Process Water Heating Yields Hot Savings

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ABSTRACT

A manufacturer of catalyst products for the oil refinery industry located in Chicago was providing hot water to the manufacturing processes utilizing direct steam injection from process boilers to a hot water storage tank. The boiler plant consisted of three gas-fired low-pressure steam boilers, to heat up incoming cold water for process water heating requirements. Although the boiler plant was in fair operating condition, the boilers were over 30 years old and had measured seasonal heating efficiencies of 60 percent and a corresponding steady-state efficiency of 75%.

To increase efficiency, reduce hot water production costs, and improve response time of hot water delivery, the boiler hot water heating system was replaced with a new and more efficient direct contact hot water heater. The new direct-contact hot water heating system was sized closer to actual load required by the plant in order to increase system efficiencies. Since the new system is better matched to the plant load, energy savings occurred as a result of the new systems reduced input capacity and higher efficiency. The new water heating system also has a steady-state system heating efficiency of over 90 percent and does not require any water treatment. The new system is providing savings in operating costs, responds quickly to hot water demand swings and is reducing overall maintenance costs. This project, which can be duplicated in other industries with facility hot water requirements, has a 2.5-year simple payback.

Introduction

Energy efficiency improvements and production enhancements have long been issues that many industrial manufacturers have tried to improve on. Unfortunately, in today's manufacturing facilities, many of the engineering services, and much of the support that was available 10 to 20 years ago, no longer exists due to downsizing. Therefore, many opportunities related to energy efficiency and improvement of production operations have been overlooked in favor of keeping production operating.

ComEd has identified the lack of on-site expertise due to downsizing as an opportunity to assist its customers by providing engineering services and support functions, previously carried out by the customers' internal engineering departments. By providing energy efficiency evaluations and identifying production enhancement opportunities, ComEd customers are able to reduce operating costs and improve competitiveness. ComEd supports their customers by performing the following:

- Visit manufacturer site and perform evaluations of electric, gas, water, and wastewater operations.
- Qualify and quantify the opportunities identified from the evaluation in the form of a report.

- Review the opportunities and further quantify initial findings through a detailed engineering analysis.
- Review the detailed analysis with the manufacturer and pursue implementation of the opportunity.
- Implement the opportunity either directly through the utility or through a third party with project management support.

By following this format, the customer and utility both benefit by strengthening their relationship and potentially expanding production output of the customer.

This methodology was followed when a catalyst manufacturer for the oil refinery industry located in Northern Illinois participated in a plant-wide energy efficiency study sponsored by the City of Chicago's Department of Environment Industrial Rebuild Program (CIRP) and managed by ComEd. The City of Chicago offers the plant-wide studies free of charge to their industrial customers and also provides low or no-interest loans for implementation of the opportunities identified in the study. This program helps manufacturers identify technologies that increase production speeds, reduce operating costs and improve product quality and offers funding for implementation.

Upon visiting the customer's site, one opportunity to save energy and enhance productivity became apparent based on visual observations and discussions with plant management. That opportunity was to replace the existing boilers for producing process hot water (see Figure 1). Conversations with facility personnel indicated that the boilers were 30-years old and were being targeted for replacement. After performing a combustion efficiency test on the boilers, ComEd revealed that the combustion efficiency was 83%, which translated into a 75% steady-state efficiency (83% - 8% jacket losses). Three boilers, two operational and one standby, with a total combined rating of 65,000-MBh provide 15-psi steam for direct injection into a 10,000-gallon process hot water tank that supplies 310-gpm at 180°F hot water for process operations. The boiler system was originally designed for additional loads in the facility that eventually were removed or downsized. Therefore, boiler system capacity exceeded plant demand , which forced the boiler system to operate inefficiently at low fire most of the time. Continued boiler operation also meant use of water treatment chemicals and continued maintenance.

Additionally, due to the volume of the hot water storage tank, the time duration required to fill the 10,000-gallon process hot water storage tank also resulted in the boilers having a longer duty cycle. This equates to extended run times and increased natural gas usage. On average, the hot water storage tank was being filled when it fell below 86% capacity and stopped filling when it achieved 95% capacity. This narrow fill band was required due to the response rate of the hot water heating system versus plant hot water demand. The opportunity to replace the existing hot water heating system became apparent. The goal would be to find a new system that would reduce operating costs, improve productivity, improve response rates and minimize maintenance costs. Throughout the process, hot water is added either as a batch ingredient or as a wetting agent for filter operations. Due to confidentiality issues, the author could not further describe plant process operations that utilize process hot water in this paper. Through discussions with plant management however, the estimated total flow rate of process water distributed to various end uses is shown in Table 1.

