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E C O L O G Y

Lean & Environment Case Study:

LASCO[®] BATHWARE



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Executive Summary

Lean & Environment Case Study: Lasco Bathware

The Washington State Department of Ecology's (Ecology) Hazardous Waste and Toxics Reduction Program and Washington Manufacturing Services (WMS) partnered in a lean and environment pilot project to provide technical assistance to a Lasco Bathware (Lasco) facility in Yelm, Washington. Lasco manufactures fiberglass and acrylic bath and shower fixtures. Ecology provided environmental expertise for this pilot project, while WMS provided lean expertise and management of the on-site activities at the Lasco facility from May 2006 through January 2007. Funding for the pilot project was provided by the National Institute of Standards and Technology and a grant from the U.S. Environmental Protection Agency (EPA). The primary pilot project objectives were to:

- Evaluate the benefits and synergies of deliberately integrating environmental considerations into on-the-ground lean practices.
- Improve product quality, production efficiency, and product flow in specific areas of the Lasco facility.
- Gain experience to offer and promote lean and environment projects to manufacturers statewide.

Project Activities and Results

Pilot project participants formed teams to address three target areas: (1) packaging and shipping, (2) fiberglass-reinforced-plastic (FRP) spray operations, and (3) acrylic vacuum mold changeover. The teams included cross-functional staff from Lasco and Ecology, as well as a WMS facilitator. The team developed current state value stream maps for the FRP and acrylic lines to identify and prioritize lean and environmental improvement opportunities and participated in three kaizen (improvement) events to implement the identified improvement opportunities.

The collective efforts of Lasco Bathware, Ecology, and WMS produced considerable operational, financial, and environmental benefits. Process improvements include reduced production bottlenecks and cleaner and more organized work areas, decreased variability in spray operations, and reduced energy use and FRP wastes. The facility was also able to reassign over 3,500 annual labor hours to other value-added activities. These improvements also positively affected the plant as a whole by improving ergonomics and internal communication and fostering a more proactive stance toward continuous improvement among production staff.

Cost savings for Lasco Bathware totaled approximately \$135,200 per year for process changes implemented to date, as shown in Table 1. Lasco expects to save another \$60,650 annually for planned process changes that were identified during this project but are not yet complete.

Table ES-1. Annual Cost, Time, Material, and Environmental Savings for Implemented Changes

Reductions	Cost Savings	Time, Material, & Environmental Savings
Labor ¹	\$34,540	2,160 hours
Raw Material and Solid Waste ²	\$1,400	29,000 lbs disposal
Energy	\$99,300	12,600 MCF natural gas ³
<i>Total Cost Savings</i>	\$ 135,240	

¹ Labor redirected for other purposes.

² Estimated potential savings for production of one of Lasco's common models. Based on measurements for one product line, at the production quantity during the kaizen event in 2007.

³ One MCF of natural gas = 1,000 cubic feet.

Table ES-2. Expected Annual Cost, Time, Material, and Environmental Savings (Activities Pending Implementation as of April 2008)

Reductions	Cost Savings	Time, Material, & Environmental Savings
Raw Material	\$ 22,950 \$6,480	43,180 pounds raw resin 1,500 rolls of tape
Labor ¹	\$29,060	1,650 hours
Disposal	\$ 2,160	43,180 pounds of dried resin
<i>Pending Annual Cost Savings Total (Unrealized)</i>	\$60,650	

¹ Labor redirected for other purposes.

In addition to these quantifiable savings, the pilot project also generated numerous other operational and environmental improvements at the Lasco facility, such as the following highlights.

Workplace Improvements

- Enhanced staff communications and morale.
- Empowered staff to suggest and initiate future process improvements.
- Improved ergonomics in the packaging and vacuum molding processes.

Process and Quality Improvements

- Increased the weight of spray on the product, resulting in a stronger, higher-quality end product.
- Freed staff time to assist with other value-added activities.
- Reduced time spent looking for finished inventory.
- Improved point-of-use storage and layout of the acrylic molding area.
- Improved organization of materials and tools in work areas.
- Increased conveyor speed and reduced the number of defects from packaging processes.

Environmental Improvements

- Increased the transfer efficiency of the FRP resin spray, which reduces overspray waste and may eventually result in less resin usage and fewer air emissions.
- Reduced forklift travel, contributing to reduction of energy and operator time.

Post-Pilot Project Activities

Lasco Bathware successfully sustained the pilot-project results in the year following the pilot project activities. The facility has hired a new plant manager who is well-grounded in lean and six sigma and has helped to expand lean efforts at Lasco. Lasco continues to look for opportunities to quantify waste and identify additional environmental improvements. These collective improvement activities have improved product quality, increased production line speed and uptime, increased available floor space, and led to cost, time, and material and energy savings. Lasco's pilot project experiences and subsequent continuous improvement efforts have been shared with Lasco's other facilities across the country.

Conclusions

The Lasco Bathware pilot project allowed participants to identify and implement opportunities to improve production processes, reduce costs, and decrease environmental impacts. The examination of environmental wastes during lean implementation helped project teams identify opportunities that may otherwise not have been considered in a traditional lean project. WMS and Ecology worked well together to provide lean and pollution prevention technical assistance during the pilot project. Lasco employees were highly engaged, and the efforts of all participants led to positive changes in staff morale and empowered staff to seek continued lean and environmental improvement efforts.

This case study summary was prepared for the Washington State Department of Ecology by the Pacific Northwest Pollution Prevention Resource Center and Ross & Associates Environmental Consulting, Ltd. For more information about this pilot project, please contact Judy Kennedy at jken461@ecy.wa.gov or 360-407-6385.

Lean and Environment Case Study

Lasco Bathware

Introduction

This case study describes a Lean and Environment Pilot Project conducted at a Lasco Bathware (Lasco) facility in 2006-07 to integrate lean manufacturing and environmental methods to improve productivity and reduce waste. The Lasco facility, located in Yelm, Washington, manufactures fiber-reinforced plastic and acrylic tub and shower units. Funding for the pilot project was provided by the National Institute of Standards and Technology (NIST), and a grant from the U.S. Environmental Protection Agency.

