RTO UPGRADE PROVIDES COST SAVINGS AND PERFORMANCE IMPROVEMENTS

Abstract

Pollution abatement systems are a standard requirement for the solvent based coating processes, with planning these do not need to be an add-on burden to the operation. By initial review and analysis, the installation of upgraded pollution abatement equipment can both improve the process controls and reduce the operational costs. Madico operated with a traditional recuperative thermal oxidizer system utilizing heat recovery. Through complete analysis of air flow, heating loads, and process constraints, a new thermal oxidizer system was installed with heat recovery, adequate to operate the entire process. This system provided a 90% reduction in gas consumption for the company, eliminated constraints in exhaust capacity and improved reliability.

Background

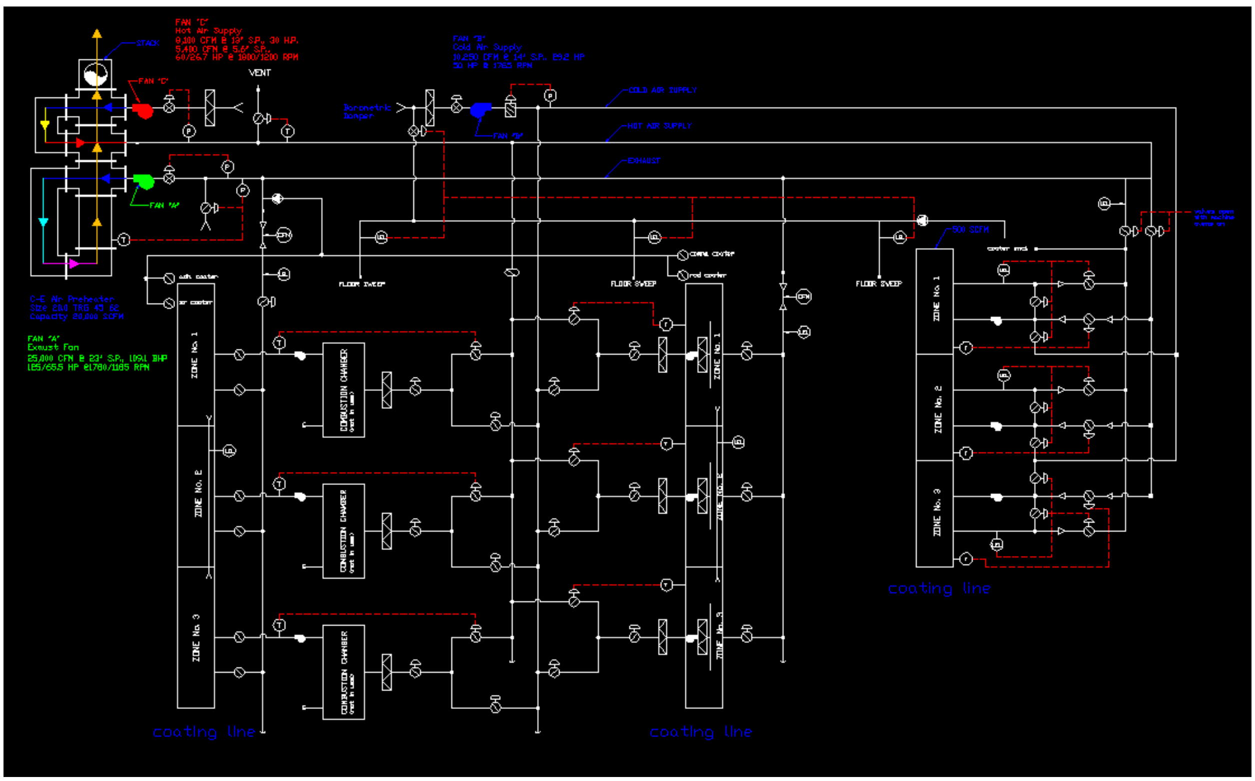
The Clean Air Act promulgated regulations requiring facilities to control emissions. During the 1980s a large number of systems were installed on solvent coating facilities. Typically, these were designed to meet BACT standards, best achievable control technologies. There were, and are, several competing technologies to address these needs. Each process, product, and solvent mix are factors in determining which is the best technology for a specific facility. Many short comings of the various technologies have been addressed through design improvements and options.

Typical technologies to be considered during the early time frame were Regenerative Thermal Oxidizer with random media, Catalytic Thermal Oxidizers, Recuperative Thermal Oxidizers, Carbon Adsorption recovery systems, Condensation recovery and simple Flairs. Each of these systems has limitations and advantages and these must be considered to match the process where they will be used.

Madico, a small coating operation, located in near metropolitan Boston, is in an area where oversight, enforcement and controls are very stringent. This drove a speedy installation and compliance to the BACT technology. There were several key considerations for Madico in the selection of a pollution abatement control system.

- Mixed Solvents: Madico has many different coatings and a broad range of solvents for these solutions. Some of these are not compatible with Carbon absorption technology.
- Space: the facility is located on a small parcel of land that limits the extent to what type of solution could be implemented. For this reason, a large recovery system would be very difficult to implement.
- Silicone Coating: Madico manufactured products where silicone coatings are applied, this presented the concern of poisoning of catalyst and fouling of beds.
- Capital Costs: Being a smaller, privately owned at the time, costs were a major concern.

