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WASTEWATER RECYCLING AND HEAT RECLAMATION AT THE RED LION CENTRAL LAUNDRY, PORTLAND, OREGON

A Project of the Hospitality Industry Forum on Energy Conservation, Energy Savers Partnerships Program, U.S. DOE

T.F. Garlick
M.A. Halverson
M.R. Ledbetter (Program Manager)

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Pacific Northwest National Laboratory
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DISCLAIMER

Summary

This report discusses water, energy, and cost savings that can be achieved in a commercial laundry through the use of a wastewater recycling and heat recovery system. Cost savings are achieved through reductions in water use, reduction in sewage charges (typically based on water use), reductions in water heating energy, and potential reductions in water treatment chemicals (because the recycled water has already been treated with soaps and conditioners.

A recovery system saves water by recycling wash water that would normally be dumped into the city sewage system. Recycling the wash water produces considerable energy savings because the recycled water has a higher temperature than fresh water. As a result, a hot water heater consumes less energy to heat the recycled water.

The demonstration project discussed in this report was based in a large commercial laundry in Portland, Oregon. The laundry serves a large hotel/motel chain and processes an average of 25,000 pounds of laundry per day. A wastewater recovery system using a membrane micro-filtration unit (MFU) was installed in the laundry in September 1995. Time series data of the water and energy consumption of the laundry were taken before and after installation of the MFU. Energy savings were measured by performing a thermal energy balance around the washing machines. Water savings were calculated by metering volumetric flow rates.

After a period of approximately five months, the MFU has achieved results of 52 percent savings in water consumption and 44 percent savings in energy to heat water. This five-month period represents a learning curve during which several small technical improvements were made to the MFU and laundry staff adjusted laundry operations to maximize the benefits of the MFU.

This report provides an economic analysis of the impact of capital investment, daily consumption, and local utility rates on the payback period. In this case study, performance measurements indicate monthly savings of approximately $3,400 on water, sewage, and natural gas. This would result in a simple payback of 4.1 years. However, it was also found that the MFU was oversized by 65 percent, making the capital investment much larger than was needed. Had the unit been more conservatively sized, the payback for the project would be 2.7 years. The payback for similar installations in other parts of the country would range from 1.2 to 2.7 years, depending on local utility rates.

Acknowledgments

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I. Introduction

The laundry wastewater recycling and heat recovery system described in this report is the first demonstration project of the Hospitality Forum on Energy Conservation (HIFEC). HIFEC is an industry consortium organized by the U.S. Department of Energy (DOE) to help the Technology Introduction Partnerships (TIPs) program speed market adoption of advanced, energy-efficient technologies. Through meetings and discussions with DOE, HIFEC and its members identify technologies and programs of high interest that are in need of DOE assistance. HIFEC's members include Holiday Inn, ITT Sheraton, La Quinta, Promus, Red Lion Hotels, and the American Hotel and Motel Association. Together, they represent about 30 percent of the hotel rooms in the United States.

In a Spring 1995 meeting, HIFEC identified this project as a top priority, and Red Lion Hotels volunteered to co-sponsor and host the project. DOE agreed to fund 50 percent of the capital cost of the project. DOE also agreed to pay to have its Pacific Northwest National Laboratory meter pre- and post-project energy and water use and prepare an evaluation report. Red Lion Hotels assumed all other costs for the project.

The primary goal of this project was to evaluate the water, energy, and cost savings resulting from installation of the wastewater recycling and heat recovery system. A secondary goal was to identify potential operational problems with the system. HIFEC also sought to generalize the results of this project for installation of the same technology in other commercial laundry facilities with varying capacities and utility rates.

A. The Project

The site selected for this study was the Red Lion Central Laundry located in Portland, Oregon. This laundry serves seven Red Lion facilities in the Portland metropolitan area. The laundry is housed in a 17,000 sq. ft. leased building and currently contains six commercial-sized washing machines of various sizes, five dryers, two ironers, two presses, and a steam tunnel. The laundry has a variable schedule, operating anywhere from 16 to 24 hours a day, 6 to 7 days a week and washing an average of 25,000 lbs per day.

The wastewater recycling and heat recovery system selected for this retrofit is a micro-filtration unit (MFU) designed and installed by Wastewater Resources, Inc. (WRI) of Scottsdale, Arizona. (The design has a patent pending.) The unit is designed to reduce water use and sewage discharge by recycling water the washing machines would normally dump to the city sewage system. Furthermore, because the recycled water has a higher temperature than fresh city water, the laundry's boiler (which heats water in a hot water storage tank via steam) was expected to consume less natural gas. The MFU also was expected to cut water treatment chemical costs due to recovery of treated water (e.g., soaps and conditioners that pass through the membrane filter), although chemical savings were not analyzed in the study.

B. Description of the Wastewater Recovery System

The MFU consists of three primary components plus auxiliary equipment. A mechanical shaker screen filters out large (>70 micron) solids. The second component is a back-washable fabric filter used as protection to prevent solids from fouling the membrane filters. This second-stage filter is important for extending the service life of the MFU and maintaining high-volume flow rates.

The third and final component is the actual MFU, where solids as small as 0.5 microns are removed. It consists of four large tubes (8 to 10 feet long, 6 to 8 inches in diameter) that are connected in parallel. (The unit has a modular design, allowing more tubes to be added if larger capacity is needed.) The membrane material is made of poly-cell foam and has the appearance of white fabric. The membrane is wound around a 1-inch pipe and placed inside the larger tube. Water filters through the membrane to the 1-inch pipe, where it is sent on for reuse.

The MFU differs from traditional filtration techniques because the flow is tangential (cross flow) to the surface of the membrane rather than perpendicular.[1] Tangential flow prevents rapid buildup on the membrane surface. Nevertheless, a computer control unit automatically backflushes the MFU every 60 seconds to remove any solid buildup on the membrane surface.

WRI rates the capacity of its MFU based on the flow of distilled water through the system. When recycled water runs through the system, capacity is reduced by about 20 percent due to fouling of the membrane. WRI typically "oversizes" its MFUs by 20 to 30 percent to account for this reduction in capacity.

Figure 1 illustrates the system and its integration into Red Lion's operation. Pre-installation estimates predicted that the water recovery system would supply 100 percent of the laundry's hot water demand, which staff at the Red Lion estimated to be 60 to 65 percent of the total water consumption. Figure 2 is a photograph of the system installed in the Red Lion Central Laundry.

C. The Technology

Because of increasing concern about water quality, national and local regulatory agencies are implementing more sewer discharge restrictions. This has caused sewage costs to skyrocket across the country. This fact, combined with the growing shortage of water, has led to an increased interest in wastewater recovery technologies. Several water purification techniques exist, such as reverse osmosis filtration, membranes, and bio reactors.

It was beyond the scope of this project to investigate all possible technologies for recycling water. The scope was limited to a single technology, membrane filtration, which is the basis for the MFU discussed in this report. Membrane filtration appears to be an attractive solution for large

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[1] Woener, D. L. Year. *Membrane Technology in Textile Operations*. Letter Report, Corporate Source Koch Membrane Systems, Inc., Wilmington, Massachusetts.