The Lasco pilot is part of an overall Lean and Environment Project involving Washington Manufacturing Services (WMS) and the Hazardous Waste and Toxics Reduction Program of the Washington State Department of Ecology (Ecology). WMS is the state's NIST Manufacturing Extension Partnership center and provides a variety of services, including lean manufacturing, to help manufacturers become more competitive. The two organizations formed a partnership to jointly deliver technical assistance to improve the operational and environmental performance at three facilities in Washington.¹

The collective efforts by Lasco Bathware, Ecology, and WMS resulted in cost reductions of over \$135,000 per year. In addition, reduced setup times for acrylic molding, reduced weight variability (and overspray) in the resin spray processes, reduced labor and repair work, improved floor layout, and improved flow of work-in-process (WIP) were achieved. Future annual cost savings of an additional \$60,000 are expected when the remaining action items are complete. Less tangible benefits include higher employee morale, increased communication between staff and management, and increased empowerment and awareness for future continuous improvement opportunities.

Pilot Project Objectives

Lasco Bathware's management in Yelm and at Lasco's corporate headquarters viewed this project as an opportunity to implement lean manufacturing.

The main objectives of the project were to:

- Evaluate benefits and synergies of deliberately integrating environmental tools into on-the-ground lean practices.
- Gain the expertise to offer and promote future lean and environment projects to manufacturers statewide.
- Develop a collaborative partnership between Ecology and WMS.

The objectives for Lasco Bathware to participate in the pilot project were to:

- Improve efficiency and product flow in specific areas of the plant.
- Improve production processes and product quality.

The pilot project addressed three areas of Lasco's operations—shipping and packaging, fiberglass reinforced plastic (FRP) spray, and acrylic vacuum molding.

¹ WMS is a not-for-profit organization that provides assistance to Washington manufacturers; it is an affiliate of the National Institute of Standards and Technology Manufacturing Extension Partnership (for more information, see www.wamfg.org). Ecology managed this pilot project through its HWTR Program, which works with businesses and citizens to prevent pollution, safely manage wastes, and raise awareness of hazards and safe alternatives (for more information, see www.ecy.wa.gov/programs/hwtr).

During this project, Lasco created value stream maps to understand the largest sources of lean manufacturing and environmental wastes, and to identify three improvement projects. Following the lean and environment training and a value stream mapping (VSM) and planning improvement workshop, the project teams participated in three kaizen events to implement changes. The changes improved flow and quality of products and reduced costs and wastes.

The remainder of this case study introduces the pilot facility, Lasco Bathware, and describes the improvement activities that occurred from May 2006 through January 2007. It also explains the post-pilot improvement activities and expected future results from actions identified during the project. The results and costs of those activities, and a summary of lessons that Ecology, WMS, and Lasco participants learned from the pilot project are also discussed.

About Lasco Bathware

Facility Background

The Lasco Bathware facility in Yelm, Washington, is one of nine Lasco manufacturing plants in the United States. Annual sales for the pilot facility are around \$40 million, while the Lasco corporate office reports sales of \$350 million for all Lasco facilities. The Lasco Bathware Corporation has been in business for 40 years, yet the Yelm facility was not acquired until 1987. The facility produces a well-known line of high-quality tubs (including jetted models), showers, shower pans, and shower-tubs. Lasco sells its products through a distributor network and to wholesalers and retailers, including Home Depot.

The facility employs about 136 staff (as of February 2008), and runs two major product lines, the FRP spray line and an acrylic vacuum-molding line. The FRP line runs two shifts per day and the acrylic line runs one shift per day. Production levels tend to fluctuate over time with home building and renovation market trends.

Previous Lean and Environment Implementation

One of the key reasons for Lasco's interest in this project was the parent company's view that lean manufacturing could improve its bottom line. The corporate vice president strongly advocated and supported lean manufacturing for all Lasco facilities. Several managers and supervisors had received lean manufacturing training prior to the pilot project participation. Lean and continuous improvement ideas are shared quarterly among the nine U.S. Lasco Bathware facilities.

The pilot facility had informally implemented 5S (the lean practice of arranging a work area to be more efficient and organized) at some stations, used visual workplace techniques to aid with production, moved some equipment to improve layout and efficiency, and implemented "better maintained inventory" systems with suppliers.

Overview of Lean and Environment Pilot Project Activities at Lasco Bathware

Project Scope and Structure

The initial phase of the project involved lean and environment training, a current-state VSM workshop for the acrylic and FRP lines, and an improvement planning and prioritization session based on the VSM. During the planning and prioritization session, the project decision-makers chose to target three focus areas for their lean and environment pilot activities. A kaizen event was conducted on each of the following target areas:

1. Packaging and shipping

2. FRP spray variability reduction
3. Acrylic molding setup reduction

Lean and Environment Integration Strategy

Ecology and WMS staff integrated environmental considerations into lean implementation by:

- Selecting one kaizen event based on its potential to reduce spray wastes.
- Adding environmental aspects to the training presentations.
- Highlighting sources of environmental wastes on the value stream maps.
- Using pollution prevention expertise to identify environmental opportunities during the VSM and kaizen events.
- Analyzing environmental waste streams and costs during both the VSM workshop and the kaizen events.
- Identifying spray transfer efficiency techniques to reduce process wastes.
- Quantifying the costs of environmental wastes (e.g., overspray, reduced material purchase and usage, and reduced calibration wastes) during lean events, along with other savings.

Lean and Environment Events and Projects

“Lean and Environment 101” Training

The pilot project kicked off in May 2006, with a one-day Lean and Environment training session for Lasco production staff and management. During the training, both WMS and Ecology facilitated and presented. Over twenty Lasco staff attended, representing several operations and departments. The training explained lean manufacturing and environmental terminology and tools, as well as strategies for communicating and working together internally. It also laid the groundwork for Lasco staff to begin to think about ways to improve their respective work zones.

