

U.S. DOE Industrial Technologies Program – Technology Delivery Plant-Wide Assessment at PPG Industries, Natrium, WV

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Executive Summary

PPG and West Virginia University performed a plantwide energy assessment at the PPG's Natrium, WV chemical plant, an energy-intensive manufacturing facility producing chlor-alkali and related products. Implementation of all the assessment recommendations contained in this report could reduce plant energy consumption by 8.7%, saving an estimated 10,023,192 kWh/yr in electricity, 6,113 MM Btu/yr in Natural Gas, 401,156 M lb/yr in steam and 23,494 tons/yr in coal and reduce carbon dioxide emissions by 241 mm lb/yr. The total cost savings would amount to approximately \$2.9 mm/yr. Projects being actively implemented will save \$1.7 mm/yr; the remainder are undergoing more detailed engineering study.

Company Background

PPG Industries is a leading manufacturer of paints and coatings, chemicals, optical products, specialty materials, and glass and fiberglass. PPG has 32,200 employees at 125 manufacturing facilities and equity affiliates in more than 20 countries around the globe. In addition to the Natrium, WV site, chlor-alkali and related products are also manufactured at sites in Lake Charles, Louisiana; Beauharnois, Quebec; and Koahsiung, Taiwan.

Chlorine and caustic soda are produced by electrolysis of sodium chloride brine in electrolytic cells. This is a highly energy-intensive process, requiring large amounts of electricity and large quantities of steam to concentrate the dilute caustic soda. At the Natrium site, downstream processes that consume chlorine and caustic soda also have significant energy input. Total annual energy consumption by the Natrium site is in excess of 13 trillion BTU.

Plant and process descriptions

The Natrium site began operation as a producer of chlorine and sodium hydroxide in 1943. In addition to its chlor-alkali output, the Natrium plant produces chlorinated benzenes, calcium hypochlorite, and caustic PELS®.

Chlorine Department: Chlorine production uses both mercury and diaphragm cells. Chlorine gas from the cells is cooled to condense as much water as possible, then dried using sulfuric acid. Dry chlorine gas is compressed and condensed to produce a liquid product.

Caustic Department: Cell Liquor from the diaphragm cells containing around 11% sodium hydroxide and 15% sodium chloride is concentrated in a series of evaporation steps to 50% sodium hydroxide. Sodium chloride is removed by crystallization, separated using screen-bowl centrifuges and returned to the cells. The DH (“dehydration”) unit removes sodium chloride and metals from 50% caustic to produce a high purity product..

MCB Department: Benzene is combined with chlorine gas from the chlorine department in a reactor to produce chlorobenzene, dichlorobenzene, and trichlorobenzene. These products are then separated and purified through distillation and crystallization. Byproduct hydrogen chloride gas is purified and absorbed into condensate to produce 32% hydrochloric acid.

Cal-Hypo Department: Calcium hypochlorite ($\text{Ca}(\text{OCl})_2$) is produced by reacting chlorine gas with a slurry of lime $\text{Ca}(\text{OH})_2$, caustic soda, bleach liquor, and water. Sodium chloride produced during the reaction is separated from the calcium hypochlorite. Calcium hypochlorite is filtered from the reactor liquid.

PELS Department: Solid, prilled (small pellets) sodium hydroxide is produced by evaporating water from 50% caustic soda in two stages using 175 psig steam and natural gas.

Power Department: The power department supplies energy to all the offices and departments in the plant. The power department has four boilers; three of them are coal fired and one is hydrogen fired. The department has four turbines coupled with generators to generate electricity.

Key elements of the assessment

The assessment was a joint effort between PPG and a team of faculty and graduate students from West Virginia University. Personnel from PPG included operations engineers for the various departments, members of the engineering department, and an engineer from research and development.

The assessment approach encompassed developing energy, material and value flow maps, identifying specific target systems and equipment for detailed analysis, and analyzing the identified systems and equipment. Because of the large size of the plant site, the energy assessment was performed on a unit by unit basis, and the results were integrated across the facility.