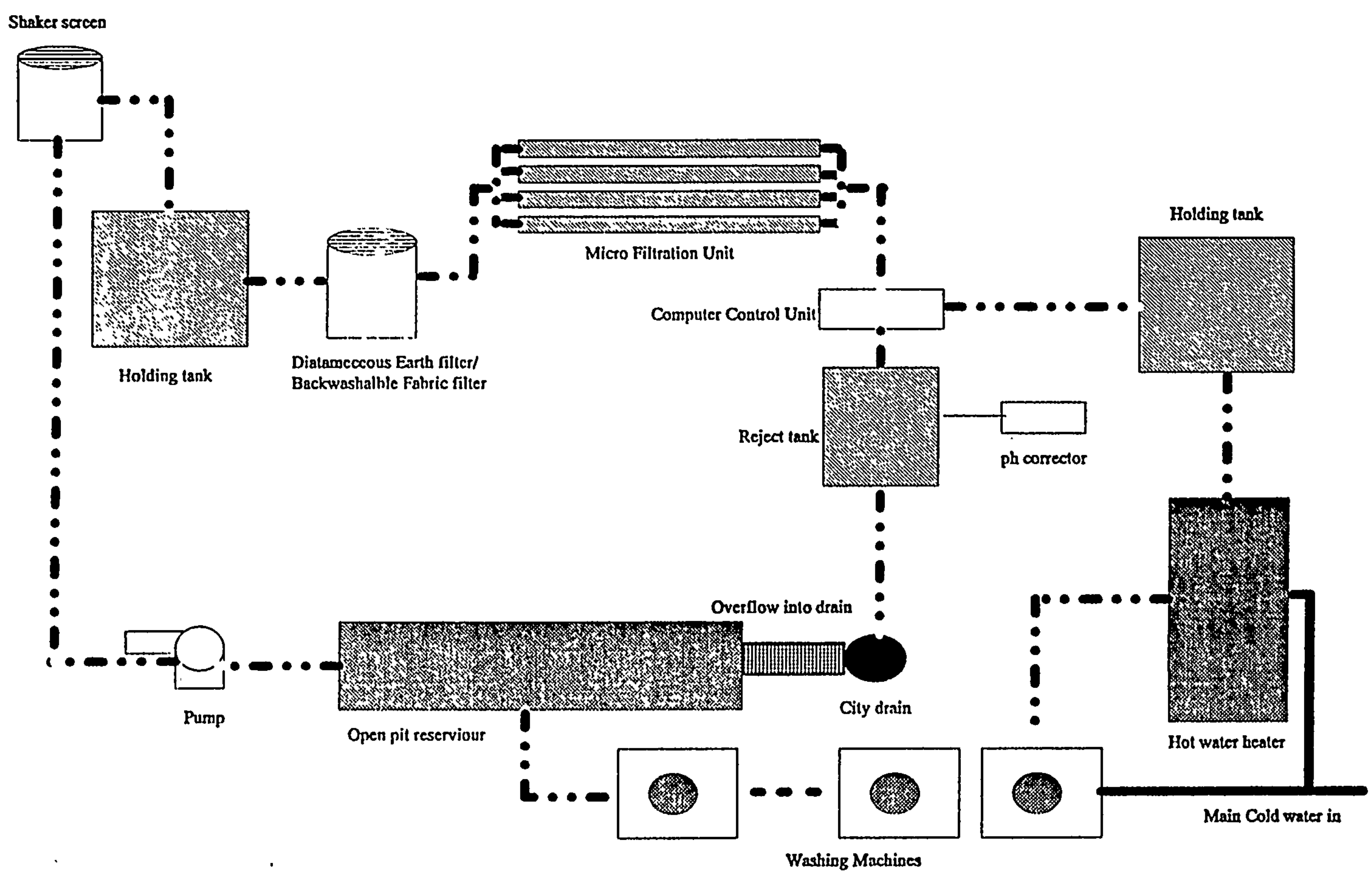


Figure 1. Water Reclamation System for Commercial Laundries

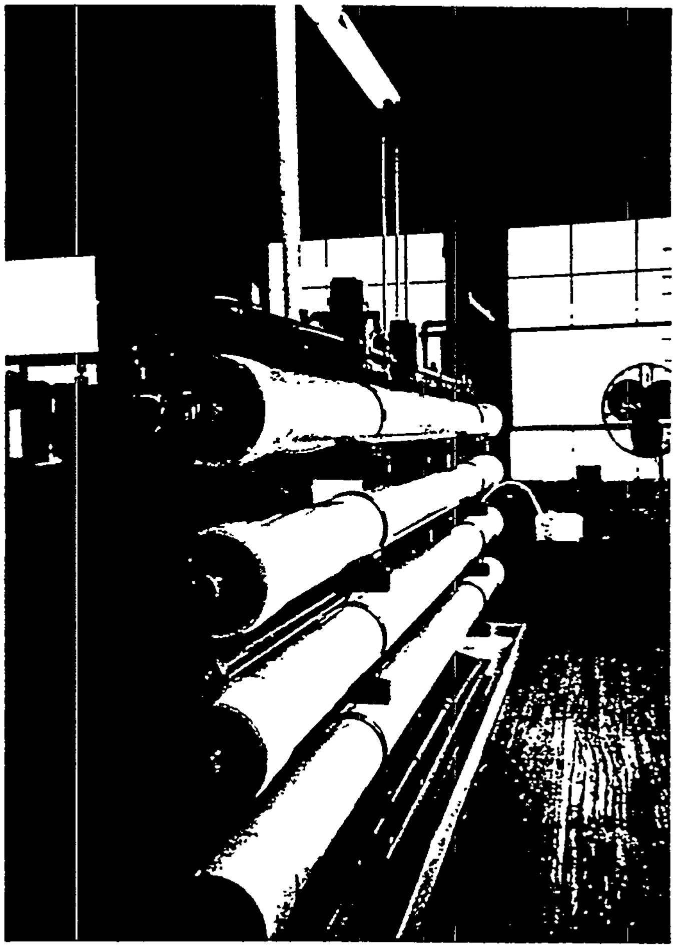


Figure 2. Photograph of Red Lion MFU

industrial processes, such as commercial laundries, because the technology meets the need for high flow rates at a low price. Historically, membrane filtration has been used in processing industries and has found applications in paint shops, dairies, sugar plants, etc. Although this technology has been available for some time, recent improvements in membrane materials and the current escalation of water and sewage costs have made it a cost-effective application in water recovery systems.

D. Disclaimer

Neither the U.S. Department of Energy nor the Pacific Northwest National Laboratory endorse the micro-filtration system manufacturered by Wastewater Resources, Inc. The vendor for the product investigated in this report was selected by Red Lion Hotels, and then agreed to by the U.S. Department of Energy and the Pacific Northwest National Laboratory. Persons interested in purchasing systems similar to the one that is the subject of this report are encouraged to investigate several potential vendors. Vendor and industry contact names appear in Appendix B of this report.

II. Approach/Plan

Because the goal of this project was to evaluate water recycling and heat recovery technology for not only the Portland case study but for other laundries as well, the following approach was adopted:

- Select a specific site and follow it from design of the system, to installation, to operation, to modification.
- Develop a detailed metering plan that enables accurate measurement of water and energy savings.
- Document installation difficulties, impacts on laundry operations, and limitations of the filter technology.
- Compare the test site to other laundry operations and other MFU installations.

A. Site Selection

As mentioned above, Red Lion Hotels offered to host the demonstration and selected their Portland Central Laundry as the test bed for this project. This particular laundry is a fair representation of central laundries within the hotel industry.

B. The Metering Plan

WRI designed its MFU to reduce water and sewage costs, save energy, and reduce chemical usage. In this study, water and energy consumption were measured prior to the retrofit to establish a baseline (pre-retrofit) and again following the retrofit (post-retrofit). Significant changes to the daily operation (other than those that were necessary for improvements to the MFU) were not permitted from the time pre-retrofit metering began to the end of the project. This minimized the chance that changes in energy and water use would occur other than those resulting from the MFU.

To ensure accurate measurements, metering instruments and with a data acquisition system were installed in the facility. The monitored points critical to the analysis were as follows (for a graphic depiction, see Figure A.1 in Appendix A):

- **Building Total Gas (M1)** - This was monitored using an electronic encoder on the central natural gas meter and recorded in cubic feet per 15 minutes.

- **Building Total Water (M2)** - This was monitored using an ultrasonic flowmeter and recorded in cubic feet per minute.

- **Hot Water Heater Intake Temperature (M3)** - The hot water heater gets its water from either the recycle water holding tank or the city mains. Both of these temperatures (degrees F) were monitored using resistive thermal devices (RTDs).

- **Hot Water Heater Output (M4)** - Flow (recorded in cubic feet per minute) and temperature (degrees F) were monitored using an ultrasonic flowmeter and an RTD.

- **Cold Water Output (M10)** - A second flow meter was added at the end of the project to verify water balance calculations. Measurements were recorded in cubic feet per minute.

- **Power Consumed by the MFU Pumps (M5)** - This was monitored using an electronic encoder on the utility electric meter. Measurements were recorded in kilowatt-hours per 15 minutes.

- **Steam Provided to the Washing Machines (M8)** - This was monitored using an Engineering Measurement Company (EMCO) vortex flowmeter. The amount of steam consumed by the washing machines varies with the temperature of the hot water supply. If the water coming into the washing machine is not hot enough, the washing machine uses additional steam to heat, or boost, the water to the threshold temperature.

The following operational data were also critical to the analysis of the system and were obtained with cooperation of the laundry staff:

- pounds of laundry processed on a daily basis
- composition of laundry (towels, sheets, uniforms) on a daily basis
- record of chemical usage on a monthly basis
- several months of utility bills before and after the retrofit
- notification of any significant deviation from normal operation (e.g. shutdowns, leaks, addition of equipment).

C. Documentation of Installation and Operational Difficulties

The MFU experienced several failures and difficulties during its installation. In addition, the facility experienced a number of operational modifications and interruptions during course of the study. Although some of these interruptions were unplanned (such as boiler failures), other modifications were required as a result of the MFU (such as an anti-backflow preventer for the hot water tank feed and a pH controller). Table E.1 in Appendix E provides a compilation of installation and operational difficulties.

D. Comparison to Other Facilities

During the study, communication was maintained with laundry technicians at the Boston Park Plaza Hotel and the Sheraton Plaza Hotel in San Francisco. Although membrane filtration can be found in other industries, these hotel laundries represented the closest examples to the Red Lion Portland project because they both have operating WRI MFUs. Contact with these hotels helped identify those problems that were unique to the Red Lion installation and problems that any commercial laundry considering an MFU might expect. The experience of these two laundries was very useful in evaluating this technology. (Appendix B lists industry contacts, including those familiar with the Boston and San Francisco installations.)

III. Considerations

It is very important to distinguish between system performance and component performance when attempting to analyze the overall performance of the MFU. Component performance addresses an isolated water recycling unit; whereas system performance addresses the entire dynamics of the laundry. Many considerations had to be taken into account when analyzing the performance of the system as a whole. These considerations are listed below, with a more in-depth description given in Appendix C:

1. Recycled water was used only for hot water applications.

2. This installation used a single drain rather than a split drain system.

3. The unit was shut off during heavily soiled loads to prevent fouling of the membrane.

4. There was some seasonal variation on the type of laundry processed.

5. Unexpected power outages occurred during the metering period.

6.. Laundry specialists routinely made subjective decisions about the best chemical formulas for specific types of laundry. This affected water consumption.

IV. Results

A. Data Verification

The instruments used in this study were tested in the laboratory prior to installation and then verified in the field after installation. Temperature sensors were verified using a hand-held unit that was later compared to a laboratory standard. Electric and natural gas consumption was measured using the utility meters. Meter readings were verified with billing data. In addition, natural gas savings were checked against energy to heat water, which was a completely separate measurement.

To verify water consumption data, the ultrasonic flow meter data was checked against the city water meter. Because these two meters are independent, a high level of confidence was expected. In addition, an independent check was made on May 30, 1996 by Panametrics field technician Ken Talbot. His results further validated the accuracy of the water consumption data. Finally, a second meter was installed on the cold water supply, providing yet another method for checking data accuracy (hot + cold = main). Table D.1 in Appendix D illustrates the results of instrument verification.

B. Pre-Retrofit Data

Although the baseline analysis was frequently interrupted by operational changes, laundry equipment failures and power outages, enough quality data was collected to establish a good basis for comparing improvement rendered by the WRI MFU. Table 1 illustrates a summary of the baseline analysis. Note that total natural gas consumption includes gas consumed by the boiler as well as gas consumed by the dryers. The primary load on the boiler is the hot water heater, which heats water for the washing process. This is where we expected to see savings. In Table 1, hot water energy is the energy used to heat the water for the washing machines. The washing machines also use a small amount of steam from the boiler to boost the final wash temperature when necessary. Although changes in steam consumption were not expected as a result of the MFU, it was important to monitor steam to account for all thermal energy consumed by the washers.

