Case Study

The Impact of Water on Energy Conservation

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ABSTRACT

This article shows how carpet dyeing plants at Shaw Industries have achieved significant energy reductions as an extension of water conservation and water heating reductions in 2007-2008. Those savings came from the following:
1. Water conservation—both water reuse and reductions in quantity
2. Rinse water temperature reductions
3. Waste-water heat recovery

The impact of these is discussed, and the overall plant performance is presented. Savings for both total water and total energy have exceeded 20% in some plants.

The article includes a process description for the continuous dye line and typical energy and water inputs for each step of the process. Specific changes are itemized, then the revised energy/water inputs for the line are presented. Finally, one plant’s total energy per unit of production over the course of two years shows the impact of the improvements on total plant performance.

ABOUT SHAW AND PROCESSES

Shaw Industries is the country’s largest carpet producer and second largest flooring supplier, with $5 billion in annual sales. The company is vertically integrated, from fiber extrusion through distribution. The company has over 50 manufacturing plants, including facilities for hardwood production, wood lamination, nylon production from caprolactam, fiber
extrusion, fiber processing, carpet production, and nylon recycling.

This article discusses actions taken in six dye plants. The dye plants take white nylon fiber, tuft the fiber into a woven polypropylene fabric, dye the intermediate product, and then apply an adhesive and fabric backing to finish the carpet. The dye process is water- and energy-intensive.

THE DYE PROCESS

The dyeing process uses water-soluble dyes. The dyes are formulated with warm or hot water and applied to the nylon face fiber of the carpet. The fabric is then passed through an atmospheric pressure steam box to set the dye. Upon exiting the steamer, the fabric is rinsed and passed through vacuum extractors for water removal. The “apply, set, rinse, vacuum” cycle is then repeated with stain block. Finally, the fabric is convection dried. All this takes place on a continuous production line. (A flow diagram is shown in Figure 1.) A typical carpet plant with dyeing will have one or two dye lines, each running up to 100 feet per minute.

The water temperature required for the dyes and rinses is $95^\circ F$. The volume of rinse water for the line is typically 150 gallons per minute. A similar volume of cold water is required for the seal water of the vacuum extractor pumps. Other production-related water requirements are boiler make-up water (60 gpm) and water for the latex adhesive. An SBR latex-based adhesive is applied to the back of the carpet in the final step of production in order to hold the face fiber in place. The adhesive requires some water in its formulation, and some water is used to rinse out the latex tanks.

WATER USE

Traditionally, all water requirements were met through the use of fresh water supplied by the local municipal utility. All water heating requirements were met with the use of steam through the use of heat exchangers or direct injection. A couple of dye plants also use more efficient direct-contact hot water heaters. A block diagram of the traditional water use is shown in Figure 2.

“Steam” is noted at applications where the water requires some level of heat. Water heating is provided by steam or natural gas. Dashed ar-
Figure 1. Dyeing Process Flow

Dye Process

Apply Dye → Steam Set → Rinse → Extract → Apply Stain Block → Steam Set → Rinse → Extract → Convection Dryer

Figure 2. Traditional Water Use

Water Flows

Fresh water → Boiler → Steam → Dye → Steam → Dye Rinse → Steam → Extractors → Stain Block → Steam → Stain Rinse → Steam → Latex Mix → Latex Tank Wash → Waste water

Figure 2. Traditional Water Use
row lines indicate a small water flow. The boiler has some blowdown, and some of the dye and stain block will come off the carpet due to saturation and the use of squeeze rollers prior to rinse on some lines.

In 2007, the state of Georgia was in its third year of drought. While Atlanta was hit particularly hard with water restrictions, the rest of the state was also facing limitations. Dalton is the carpet capital and home to many carpet dyeing operations. The local utility was seeking significant conservation measures from the local carpet dye houses in order to insure that there would be a sufficient quantity of water to keep the industry supplied.

WATER CONSERVATION

The most significant conservation step is to divert the extractor seal water for use as rinse water. These vacuum extractors are liquid ring vacuum pumps up to 150 hp. The seal water picks up a few contaminants, but it is still clean enough to be used as rinse water. The seal water also rises 38°F in temperature. The water is warm enough during most of the year that no additional heating is required. Boiler make-up and water to mix dyes require very clean water, so the seal water is not suitable for those applications.

The next conservation step is to use a portion of the stain rinse for the formulation of the stain block. Since stain block is essentially a clear dye, there are fewer color concerns that could impact quality. A similar recovery is not performed with dye rinses to formulate the dye mixtures. The recovery of the stain block recovers both the water and the heat in the water. With this configuration, some water will first be used as seal water, then as stain block rinse water, and finally as part of the stain block formulation.

One final conservation step is to recover water used to wash out latex adhesive tanks for use as the water needed to formulate subsequent latex batches.