The Lean 101 training incorporated slides and examples of how environmental tools and considerations can be used in conjunction with lean. For instance, a “process waste” box was added into the standard “House of Lean” image, which focused on wastes, emissions, and energy. A process mapping chart and exercise were also added to the presentation. The waste management hierarchy² was discussed, and slides were added to identify specific sources and examples of environmental waste typical of the fiberglass industry. Ecology staff provided examples of Washington businesses that had reduced hazardous waste by implementing lean manufacturing methods.

Value Stream Mapping (VSM) Event

The four-day VSM event was conducted in two parts, with a two-week period between the initial and final days of the event.³ The objectives of the VSM event were to:

- Review lean manufacturing and environment strategies.
- Complete current-state and future-state value stream maps for the acrylic and FRP lines.
- Identify and start quantifying the major environmental and production inefficiencies.
- Identify kaizen event target areas.

² The waste management hierarchy offers a prioritization system for waste and pollution streams. The order of priorities is (1) source reduction, (2) reuse and remanufacturing, and then (3) recycling and composting. If these options are not feasible, then the remaining priorities are (4) converting waste to energy and (5) treatment and disposal.

³ VSM is a process mapping method used to document the current and future states of the information and material flows in a value stream from customer to supplier. Lean practitioners use VSMS to identify targets for future process improvement activities.

The current-state VSM event convened with a short training on mapping methods, followed by charting and analyzing the acrylic and the FRP lines' "current state." Fifteen Lasco staff and four Ecology staff supported the preparation of the maps. Several shift leads attended, representing the FRP spray, acrylic mold preparation, shipping, plumbing, and packaging processes.

The participants constructed a line of yellow sticky notes for each processing step in the value streams and ground-truthed the processing steps. Remaining data gaps were identified and filled-in. The participants looked at in-process wastes as well as those associated with preventive maintenance, clean-up, and other environmental emissions or effluents not typically considered during lean implementation.

The event resulted in the identification of several priority areas:

- Reducing overspray.
- Reducing variability in spray thicknesses.
- Elimination of acetone tool cleaning.
- Reducing inventories of finished units and acrylic shells.
- Pull/kanban systems for highest-volume models.
- Reducing long setup times for acrylic molding.
- Flow of work in process through packaging and shipping.

During the VSM process, Ecology identified a toxic primer used for gluing plumbing fixtures in jetted tubs that contains cyclohexanone, methyl ethyl ketone, and tetrahydrofuran. As of March 2007, after formally completing lean and environment pilot project activities, Ecology and Lasco are discussing a less-toxic alternative.

The current-state VSM concluded with a report-out presentation and visit by the plant manager who provided additional information and perspectives, including future plans for a press to recycle overspray, and a method to reduce polyethylene wrap waste at all Lasco plants.

Two weeks after the current-state value stream maps were developed, the teams used these maps along with waste data to prioritize the improvement areas. Ecology staff presented an analysis of the facility's environmental wastes and costs based on data gathered during the development of the value stream map. Further analysis allowed the team to develop an initial plan for five kaizen events. During the course of the project, the number of kaizen events was scaled back from five to three, due to time and resource limitations.

Kaizen Event Structure

The kaizen event implementation dates and the focus areas ultimately selected were as follows:

Event	Dates	Focus
1	July 19 and August 5, 2006 (Planning) August 12 and 14, 2006 (Implementation)	Packaging and Shipping
2	October 12, 25, and 31, 2006 (Preparation/Planning) December 11-15, 2006 (Implementation)	FRP Spray Variability
3	January 15-19, 2007	Acrylic Mold Changeover Reduction

Separate planning sessions occurred for the first and second kaizen events. During the first kaizen event, the team received a brief training on lean manufacturing and environmental method. Then they brainstormed, planned, and prioritized actionable items for each week, and proceeded to implement the process changes.

Kaizen Event #1 – Packaging and Shipping

The first kaizen event focused on improving overall flow through the shipping and packaging areas. The primary problems identified in packaging and shipping area were:

- Lack of organization.
- Clutter (including an unwieldy shrink-wrap oven).
- Inefficiently placed or misplaced tools and packaging supplies.
- Ergonomic issues associated with loading heavy products into boxes.
- Bottlenecks on the conveyor track for FRP products.
- Potential product damage on the conveyor and during packaging operations.
- Wasted time looking for specific models to ship.

After two planning days for the event, implementation happened on August 12 and 14, 2006, involving 22 Lasco staff, four Ecology staff, and the WMS facilitator. Several teams supported the kaizen activities, including the shipping yard, 5S, acrylic product flow, standard work and training, and conveyer flow.

Activities centered on:

- 5S for the acrylic and FRP packaging areas, shipping dock, and outside storage yard.
- Flow improvement and product flow balancing through packaging and shipping.
- Creation of a standard work manual and training video for packaging.
- Ergonomic improvements for packaging jetted products.

Additionally, during the planning days, the team identified an opportunity to completely eliminate a shrink wrap heating oven located in the production/conveyor area. The oven was removed prior to the event implementation dates.

Tables 1 and 2 list the specific activities and results of the event. In addition to these results, the collective improvement efforts have reduced defects associated with the packaging processes.

Table 1. Process Changes and Results for Acrylic Packaging and Shipping

Activity	Results
Created a better method to facilitate loading heavy jetted tubs into boxes, including a new table.	Saved time and reduced ergonomic issues.
Created a pan and skirt cart to help reduce time spent walking for supplies.	Saved approximately five minutes per hour per employee or \$8,000 in labor per year.
Combined use and procurement for two same-sized boxes.	Freed three storage rack spaces in shipping area with a 30% reduction in box inventory.
Organized the area.	Improved general efficiency.