Tools provided by the BestPractices program in the U.S. Department of Energy's (DOE) Industrial Technologies Program were used extensively during the assessment. These tools included:

- 1) Motor Master + 3.0
- 2) Pump Evaluation Tool (PSAT)
- 3) Compressed Air System Tool (Air Master +)
- 4) 3E Plus Insulation software
- 5) Steam System Scoping Tool (SSST)
- 6) Adjustable Speed Drives software
- 7) Process Heating Assessment and Survey Tool (PHAST)

"Pinch" techniques were used to determine the minimum practical energy requirement for the chlorobenzenes unit.

Project descriptions

AR No. 1: Insulate Hot Surfaces and Pipes

Some hot surfaces and pipes were found to be radiating significant heat due to lack of insulation. These surfaces can be insulated, thereby reducing the heat losses. The 3E Plus® Software Program, an industrial energy management tool developed by the North American Insulation Manufacturers Association (NAIMA), was used to simplify the task of determining how much insulation is necessary to use less energy, reduce plant emissions, and improve process efficiency. Prioritized energy savings were calculated for each uninsulated surface in each process area. Total estimated energy savings were 217,122 Mlb/yr steam, 150 tons of coal, and 2269 mm BTU natural gas. Some of the identified insulation projects were known to operations and planned for insulation maintenance. Use of the 3E Plus software tool allowed this work to be prioritized and identified new areas for attention.

AR No. 2: Inspect, Repair and Maintain Steam Traps

A preliminary steam trap survey done using ultrasonic equipment found 42/54 steam traps failing. Based upon this result, all 1600 operating traps were surveyed; results indicated an overall failure rate of 30%. It was recommended that the plant institute a permanent steam trap management program. The program should include inspecting the steam traps, cleaning the traps, replacing the trap disc or lever if not working properly and replacing the trap itself if it is defective. This program could be implemented by the plant maintenance staff.

Savings were calculated assuming the trap failure rate would be reduced from 30% to 10%, eliminating an average steam loss of 478.5 M lb/yr per leaking trap.

AR No. 3: Install Economizer on Boilers to Preheat Feed Water

The Power Department has four boilers, with only one having a feed water economizer. Savings were based upon dropping the exit stack gas temperature from 350°F to 250°F. (Dropping the temperature of the stack gas below approximately 250°F can condense corrosive liquids on the heat exchanger, which could reduce the life of the economizer.) The heat content of the stack gas will raise the boiler feed water from an average of 55°F to an average of 71.7°F, saving 4878 tons coal/yr.

Each of the three boilers considering this retrofit also has an air heater that uses flue gases to heat the incoming air. The likely location for the boiler feed water economizer is upstream of the air heater. Further process evaluation is needed to determine if the retrofit will affect energy currently recovered by the air heater.

AR No. 4: Reduce Boiler Blowdown

As water evaporates in the boiler steam drum, solids present in the feedwater are left behind. The suspended solids form sludge or sediments in the boiler, which degrades heat transfer. The dissolved solids promote foaming and carryover of boiler water into the steam. To reduce the levels of suspended and total dissolved solids to acceptable limits, water is periodically discharged or “blown down” from the boiler.

Insufficient blowdown may lead to carryover of boiler water into the steam, or the formation of deposits. Excessive blowdown will waste energy, water, and chemicals. The optimum blowdown rate is determined by various factors including the boiler type, operating pressure, water treatment, and quality of makeup water. Blowdown rates typically range from 4% to 8% of boiler feedwater flow rate, but can be as high as 10% when makeup water has high solids content.

Reducing blowdown rate from 10% to 6% will save 13,660 tons/yr coal. This could be accomplished by feeding demineralized water, produced at a cost of approximately \$0.0011/gallon. Savings are highly sensitive to the cost of demineralized water; they disappear at a cost of \$0.0017/gallon. However, the Natrium plant has several condensate suppliers, and usually runs with an excess of available condensate, due to the creation of condensate during the caustic evaporation process. Consequently, it should be feasible to identify and monitor streams for dissolved solids, perhaps replacing only a fraction of the supplied condensate with demineralized water.