Table 1. Average Readings for Pre-retrofit Data (Sept, Oct, Nov 1995)

	Total Water Flow	Total Gas Consumption	Hot H_2O Energy	Steam Energy	Input Temperature	Hot Water Temperature
Per Hour	2900 gal/hr	3600 kbtu/hr	1250 kbtu/hr	251 kbtu/hr	55 ^{0}F	155 ^{0}F
Per Pound	2.46 gal/lb	2.91 kbtu/lb	1.12 kbtu/lb	0.29 kbtu/lb	55 ^{0}F	155 ^{0}F

C. Post-Retrofit Data

Several problems were encountered during installation and initial operation of the MFU that delayed its continuous operation of the MFU. Although some of the interruptions in operation were unavoidable, most of them represent the learning curve required to bring the unit online (see Table E.1 in Appendix E for a list of interruptions and modifications.

The primary problem was the failure of the diatomaceous earth pre-filters. This problem was remedied by replacing these filters with back-washable tube filters (using polypropylene fabric). The MFU came on line December 11, 1995. However, this was followed by a series of interruptions including a December 12 windstorm that knocked out power for more than 24 hours.

Because of these interruptions, the time periods used to analyze system performance were carefully chosen to reflect the fairest assessment of the technology and represent the most likely experience of any commercial/hotel laundry. Tables 2A and 2B below highlight average consumption for these periods of post-retrofit operation.

The January period was selected because the amount of hot water used in January was equal to that of the pre-retrofit period (about 50 percent of the total water used was hot). The remaining periods were selected because they each represent the steady state condition for that particular phase of the MFU learning curve. In the second period (3/29 to 4/9), the laundry had changed its consumption of hot water to less than 45 percent of the total, thus the increase in water consumption. The third period represents an increase of hot water consumption from 45 percent to 58 percent. The final period in June represents a series of changes and improvements, such as a larger hot water pump and sump pump replacement. For more complete data see Appendix F.

Table 2A. Post-retrofit Data (Time Normalized)

	Total Water Flow	*Total Gas Consumption*	*Hot H_2O Energy*	*Steam Energy*	*Input Temperature*	*Hot Water Temperature*
1/10 - 1/16	1763 gal/hr	2787 kbtu/hr	530 kbtu/hr*	316 kbtu/hr	97 ^{0}F	144 ^{0}F
3/29 - 4/9	1871 gal/hr	2800 kbtu/hr	748 kbtu/hr	430 kbtu/hr	100 ^{0}F	155 ^{0}F
4/22 - 4/28	1620 gal/hr	2990 kbtu/hr	945 kbtu/hr	300 kbtu/hr	95 ^{0}F	155 ^{0}F
6/2-6/30	1494 gal/hr	2690 kbtu/hr	761 kbtu/hr	** kbtu/hr	110 ^{0}F	154 ^{0}F

*A drop in hot H_2O energy resulted from a drop in hot water temperature settings. ** Steam metering equipment was removed 5/30/96.

Table 2B. Post-retrofit Data (Weight Normalized)

	Total Water Flow	*Total Gas Consumption*	*Hot H_2O Energy*	*Steam Energy*	*Input Temperature*	*Hot Water Temperature*
1/10 - 1/16	1.41 gal/lb	2.22 kbtu/lb	.42 kbtu/lb*	.25 kbtu/lb	97 ^{0}F	144 ^{0}F
3/29 - 4/9	1.33 gal/lb	1.99 kbtu/lb	.53 kbtu/lb	.3 kbtu/lb	100 ^{0}F	155 ^{0}F
4/22 - 4/28	1.2 gal/lb	2.22 kbtu/lb	.70 kbtu/lb	.23 kbtu/lb	95 ^{0}F	155 ^{0}F
6/2-6/30	1.1 gal/lb	2.00 kbtu/lb	.57 kbtu/lb	**	110 ^{0}F	157 ^{0}F

*A drop in H_2O energy resulted from a drop in hot water temperature settings ** Steam metering equipment was removed 5/30/96.

Although averaging measurements over a long period of time provides greater certainty of the results and is most useful for performance and cost analysis, a snap shot of a single day can also provide much valuable information. Figure A.2 in Appendix A provides such a snap shot, illustrating water consumption for two typical Tuesdays in December (December 5 [unit off] and December 19, 1995 [unit on]). Figure A.3 in Appendix A illustrates the difference in energy consumption for these same two days.

D. Comparison of Pre- and Post-Retrofit Data

The methodology used to analyze water and energy savings is described below:

1. Water Savings Analysis

Average water consumption was measured before the MFU was installed and then again after installation. The percent savings was calculated using Equation 1. Although this is an accurate technique, it assumes that there was no change to the type of laundry during the course of the study. For example, more table linens could have been washed during the baseline period (table linens require slightly more water per pound).

$$Eqn:1=\frac{Main_{before}-Main_{after}}{Main_{before}}(100\%)$$

In May, a second flow meter was installed to monitor cold water. This new meter provided a better technique for measuring water savings. By monitoring both hot and cold water consumption, it was possible to establish a current baseline. Total water consumed by the washing machines (hot + cold) became the baseline (i.e., what the city water meter would read if there were no MFU). The new water savings formula was calculated using Equation 2. This method agreed with the first method to within 2 to 3 percent.

$$Eqn2:=\frac{Hot_{now}+Cold_{now}-Main_{now}}{Hot_{now}+Cold_{now}}(100\%)$$

Using Equation 2, the final percent savings achieved by the laundry was calculated at 52 percent for the month of June. This is the savings figure used throughout the remainder of this report. Although weight normalized data (such as in Table 2B) is a useful reference for the industry, it is more subject to question than time normalized data (gallons per hour), such as in Table 2A. The time normalized data was based on accurate calibrated instrumentation under the control of the researches. The weight normalized data was dependent on the daily logs recorded by the wash staff.

2. Energy Savings Analysis

To accurately measure energy savings a complete energy balance around the entire laundry process would be optimum. However, several energy measurements were either unnecessary (such as washing machine electricity) or too costly (hot water heater steam consumption) and were not monitored. The key to energy savings was that the hot water heater had to work less because recycled water was much warmer than city water. Once again, the analysis approach was to monitor the thermal energy consumption of the washing machines before the retrofit and again after the retrofit. The measured savings (calculated in kbtu) could be compared to a similar reduction in total natural gas consumption (measured in kbtu).

The formula used to calculate the amount of thermal energy contained in the hot water feed to the washing machines was based on the hot water volumetric flow rate multiplied by the temperature difference between the incoming and outgoing water to the hot water heater. This formula is expressed in Equation 3.

$$Eqn3 := \frac{499 * Flow_{rate} * (Temp_{hot} - Temp_{incoming})}{1000} (KBTU/hr)$$

E. Learning Curves

Originally the MFU was expected to save approximately 60 percent on water cost. This estimate was based on what was thought to be the hot water consumption of the laundry. (If 60 percent of the total water used in the wash process was hot water, the maximum potential water savings would be 60 percent.) Pre-retrofit results quickly revealed that only 50 to 52 percent of water used in the wash process was hot water. This meant that (without any changes) the best the MFU could achieve was a 52 percent reduction in water.

One of the more significant findings of this study was that the entire laundry system must be adjusted to achieve the theoeitical maximum performance. Hardware modifications (such as new plumbing) must be made as well as changes in operation and especially changes in the washing process (i.e., adding or subtracting soaps and conditioners). It quickly became apparent that cooperation from the vendor (WRI), the laundry specialist (ECO Labs) and the operation and maintenance staff (Red Lion) were required to make necessary improvements to the system.

Figure 3 illustrates the concept that system performance improves with time. The lighter (larger) curve represents the theoretical percent savings based on the laundry's total hot water consumption. Notice that after the MFU came on line, the percent of hot water used dropped to below 50 percent, thus the theoretical savings dropped (see the dip in the curve in March). Because the MFU does not completely filter out soaps and other chemicals, the pH level of the water became too high (pH 11). This forced the laundry to increase the amount of cold city water to act as a diluting agent and lower the pH. By the end of March, a pH controller was added and hot water consumption increased to 57 percent of the total water consumption. Changes in the measured savings (lighter curve) were not only due to changes in hot water

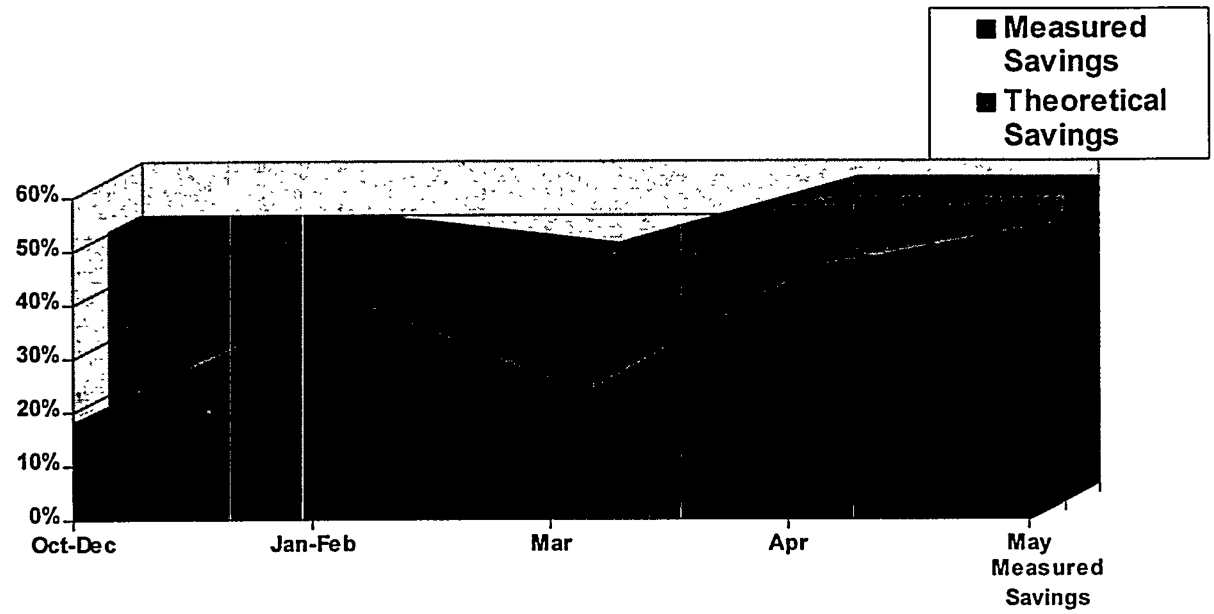


Figure 3. System Learning Curve

savings, but also to a numberof other factors as previously discussed in Section IV.C and highlighted in Appendix E.