The selection lead to the installation of a Combustion Engineering Preheater, rated at 20,000 SCFM. This unit had two steps of heat recovery in order to make it more efficient. It utilized an air to air heat exchanger to increase the process exhaust air temperature prior to introduction to the burner zone of the unit (hence the name pre-heater) in order to reduce the amount of energy required to completely destroy the VOCs. Also, taking advantage of the heat recovery at that time involved the use of a second air to air heat exchanger to return air heated air to the drying processes. This hot air was controlled as a pressure plenum into the processes, with a cold air plenum provided as well. Controls for these fans were through inlet vane control on a pressure controller. The individual oven zones would have the exhaust and cold air supply adjusted to assure negative oven pressure, and the hot air would be controlled through a temperature controller. The oxidizer utilized a two speed exhaust fan to draw air from the processes, the duct pressure was controlled by adjusting the inlet vanes of the fans.



This system was quite energy intensive in gas consumption and electricity of the fans as damper controlled was utilized rather than variable speed controls. At the time this project was implemented, technology was not nearly as advanced as it is today, PLCs were limited and not standard equipment as they are today, VFDs were not as reliable and were also very costly.

Over a period of time, the process requirements for the equipment changed; new coatings, additional machinery, and increased fugitive controls, all of which pushed the unit to its capacity. As production demands increased and energy costs moved up, the CE Preheater became the operational bottleneck for Madico. Numerous process adjustment projects and efforts were completed to manually control and optimize the performance. This task was complicated and required operators and technicians to review the system and make adjustments whenever there were any process changes. While it did reduce gas consumption, it was a burden and distraction to the process of making product.

Project Definition

With these driving requirements, a project was organized to review alternatives and plan replacement of the thermal oxidizer. The project outlined several key criteria/objectives for the project:

1. Energy reduction needed to be large enough to pay for the capital investment over several years.
2. Environmental compliance must be maintained. Madico operates as a 100% capture facility with 99% controls of the emissions.
3. Operating efficiency of the machines needs to be improved, and work independently of the oxidizer.
4. This must be installed in the shortest period possible in order to minimize customer service disruption.
5. There should be enough capacity in the unit so additional machinery can be added in the future.
6. A means to provide heat to the process must be determined

This last item, process heat, presented the largest challenge. The existing system provided "hot air" to the process that typically was over 750°F, with a hot valve bypass pushing most of the recovered hot air directly to atmosphere. This coupled with various product mixes presented a significant engineering challenge as the replacement of this system could be accomplished possibly by a large burner system for hot air to all the lines or some other type of heat recovery from a new thermal oxidizer. In any case, the requirements had to be carefully defined and this would require additional expertise.

Several potential "experts" were interviewed and the answers and solutions ranged widely depending upon expertise and product considerations.

THERMAL OXIDIZER CONSULTANT COMPARISON

FACTOR	Consultant Service	RTO/Dryer Builder	Local Consultant
Cost Analysis of various options	yes, modeled(excel)		
Total Air Flow Analysis	yes	yes	yes
Testing & data collection	yes	yes, 2 people 5days	yes
Duct checks	yes	yes	
Dryer analysis	yes	yes	yes
Make Up Air Consideration	can do (not inc.)	yes	
Existing Unit Analysis	yes	yes	
Exhaust & Supply damper for coating operation	yes	yes	
Proposal Flow Diagrams	yes	yes	yes
Familiar	Yes	Yes	No
Local - Travel Factor	Poor	Poor	Excellent
References - Reputation	Good	Excellent	Good, ? On actual installations
Costs Phase I (analysis & data)	$20,000 travel extra	$25,365	$18,000
Costs Phase II (spec. & quote)	$30,000		
Permitting Assitance			yes
Know Mass DEP	late 80s		yes
Credits towards a T.O.	no	yes	no
Hold a Schedule	claim yes		

After a careful review, the RTO/oven supplier was selected. The single largest consideration was confidence in their ability to design a heat recovery system for the process.

Process Study

This required a complete analysis of all air flows and direct measurement all points possible and solvent loading analysis for the various products. In order to complete the readings, a digital micromanometer was utilized, this is piece of equipment that greatly simplifies air flow measurements and should be a fundamental instrument in this type of project. An FID system was also utilized to make an accurate measurement of the solvent loads for the various exhaust points. Product mix and machine conditions had to be carefully monitored during the tests to determine a range of requirements.

The exhaust points, enclosure capture measurements, and several supply values could be directly measured; however, the hot air system was far too hot to safely conduct a direct measurement. This required several methods to determine the amount of heat load that was required. Depending upon the machine, and conditions, the total air supply per zone was measured, the nozzle velocities and gaps measured, and web slot velocities. This data, coupled with the engineering data for the fans, and original oven design criteria, where available were utilized to calculate the total heat load and determine the air use.