AR No. 5: Install Adjustable Speed Drives on the Fans of Boilers

Induced draft (ID) and forced draft (FD) fans supply air to three boilers at the powerhouse. The load on these ID and FD fans vary with the variation with the steam load, and the steam load varies by up to 46%; the fans operate only forty percent of the time at full load.

During the time assessment, the current on each of these fans was monitored for a seven day period. There were fluctuations in the current (amp) reading which indicates that there was considerable variation in load. This creates an opportunity for installing variable speed drive (VSD) on the ID and FD fans. In addition to energy savings, other advantages of VSDs include smoother control, softer starts, reduced noise, reduced damper/valve maintenance, reduced flow friction heating, and faster response. It was estimated that the total annual electrical energy cost savings for all the ID and FD fans is 4,096,224 kWh/yr, however, only one 1500 hP fan appeared to be marginally viable economically, saving 2,049,696 kWh/yr.

AR No. 6: Repair Steam Leaks

Steam leaks usually develop around valve packing and stems, pressure regulators, and pipe joints. Even a small leak signifies a significant loss of steam produced annually. Steam leaks are one of the most visible forms of energy waste. They should be fixed as soon as possible and its payback is very short. Steam will cause an increase in boiler load and makeup water consumption, as the steam lost has to be compensated by an addition of steam in the system to meet the needs.

Steam leaks were detected visually as a plume of white vapor from a pipe joint, valve or a pressure regulator. Plume Length method was used to estimate steam loss rate. Annually, 153,120 M lb steam could be saved by eliminating steam leaks.

AR No. 7: Perform Vibration Analysis on the Motors

Electric motors generally attract attention of the maintenance personnel only when some the motors burn out or the bearing fails; both resulting in production downtime. However, there is a significant drop in motor efficiency before a complete failure occurs. Vibration analysis is a method that can be used by the maintenance personnel to determine mechanical faults in rotating equipment. The equipment (for example, motors) can be monitored while it is operating and can detect signs of failures, thereby reducing the risk of catastrophic failures¹.

Energy losses can occur due to bearing failure, inadequate lubrication (greasing), belt tension, misalignment and unbalances in the equipment. These losses surface out as vibration, heat and noise. The equipment used to perform vibration analysis is "Miniature Vibration Meter²", and measures vibration velocity in an equipment in inches per second. It can be used to check vibrations in motors, pumps, compressors, and fans. Typical energy savings of 2% of annual energy usage, or 2,001,776 kWhr , were assumed to be recovered by implementing a vibration analysis program.

AR No. 8: Install Moisture Traps To Avoid Moisture Bleeds and Reduce Compressor Air Pressure

Presently there are three 350-hp and two 125-hp rotary screw compressors supplying compressed air to the plant header. All the departments in the plant use the compressed air from the plant air header. Based upon discussions with plant personnel and data collected during the assessment there are approximately forty 1/8" diameter moisture bleeds though out the plant to avoid the excess moisture in the plant air header. These moisture bleeds and utility system leaks lead to artificial air demand.

By installing moisture traps and fixing the air leaks, the artificial demand can be reduced. During the assessment, a maximum pressure drop of 20 psig was observed using the digital pressure gauges and data loggers. Therefore, the reduction in operating pressure from 100 psig to 90 psig will still be able to meet the production demand (80 psig). Combined savings from the lower pressure and reduction in artificial demand result in reduced annual energy consumption by 1,619,218 kWhr.

To prevent the bleeding for moisture removal, we recommend installing moisture traps or desiccant beds to dry the generated air. Because the large network of compressed air piping could lead to moisture collecting in low spots, the latter would be a more reliable solution.

AR no. 9: Lighting Improvements

A variety of projects were identified to reduce energy consumed for lighting. While some are mutually exclusive, all are mentioned below. Total annual cost-savings of the projects was \$46,300.

