ENERGY EFFICIENCY IMPROVEMENTS FOR PROCESS UTILITY SYSTEMS AT GARLOCK SEALING TECHNOLOGIES

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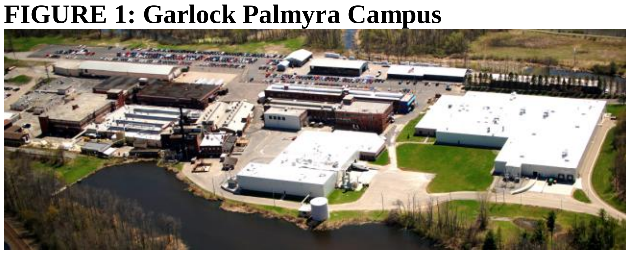
ABSTRACT

Over the past two years, Garlock Sealing Technologies has taken on a comprehensive energy management program to improve the overall energy efficiency of the process utility support systems from both a supply and demand standpoint, resulting in in savings of over 2.8 million kWh in electricity and 500,000 therms of natural gas.

Garlock Sealing Technologies (Garlock) is an EnPro Industries, Inc. company headquartered in Palmyra, NY (Reference Figure 1). Garlock is a global leader in providing innovative fluid sealing solutions for process industries. Garlock's manufacturing complex is comprised of several buildings totaling over 600,000 square feet. The buildings are of various age and condition; some have been in operation for over a century. Manufacturing is operational 24 hours per day, seven days a week with approximately 525 employees.

FIGURE 1: Garlock Palmyra Campus



The facility manufactures gaskets, mechanical and oil seals, bearing isolators, and expansion joint and hydraulic components. The process utility support systems and equipment include air compressors, steam boilers, and chillers.

Total annual electric consumption is approximately 23.0 million kWh, with a peak electric demand of 4,171 kW, and annual cost of $1.35 million. Natural gas annual consumption is approximately 1.7 million therms at a cost of $1.1 million.

This presentation will begin with a historical overview of the Garlock facility and energy performance of the process utility support systems. It will continue to discuss the approach for identifying energy efficiency improvements through the use of a team approach in executing comprehensive energy studies with local staff, energy consultants, and state and utility program support.

The session will discuss the energy conservation measures identified, the selection process for moving forward with implementation of the selected measures, and the overall implementation method. It will also discuss the measurement and verification process that was followed to confirm actual energy efficiency improvements attained. For the compressed air, steam, and chilled/process water process utility support systems, savings of over 2.8 million kWh in electricity and 500,000 therms of natural gas have been achieved.

Finally, the presentation will close with lessons learned and keys to success in implementing a comprehensive and sustainable energy management program.

GARLOCK FACILITY HISTORICAL OVERVIEW

The Garlock Packing Company was started in 1887 when Olin J. Garlock introduced cotton duck and rubber packing for steam piston applications. By the 1950's Garlock had introduced several synthetic rubber and molded rubber sealing products to make major advancements in the sealing of locomotive cylinders, rotating shafts, and piping systems.

In the 1970's, Garlock developed and introduced the first safe alternatives to heat resistant gasketing for superheated steam, caustic, and other hazardous applications. With over 125 years of history, Garlock continues to be the world leader in sealing products and the development of the next-generation technologies that change the way industrial and infrastructure users meet their sealing requirements.

The Palmyra facility has a central utility plant referred to as the "Powerhouse" which contains the majority of the campus' centralized equipment, including the steam boilers, chillers, compressors, and pumps. With the site's changes over the years and modernization program begun in 2005, the systems were significantly oversized for the current operations, were beyond their useful lives, and in need of replacement.

Steam System

The Powerhouse contained four high pressure (425 psig) steam boilers (Reference Figures 2 & 3). One boiler was installed in 1940 and designed to produce 60,000 lbs/hr of steam. The other boiler was installed in 1953 and designed to produce 100,000 lbs/hr steam. The remaining two boilers were decommissioned and not operational.