F. Other Sites

Boston Park Plaza Hotel

The laundry at Boston Park Plaza Hotel was a good reference point because it has had a WRI MFU in operation for the past three years. This laundry operates seven days a week and requires 24,000 gallons of water per day. Unlike the Red Lion laundry, Boston Park has a small washing machine isolated from the recycling system (i.e., water from this machine goes directly to the city drain and is not recycled). This extra machine allows for continuous operation of the MFU because oily or heavily soiled loads can be washed in the isolated machine to avoid clogging the MFU membrane.

Staff at Boston Park laundry estimate approximatley $35,000 to $40,000 annual savings as a result of the MFU. This savings includes everything from water and sewage costs to lower maintenance cost on the boiler. The savings estimates at Boston Park Plaza are not based on rigorous metering, but rather on billing data and intuitive reasoning of the operations staff. Listed below are additional experiences relevant to assessing the cost-effectiveness of the Boston MFU:

- The city of Boston would not allow any connection from the recycled water loop to the city mains (such as the anti-backflow preventer used by Red Lion). So, if the laundry ever wants to go back to city water (e.g., if the MFU goes down for a significant period of time), they will have to break the connection in the water pipe and reconnect it to the hot water heater, rather than simply turning on a valve.

- A 30-micron shaker screen is the only pre-filter for the MFU.

- Using a liquid soap dispensing system, the laundry is able to easily maintain a pH level between 9 and 10.

- The pumps were initially undersized, slowing down the laundry operation by 35 minutes per day.

- The sump pump failed after three years, possibly due to the high temperature of recycled water.

- A recent O-ring failure temporarily allowed dirty water to filter through, lowering the quality of the laundry.

Overall, the staff at Boston Park Plaza are very pleased with the MFU and its resultant savings.

San Francisco Sheraton Plaza Hotel

The Sheraton Plaza Hotel has a much smaller unit than the Red Lion or Boston Park laundries, with a maximum capacity of 30 to 35 GPM (compared to 80 GPM at Red Lion). The San Francisco unit uses a 32-micron shaker screen as its only prefilter. Early after installation, a tear in the shaker screen allowed debris to pass directly to the membrane causing irreparable damage to the membrane. This damage has limited the effectiveness of this unit and requires a slightly stricter cleaning program (i.e., more frequent) than Boston or Portland. Staff do not know what caused the shaker screen to tear. Although the staff at the San Francisco Sheraton did not have much information or records to report, they also are pleased with the savings from the MFU.

G. Lessons Learned

The lessons learned from the Portland, Boston, and San Francisco MFU installations include the following:

1. Pre-Filtration Is Required

Initial installations of the MFU (such as those in Boston and San Francisco) used only a shaker screen to filter out debris before water entered the membrane. This was found to provide insufficient protection for the membrane. The original installation at the Portland Red Lion used a diatomaceous earth filter between the shaker screen and the membrane (see Figure 1). This quickly proved to be a maintenance problem, requiring personal attention as often as every two hours. The solution was to replace the diatomaceous earth filter with a back-washable sleeve filter. This intermediate sleeve filter has proven successful both in operation and from a maintenance perspective.

2. *Accurate Data on Pre-retrofit Water Consumption is Necessary to Ensure Proper Sizing*

Oversizing the MFU beyond the recommended 20 to 30 percent unnecessarily increases the capital cost and significantly impacts system cost-effectiveness. To avoid undersizing or oversizing the MFU, it is important for laundry owners to provide accurate data on pre-retrofit water consumption.

3. *Ability to Control pH Buildup is Critical to Increasing Water Savings*

The MFU does not filter out soaps and conditioners dissolved in the water. If the amount of these chemicals is not reduced, the pH level of the hot water will quickly build until it reaches an equilibrium point. Red Lion experienced this phenonmenon, reporting pH levels exceeding 11. A high pH causes more wear and tear on equipment. It also degrades the quality of the laundry by turning it grey. The quick fix to this problem is to increase the amount of cold water (fresh city water) used in the wash, lowering the pH through dilution. This approach obviously reduces water savings. When the Red Lion laundry reached its equilibrium point, hot water savings from the MFU was only 38 percent. Because the Red Lion laundry did not have direct control over chemical dispension (a solid dispensing system does not allow changes in quantity of soap versus conditioner, etc.), a pH controller was installed that automatically dispenses acid. The amount of hot water reused increased to approximately 57 percent.

4. *Pump Sizing is Critical to Maintaining High Delivery Pressures to the Washdeck*

Pumps on both the sump (where water exits the washing machine) and the holding tank that feeds into the hot water heater were slightly undersized. These miscalculations resulted from not getting enough prelimnary data on the system dynamics (i.e., pre-retrofit flows and temperatures) before completing the design.

Undersizing the holding tank pump resulted in increased time required to fill the washing machines with hot water and thus slowed down the operation. Undersizing the sump pump allowed debris and lint to form in the pipe and on the intake, which caused frequent clogging of the uptake pipe. Boston also reported a slow down in the laundry operation as a result of undersized pumps. New properly sized pumps at the REd lion laundry appear to have resolved these problems.

5. *Pit Size May Be the Limiting Factor*

If the size of the open channel pit (which contains the city drain) is too small, then under certain scenarios it will be sucked dry, leaving no water available for the MFU to recycle. At other times, the pit will overfill, dumping water that could otherwise be recycled into an overflow drain. If there is sufficient space, the pit (or a holding tank) should be large enough to capture 100% of the hot water demanded by the laundry.

6. *Specify Equipment for High Delivery Temperatures and Pressures to Avoid Gasket, Seal and PVC Failures*

Red Lion experienced numerous gasket and seal failures as a result of the high recycle temperatures. This problem was partially controlled by installing a temperature sensor that turns off the MFU when a certain temperature is exceeded. However, a better solution would be to design a system that specifies high-temperature materials, which can handle the severe thermal shocks associated with the process.

Water hammer produced by high pressures (up to 250 psi) and quick motor startups broke a few of the schedule 80 PVC fixtures contained on the MFU. These failures caused the unit to go off line and led to water damage as a result of flooding. As of June 30, Red Lion reported five incidences of plastic valves and fittings breaking. The current solution for this problem is to use a soft motor startup (i.e., the motor will gradually ramp up to speed), thus reducing the water hammer. WRI reports that future units will be designed with heavier gauge components.

7. *Allow Sufficient Time for the Operational Learning Curve (i.e., key maintenance areas, unit runtime)*

Similar to any new technology, there is a training period for operations and maintenance staff to become adjusted to the MFU. However, mistakes in operation and maintenance can be costly and are almost never considered in an economic assesment.

For example, one day the Red Lion MFU was inadvertantly left on during a dye load. Dye loads inject a highly soluable dye into the washing machine to change the color of table linen. When this water was recycled it caused the next few loads of wash to turn pink. Extra expense and time were required to remove the pink from these loads. The entire system had to be shut down and rinsed while the tainted laundry was rebleached.

Another problem in operations was remembering to turn on the MFU at the beginning of the day as well as after doing a load of oily rags. Figure 4 compares how often the MFU was in operation with how long the laundry was operating. Notice that on April 10 the unit was inadvertently turned off during the graveyard shift. Also note that at approximately 12:00 on both days the unit was turned off to run a load of oily rags. However, on April 11 the unit was not returned to service until the next morning. It was later verified that the wash crew forgot to turn on the MFU.

8. *Isolate One Machine for Dirty Loads*

Perhaps the easiest solution to keeping the MFU in steady operation without running the risk of tainting the recycled water is to isolate the drain in one machine from the MFU. Under this configuration one of the six washing machines would be designated for "special" loads. No modification would be made to that machine other than diverting the drain directly to the city sewer. Although this arrangement is more likely to develop a "dry" condition (i.e., no water available for the filter to recycle), it is an unlikely scenario. (A dry condition would only be a problem when the the recycle holding tank is empty.) Using an isolated machine judiciously (i.e., during peak conditions and only for special loads) would further reduce the likelihood of a dry condition.

9. *Chemical savings depend on the type of chemical dispensing system used.*

This MFU is advertised to save not only water and energy but wash chemicals as well (soaps, conditioners, etc.). Some wash chemicals are not filtered out and remain in the recycled water. If the laundry specialist who monitors the chemical formulas is careful, he or she can reduce the amount of soap used in the washing machine. However, this scenario assumes that the laundry has a liquid dispensing system, which allows each chemical to be individually adjusted. In a solid dispensing system, such as at Red Lion-Portland, all the chemicals are contained in one large block with the ratio of different chemicals already predetermined. This eliminates the potential for any wash chemical savings and adds the extra cost of a pH controller to maintain a reasonable pH in the recycled water.