Figure 1. Existing Steam Boiler Plant

Table 1. Annual Process Hot Water Usage

End Use	# of Units	Disposal	Volume	Frequency	Days/yr	Annual Vol. (mcf)	%
A1		Batch	90,500 lbs per batch	4 Batches/week		80,681	1%
A2		Batch	200,000 lbs per batch	3 Batches/day	200	2,139,594	14%
Filters (50,000 lbs/hr/filter)	2	Sewer	50,000 lbs/hr/filter	18 Hrs/Day	200	6,418,781	42%
Filters (25,000 lbs/hr/filter)	1	Sewer	25,000 lbs/hr/filter	18 Hrs/Day	200	1,604,695	10%
Drum Washers	3	Sewer	25,000 lbs/hr/filter	18 Hrs/Day	150	3,610,564	24%
Wet Scrubbers	4	Sewer	1 gpm/scrubber	18 Hrs/Day	200	57,615	0.4%
					Total	**13,911,929**	

Analysis

Once the opportunity to replace the existing boiler system had been identified under the CIRP program, the site requested ComEd to coordinate and commission a detailed engineering study in order to determine the technical feasibility, pricing and system integration of an alternate hot water heating method. The study consisted of evaluating project economics, ability to interface with the existing process and floorspace availability. This study was performed at a cost of $4,000 to the site. The new process heating system needed to:

- Operate safely
- Increase system efficiency
- Increase system reliability
- Decrease overall operating costs
- Provide ease of maintenance
- Produce 180°F water at 310-gpm
- Utilize a proven technology
- Reduce stack emissions
- Require minimal floorspace
- Demonstrate technical feasibility
- Demonstrate economic feasibility
- Integrate into the existing system seamlessly

ComEd was hired as the project manager for the detailed engineering study project to save the plant's engineering staff valuable time in researching an alternate technology. Since ComEd has contact with an extensive network of mechanical and electrical engineering firms as well as several manufacturers representatives', the overall design and costing of this project would be unbiased and provide the best project economics for the site. In addition, ComEd was able to utilize industry "best-practices" to provide a solution to the site that could improve operations, decrease costs, and improve system reliability. After several weeks of analysis, the results were presented to the facility for their review.

There were several technologies available to perform process water heating at the required rate. Competing technologies included high efficiency modular boilers, direct contact hot water heaters (DCWH), and electric boilers. DCWH was recommended for the following reasons:

- Proven reliability at other local installations ensures technology is available at all times
- Reduced operating costs:
  - Fuel – 99% efficiency equates to decreased fuel costs
  - Maintenance – Low maintenance allows personnel to focus on other maintenance activities
  - Chemicals – No water treatment necessary
- Produces 180°F water at 310 GPM which meets process requirements
- Safety of system – Integrated PLC and flame safeguard controls
- Hot water recovery rates – Faster recovery rate allows for increased product quality. This analysis, however, was not evaluated by ComEd as part of the study.
- Environmental impact – Less stack emissions and water treatment chemicals
- Reduced stack emissions due to water "scrubbing" the flue gases. CO_2 is dissolved in flue gas – forms a weak solution of carbonic acid (weaker than club soda)[1]
- Reduced footprint
  - 25-MMBtu unit footprint is 14' X 10' including burner assembly and gas train
  - Frees up floor space which is already at a premium
- Technically simple with "off-the-shelf" parts means that the unit is back up and running in the event of failure
- Good economic return – 2.5 year simple payback
- Integration into existing boiler system (backup) – standard controls and open communication added flexibility for system integration

The site decided to replace the existing hot water generation with the DCWH because the benefits of this system not only included fuel savings but also included product quality, maintenance, flexibility and other benefits.

Since the product produced at this site is a high value commodity, the site elected to keep the existing boiler system as a backup system. Controls for the DCWH and modification of existing boiler and storage tank PLC's had to be upgraded. The existing manual steam valves

[1] Wulfinghoff, Donald R. 1999. *Energy Efficiency Manual. Pages 463-467.* Wheaton, Maryland: Energy Institute Press.

had to be automated with pneumatic actuators. These changes added complexity to a fairly basic system, but increased system flexibility and reliability.