FIGURE 2: Existing Steam Boilers

FIGURE 3: Existing Steam Controls

Average boiler efficiency was around 70%, annual gas usage was 158,576 MMBtu. Baseline steam boiler output was 112,849,546 lbs. at 365 psig, however, 22,575,896 lbs. was being wasted due to venting as the oversized boilers could not be tuned down low enough. Therefore, the true demand for the system was 90,273,650 lbs. (112,849,546 – 22,575,896), equating to an efficiency metric of natural gas per lb. of steam of 1,757 Btu per pound.

Compressed Air System

Compressed air was provided to a majority of the campus by the Powerhouse containing one 300 HP rotary screw compressor (20 years' old) and two backup rotary screw compressors that are 200 HP and 300 HP units (57 and 40 years' old, respectively). The 20 year old 300 HP compressor was the primary unit and is oversized for current operations. Due to age and increasing maintenance costs, replacement needed to be considered. The system operated at approximately 100 psig and has a significant amount of leaks. Overall system efficiency was 0.395 kW per cfm of compressed air supplied.

Process Water Systems

The Powerhouse is the generation/distribution point for the chilled water and lake water systems. Chilled water was generated by an air cooled chiller and distributed by two pumps located in the Powerhouse. Lake water is delivered to the powerhouse by a gravity fed system, which runs from Canandaigua Lake, and enters the campus and is distributed via pumps in the Powerhouse.

The Powerhouse contains two lithium bromide 125 ton absorption chillers, which once served the open loop chilled water system. The chillers had recently been decommissioned, and the system was currently served by a rental air cooled 200 ton electric chiller located outside, adjacent to the Powerhouse. The two stage, scroll chiller has 12 condenser fans and two compressors. Chilled water supply temperature set point was 43°F. Overall system efficiency was 2.21 kW per ton of chilled water supplied.

The lake water system has an overall efficiency of 0.080 kW per ton of lake water supplied which is due to pumping power only.

TEAM APPROACH FOR IDENTIFYING ENERGY EFFICIENCY IMPROVEMENTS

The reasons for a company to pursue Energy Management extend beyond cost savings and improved competitiveness. It will reinforce the corporation as a good corporate citizen in its community and state, while minimizing the impact on the environment, supporting load reduction on the grid, helping maintain or increase employment levels, and attraction of millennial workforce seeking out green companies, and staying ahead of increasing energy costs.

Consuming less energy can be multi-faceted including conserving resources, maintaining optimal system and operational performance, investing in new technology, and adjusting effectively to business changes. In order to consume less, real time measurement and tracking of energy consumption and production of process utilities must be an integral component of the energy management. Without this performance metric, you cannot control it nor have a goal to improve it. By having a system in place and empowered resources to act, operations can be kept under control and actions taken.

With any improvement system, education and awareness are paramount to achieving a conservation culture throughout an organization. Unless staff knows the impact energy costs have on the operation, they are unlikely to act. All staff needs an understanding of the relationship between their actions and energy consumption.

Improvement targets must be set so there is a clear understanding of the criteria for success and a culture that continually challenges the norm. Why are machines, systems, and processes operated the way they are? What is being wasted? What are alternatives?

The authors have interfaced with all sizes and types of process utilities in industrial applications and those with successful energy management programs have many of these elements. The following outlines Garlock's approach for identifying energy efficiency improvements:

Start by creating an energy team that is enthusiastic about reducing the company's carbon footprint and saving utility costs. The team should have representatives from all departments of the business from customer service representatives to product designers, from maintenance to human resources, from production operations to finance, and so forth so that all opportunities and ideas are captured, as people with different backgrounds will find a wider variation of opportunities.

The Garlock Energy Team was started in 2013 and was the driving force behind getting energy efficiency projects completed as the diverse team was able to gather support from all departments. The team found that high level energy assessments by experienced engineers and technical sales people were available as a free service through engineering firms associated with local state energy authority. Garlock chose CHA Consulting, Inc. to perform such an assessment due to the depth of their industrial experience and strong working relationships with the local state energy authority and utilities.

The result of the assessment was a list of Energy Conservation Measures (ECM's) that broadly listed the ideas and their estimated investment and savings opportunity. This allowed Garlock to choose the projects to focus on based on what would yield the quickest and highest return given a specific investment. Every business has limited resources, so performing this high level assessment is the key in knowing what and where to start your conservation efforts.