Table 2. Process Changes and Results for FRP Packaging and Shipping

Activity	Results
<p>5S</p> <ul style="list-style-type: none"> ▪ Created shadow boards for tools. ▪ Created storage for banding coils. ▪ Organized storage for supplies. ▪ Cleaned off work bench. ▪ Created storage for the foam. ▪ Reorganized boxing so units are all together. ▪ Labeled supplies and tools. ▪ Posted identification signs for outdoor finished inventory storage and developed a locator display board to ensure the most frequently handled units are easily accessible. ▪ Removed materials no longer needed. 	<ul style="list-style-type: none"> ▪ Improved efficiency and access to needed tools and supplies. ▪ Improved unit storage saves one to two hours per shift, per employee, previously spent searching for a specific model in finished inventory, for an average of \$12,000 in labor that can be used for other value-added tasks.
<p>Flow</p> <ul style="list-style-type: none"> ▪ Painted yellow no-go spaces on the conveyor line to ensure units are adequately spaced as they come down the conveyor line. ▪ Worked with detail/repair process so that quality control (QC) will be the check off for patching instead of a supervisor. ▪ Worked with the detail/repair process to standardize the spacing of the units. ▪ Moved quality control desk so that patch repair staff bring the units to the top of the line, one at a time. ▪ Decided to remove and discontinue use of a shrink-wrap oven in the packaging area by using a blow torch instead of the oven. 	<ul style="list-style-type: none"> ▪ Increased track speed from 2:10 to 1:45 minutes per revolution, allowing staff to keep up with the normal production rate. ▪ Reduced bottlenecks and minimized rushed and idle periods by having patchers bring one unit over at a time rather than multiple units. ▪ Saved an estimated 20 minutes per shift spent adjusting units, or \$2,640 per year in labor. ▪ Reduced defects and repair work formerly associated with units ramming or falling against each other by creating conveyor spacing zones. ▪ Potentially improved ergonomic-related problems due to fewer adjustments. ▪ Reduced an average of \$8,274 per month in natural gas consumption, for an annual savings of \$99,288 by removing the oven.
<p>Standard Work</p> <ul style="list-style-type: none"> ▪ Standardized the shrink-wrapping and packaging processes by creating a manual and video of the process. 	<ul style="list-style-type: none"> ▪ Helps ensure a sustainable method over time.

Kaizen Event #2 – Fiber-Reinforced Plastic (FRP) Spraying

The second kaizen event focused on the resin spraying process for FRP products, particularly on reducing the variability in the application of resin spray to the units, along with other associated inefficiencies. The key issues addressed by the teams were variability in the weights and thicknesses of different parts of the units—a key to defects and cracking of the finished units—overspray, an unbalanced production schedule, and spray gun calibration waste and time.

The FRP line ran about 2,400 units per week at the time of this event. Production occurs on a conveyer belt that holds the molds through the different parts of the process. A mold is first positioned on the conveyor, and then sprayed with a thin layer of gel coat as shown in Figure 1. As it moves down the line and the gel coat begins to

cure, a barrier coat layer is added, and then chopped fiberglass-reinforced plastic containing a fire-retardant filler and catalyst is applied. Air pockets are removed with rollers. Next, the structure is reinforced with corrugated material and wood. Finally, another laminate layer of fiberglass and resin is spray-applied on top of the reinforcement. After curing, the tub is released from its mold, weighed, and inspected.

One of the main goals of this event was to reduce variability in the amount of resin spray applied to a unit. The measurable goal was to reduce the variation in weight of the finished units from ± 13 pounds per unit to ± 4 pounds per unit. Achieving this reduction in variability has the effect of reducing overspray waste and improving resin use efficiency. The project assessed one of Lasco's common products, Model 1603SG. In addition to weight, thickness measurements were recorded to determine if this was another reliable way to measure spray variability. The longer term goals are to sustain the ± 4 pound limit, and to apply the lessons learned from evaluating the 1603SG unit to implement similar controls for other FRP models.

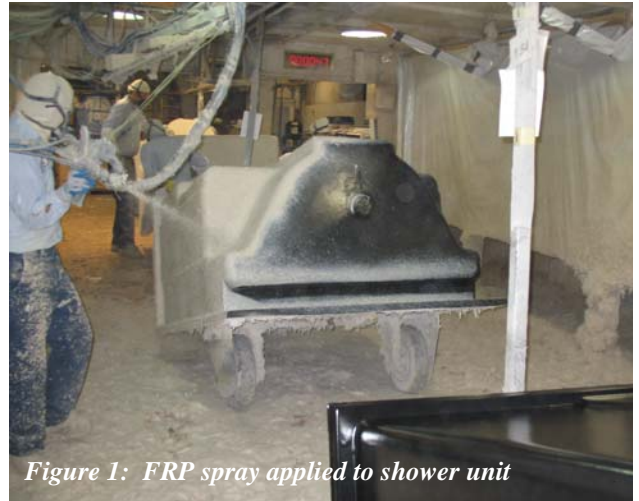


Figure 1: FRP spray applied to shower unit

While some lean tools were used, the approach to address spray variability involved extensive data collection to determine how to best measure and reduce resin fluctuations and final unit weights. Lean manufacturing and related tools used included six sigma⁴, design of experiment⁵, flow, visual workplace, and standard work. Environmental strategies included research on other fiberglass pollution prevention case studies, techniques to improve transfer efficiency, and total cost assessment.

During the course of four days, four teams gathered data on the gun operators' techniques, line scheduling, spray thickness, final unit weights, resin characteristics, gun calibration, wastes, disposal fees, and other factors. An outside consultant trained in spray techniques assisted by demonstrating how to use laser spray equipment and Lasco's laser equipment to optimize spraying techniques.

The teams reached these conclusions:

- Feedback to the gun operators on thickness (in millimeters) and total weight is important.
- When gun operators know their work will be charted for final weight, they were able to consistently meet the new ± 4 pound limit, even with variability of the resin.
- Scheduling a balanced square footage on the line, which equates to an average unit spray time very close to the takt time (pace of production) for this process, is important to maintaining the ± 4 pound limit.
- Gun calibration is important to maintaining the ± 4 pound limit.
- Techniques and training are important on topics such as gun angle, gun distance, and maintaining target shot times.
- Improved spraying efficiency and technique leads to less overspray waste, a more uniform finished product, and heavier finished units that are more resistant to cracking.

Table 3 lists the completed activities, results of the event, and one pending action (as of April 2008). The combined activities and accomplishments eliminated bottlenecks and reduced down time on the line. In

⁴ Six sigma is an improvement methodology and collection of statistical tools that aim to reduce defects and other forms of process variation.

