Water Resources Journal*).

The F/M ratio in this example shows that even though the SRT of 16 is the same, the influent characteristics have changed. Therefore, the influent needs to be taken into consideration as a reliable source of information for process control determination.

Example 4

The F/M ratio is not the best way to run the plant because the CBOD test takes five days for incubation, which is too long to wait when flows are close to plant capacity. Still, the F/M ratio is a good tool to double-check process control.

Sludge Age is not as accurate as the F/M ratio, but it is quick because of the use of the influent total suspended solids (TSS) and aerator MLSS. Since TSS and CBOD to the plant change dramatically with season, sludge age can be used first and later checked against the F/M ratio.

From Equation 3, the sludge age for the example plant during the summer is:

S.A. = (2200 mg/l X 0.945 MGD X 8.34)/(150 mg/l X 0.500 MGD X 8.34) = 28 days.

During the winter:

S.A. = (2200 mg/l X 0.945 MGD X 8.34)/(180 mg/l X 0.85 MGD X 8.34) = 14 days.

The desired pounds of MLSS under aeration = Desired S.A. X Influent TSS lb [from equation 3]

= 28 days X (180 mg/l X 0.850 MGD X 8.34) = 35,728 lb.

The concentration of MLSS is then:

MLSS = 35,728 lb/8.34/0.945 MGD = 4533 mg/l.

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