After a free or low cost high level audit is done, the team will want to gain a thorough understanding of the ECM's they have chosen. An in depth analysis is necessary to document the details of the current state, perform the data logging needed, conduct an energy analysis, propose options for a future state, develop accurate budgetary costs, and calculate the savings and payback. These efforts will require funding as they are very specific and detailed. In many cases, local utilities and/or state agencies offer programs to cover part of these costs.

We have found that it is well worth the time and cost to purchase meters and data loggers during this detailed documentation stage. It is critical to gain an accurate up front measurement of the utility profile to determine the existing conditions, requirements, and efficiencies. Without performing this up front data collection, specific utility loads may be missed and even the best designs with the most efficient equipment may fail to effectively meet the variation in process needs. As an example, our pre-metering of the compressed air system found that 25% of the load was due to air leaks. Once repaired, we found that we could install smaller compressors that more closely matched the true load requirements. When chosen carefully, the meters and other measurement equipment can be used in the new system to conduct post project Measurement & Verification (M&V) and will be a key part of tracking system lifecycle performance to ensure optimum efficiency is maintained.

While several other projects have been completed, the focus of this paper is on the ECM's for the steam, compressed air, and chilled/process water plant utilities.

ENERGY CONSERVATION MEASURES IDENTIFICATION & SELECTION

Steam Systems

For the steam systems, assessments were conducted to evaluate both the supply and demand side. On the supply side, the 365 psig steam produced by the power house was only required in two pieces of equipment in the functional test lab. The remainder of the facility required 130 psig steam. During summer months some steam was vented to atmosphere. The existing boilers could only turn down to around 12,000 lbs/hr; however, summer loads could reach as low as 6,000 lbs/hr. During these low load periods, unused steam was vented to atmosphere to prevent over pressurization of the system.

After evaluation of alternative concepts, the proposed energy conservation measure for the supply side of the system consisted of two low pressure boilers and one high pressure boiler to be dedicated to the testing lab. Reducing the operating pressure of the main two boilers increased boiler efficiency and resulted in reduced heat loss in distribution piping. The proposed & implemented boilers were (2) 350 HP boilers with a maximum output of 12,000 lbs/hr at 168 psig for low pressure use, with a 10:1 turndown which will allow the plant to meet the minimum low load points without venting any steam produced. The proposed & implemented high pressure boiler dedicated to the functional test lab was a 60 HP boiler rated for 2,000 lbs/hr at 365 psig.

Calculated annual savings attributed to the boiler upgrade was 51,118 MMBtu, and improved the efficiency metric by 32% to 1,190 Btu per lb of steam produced. Simple payback with incentives was 3.7 years.

On the demand side of the steam system, the following areas were evaluated for energy efficiency opportunities:
- Steam trap repair and replacement
- Steam trap misapplications
- Condensate return system effectiveness
- Steam leaks
- Steam Use Optimization

Recommended energy conservation measures included steam trap and leak repair, process steam optimization, and condensate return improvements. Eight percent of the over 450 steam traps (Reference Figure 4) were determined to be faulty and in need of repair/replacement. Annual savings were estimated to be 4.8 million lbs of steam, 7,422 MMBtu of natural gas, 577,000 gallons of water, and associated chemicals, resulting in a payback of less than 6 months. One significant steam leak was identified that when repaired would save annually 1.7 million pounds of steam, 2,688 MMBtu of natural gas, 209,000 gallons of water, and associated chemicals, resulting in a payback of less than one month.

FIGURE 4: Steam Trap

Several process optimization opportunities were identified and centered around achieving "zero energy" status when production machinery was down while allowing for proper heat up and cool down periods. These measures would save annually 14.6 million pounds of steam and 19,244 MMBtu of natural gas, resulting in a payback of less than 6 months.

The final steam measure recommended was to maximize condensate return and capture condensate from two process loads. These measures would save annually 2.4 million pounds of steam, 506 MMBtu of natural gas, 293,000 gallons of water, and associated chemicals, resulting in a payback of less than 3 years.