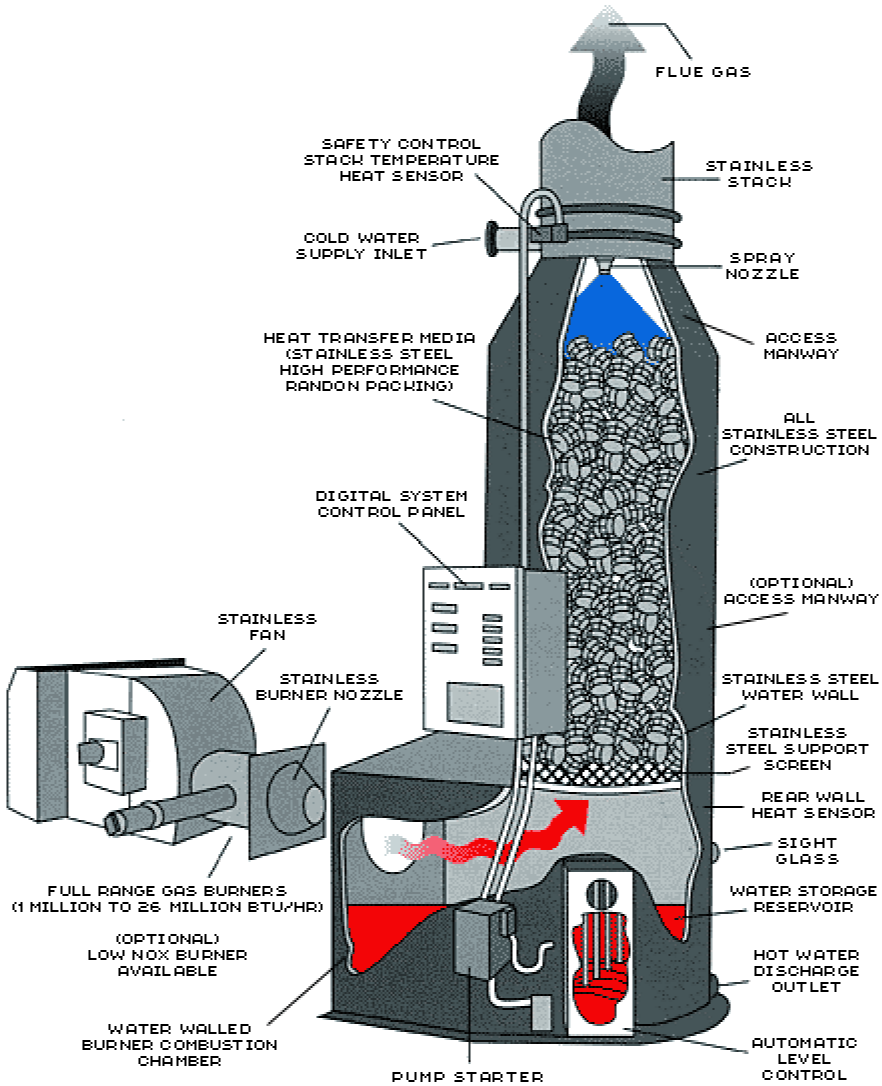
Technology Overview

The Direct Contact Water Heater (DCWH) operates as its name implies. Cold inlet water enters the unit and is sprayed onto stainless steel packing material via a spray nozzle. Exhaust gases from the full-modulating burner assembly rise in a spiral vortex through this packing material and interact with the cascading water, which is then heated. The packing material is randomly packed in the unit and is arranged such that the water cascades down over the material. This increases residence time and the heat transfer rate. Due to the high heat transfer rate of this arrangement and the unit's compact size, the outlet temperature from the exhaust stack is typically 10°F higher than the inlet water temperature. The heated water then is collected in a small reservoir integral to the unit and is then pumped out to hot water processes via a circulating pump. Since the exhaust gases and the inlet water both operate at atmospheric pressure, the DCWH is not listed as a pressurized water vessel and did not require additional employee monitoring or city permitting. The non-pressurized vessel also afforded an extra level of site and personnel safety.

However, since the flue gas temperature can be 10°F above the inlet water temperature, it is primarily water vapor in the stack itself. Mixing with oxygen will cause this mixture to be somewhat corrosive so materials must be chosen with this in mind. Additionally, since the incoming water will mix with the flue gas, the cleanliness of the water could be compromised. For gaseous fuels, the water can be potable due to the clean burning nature of these fuels. However, if other types of fuels are used, the water may become contaminated and may not be potable[2]. Therefore, applications of this technology must be reviewed on a case-by-case basis for applicability. An overview of this technology is shown in Figure 2 below.