⁵ "Design of Experiment" refers to a structured, organized method for determining the relationship between factors affecting a process and the output of that process.

addition, with more of the spray adhering to the product (an average of about five pounds more spray per unit), the units have improved quality and strength without increasing resin use or air emissions, and while reducing solid waste from overspray. The improved transfer efficiency could allow Lasco to consider reducing the standard weights for each model to pre-kaizen median weights. This would result in reduced hazardous material use, air emissions, and solid waste disposal.

Table 3. Process Changes and Results for FRP Spray Operations

Completed Activity	Results
<p>Overall Event</p>	<ul style="list-style-type: none"> • Proved tighter limits are achievable. • Reduced overspray and calibration waste, and offers potential to reduce resin usage. • Increased management recognition of gun operator’s abilities.
<p>Operator Feedback / Visual Workplace¹ Created methods to provide timely performance feedback to gun operators and management—on final unit weight (for one shower model). Since this kaizen event, Lasco added two additional models to the visual monitoring system to show final unit weights.</p>	<ul style="list-style-type: none"> • Proved that gun operators can meet tighter spray limits given a balanced line and the visual charting of spray performance by weight. • Determined that there is potential to increase the amount of spray that transfers to each unit, making a stronger product. • The potential for more spray on the product infers that overspray is reduced. Assuming five pounds of overspray can be reduced per unit. For the model (1603SG) tested during the kaizen event, this would equate to an annual total of 29,000 pounds of overspray saved, and \$1,400 per year in disposal fees. (The 1603SG line represented about 10% of total production at the time of this activity).
<p>Flow</p> <ul style="list-style-type: none"> • Developed and posted a balanced production/mold schedule based on square footage of each unit and target spray times for each unit. • Established a gun operator rotation protocol. 	<ul style="list-style-type: none"> • Supports meeting the upper and lower weight limits by scheduling units so the average spray time for the units balances out and gun operators can meet the overall production schedule with less idle time for some units and without rushing the spray step on other units. • Improved operator morale.
<p>Calibration</p> <ul style="list-style-type: none"> • Measured impact of gun calibration on spraying quality. • Standardized gun calibration check intervals. • Justified an investment for five in-line flow meters. Purchased in March 2008. 	<ul style="list-style-type: none"> • Determined some of the variability introduced by inadequate gun calibration. • [Once installed] Eliminate the manual gun calibration method of spraying resin into a waste receptacle. The meters will save \$25,114 in disposal and material costs, eliminate 43,180 pounds of solid waste, eliminate the purchase of 43,180 pounds of the resin formulation annually, and reduce 840 hours associated with gun calibration.
<p>Resin Variability</p> <ul style="list-style-type: none"> • Collected data on resin properties and process variables that affect resin consistency, such as density, viscosity, temperature, and thixotropy. 	<ul style="list-style-type: none"> • Increased awareness of factors possibly affecting resin variability, and verification of gun operators’ ability to compensate for any inconsistent properties of the resin.

Completed Activity	Results
<p>Standard Work</p> <ul style="list-style-type: none"> Created more formal spray training tools, a video, and a photo-documented training manual. Evaluated and optimized gun operator techniques. Demonstrated effective use of Lasco's laser-guided training equipment for training purposes. 	<ul style="list-style-type: none"> Helps sustain the improved spraying method over time.

¹Estimated savings for production of one model, based on measurements and production level at time of kaizen event in 2007. The monitoring system remains in place but Lasco has not determined a quantifiable overspray savings for all three units being monitored, or savings potentially attributable to improved spray techniques.

Following the second kaizen event, Lasco Bathware added two more units to the monitoring system for upper and lower spray weight limits. The initial data showed a definite decrease in units that are under the -4 pound lower limit, and also showed that operators can produce units within the ± 4 pound limit. These data have shown that Lasco has an opportunity to either reduce the spray flow rate (pounds per minute) or the spray time per unit, both of which would reduce resin usage and styrene emissions over time.

Since the initial project, staff turnover and spray formulation changes have temporarily affected performance in spray variability. Lasco is responding by revising the standard work procedures and will conduct training (or refresher training) for spray operators. Thus the tools developed during the kaizen event are helpful. They continue to measure and post the data for the operators to review, however, until the operators are retrained, cannot quantify overspray reductions.

If most or all of the sprayed shower and tub models are monitored, spray weights are consistently maintained within the ± 4 pound limits, the potential additional solid waste disposal savings could run over \$14,000 per year and solid waste reduction could be significant. Note, however, that savings potential fluctuates due to changing production schedules, square footage of the units to be sprayed, and other factors.

Another positive outcome of the second kaizen event was an increase in the openness of communications at the facility, especially between production staff and management, and between production and scheduling.

Kaizen Event #3 – Acrylic Mold Setup and Changeover Reduction

The final kaizen event focused on reducing the acrylic mold changeover time for the vacuum former. At the time of this event, the acrylic vacuum former operated for two shifts per day—producing about 114 to 171 units per shift. As of February 2008, the acrylic molding station operates for one shift only.

Production commences with acrylic sheets that are heated to 300 to 400 degrees Fahrenheit depending on the specific material, preceding placement into a vacuum mold. By applying a vacuum, the heated acrylic sheet takes the shape of the mold. After vacuum forming, the back of the acrylic shell is reinforced with a fiberglass-resin-catalyst system, other reinforcements, and a final coat of fiberglass. The back side of the tub is then sanded and finished. Pipes are connected to water jet models. Finally, the acrylic units are weighed and inspected for quality control.

The event relied on lean manufacturing tools such as changeover reduction, flow, total productive maintenance, kanban, point-of-use storage, and spaghetti diagrams, as well as collective brainstorming. A few environmental opportunities were also identified. The setup reduction observation and analysis helped the team to identify and prioritize improvement opportunities. The team set an ambitious goal to cut single mold change-over time of 36.1 minutes, by about 50 percent.