Compressed Air System

For the compressed air system, an assessment was conducted to evaluate both supply and demand and included evaluation:
- Variable speed/flow compressor and dryer technology
- Pressure control
- Compressed air leaks
- Misapplications

On the supply side for the Powerhouse system, several arrangements of compressors and dryers with pressure control were evaluated based on actual and projected demand profile with a recommendation for two (2) 150 HP single stage rotary screw variable speed compressors (one operating, one standby) with cycling refrigerant dryers. Calculated annual savings was 749,550 kWh with a payback of less than 2.5 years with incentives.

On the demand side for the campus, 181 leaks were identified on the campus totaling approximately 195 CFM. The leaks consisted of about 36% of the total demand in the system. Calculated annual savings was 211,170 kWh with a payback of less than 1.5 years.

For misapplications on the campus, several opportunities were identified including demand control of users such as air knives and sensors, and alternate non-compressed air technologies for vacuum generators, pumps, agitators, and mixers. Calculated annual savings was 175,030 kWh with a payback of less than 1.5 years.

Combining the Powerhouse system recommended measures with interactive effects, resulted in calculated energy savings of 962,200 kWh with a payback of less than two years with incentives and improved system efficiency to 0.199 kW per cfm of compressed air supplied or 50% improvement.

Process Water Systems

For the process water systems, an assessment was conducted that focused on the chilled water and lake water systems, to determine potential energy saving opportunities related to satisfying process cooling loads using lake water in place of chilled water. The following areas were evaluated for energy efficiency improvements:

- Use Lake Water for processes
- Elimination of Central CHW System – Use Lake Water & Localized Chiller
- Variable pumping

The first measure assessed using lake water in lieu of chilled water for one of the site's process system. The design criteria for the system only required 75°F supply. Average load for this area was 32.2 tons, with a maximum load of 218.5 tons. Based on the lake water annual temperature (37-59°F) and flow (283-625 gpm) profiles, there was sufficient lake water available to satisfy the cooling needs for this system. Calculated annual savings was 477,730 kWh with a payback of less than five years, taking into account additional lake water charges.

By implementing the proposed lake water measure, the overall chiller capacity could be reduced to 135 tons for the remaining loads. Implementation of two more efficient properly sized chillers with variable pumping had calculated energy savings of 544,898 kWh with a payback of less than four years. Overall system efficiency improved to 1.16 kW/ton or 48% improvement.

Table 1 provides a summary of improvements identified for each of the process utility support systems.

TABLE 1: Plant Utility System Summary – ECM Assessment

System	Baseline		New Projected	
	Energy	Effic.	Energy	Effic.
Steam	158,576 MMBtu	1,757 Btu/lb	107,458 MMBtu	1,190 Btu/lb
Compressed Air	1,376,680 kWh	0.395 kW/cfm	694,093 kWh	0.199 kW/cfm
Process Water	1,716,004 kWh	2.21 kW/ton	693,377 kWh	1.16 kW/ton

IMPLEMENTAION AND MEASUREMENT & VERIFICATION METHOD

For all energy conservation measures implemented, third party technical reviews were conducted to confirm installation met incentive program requirements and measurement & verification conducted.

Steam System

For the steam system energy conservation measures, the low pressure boilers installed included O_2 trim, a combustion fan VFD, and economizers (Reference Figure 5). The high pressure boiler included an economizer but does not have the O_2 trim or combustion fan VFD due to size. A new deaerator tank and feedwater pumps were also installed.

FIGURE 5: New Steam Boilers

Three years of pre-installation data was used to determine both baseline boiler plant efficiency and the amount of steam blowoff. For the post-install period of one year, boiler logs for both steam produced and gas used for newly-installed Boilers #1, #2, and #3 were taken every eight hours. The efficiencies generated from the steam and gas data were checked against efficiency calculated from stack temperature rise and flue gas percent oxygen and the values aligned. All data was also normalized for weather.