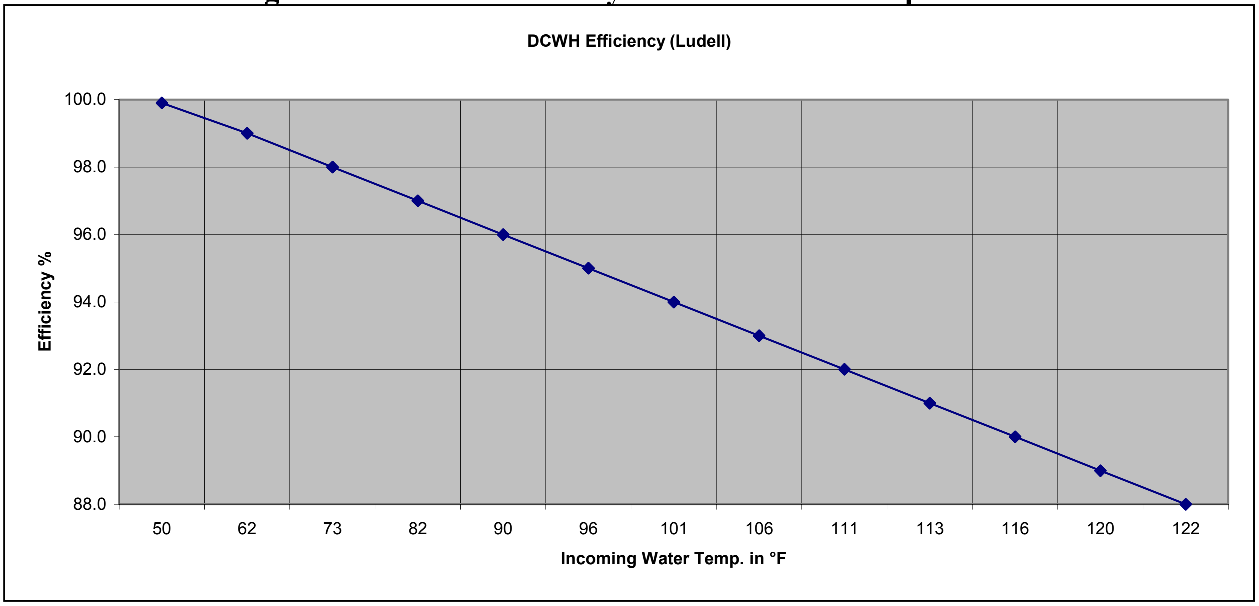
[2] Ludell Manufacturing – Division of Ellis Corporation. *Phone consultation with Mark Liberto and Donald Betts.*

Figure 2. DCWH (Courtesy of Ludell Manufacturing)



Additionally, the incoming water temperature, as shown in Figure 3, impacts the water heater efficiency. For this installation, the average annual incoming water temperature is 55°F.

Figure 3. DCWH Efficiency vs. Inlet Water Temperature



Results

The facility decided to install the DCWH as the primary means of hot water generation and use the existing boiler system as backup. Based on existing hot water demands in the facility, it was determined that 20,000-MBh would be satisfactory. However, anticipating additional production growth in the future, a 25,000-MBh unit would was ordered and arrived at the site 7 weeks later.

The unit was installed on a 4" concrete reinforced pad capable of providing space for the unit itself plus the burner and gas train assemblies, transfer pump, and motor as well as providing room to operate the unit from the field installed control panel. The installation required 3 weeks, with two additional weeks for debugging and training for the operators. Once installed and operating, gas usage and water inlet and outlet temperatures were metered and logged on a monthly basis. This metered data enabled analysis of operations and adjustments based on inlet and outlet water temperature. This information was also used to determine actual project savings.

Since the DCWH installation was completed in late 2004, the site has been realizing an average fuel savings of $700 per day or $175,000 per year. Maintenance savings of $8,000 per year and water treatment cost avoidance of $22,000 per year are expected. Plant operators base energy savings on the tracking of energy and water usage via field installed metering plus manual logs. With a total site savings of $205,000 per year from each of the above mentioned savings areas, the calculated simple payback period is estimated at 2.5 years. It is important to note that the above stated savings are averages. Actual savings will vary based on the type of product being manufactured and the duration of manufacture since each product requires a different level of hot water usage.