V. Cost Analysis

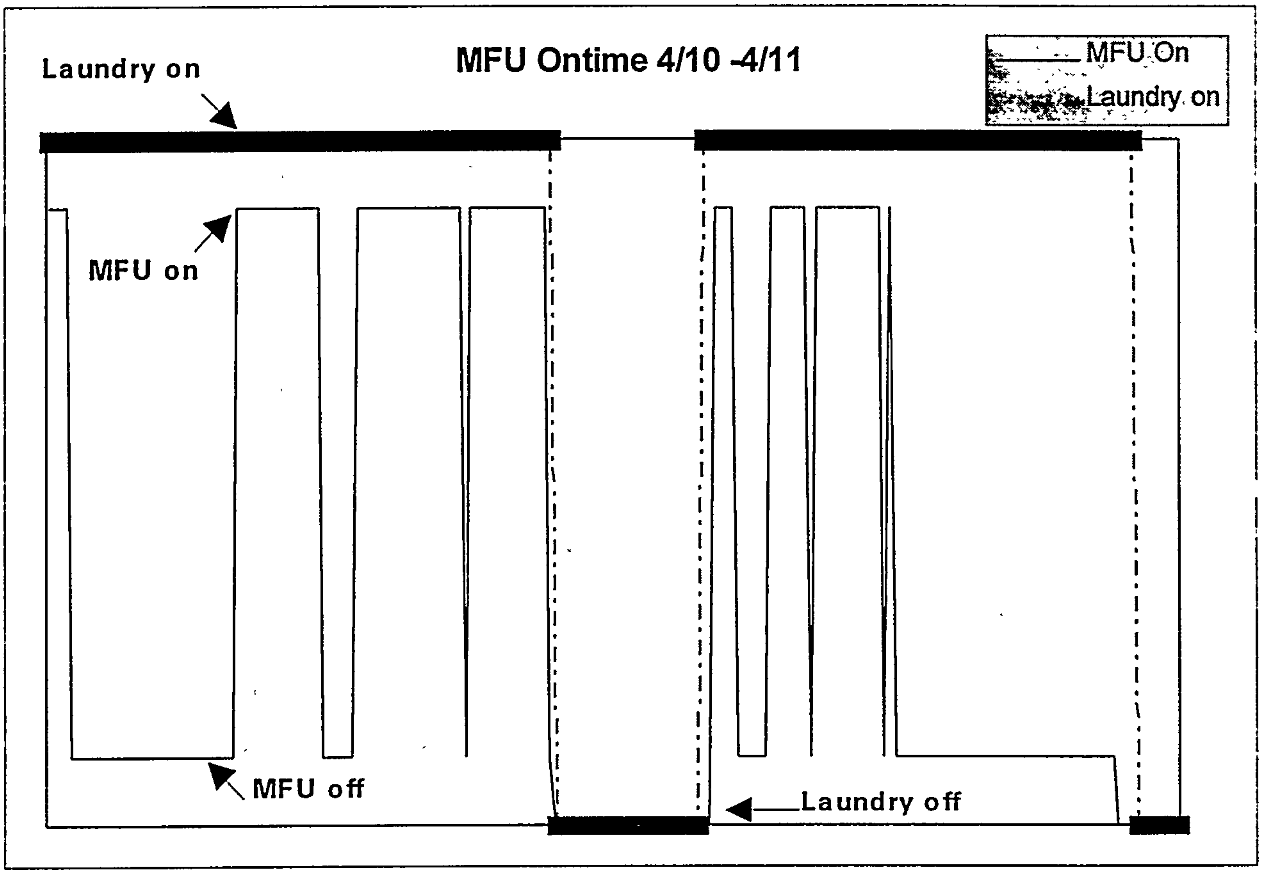
A. Economic Considerations

To evaluate the cost-effectiveness of this MFU many considerations must be taken into account. These include the following costs and savings items:

- initial cost (including installation, plumbing , new services, facility modifications)
- maintenance (one to two major cleanings per year)
- operational failure (what is the cost if the system is operated incorrectly?)
- membrane cleaning chemicals
- MFU power consumption
- water savings
- washer chemical savings
- sewage savings
- energy savings

B. Monthly Savings

All of the above quantities were used in this analysis with the exception of washer chemical savings and operational failures. (No analysis was done on chemical savings because a solid dispensing system was used as described in Lessons Learned #9. Operational failures were



Note: The few spikes when the MFU momentarily turns off are considered normal functioning.

Figure 4. MFU Ontime 4/10-4/11

excluded because, as discussed in Lessons Learned #6 and #7, it is difficult to estimate the number of failures and resulting cost associated with each failure.) MFU cleaning chemicals and maintenance estimates were provided by the manufacturer as a percentage of total water consumption rather than as a percentage of water processed by the unit.

Table 3 highlights expected monthly savings based on Red Lion's water consumption of 55,000 gallons of water per day or 1,383,000 gallons per month. In addition, this table uses the 52 percent water savings and 44 percent energy savings achieved at the end of the Red Lion study.

C. Payback Calculations

The bottom line for most organizations is how long it takes for an investment to pay for itself. The three variables that affect the MFU payback period[2] are: 1) the capital cost of the unit, 2) saving performance of the system, and 3) monthly hot water demand. The first item is fixed and the second item we have discussed at length. The third item (hot water demand) can vary and

[2]Payback calculations do not use a discount rate.

Table 3. Expected Monthly Savings			
Utility	*Utility Rate**	*Monthly Savings*	*Cost Savings*
Sewage	$2.12/ccf**	962 ccf/mo	$2040.00/mo
Water	$.87/ccf**	962 ccf/mo	$836.00/mo
Gas	$.39086/therm***	3040 therm/mo	$1187.00/mo
Electricity	$.0691/kWh	-5800 kWh/mo	- $400.00/mo
Maintenance	$.12/1000gal	1,383,000/mo	-$166.00/mo
MFU cleaning chemicals	$.05/1000gal	1,383,000/mo	-70.00/mo
Total			**$3427/mo**

**Effective rate based on Red Lion's November 1995 billing information **1 ccf = 748 gal ***1 therm = 100 KBTU*

may mean the difference between a long payback and a short payback. Simply put, 52 percent of 100 gallons is a lot less than 52 percent of 1,000 gallons. Furthermore, because the capital cost is roughly proportional to capacity, the closer the unit is sized to the water consumption of the laundry, the shorter the payback period. Because system capacity is rated based on distilled water flow, the vendor (WRI) typically oversizes the unit by 20 to 30 percent. WRI may recommend additional oversizing when there is anticipated growth or uncertainties with current consumption.

Table 4 shows simple paybacks for both the existing unit as well as a unit that is only 20 percent oversized and has a capital cost of $100,000. The following assumptions were

1. Unit cost equals $160,000 (existing), $100,000 (if properly sized)

2. $10,000 in facility modifications, required prior to installation.

3. Monthly consumption before installation equals 1,383,000 gallons

4. System performance as measured equals 52 percent water savings and 44 percent hot water energy savings.

5. Calculations do not consider the lower water and energy savings measured during the learning curve or training period. This could add three to four months to the payback period.

6. Utility rates for water and sewage are taken from a 1995 Arthur Anderson survey of national utility rates.

Although they are a good approximation, they may not accurately reflect the actual rates in the designated area. Electric prices are taken from commercial rate results and gas from industrial rate results.

Table 4. Red Lion Payback Calculations					
	Utility Rates				
Location	*Water/Sewer*	*Gas*	*Electric*	*Net Savings*	*Payback*
$170K (65% oversized)	$2.94/ccf	$.39/therm	$.0691/kWh	$3427/mo	4.1 years
$110K (20% oversized)	$2.94/ccf	$.39/therm	$.0691/kWh	$3427/mo	2.7 years

D. Comparison to Other Locations

Table 5 shows simple payback periods for installing the Red Lion MFU system in selected areas of the country. This table uses the same assumptions as in Section C above except it assumes the unit is properly sized, with a capital cost of $110,000 ($100,000 + $10,000 = $110,000).

Table 5. Cost Comparisons Around the Country					
	Utility Rates				
Location	*Water/Sewer*	*Gas*	*Electric*	*Net Savings*	*Payback*
Portland	$2.94/ccf	$.39/therm	$.0691/kWh	$3427/mo	2.7 years
Seattle	$5.79/ccf	$.39/therm	$.0331/kWh	$6235/mo	1.5 years
San Francisco	$6.25/ccf	$.36/therm	$.1231/kWh	$6156/mo	1.5 years
San Diego	$3.54/ccf	$.36/therm	$.1246/kWh	$3540/mo	2.6 years
LA area	$5.22/ccf	$.36/therm	$.1246/kWh	$5250/mo	1.8 years
Boston	$7.65/ccf	$.39/therm	$.1314/kWh	$7455/mo	1.2 years
Tampa Bay	$5.30/ccf	$.33/therm	$.0665/kWh	$5570/mo	1.7 years

VII. Conclusions

Preliminary results indicate that the MFU is performing well. After five months of operation, the system is providing 52 percent savings in water consumption and 44 percent savings in energy to heat water. It is anticipated that these percentages will increase somewhat as the laundry staff become more familiar with the MFU operation and further adjust the laundry operation to maximize savings. Economic analysis shows an estimated simple payback of 4.1 years for this particular installation. This payback would be 2.7 years had the system been oversized by only 20 percent, rather than 65 percent as installed. Assuming 20 percent oversizing, the simple payback for similar installations throughout the country is estimated to range from 1.2 to 2.7 years depending on initial system cost, daily consumption, and local utility rates.

In addition to confirming the water, energy, and cost savings, this project provided several important findings related to installation and operation of MFUs. The most important lesson is that it takes time and effort to get the most out of a laundry wastewater recycling and heat recovery system. To achieve maximum theoretical performance, hardware modifications are required as well as changes in operation and particularly changes in the washing process (adding or subtracting soaps and conditioners). Staff need adequate training and time to bring the MFU into harmony with their daily routine. A learning curve of several months is to be expected. In this installation, system performance started out at 38 percent and grew to 52 percent at the end of five months.