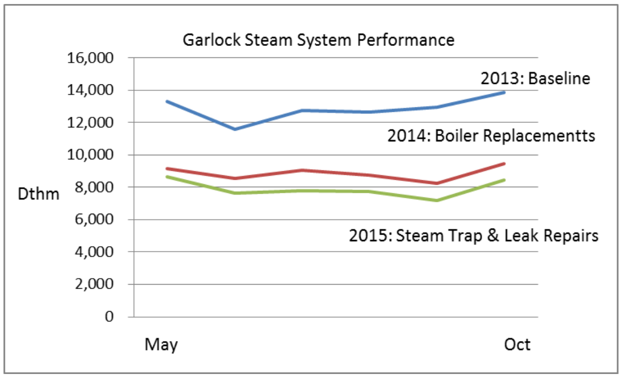
For the boilers, the following points were collected:

- Boiler Operating Steam Pressure
- Boiler Room Temperature
- Boiler Stack Temperature (after economizer)
- Boiler Stack %O_2
- Boiler Steam Flow
- Boiler Gas Flow
- Boiler Firing Rate
- Boiler Runtime

M&V was also performed to determine the savings from the steam trap repair. The average steam flow rate prior to trap repair was compared to after trap repair. The only difference in process steam load during that time would have been from steam trap repairs.

M&V results for the boiler replacement project showed actual annual savings of 39,606 MMBtu of natural gas and 656,806 kWh of electric, resulting in an efficiency of 1168 Btu per pound which was within 2% of estimated efficiency. Lower than planned capital costs resulted in an actual payback of 3.2 years with incentives. For the steam trap repairs and replacements, M&V showed actual annual savings of 10,359 MMBtu of natural gas which was 28% better that originally estimated. Table 2 illustrates the improvements made to the steam system as these measures were implemented.

TABLE 2: Annual Summer Steam Demand Profiles



Compressed Air System

For the compressed air measures, to date, leak repairs have been completed (Reference Table 3) and the recommended two 150 HP single stage rotary screw variable speed compressors (one operating, one standby) with cycling refrigerant dryers were installed (Reference Figure 6). At the time of this report, M&V is currently being conducted and results were not available.

TABLE 3: Compressed Air Demand Profiles

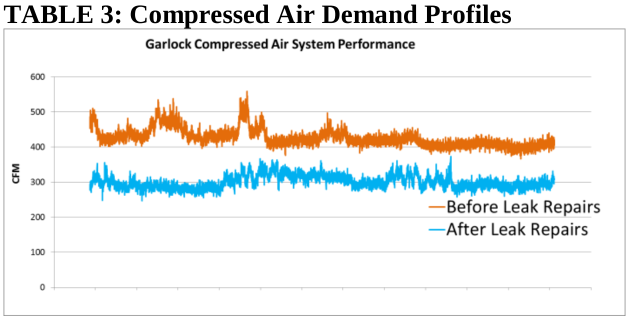


FIGURE 6: New Air Compressors/Dryers

Process Water Systems

All recommended measures have been implemented on the process water system. Seven months of post installation M&V data was collected and analyzed and compared to baseline data gathered as part of the original system assessment.

The largest process load was converted to raw lake water cooling utilizing a plate and frame heat exchanger with 7.5 HP circulating pump. Actual annual energy savings of 519,192 kWh was achieved or 8.7% improvement over the projected savings.

With the proposed lake water measure implemented, the overall chiller capacity was reduced to 135 tons for the remaining loads. The campus was divided into two sections and two chilled water systems. An open loop water system was installed on the east end of the campus as this design was the best fit for the processes of molding operations. A closed loop water system was the best fit for the processes on the remainder of the site, and was installed as the central Powerhouse system. This approach was developed to match the chilled water supply equipment with the load demand most efficiently. Implementation of the two efficient properly sized chillers with variable pumping resulted in actual energy savings of 665,446 kWh and an overall system efficiency of 0.89 kW/ton or a 22% improvement over what was originally estimated.

Table 4 provides a summary of actual M&V results of the improvements implemented for each of the process utility support systems.