Specific areas identified for improvement were:

- Floor space layout
- Positioning molds in the press
- Taping rims
- Positioning foil on screens

Table 4 lists the activities and results that were identified during the event, and implemented during or after the actual event. Table 5 lists activities identified during the kaizen event but not completed as of April 2008, along with the final results expected.

Table 4. Vacuum Mold Changeover and Setup Reduction Actions and Results

Activity	Results
<p>Flow and Layout</p> <ul style="list-style-type: none"> • Used spaghetti diagrams to identify opportunities to improve storage, movement, travel, and flow of materials and forklifts. • Flow and layout improvements included: <ul style="list-style-type: none"> - Moved mold storage to presses. - Moved bulk sheet storage to adjoining room. - Moved the colored-sheet cutting table next to the colored sheet stock. - Stationed forklifts next to presses. - Moved finished skins storage near the next process step, acrylic spray. - Moved pallet storage to a far corner. - Cleared out unnecessary items blocking the path of the lifts. 	<ul style="list-style-type: none"> • Reduced time to retrieve and replace a mold from (or to) the storage rack by 7.8 minutes per mold changeover and setup, saving around \$7,800 per year in labor. • In addition to less time, the changes reduced the number of lifts, distance moved, and number of molds moved and transferred, which translates to energy savings for the electric forklifts. • Saved several miles of foot travel per year by moving the colored sheet cutting table next to the materials. • Decreased the changeover time, which will allow more on-demand production of skins and therefore will reduce skin inventory and storage.
<ul style="list-style-type: none"> • Replaced the thin (“grocery-store”) foil that is used as a heat distributor during molding with a permanently mounted, adjustable foil sheet. It is mounted on rails and is easily and quickly adjusted to the right position for the particular mold. 	<ul style="list-style-type: none"> • Reduced time spent repositioning and/or replacing the heat distributor sheet by approximately six minutes per any changeover¹ that requires the foil deflector. This amounts to \$2,000 per year in labor savings and reduces purchase of disposable foil material.
<ul style="list-style-type: none"> • Replaced shimming and blocking steps (which were required to ensure proper height and positioning of the mold) with a scissor lift system. One prototype lift is installed and being optimized, prior to plans to purchase three more. 	<ul style="list-style-type: none"> • Reduced shimming and adjustment time by around 2.1 minutes per mold changeover, for an annual cost savings of around \$2,100.² • Improved ergonomics.

¹Not every mold change requires adjustment of this heat deflector.

²This savings will be fully realized when all four lifts are operating.

Table 5. Vacuum Mold Changeover – Remaining Actions and Anticipated Results

Remaining Action Items (as of April 2008)	Anticipated Results
<ul style="list-style-type: none"> Place a semi-permanent silicon seal on all 26 adaptors (the adapter is seated on the mold prior to entering pressing station) as an alternative to the use of high-temperature masking tape to seal the mold each time. The mold that was prototyped at the time of this kaizen event has held up well for a full year. Adaptors and/or molds can also be manually trued to ensure an even better seal. 	<p>If all 26 adaptors are fitted with the silicon seal and the molds are trued, the process changes could:</p> <ul style="list-style-type: none"> Reduce the cost of purchasing high-temperature tape by approximately \$6,480 per year. Minimize tape application and removal for each mold run, which should save about 11 minutes per changeover, or approximately \$11,000 per year in labor. Reduce the amount of tape in the solid waste stream.
<ul style="list-style-type: none"> Create standard work protocols once the final process is set in place. 	<ul style="list-style-type: none"> Will provide important refresher and training material tool to sustain process improvements and ensure that the process operates efficiently

At the end of the kaizen event, the first run through with some of the setup and layout changes complete, the operator achieved a 20 percent time reduction in a single mold changeover. After installation of the first lift, and due to the switch to a more durable foil heat deflector, they were able to achieve a total time reduction of 15.9 minutes (for changeovers that require the foil heat deflector adjustment). Once all the lifts are installed, these time savings are expected to be consistent and sustainable, and to cut mold changeover time from 36.1 minutes to 20.2 minutes. If the silicon seals are fully installed, additional time will be saved.

Post- Pilot Project Activities

Lasco Bathware successfully sustained many of the pilot-project results in the year following the project, and pursued many new continuous improvement activities since then. The facility hired a new plant manager who is well-grounded in lean and six sigma and significantly expanded and matured lean efforts at Lasco.

As part of its ongoing continuous improvement efforts, Lasco Bathware:

- Held 15-minute improvement meetings every two weeks, based on topics from the following book: *Twenty Keys to Workplace Improvement* by Iwao Kobayashi.
- Implemented a 5S scorecard for each working area on a weekly basis. Overall 5S scores have increased over time with an estimated 60 percent of employee continuous improvement ideas being implemented.
- Added weight variability monitoring (as developed in kaizen event #2) to two additional units along with a database system to enter and track various types of defects and the manufacturing process associated with it. A new monitor outside the first lamination booth allows spray operators to view this information and receive immediate, visual feedback on their work.
- Eliminated acetone for tool cleaning in a lamination booth, reducing the use and disposal of approximately 35 gallons per week.
- Improved preventive maintenance, cleaning, and leak detection in the mixing room, mold repair room, and spray gun maintenance.
- Rebuilt conveyor in packaging area to be able to increase conveyor speed to match new takt time.
- Applied 5S to the mold repair room, and to supply room (resulting in disposal of old chemicals).

- Installed a newly redesigned spray boom that reduces operator fatigue.
- Redesigned the break room and equipped it with air conditioning, which should help to reduce operator fatigue on hot days.
- Revamped the existing vendor maintained inventory program to provide improved just-in-time parts management.
- Improved layout in several areas to reduce travel time and material movement.

Plans for a styrene emissions concentrator and thermal oxidizer were already in place prior to the pilot project, to control styrene emissions from the facility. Lasco made the final purchase and installed this equipment in summer 2007.

While environmental improvements are not as high priority for Lasco as productivity improvements, they definitely found value from the pilot project by becoming more cognizant of waste quantification, and identifying additional environmental improvements.