The project also highlighted some design and installation issues that need to be addressed in MFU applications. These include:

- providing accurate data on pre-retrofit water consumption to ensure proper sizing
- specifying equipment for high delivery temperatures and pressures
- designing the system to include a back-washable sleeve pre-filter to protect the membrane from debris and reduce system maintenance
- considering a supplemental holding tank for water to be recycled if the open channel pit is not large enough to ensure an adequate supply of recyclable water for the MFU
- adequately sizing system pumps to avoid slowing down the laundry operation
- isolating one washing machine that can be used for heavily soiled or oily loads
- installing a pH controller, particularly in a laundry with a solid chemical dispensing system

Finally, chemical, water, and energy savings are influenced by the type of chemical dispensing system used in the laundry, the laundry formulas used to process specific types of laundry, and the actions of the laundry specialist who monitors these formulas. A liquid chemical dispensing system gives the laundry specialist the greatest flexibility to adjust individual chemicals and maximizes savings without the need for a pH controller.

Appendix A

System Metering Plan and Water Savings

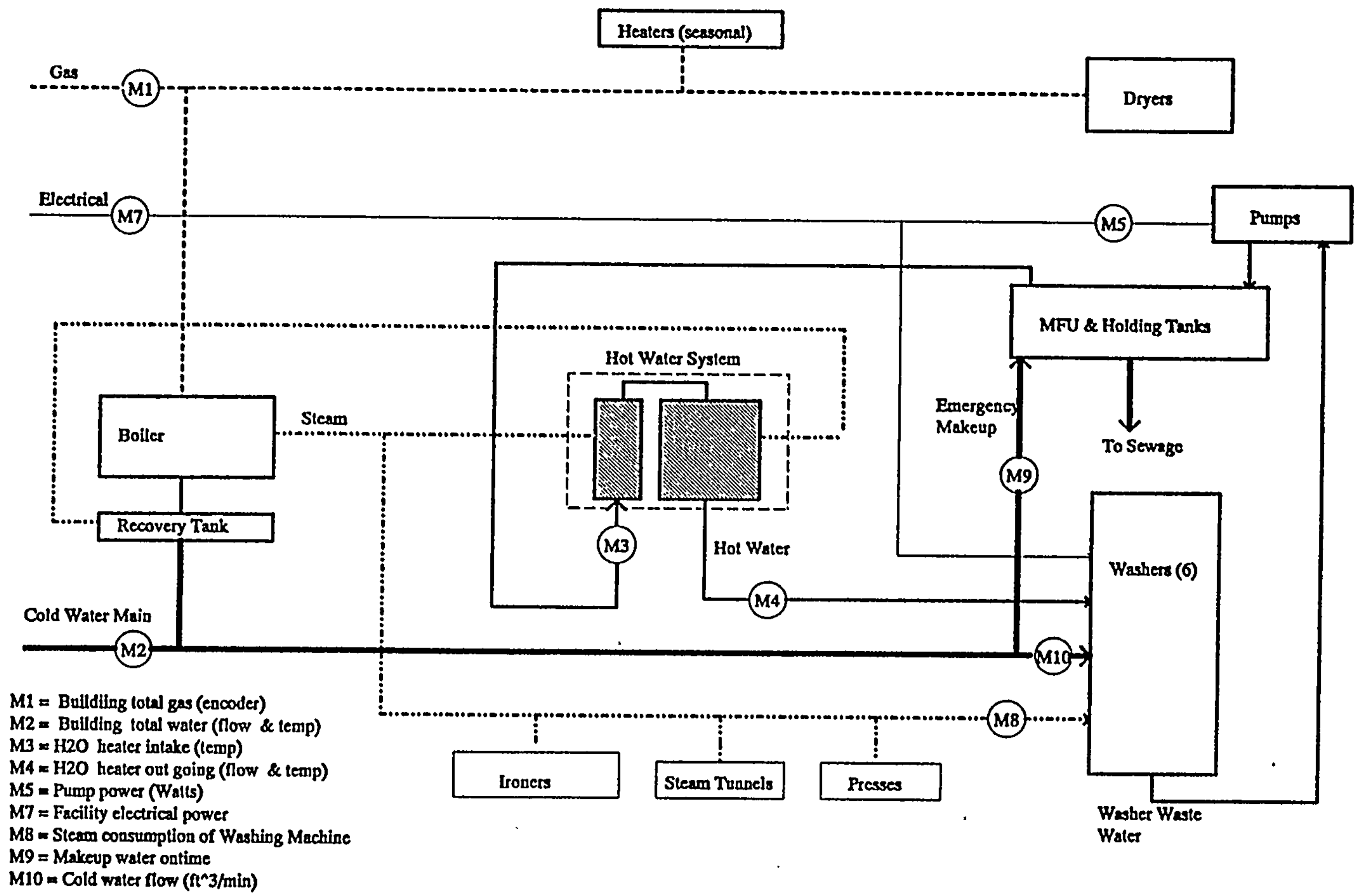


Figure A.1. System Metering Plan

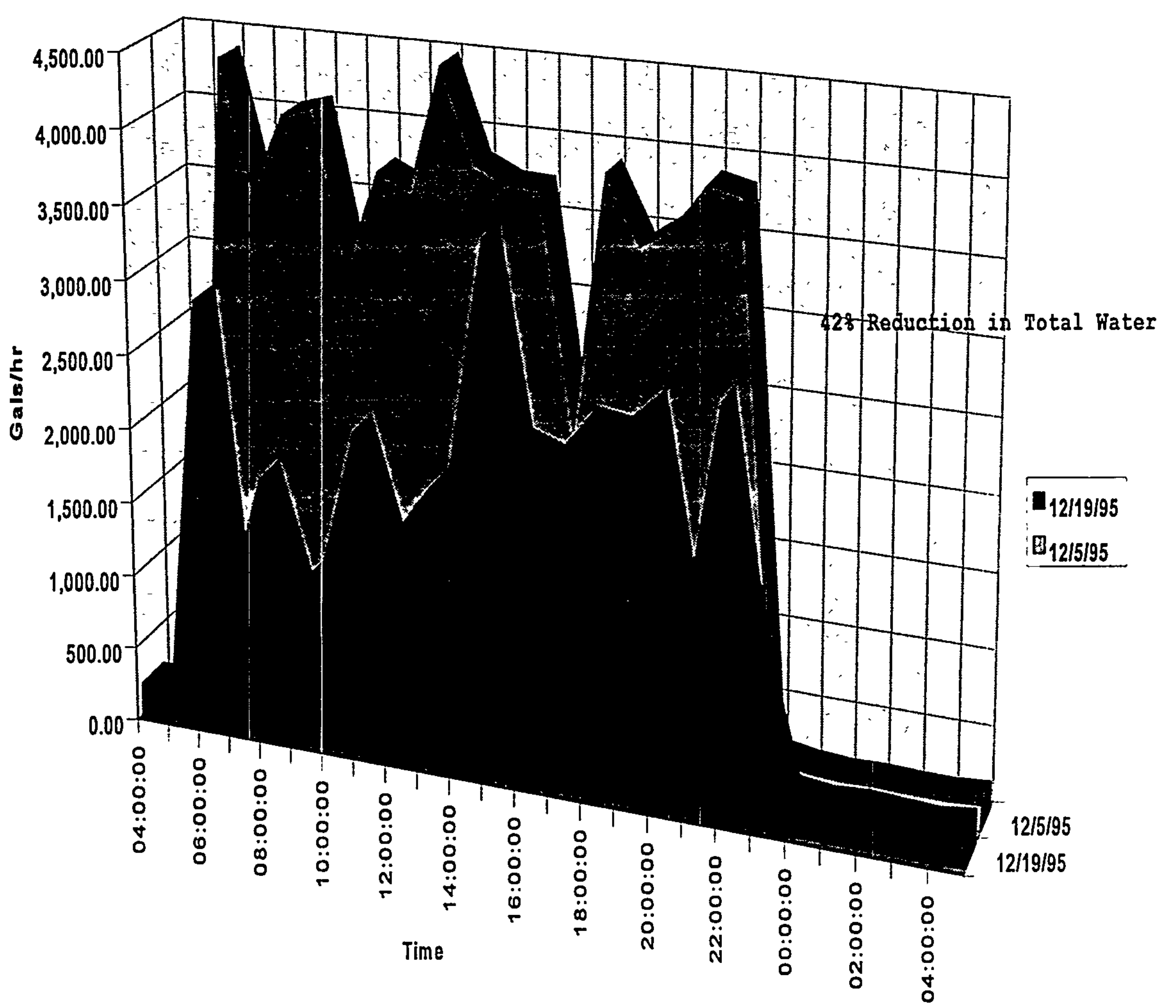


Figure A.2. Water Savings for December 5 and December 19, 1995.