¹ <http://www.troyelectric.com/techserv.htm>, as in January 2006.

² Miniature Vibration Meter, Model 5500, Metrix Instrument Co. Houston, TX.

- Incandescent bulbs are still used in some laboratory and office areas. Replacing the incandescent lamps with compact fluorescent lamps will save \$9,500 annually with virtually an immediate payback.
- Some areas of the plant were identified as over-lit. Reducing lighting in these designated areas will save \$1,200 annually.
- Simply replacing the 400W metal halide lamps with 360W metal halide lamps will save \$ 6,600 annually.
- Replacing the metal halide, high-pressure sodium, and mercury vapor fixtures and bulbs with T5 bulb fixtures and reflectors will save \$29,000 annually.

AR No. 10: Smaller Projects

Projects with smaller cost savings were lumped together. Total annual energy savings from these smaller projects 2,990,858 kWhr, 3,844 mm BTU natural gas, and 8,623 Mlb steam.

- Implement motor management system
- Install occupancy sensors in designated areas
- Adjust Air Fuel Ratio on the process heaters in PELS and Chlorine department
- Shut off steam supply to building space heaters during summer months
- Repair compressed air leaks
- Use isolation valves to reduce compressed air losses in distribution lines in CS2 department
- Use synthetic lubricants in compressors
- Replace Existing Burners in the PELs and Chlorine department process heaters with higher efficiency burners
- Reduce the heating setpoint temperature for the HVAC system
- Replace drive belts on motors with energy efficient cog belts

Projects planned for implementation

Projects are implemented based upon an economic justification. Payback requirements less than 2-3 years are required.

The following projects are being actively implemented.

- AR No. 1: Insulate hot surfaces and pipes
- AR No. 2: Inspect, Repair and maintain steam traps
- AR No. 6: Repair Steam Leaks
- AR No. 10: Smaller Projects

The following projects are being evaluated by engineering to generate detailed economics.

- AR No. 3: Install Economizer on Boilers to preheat feed water
- AR No. 4: Reduce Boiler Blowdown
- AR No. 5: Install Adjustable Speed Drives on the fans of boilers

AR No. 7: Perform vibration analysis on the motors
AR No. 8: Install Moisture Traps To Avoid Moisture Bleeds and Reduce Compressor Air Pressure
AR No. 9: Lighting Improvements

Projected non-energy benefits

Improvement of the steam trap reliability will reduce the likelihood of freezing condensate lines in the winter, saving maintenance costs. Similarly, elimination of moisture in the compressed air will reduce the likelihood of freezing compressed air lines. Installation of longer-lasting compact fluorescent light bulbs will reduce maintenance to replace bulbs.

Replication plan

Results from this assessment have been communicated to the Organics Technology Committee and to the energy technology manager at Lake Charles, Louisiana. This allowed dissemination of the cost savings ideas to Lake Charles, Louisiana and LaPorte, Texas sites. The results will also be published to the Chlor-Alkali and Derivatives "Operational Excellence" internal web-site.

PPG is a major chlor-alkali producer in the U.S., with Natrium and Lake Charles represent 12.6% of total U.S. industry capacity . Thus, the potential for savings across the industry through replication is significant. PPG has historically been an industry leader in the development and implementation of chlor-alkali production technology.