These collective improvement activities have improved product quality, increased production line speed and uptime, increased available floor space, and led to cost, time, and material and energy savings. Lasco’s lessons from the pilot project and their subsequent continuous improvement efforts have been shared with Lasco’s other facilities across the country.

Summary of Pilot Project Results

The pilot project efforts at Lasco Bathware resulted in substantial improvements in productivity, cost, and environmental performance, as well as other benefits for the company and employees.

Cost and Environmental Savings

The lean manufacturing and environment efforts, along with other related process changes at the Lasco facility, are expected to result in annual savings of about \$135,230 from completed changes and another \$60,650 from pending actions.

Table 6 summarizes the quantifiable cost, time, and material savings from implemented actions identified during the pilot project, while Table 7 summarizes savings expected from actions that are pending implementation.

Table 6. Annual Cost, Time, Material, and Environmental Savings from Actions Implemented

Reductions	Source of Savings	Annual Cost Savings	Annual Time, Material, & Environmental Savings
Labor	Event 1 - Productivity improvements	\$22,640	1,420 hours
	Event 1 – Reduced repair of units from poor unit spacing on conveyor	Not quantified	Not quantified
	Event 3 - Layout (excludes shim and taping time reduction)	\$7,800	490 hours
	Event 3 - Prototype lift installed to reduce shimming and mold adjustment. (Savings reflect future when all four lifts are installed).	\$2,100	130 hours

Reductions	Source of Savings	Annual Cost Savings	Annual Time, Material, & Environmental Savings
	Event 3 – New foil heat distributor sheet system	\$2,000	130 hours
Disposal	Event 2 – More spray-on product, thus less disposal ¹	\$1,400	29,000 pounds
Energy	Event 3 – Reduced use of forklift	Not quantified	Not quantified
	Pre-Event 1 – Eliminate shrink oven	\$99,290	12,600 MCF of natural gas ²
Total Quantified Cost Savings		\$ 135,230	

¹ This is the potential savings quantified for one model only assuming operators maintain transfer efficiency measured at the time of the kaizen event. Potential for solid waste and cost savings are significantly greater if spray variability is reduced for all models.

² One MCF of natural gas = 1,000 cubic feet.

Table 7. Expected Annual Cost, Time, Material, and Environmental Savings from Actions Pending Implementation (as of April 2008)

Reductions	Source of Savings	Annual Cost Savings	Annual Time, Material, & Environmental Savings
Raw Material	Event 2 – Avoid resin purchase with five in-line flow meters that will eliminate calibration wastes	\$22,950	43,180 pounds
	Event 3 – Avoid tape purchase	\$6,480	1,500 rolls of high-temperature tape
Labor ¹	Event 2 – in-line flow meters	\$15,960	830 hours
	Event 3 – Avoid taping and shimming ²	\$13,100	820 hours
Disposal	Event 2 – in-line flow meters	\$2,160	43,180 pounds calibration waste
Annual Cost Savings Total (Unrealized)		\$ 60,650	

¹ Labor redirected for other purposes.

^{2a} Pending completion of all silicon seals and truing of molds/adaptors.

The pilot project also resulted in the following additional improvements:

Workplace Improvements

- Enhanced staff communications and morale.
- Empowered staff to suggest and initiate future changes and improvements.
- Improved ergonomics in the packaging and acrylic vacuum molding processes.

Process Improvements

- Increased transfer efficiency of the FRP resin spray onto shower units (with less overspray), which may allow a future reduction in spray flow (pounds per minute) or spray time per unit.
- Decreased the amount of time per shift required to finish the acrylic molds.
- Freed staff time to assist with more value-added activities.
- Reduced time spent looking for finished inventory.
- Documented standard processes, which can be used in refreshers and training.
- Improved layout, point-of-use storage, and general organization of materials and tools.
- Increased conveyor speed for the packaging processes and increased work flow through the area.

Quality Improvements

- Increased the weight of spray on the product for monitored FRP units, resulting in a stronger, higher-quality end product.
- Fewer defects associated with previous packaging processes.

Environmental Improvements

- Increased transfer efficiency of the FRP resin which may eventually result in less resin usage and less air emissions.
- Reduced forklift travel, which contributes to energy reductions and reduces operator time.
- Reduced raw material purchasing costs and wastes with the use of a more durable foil heat deflector.

Project Costs

The total direct costs to Lasco Bathware to conduct this project are shown in Table 8.

Table 8. Direct Project Costs to Lasco Bathware

Project Activities	Costs
Lasco Staff: Lean Training 101	\$2,900
Lasco Staff: Value Stream Mapping	\$6,600
Lasco Staff: Kaizen 1	\$6,800
Lasco Staff: Kaizen 2	\$4,200
Lasco Staff: Kaizen 3	\$3,900
Lasco Staff: Preparation and evaluation between events ¹	\$2,500
Lean Consultant (WMS)	\$6,000
Capital Expenditure ²	\$34,700
Total	\$75,900

¹Conservative estimate.

²Includes recent purchase of five in-line flow meters (pending installation as of April 2008) and one platen lift purchased and in use on the vacuum molding line.

Grant Contributions to Conduct the Pilot Project at Lasco Bathware

Table 9 shows project costs that were not covered by Lasco Bathware, including a portion of WMS facilitation services, Ecology staff participation, and outside assistance documenting project activities and results.

Table 9. Other Project Costs Not Incurred Directly by Lasco Bathware

Costs	
Labor: Ecology Staff Training ¹	\$10,600
Labor: Assistance to Business ¹	\$11,600
Labor: Overhead ²	\$14,000
WMS ³	\$24,000
Total ⁴	\$60,200

Funding	
Ecology	\$22,200
National Institute of Standards and Technology (NIST)	\$8,500
Pollution Prevention Grant (A 50/50 split of U.S. Environmental Protection Agency and Ecology funding)	\$26,600
U.S. EPA National Center for Environmental Innovation	\$2,900
Total	\$60,200

¹This pilot project also served as an opportunity to train Ecology staff. In the future, it is likely that fewer Ecology staff will attend training at a facility, and only those needed to provide service at environmental events will participate.