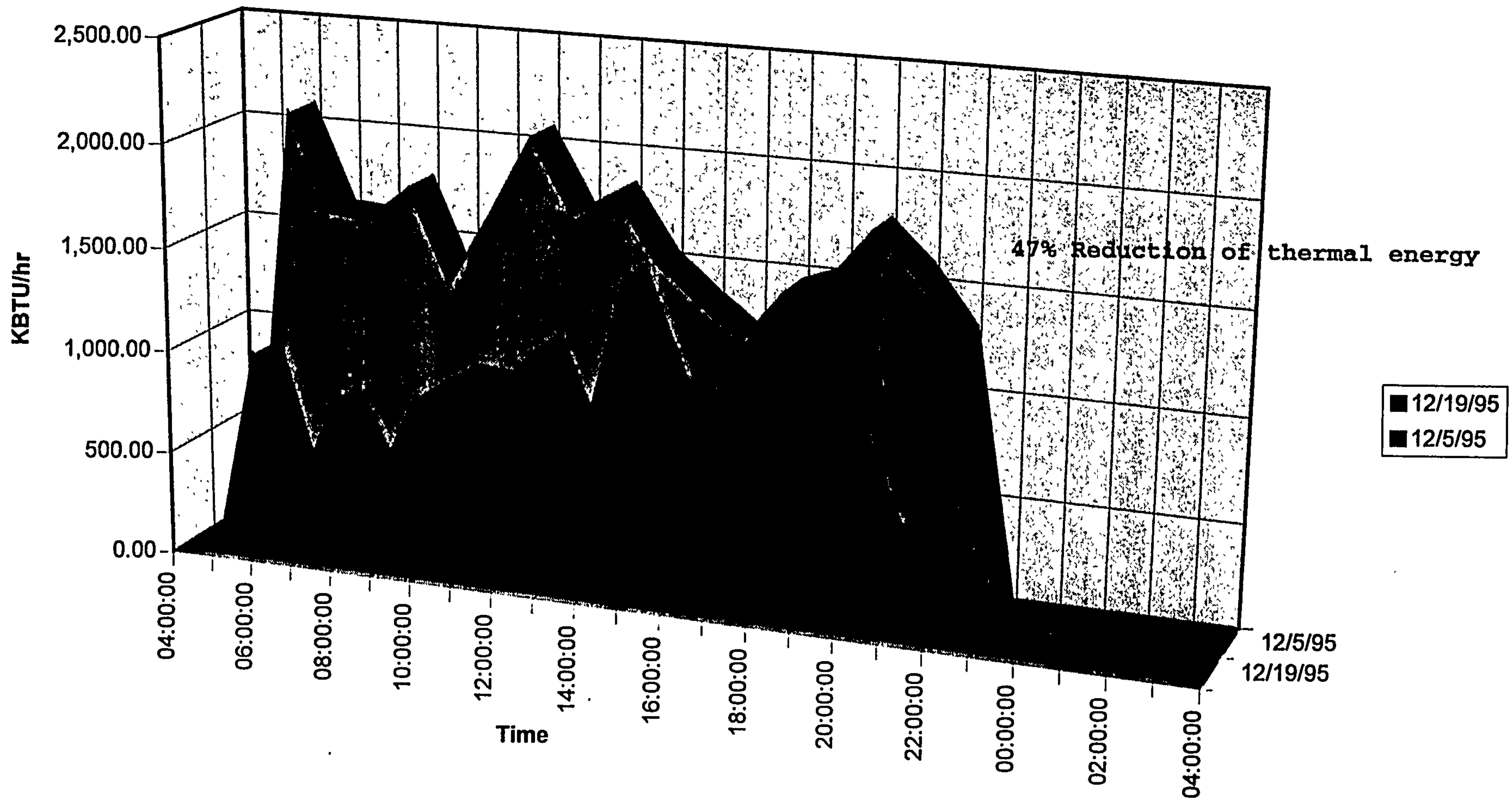


Figure A.3. Thermal Energy Consumption for December 5 and December 19, 1995

Appendix B

Industry Contacts

Appendix B

Industry Contacts

This appendix lists contact information for individuals that can provide additional information on laundry waste water filtration systems and their performance.

Laundry Staff

1. Bob Brewer
   Corporate Energy Manager
   Red Lion Executive Offices
   P.O. Box 1027, 98666
   4001 Main Street
   Vancouver, WA 98663
   (360) 696 - 0001 ext 4272

   Bob Brewer is a great resource for understanding the corporate decision making process in regards to engineering, procuring and maintaining the MFU.

2. Alice Furey
   Laundry Manager
   Red Lion Laundry Division
   738 S.E. Lincoln
   Portland, OR 97214
   (503) 230-8085

   Alice Furey is the laundry manager at the Red Lion-Portland laundry and understands every detail of the operation.

3. Alex Furey
   Laundry Supervisor
   738 S.E. Lincoln
   Portland, OR 97214
   (503) 230-8085

   Alex Furey is one of the principal maintenance engineers at the laundry and is chiefly responsible for the maintenance and operation of the MFU.

4. Jim Karlekas
Laundry Supervisor
Boston park Plaza
64 Arlington Street
Boston, MA 02116-01392
(617) 457 - 2263

Jim Karlekasis one of the principal maintenance engineers at the Boston laundry and is chiefly responsible for the maintenance and operation of the MFU. He has close to three years of operating experience on the system.

5. Charley Brown
Laundry Supervisor
Sheraton Plaza Hotel
New Montgomery Ave
San Francisco, CA
(415) 392 - 8600 ext 6109

Charley Brown is one of the principal maintenance engineers at the San Francisco laundry and is chiefly responsible for the maintenance and operation of the MFU.

Manufacturers

6. Randall Jones
President
Wastewater Resources Inc.
9379 East San Salvador
Suite 200
Scottsdale AZ 85258
(602) 391 - 9939

Randy Jones has a strong background in water filtration experience and understands industrial needs very well.

7. Gerry Miller
Vice President Technical Services
Wastewater Resources Inc.
9379 East San Salvador
Suite 200
Scottsdale AZ 85258
(602) 391 - 9939

Gerry Miller is the lead person for installing WRI micro-filtration systems.

8. Francis J. Brady
Manager
Process Technology
Koch Membrane Systems Inc.
850 Main Street
Wilmington, MA 01887-3388
(508) 657 - 4250

Francis Brady is engineering manager for the largest supplier of membrane material.

9. Louis Vuilleumer
Vice President
The Conservation Consortium
4380 Main Street
Yarmouth Port, MA 02675
(508) 362 - 2484

Louis Vuilleumer represents a number of environmental products including recycling systems for laundries and laundromats.

10. Thomas Carrol
Vice President
Hydrokinetics
51 Faith Ave.
Auburn, MA 01501
(508) 832-8071

Hydrokinetics is a small company that focuses its efforts on clean water reuse rather than water filtration. These systems capture water from the rinse cycle only and then reuse the water for the next wash cycle. Since the rinse water is fairly clean only a lint filter is required. Although these systems have a lower capital cost than a membrane filtration system, the percentage savings is also lower.

Chemical Specialists

11. Brad Ashmore
ECO Labs
P.O. Box 100512
Pasadena, CA 91189 - 0512
(800) 553-8683

As the chemical specialist, Brad Ashmore is a very important member of the Red Lion laundry team. He is in charge of developing the "recipe" of chemicals that is used in the cleaning process. This also involves setting the duration of the rinse cycle, the amount of hot water used, etc. These all have an important impact on savings and must not be overlooked when considering a water reclamation system.

Appendix C

Analysis Considerations

Appendix C

Analysis Considerations

1. The washing process uses both hot and cold water. In the Red Lion installation, only the hot water process uses the recycled water. Because hot water consumption is only 50 to 60 percent of total water consumption, facility water savings is already limited to a maximum of 60 percent.

2. This installation uses a single drain rather than a split-drain system (i.e., water from both the cold and hot water cycles are mixed together in the drain pit). This water combination is the source for recycled water.

3. The unit is shut off for kitchen rag loads and heavily soiled loads because a high oil or soil content fouls the system. The MFU is off line for 30 to 45 minutes a day for the kitchen rags and 60 minutes a week for the heavily soiled loads.

4. During the holiday season more table linens are processed than at other times of the year. This requires higher temperature water per pound of laundry. The pre-retorfit data was gathered during both normal and holiday seasons.

5. Shortly after the MFU came on line on December 11, 1995, a violent wind storm cut power to the laundry for almost 24 hours. This not only put a "hole" in the data, it also affected the operation of the equipment and operating hours of the laundry.

6. Evaluation of laundry performance (such as cleanliness and appearance of the towels, linens, and uniforms) is a very specialized endeavor, perhaps more of an art than a science. Red Lion employs a laundry specialist to oversee the development and maintenance of laundry "recipes" (or "formulas") for cleaning various kinds of laundry. This specialist is responsible for evaluating the performance and maintaining the quality of the laundry.

   Using the MFU to recycle water affects laundry performance. Although the MFU removes particles down to the submicron size, it does not remove smaller particles, nor does it remove chemicals that are soluble in water (soaps and softeners). These chemicals have the potential to change the quality of the final, clean products. Consultation with Red Lion's laundry specialist was necessary during initial operation of the WRI system. Because the laundry specialist has control of chemical usage, there can be no chemical savings unless the "recipes" are changed by the laundry specialist.

   Although the primary impact of altering these "recipes" is the consumption of chemicals, energy and water consumption can also be affected. For example, a change in the formula may call for increasing the wash cycle water temperature by 10 degrees, or an extra cold rinse cycle may be added. It is anticipated that four to six weeks of recipe adjustments are necessary to stabilize the formula.

Appendix D

Data Verification

Appendix D
Data Verification

Pt.	Description	Checked by	Check	Measured	Difference
M2,4	Water Consumption	October Water Bill	2162 ccf	2153 ccf	0.4%
		November Water Bill	2026 ccf	2018 ccf	0.4%
		Field technician check	na	na	1.0%
M1	Gas Consumption	October Gas Bill	20120 ccf	19114 ccf	5.0%
		November Gas Bill	17372 ccf	17863 ccf	2.8%
M7	Main Electric Meter	October Electric Bill	36480 kWh	34650 kWh	5.0%
		November Electric Bill	35200 kWh	35546 kWh	1.0%
	Second Electric Meter	October Electric Bill	3967 kWh	3947 kWh	0.5%
		November Electric Bill	3869 kWh	4103 kWh	5.7%
M7a	MFU Electric Meter	October Electric Bill	493 kWh	*	*
		November Electric Bill	2825 kWh	2955 kWh	4.4%
M8	Washer Steam Consumption	Field check 2nd meter	355.16 lbs/hr	calibrate	*
M2	Cold H2O Temperature	Field check w/ handheld meter	50.5	51.5	1.9%
M4	Hot H2O Temperature	Field check w/ handheld meter	153.5	153.9	0.3%
M3	Recycled H2O Temperature	Field check w/ handheld meter	110	110.5	0.3%