Project partners

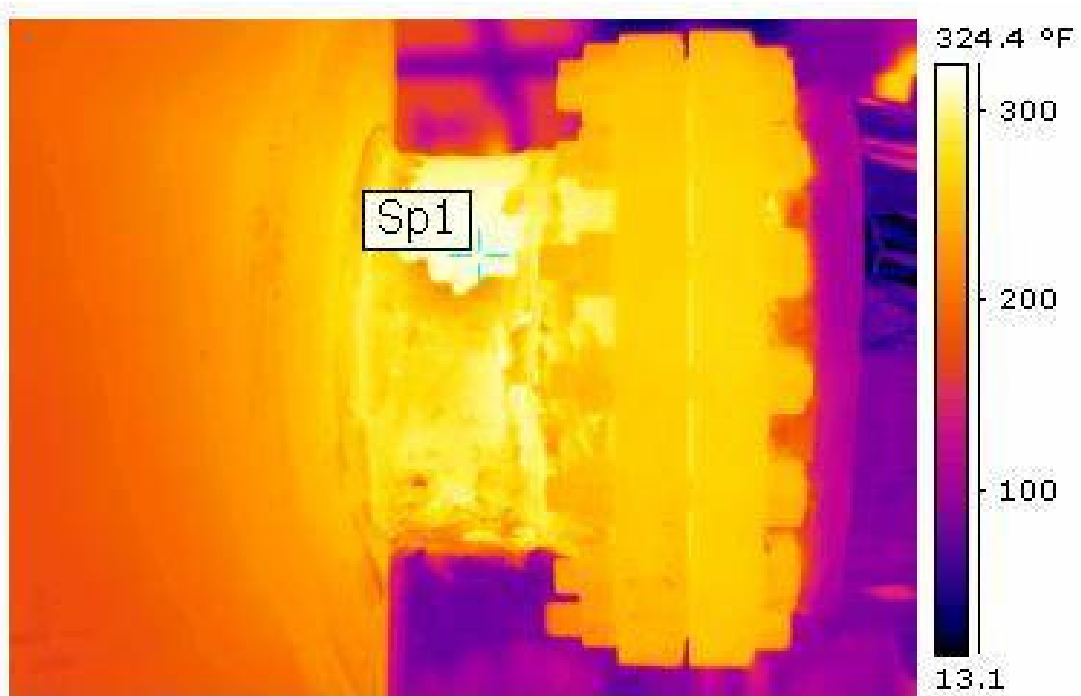
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Plant and/or equipment or process photos



Infra-Red photo showing uninsulated vessel flange.

Table 1: Summary of Recommendations

Final Report	Planned to be Implemented?	Description	Natural Gas MMBtu	Steam Mlb	Coal tons	Electricity kWh	Emissions CO2 (lb)	Annual Cost Savings	% Savings from energy	Implementation Cost	Simple Payback
1	yes	Insulate hot surfaces and pipes	2,269	217,122	150	-	54,471,637	\$ 804,345	100%	\$ 448,908	7 months
2	yes	Inspect, Repair and maintain steam traps	-	153,120	-	-	37,696,457	\$ 656,920	100%	\$ 206,400	4 months
3	pending*	Install Economizer on Boilers to preheat feed water	-	-	9,684	-	49,207,309	\$ 614,934	100%	\$ 440,000	9 months
4	pending*	Reduce Boiler Blowdown	-	-	13,660	-	69,410,558	\$ 299,997	100%	\$ 180,720	8 months
5	pending*	Install Adjustable Speed Drives on the ID and FD fan of boilers	-	-	-	2,049,696	4,488,834	\$ 70,161	100%	\$ 314,747	54 months
6	yes	Repair Steam Leaks	-	22,291	-	-	5,487,799	\$ 90,466	100%	\$ 67,502	9 months
7	pending*	Perform vibration analysis on the motors	-	-	-	2,001,776	4,383,889	\$ 65,513	100%	\$ 25,000	5 months
8	pending*	Install Moisture Traps To Avoid Moisture Bleeds and Reduce Compressor Air Pressure	-	-	-	1,619,218	3,546,087	\$ 55,426	100%	\$ 240,000	52 months
9	pending*	Lighting Improvements	-	-	-	1,361,644	2,982,000	\$ 46,612	100%	\$ 120,927	66 months
10	yes	Smaller Projects	3,844	8,623	-	2,990,858	9,107,239	\$ 160,898	100%	\$ 48,978	4 months
		TOTAL	6,113	401,156	23,494	10,023,192	240,781,810	\$ 2,865,272	100%	\$ 2,093,182	9 months