The DCWH, with its fast response rate, now cycles on when the hot water storage tank is at 50% capacity and turns off when the storage tank fills to 92% capacity. This increased fill band window equates into less natural gas usage and less overall operational costs. To fill the storage tank with hot water previously, it would have taken over 30 minutes. With the DCWH system, total time required has gone down to less than 20 minutes largely in part due to the instantaneous heating of the water.

A calculation based on field recorded gas usage data from plant operators for the month of March is shown below in Figure 4. Data for this calculation was extracted from the inline metering upstream of the DCWH that was installed as part of this project. For the month of March, hot water usage was slightly above average however the cost of natural gas was considerably higher than forecasted. January and February 2005 data was not accurate due to unit startup issues that prevented a full month of data from being recorded. Therefore, the month of March is the first full month of credible data.

Figure 4. March Natural Gas Savings Calculation

March 2005 Natural Gas Consumption Analysis									
A1)	Conversion Constant from scf to Therms:	100	(100 scf/therm)						
A2)	**March 2005 Reported Therms:**	**71,760**							
A3)	Calculated scf from Reported Therms	=	A1	*	A2				
		=	100	*	71,760				
		=	7,176,000		scf				
A)	March DCHW Usage (actual):	7,176,000	scf		(@ STP; 60°F, 1 ATM)				
B)	DCHW Steady State Efficiency:	99%							
C)	Boiler Steady State Efficiency:	75%							
D)	Equivalent March Boiler Usage	=	(A	x	B)	/	C		
		=	7,176,000	x	0.99	/	0.75		
		=	9,472,320		scf				
E)	Higher Heating Value (natural gas):	1,050	BTU/scf						
F)	March 2005 Cost per Therm:	$0.786							
G)	Consumption Savings (scf)	=	(D	-	A)				
		=	9,472,320	-	7,176,000				
		=	2,296,320						
H)	$ Savings	=	(G	x	E	x	1 Therm/100,000 BTU	x	F)
		=	2,296,320	x	1,050	x	0.00001	x	$0.786
		=	**$18,952**						

The turnkey installation of this technology at the site exceeded the original budget for this project due to the installation of additional technologies supporting the DCWH system requested by the site. Additional work that increased the total project costs included the integration of the existing boiler system with the DCWH for redundancy purposesand installation of pneumatic control valves to aid in the control and safe operation of the DCWH. In total, the project cost over $500,000 to implement and consisted of the following key costs:

- Equipment & Material = $275,000
- Labor = $180,000
- A/E Fees = $67,000

If the DCWH unit were not incorporated with the existing boiler plant for reasons of redundancy, the total project cost would have been over $350,000. The additional engineering, material and labor added costs to the base project once redundancy was desired and ultimately implemented.

Conclusions

The implementation of a direct contact hot water heating system for process water heating is not a new idea. This technology has been used for other applications for quite some time. However, as the cost of fossil fuel continues to rise, energy efficiency is becoming more important from an operations perspective. The need for energy efficient technologies to displace traditional technologies is becoming a more common practice. The installation of the DCWH for process water heating at this catalyst manufacturer was one of the first of this type of application. To date, most installations have been used for commercial laundering and process water applications in the concrete industry. The main driver was to reduce operating costs. Traditional approaches to improve the efficiency of the existing boiler or go to a more traditional solution were not options after a preliminary review since these technologies could not match the efficiency gains of the DCWH. Quite simply, the efficiency of the DCWH and its associated reduced operating costs were factors that made this project feasible. The secondary benefits such as increased reliability, increased response times and reduced maintenance helped management embrace the new technology.

Although this technology has proven itself from an economics perspective, the main hurdle was the technical implementation. This often proves to be the main barrier to implementation of new energy efficient technologies, as most businesses dislike the risk associated with them. However, with proper education, an explanation of the benefits, assurance from a serviceability perspective, and review of other similar installations, many end users will come to embrace the installation of new technologies such as the DCWH.

References

Wulfinghoff, Donald R. 1999. *Energy Efficiency Manual. Pages 463-467.* Wheaton, Maryland: Energy Institute Press.

Ludell Manufacturing – Division of Ellis Corporation. *Phone consultation with Mark Liberto and Donald Betts.*

General Energy Corporation. *Phone consultation for various manufacturer performance data with Prem Mehrotra – President.*