A flow chart of the reconfigured system is shown in Figure 3, where “wwhx” indicates fresh water that is first heated with a waste water heat exchanger. The boiler make-up water is further heated in the deaerator. Some plants will heat the dye make-up water further, depending on specific process requirements. Tanks and pumps have been installed to collect and redistribute water, but imbalances that exceed capacity still dump excess or bring in fresh water as needed. Often some fresh water is needed
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in order to keep the contamination level from building too high. These smaller flows and imbalances are noted as dashed lines in Figure 3.

The Impact

The water savings from recovering the vacuum extractor seal water for use as rinse water is 150 gpm. The energy recovery is tied to the 38°F temperature rise of the water. With a combined water/sewer rate of $5 per thousand gallons, a net steam cost of $8 per MMBtu, and 5760 operating hours per year, the savings for this portion of the effort work out as follows:

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**Liquid Ring Vacuum Pumps**

A liquid ring pump is a rotating positive displacement pump. Such a pump is typically used as a vacuum pump but can also be used as a gas compressor. The function of a liquid ring pump is similar to a rotary vane pump, the difference being that the vanes are an integral part of the rotor and churn a rotating ring of liquid to form the compression chamber seal. They are of an inherently low friction design, with the rotor being the only moving part. Sliding friction is limited to the shaft seals. Liquid ring pumps are typically powered by an induction motor.

The liquid ring pump compresses gas by rotating a vane impeller within an eccentric to a cylindrical casing. Water is fed into the pump and, by centrifugal acceleration, forms a moving cylindrical ring against the inside of the casing. This liquid ring creates a series of seals in the space between the impeller vanes, which forms compression chambers. The eccentricity between the impeller’s axis of rotation and the casing geometric axis results in a cyclic variation of the volume enclosed by the vanes and the ring.

*Nash (a division of Gardner-Denver) is a leading manufacturer of liquid ring extractors. Nash is credited with the development of the pump in the early twentieth century.*
Water
(150 gal/min)(60 min/hr)
(5760 hr/yr)($5/mgal)
= 52 million gallons/yr and $259,000/yr

Energy
(52 MMgal/yr)(38°F)(8.34 lb/gal)($8/MMBtu)
= 16,400 MMBtu and $131,400/yr

Savings for recovering the warm rinse water for use in the stain block formulation can be determined in a similar fashion. Here the flow rate is 60 gpm and the temperature rise is 33°F. For this, the water savings work out to be 21 million gal/yr and $104,000/yr. The energy savings become 5700 MMBtu/yr and $45,700/yr.

The savings for the latex water recovery is smaller, and it also contributes to the plant’s overall reduction.

On a plant level, water and energy are key performance indicators (kpi). They are measured weekly. A typical water chart for one of the dye plants for the two-year period that includes implementation of the conservation measures is shown in Figure 4. Conservation measures were implemented during 2007, which is the first half of the chart shown in Figure 4 (in gal/lb).

OTHER MEASURES

Water conservation has had a powerful impact on energy use, but there were also some other steps taken during 2006-2008 that reduced the amount of energy used for water heating. Those measures included waste-water heat recovery, boiler economizers, boiler blowdown heat recovery, more efficient direct-fired gas water heaters, lowering the rinse
water temperature requirement (from 140°F), and reducing rinse water volumes. Together, these measures have reduced the amount of energy required for carpet dyeing. A thermal energy chart (in Btu/lb) for a typical plant is shown in Figure 5.

WHAT IS NEXT?

The first step is to get all accepted and proven conservation measures established at all dye plants. Shaw has one plant that will completely eliminate the use of steam and gas for water heating in 2009. All the water heat will come from waste heat, including the high temperature water required at the deaerator. The objective is to move more plants toward this state.

CONCLUSION

Shaw embarked on a program to reduce water use and increase water reuse. While initially done in response to anticipated shortages, the resulting savings have been dramatic. Not only have the monetary sav-
ings been attractive, but water conservation is a worthy endeavor that promotes green marketing efforts.

There is heat in the recovered water. That heat reduced or eliminated the need to heat water through the use of steam or gas-fired hot water heaters. Like water reuse, the energy savings is also financially attractive and makes a positive environmental statement.

References

ABOUT THE AUTHOR

Jerry Zolkowski, PE, CEM, has a B.S. in Mechanical Engineering from the University of Rochester and an MBA from Columbia State College. His experience includes 10 years at the state industrial extension service at Georgia Tech (energy conservation, environmental compliance, plant & design engineering), 8 years at Pratt & Whitney as a facilities and equipment engineer (equipment modifications and installations for safety and productivity; environmental compliance and waste reduction), 2 years at Harris Press (mechanical design, structural steel stress analysis). He has been finding and evaluating energy conservation opportunities for Shaw Industries’ manufacturing operations since 2004. He can be contacted at: Jerry.zolkowski@shawinc.com (706-275-4750; Fax 706-275-4865).