²Overhead costs cover direct pilot support and management activities including contract management, conducting initial research, attending event report-out sessions, conducting interviews of various participants, contract management, documenting project activities and results, and preparing the case study. Overhead costs do not include overall project start-up costs such as marketing.

³The costs of WMS's lean manufacturing services were paid as follows: \$15,500 by Ecology, \$8,500 by NIST, and \$6,000 covered by Lasco (as noted in Table 8).

⁴Total cost does not include administrative costs to update the report one year following the initial pilot project activities.

Challenges, Successes, and Conclusions

To help others interested in using this model of combining lean manufacturing and pollution prevention technical assistance delivery, some of the challenges, successes, and conclusions from the Lasco Bathware pilot project are listed below.

Challenges

Although the project resulted in significant performance improvements, pilot project participants faced several challenges during the course of the project. A description of these challenges and how participants learned from and addressed them follows.

- **Project Expectations:** The overall objective for Ecology in conducting the lean and environment pilot projects was to obtain and sustain environmental improvements along with lean manufacturing improvements. Because productivity and quality were higher priorities for Lasco Bathware, both Lasco and Ecology had to compromise to achieve their desired outcomes.
- **Target Kaizen Event and Date Selection:** The first two events (the VSM workshop and Kaizen event #1) were conducted in two, non-consecutive, two-day periods. The second kaizen event also had several weeks between the planning days and the four-day event. In contrast, the final kaizen event was fully planned and completed in five consecutive days. While consecutive-day events tend to keep the team(s) focused, in this case, event participants commented that the break between planning and implementation days in the events allowed time to prepare and procure necessary materials.
- **Measurement and Reporting:** Lasco's corporate data management system yielded useful data, but that data required compilation and analysis for use on this project. Ecology found that it can be more complicated to gather data to support environmental efforts than to gather or directly measure lean-related production data during events.

- **Communication and Coordination:** Although communication and coordination throughout the project were very good in general, there were a few challenges. WMS and Ecology had not worked together before, which required some initial acclimation. WMS and Ecology also had different expectations regarding the quantity and frequency of communication.

The first kaizen event posed a bit of a coordination challenge, partly because it was the first implementation event. For example, many more Lasco team members showed up than originally expected, and some had not attended the lean training. On the other hand, having more people allowed the team to address many more 5S and flow projects during the event.

- **Schedule and Resource Limitations:** Originally, five kaizen events were planned. However, following the first kaizen event, participants determined that five total kaizen events was more ambitious than project resources would allow, and narrowed it down to three.

Another challenge was the short timeframe between the second and third kaizen events, compounded by wind storms, holidays, and a power outage that cut one day from kaizen event #2. The ambitious schedule did not allow for the completion of action items from the second event prior to starting the third event. At the end of the project, several action items remained from the second and third kaizen events.

These challenges were not insurmountable; in fact, many of the solutions to these challenges are considered valuable lessons and even successes of the project.

Key Successes and Elements of Project Design and Implementation

Several key aspects of the Lasco Bathware pilot project helped make it successful:

- **Lean and Environment Tools:** Environmental opportunities and examples were successfully incorporated into the lean training and VSM events. Four new opportunities were added to Lasco's state pollution prevention plan as a result of the pilot project. Highlighting the environmental wastes and issues on value stream maps increased awareness of these items and helped the team to address root causes.

In the second kaizen event, the teams used design of experiment and six sigma methods, which demonstrated flexibility and adaptability to the needs of the project.

- **People and Participation:** The WMS facilitator provided excellent direction and cohesion to the cross-functional project teams, and the facility felt the facilitator's services were invaluable during the pilot project. Ecology staff working side by side with Lasco staff helped to ensure that process changes met environmental objectives.
 - After the first kaizen event, the facilitator found it was helpful to develop a "charter" to clarify roles and responsibilities of project team members. By the third kaizen event, there was increased awareness among staff of lean and environmental objectives. Production staff was completely engaged and highly interactive in the final event, and they came up with some ingenious ideas to improve efficiency.
 - The overall project helped institute a system that allows every worker to bring about improvements.
- **Management Involvement:** The strong direction and support of the company's lean champion from the onset was crucial to the success of the project. Additionally, management check-ins during events allowed managers to see first-hand and better understand the value and expertise of their line staff. This opened communication channels between production and management. As the project and events progressed, management became increasingly supportive.

Conclusions

All of the organizations participating in the project—Ecology, WMS, and Lasco Bathware—agree that the environmental component of the project added value to lean implementation efforts and set a precedent for significant future environmental improvements. Without the environmental focus of the grant, teams would likely not have focused on reducing overspray as one of their main events; however, attention to this process resulted in the potential to significantly lower material wastes.

A few overarching conclusions stand out from this pilot project:

- Applying lean manufacturing methods at Lasco Bathware and examining environmental implications during the project helped identify opportunities and value that may not have been considered in a straight lean project. Without explicitly addressing these considerations, project teams may have missed important opportunities to reduce material wastes, improve product quality, and save costs.
- The efforts of Lasco, WMS, and Ecology allowed Lasco to take an initial plunge into lean manufacturing. Since the pilot project, the facility has significantly evolved their “lean culture”. The pilot project also set the stage for looking for waste reduction opportunities and quantifying resulting savings.
- The project improved communications at Lasco and gave staff a sense of ownership and pride in the process improvements made. With the improved staff morale and increased awareness of lean and environmental goals, Lasco employees are more likely to initiate and support future process improvement efforts. In addition, some of the work done at the Lasco Yelm facility may be transferable to other Lasco facilities.
- Because linking lean manufacturing and environmental improvement methods is still a pioneering strategy, client companies must be made fully aware of and sign on to both facets of the project. Expectations at the beginning of the project were different for Ecology than for Lasco. Ironing these out at the onset of the project and making it even more explicit in the signed contract would have made for smoother sailing during kaizen event selection and implementation.
- WMS and the Department of Ecology worked effectively together in helping Lasco Bathware improve operational and environmental performance. After some cultural acclimating and learning about each other’s strengths, WMS and Ecology realized that their people and services effectively complemented each other and enhanced their overall effectiveness at service delivery.

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