TABLE 4: Plant Utility System Summary – M&V Results

System	Projected		M&V	
	Energy	Effic.	Energy	Effic.
Steam	107,458 MMBtu	1,190 Btu/lb	127,586 MMBtu	1,168 Btu/lb
Compressed Air	694,093 kWh	0.199 kW/cfm	TBD	TBD
Process Water	693,377 kWh	1.16 kW/ton	531,366 kWh	0.89 kW/ton

LESSONS LEARNED & KEYS TO SUCCESS

Based on the experience of the authors in identifying, quantifying, and executing energy efficiency for industrial process utilities, integrating energy management into the continuous improvement culture of an organization is the most effective way to achieve maximum resource conservation in a cost effective manner. The methodology to achieve success should consider the following:

- The analysis of industrial process utility energy efficiency is often contingent on fundamental engineering principles such as energy and mass

balances to identify and quantify waste both at the supply and demand sides of the systems.
- The best results are based on actual field measurement of critical parameters such as flows, temperatures, pressures and power. Data logging is vital when there is variability over time.
- When seeking energy conservation opportunities that directly impact process operations, the concerns of the process engineers and managers must be considered. In most industrial plants, product quality and production efficiency are priority. Energy conservation efforts must not override these metrics, and for energy efficiency projects to be successful, buy-in from the production group is critical.
- When seeking energy conservation opportunities that directly impact maintenance operations, the concerns of the maintenance staff and managers must be considered. In most industrial plants, equipment and systems uptime is the priority. Energy conservation efforts must not override these metrics, and for energy efficiency projects to be successful, buy-in from the maintenance group is also critical.
- Energy efficiency measures for process utilities should be tied to energy per unit of utility production.
- Measure, track, and establish goals.
- On-going measurement is critical to maintain performance.
- On-going maintenance practices are critical to maintain performance, including but not limited to steam trap, water quality, and compressed air leak management programs.
- Establish, empower, and reward an active Energy Team that measures, monitors, and takes action.

Key aspects that can be identified and transferred to many industry sectors include the following:

- OEM supplied equipment is typically provided to minimize first time costs, not optimize energy efficiency
- Process utilities are used, added, or expanded to support process needs and are not always the most efficient method
- More efficient methods of control are available today than when process utilities were first installed
- Utilize subject matter experts that have deep experience in both the generation and application of process utilities, including leading technologies
- Utilize funding mechanisms, such as federal, state, & utility based programs to support identification and implementation of energy efficient solutions

Many opportunities exist for achieving energy efficiency in industrial process utility systems which will benefit companies in maintaining their competitiveness in a global environment.

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BIOGRAPHY

Richard F. Rappa, P.E., C.E.M. is a Sr. Vice President at CHA, a full service engineering and construction management firm that provides services to clients throughout North America. He is manager of all manufacturing and energy services provided by the company. He has over 37 years of experience in industrial facilities' operations management, plant engineering, and project/program management.

Mr. Rappa has extensive experience providing energy management solutions, including conducting and managing industrial energy studies, implementing energy solutions, and also performing cogeneration feasibility analyses and Combined Heat & Power (CHP) engineering and design.

Mr. Rappa, who received his B.S. in Mechanical Engineering from Rensselaer Polytechnic Institute, is a registered Professional Engineer in New York State. He is a member of the Society of Plastics Engineers, Association of Facilities Engineers, and Association of Energy Engineers.

Prior to joining CHA, Mr. Rappa was Global Engineering & Environmental Health & Safety Director for ExxonMobil Chemical's Film Division, where he was responsible for capital upgrades and expansions worldwide. He was also Manufacturing Engineering Manager for Bausch & Lomb's Contact Lens Division where he was responsible for development and expansion of contact lens manufacturing processes.

Andrew J. Geoghan is a Sr. Electrical Engineer at Garlock Sealing Technologies, a global leader in high-performance fluid sealing products that serve a wide industry range of chemical, refining, pulp and paper, power generation, petrochemical, semiconductor, primary metals, food and pharmaceuticals, mining and original equipment manufacturers. His main responsibility is the development and upkeep of the building infrastructure and utilities. He has over 21 years of experience in high speed manufacturing, machine design, and project/energy management.

Mr. Geoghan received his M.S. in Electrical Engineering from Clarkson University, is a member of the Association of Facilities Engineers and is working towards his PE license as he currently works as an EIT.

Mr. Geoghan's previous experience was gained at ITT Industries where he was responsible for several automotive component manufacturing lines as they were retooled and upgraded for each new vehicle model.