Table D.1. Data Verification

* No data available

Appendix E

Deviations from Normal Operation

Appendix E

Deviations from Normal Operation

Laundry Log		
Date	***Time***	***Description***
10/8	16:00 - 22:00	Power outage
10/23	1:00 - 12:15	Power outage
10/5 - 11/15		Intermittent operation of recovery system
12/10		Recovery system back online
12/12 - 12/13	13:15 - 10:30	Power outage (windstorm)
1/9		Operation down for press conference
1/22		Added another cold cycle
1/25		Boiler inspection laundry shut down
2/2 - 2/3	18:19 - 5:15	Power outage
2/2 - 2/9	18:19 - 14:30	No water consumption data
2/9 - 2/10	18:30 - 6:00	Power outage
2/11		Discovered steam leak, shut off part of H_2O heater
2/18		Fixed steam leak
3/20		City water tested for rust content
3/22		Changed main formula from a hot - cold - cold to a hot - hot - split
3/22		Began testing new pH controller unit
3/29		Finished test pHase of new pH controller
4/2		Changed the "sour' chemical formula from an expensive laundry acid to vinegar.
4/19		Installed new hot H2O pump (15HP)
4/29		Boiler down
4/30		

Laundry Log		
Date	***Time***	***Description***
5/7		Added more instrumentation
5/8		Discovered bottle cap in recycle pump
5/22		Replaced recycle pump
5/24 - 5/31	19:00 / 07:00	Plastic ball valve on recycle system blew off. Shut down MFU for 5 days.
5/30 - 5/31	05:00 / 12:00	Bearing failure on the 700 washing machine
5/30	12:00	Meter cal check by Ken Talbot of Panametrics

Appendix F

Back Up Data Sheets

Appendix F:

Back Up Data Sheets

Backup data for Tables 1, 2A and 2B

Table F1 Performance Analysis Snapshots

Period #	Description	Dates Start	End	Avg ft^3	% Savings	% MFU On	Lbs/hr	gal/lb	H20 Enrg kbtu/hr	gas kbtu/hr	steam kbtu/hr	Hot Temp Deg F	MFU temp Deg F	%h20en	%gas	%temp
1	Baseline	11/16/96	12/8/95	6.46	0.00%		1,190.00	2.44	1,252.00	3,600.00	251.00	152.60	53			99.60
2	September	9/1/95	9/28/95	6.05	6.35%		1,140.00	2.38	1,338.00	3,287.00	376.00	152.60	53			
3	January	1/10/96	1/16/96	3.93	39.16%	74%	1,254.00	1.41	530.00	2,787.00	316.00	144.00	97.8	57.67%	22.58%	53.61%
									0.42	2.22	0.25					
4	March (Lot o cold)	2/29/96	3/16/96	5.39	16.56%	68%			649.00	3,067.00	468.00	158.00	92	48.16%	14.81%	33.73%
											#DIV/0!					
5	April (Lot o hot)	3/29/96	4/9/96	4.17	35.45%	75%	1,406.00	1.33	748.00	2,802.00	428.00	154.50	100	40.26%	22.17%	45.28%
									0.53	1.99	0.30					
6		3/25/96	3/30/96	3.96	38.70%	84%										
7	New Pump	4/22/96	4/28/96	3.61	44.12%	100%	1,348.00	1.20	945.00	2,989.00	309.00	153.00	95	24.52%	16.97%	41.77%
									0.70	2.22	0.23					
8	May	5/21/96	5/23/96	3.57	44.74%	72%			727.00	2,654.00	465.00	158.00	109.5	41.93%	26.28%	51.31%
9	June	6/2/96	6/30/96	3.3	48.92%		1,346.00	1.10	761.00	2,690.00						
									0.57	2.00						
8	June	6/2/96	6/3/96	3.04	52.94%	80%	1,346.00	1.01	700.00	2,406.00		157.00	110	44.09%	33.17%	52.81%

Backup data for Table 4

Portland							
Utility	*Rate*	*Monthly* Consumption*	*Units*	*%Savings***	*monthly Savings*	*Units*	*Cost Savings*
Water $/ccf	2.12	1850	ccf	52%	962	ccf	$2,039.44
Sewage $/ccf	0.87	1850	ccf	52%	962	ccf	$836.94
Gas $/therm	0.39	6900	therm	44%	3036	therm	$1,184.04
Electricity $/kwh	0.1231	5800	kwh	0%	0	kwh	$0.00
MFU Electricity $/kwh	0.0691	5800	kwh		-5800	kwh	($400.78)
Maintenance $/1000gal	0.12	1383	1000gal		-1383	1000g	($165.96)
Chemicals $/1000gal	0.05	1383	1000gal		-1383	1000g	($69.15)
Capital cost	$110,000						
Total monthly savings							$3,427.00
Years to pay back (no interest)							2.67
Years to pay back (@7%)							2.97

Backup Data for Table 5

LA DWP							
Utility	*Rate*	*Monthly* Consumption*	*Units*	*%Savings***	*monthly Savings*	*Units*	*Cost Savings*
Water $/ccf	2.73	1850	ccf	52%	962	ccf	$2,626.26
Sewage $/ccf	2.49	1850	ccf	52%	962	ccf	$2,395.38
Gas $/therm	0.3909	6900	therm	44%	3036	therm	$1,186.77
Electricity $/kwh	0.1246	5800	kwh	0%	0	kwh	$0.00
MFU Electricity $/kwh	0.1246	5800	kwh		-5800	kwh	($722.68)
Maintenance $/1000gal	0.12	1383	1000gal		-1383	1000g	($165.96)
Chemicals $/1000gal	0.05	1383	1000gal		-1383	1000g	($69.15)
Capital cost	$110,000						
Total monthly savings							$5,250.62
Years to pay back (no interest)							1.75
Years to pay back (@7%)							1.87
Seattle							
Utility	*Rate*	*Monthly* Consumption*	*Units*	*%Savings***	*monthly Savings*	*Units*	*Cost Savings*
Water $/ccf	0.7	1850	ccf	52%	962	ccf	$673.40
Sewage $/ccf	5.09	1850	ccf	52%	962	ccf	$4,896.58
Gas $/therm	0.36	6900	therm	44%	3036	therm	$1,092.96
Electricity $/kwh	0.1246	5800	kwh	0%	0	kwh	$0.00
MFU Electricity $/kwh	0.0331	5800	kwh		-5800	kwh	($191.98)
Maintenance $/1000gal	0.12	1383	1000gal		-1383	1000g	($165.96)
Chemicals $/1000gal	0.05	1383	1000gal		-1383	1000g	($69.15)
Capital cost	$110,000						
Total monthly savings							$6,235.85
Years to pay back (no interest)							1.47
Years to pay back (@7%)							1.56

Backup Data for Table 5 (cont.)

San Francisco							
Utility	*Rate*	*Monthly* Consumption*	*Units*	*%Savings***	*monthly Savings*	*Units*	*Cost Savings*
Water $/ccf	1.56	1850	ccf	52%	962	ccf	$1,500.72
Sewage $/ccf	4.69	1850	ccf	52%	962	ccf	$4,511.78
Gas $/therm	0.36	6900	therm	44%	3036	therm	$1,092.96
Electricity $/kwh	0.1231	5800	kwh	0%	0	kwh	$0.00
MFU Electricity $/kwh	0.1231	5800	kwh		-5800	kwh	($713.98)
Maintenance $/1000gal	0.12	1383	1000gal		-1383	1000g	($165.96)
Chemicals $/1000gal	0.05	1383	1000gal		-1383	1000g	($69.15)
Capital cost	$110,000						
Total monthly savings							$6,156.37
Years to pay back (no interest)							1.49
Years to pay back (@7%)							1.58
San Diego							
Utility	*Rate*	*Monthly* Consumption*	*Units*	*%Savings***	*monthly Savings*	*Units*	*Cost Savings*
Water $/ccf	1.89	1850	ccf	52%	962	ccf	$1,818.18
Sewage $/ccf	1.65	1850	ccf	52%	962	ccf	$1,587.30
Gas $/therm	0.36	6900	therm	44%	3036	therm	$1,092.96
Electricity $/kwh	0.1246	5800	kwh	0%	0	kwh	$0.00
MFU Electricity $/kwh	0.1246	5800	kwh		-5800	kwh	($722.68)
Maintenance $/1000gal	0.12	1383	1000gal		-1383	1000g	($165.96)
Chemicals $/1000gal	0.05	1383	1000gal		-1383	1000g	($69.15)
Capital cost	$110,000						
Total monthly savings							$3,540.65
Years to pay back (no interest)							2.59
Years to pay back (@7%)							2.86

Backup data for Table 5 (cont.)

Boston							
Utility	*Rate*	*Monthly* Consumption*	*Units*	*%Savings***	*monthly Savings*	*Units*	*Cost Savings*
Water $/ccf	2.63	1850	ccf	52%	962	ccf	$2,530.06
Sewage $/ccf	5.02	1850	ccf	52%	962	ccf	$4,829.24
Gas $/therm	0.36	6900	therm	44%	3036	therm	$1,092.96
Electricity $/kwh	0.1246	5800	kwh	0%	0	kwh	$0.00
MFU Electricity $/kwh	0.1314	5800	kwh		-5800	kwh	($762.12)
Maintenance $/1000gal	0.12	1383	1000gal		-1383	1000g	($165.96)
Chemicals $/1000gal	0.05	1383	1000gal		-1383	1000g	($69.15)
Capital cost	$110,000						
Total monthly savings							$7,455.03
Years to pay back (no interest)							1.23
Years to pay back (@7%)							1.29
Tampa Bay							
Utility	*Rate*	*Monthly* Consumption*	*Units*	*%Savings***	*monthly Savings*	*Units*	*Cost Savings*
Water $/ccf	1.94	1850	ccf	52%	962	ccf	$1,866.28
Sewage $/ccf	3.03	1850	ccf	52%	962	ccf	$2,914.86
Gas $/therm	0.36	6900	therm	44%	3036	therm	$1,092.96
Electricity $/kwh	0.1246	5800	kwh	0%	0	kwh	$0.00
MFU Electricity $/kwh	0.0665	5800	kwh		-5800	kwh	($385.70)
Maintenance $/1000gal	0.12	1383	1000gal		-1383	1000g	($165.96)
Chemicals $/1000gal	0.05	1383	1000gal		-1383	1000g	($69.15)
Capital cost	$110,000						
Total monthly savings							$5,253.29
Years to pay back (no interest)							1.74
Years to pay back (@7%)							1.87