Once a heat load by product was determined, a new "hot air" temperature set point had to be determined along with targeted machine speeds. Many of the speeds during this testing were constrained by lack of exhaust pressure. Based upon the plan to increase the machine speeds, the heat load would also have to be scaled to match the increased exhaust demand.

Ultimately, after the measurements were gathered, the design point for the exhaust was determined through a solvent loading spread sheet analysis. Below is a typical analysis for one of the coating lines. The solvent types were analyzed for air requirements to meet the LEL criteria of 25% of LEL by volume, the design point for ovens as defined in NFPA 80. Madico utilizes LEL monitoring equipment which does allow operation up to 50% of LEL, but prudent engineering practice is to design to the 25% of LEL level.

SOLVENT LOADING CALCULATION

				Cubic Ft. air / lb. Solvent		
				100% LEL		25%LEL
	LC-2		ethyl acetate		192	767
	HIGH		toluene		365	1460
Ctg	AP-15-02		MEK		379	1516
Ct Wght	4.9	g/sq.m dry	Hexane		424	1695
% solids	15.31%		IPA		314	1255
Speed	125	FPM				
max. width	61	inches				
min. width		inches	Raw Cuts			
coat spread	32.00523	g/sq.m.	AP-15			% of 15-02
solvent spread	27.10523	g/sq.m.	ethyl acetate		44.00%	14.10%
	0.005552	lb./sq.ft.	Hexane		11.00%	3.53%
# solvent/min	3.527818	lbs/min				
#solvent/hour	211.6691	lbs./hour				

Specific Solvents		lb./min	cfm for 25% LEL
Ethyl Acetate	14.10%	0.59	450.56
MEK	33.23%	1.38	2099.37
Toluene	33.83%	1.41	2057.44
Hexane	3.53%	0.15	248.84
TOTALS	84.69%	3.53	4856.21

The following is the typical analysis conducted for the supply system and heat load requirements in the design of the heat recovery system.

		Flow rate		Temperature			Solvent (#/hr)	
Point	Label	SCFM	ACFM	F	R	C	max	min
1	TOTAL Hot Supply L/C 2	820	1254	350	810	176.6667		
2	TOTAL Cold Supply L/C 2	2120	2120	70	530	21.11111		
1A	Hot Supply Z1	137	209	350	810	176.6667		
2A	Cold Supply Z1	843	843	70	530	21.11111		
--	Blended Supply Z1	980	1052	109.0698	569.0698	42.81654		
--	Recirc Z1	0	0	100	560	37.77778		
4	Total Supply Z1	980	1052	109.0698	569.0698	42.81654		
1B	Hot Supply Z2	342	522	350	810	176.6667		
2B	Cold Supply Z2	638	638	70	530	21.11111		
--	Blended Supply Z2	980	1161	167.6744	627.6744	75.37468		
--	Recirc Z2	0	0	120	580	48.88889		
5	Total Supply Z2	980	1161	167.6744	627.6744	75.37468		
1C	Hot Supply Z3	342	522	350	810	176.6667		
2C	Cold Supply Z3	638	638	70	530	21.11111		
--	Blended Supply Z3	980	1161	167.6744	627.6744	75.37468		
--	Recirc Z3	0	0	120	580	48.88889		
6	Total Supply Z3	980	1161	167.6744	627.6744	75.37468		
7	Exhaust Z1	1680	1775	100	560	37.77778		
8	Exhaust Z2	1680	1838	120	580	48.88889		
9	Exhaust Z3	1680	1838	120	580	48.88889		
3	Oven Exhaust Total	5040	5452	113.3333	573.3333	45.18519	211.8	25.1
9A	Floor Sweep	1540	1540	70	530	21.11111		
9B	Infiltration	1050	1050	70	530	21.11111		
9C	Infiltration	1050	1050	70	530	21.11111		

With this analysis completed, the sizing of the RTO could be completed, but consideration needed to be provided for future expansion. The initial "wish" list would have required almost doubling the size of the unit, with a nearly 50% cost increase. Additional capacity was provided for one additional machine similar to the existing lines.

POINT	SCFM
Machine Load	25,500
Enclosures	3,000
Mixing area	3,000
General Fugitives	1,500
Future Addition	10,000
TOTAL REQUIRED	**40,000 SCFM**

With the study complete, and air flows clearly defined, and heat recovery requirements understood, the final proposal and specifications were developed and quotations obtained for the planned solution. The key design features of this system were:

- CFM capacity was doubled to 40,000 scfm
- All Fans were run on VFDs with controls New main exhaust fan of 250 HP
- New pressure controlled exhaust fans for each machine
- T-Dampers for each machine
- Self Sustain somewhere in the area of 5 to 6% of LEL
- Heat recovery system for process ovens
- RTO “bottle-up” feature to reduce reheat time after shutdowns
- Operator interface through touch screen
- Cold Air make up from outdoors
- Fugitives directly to RTO
- Reduced energy consumption

Oxidizer Comparison for Madico, Inc.

			Thermal Recup Costs		RTO Costs		Thermal Recup Costs			RTO Costs		
Air Flowrate	Air Temp (F)	Solvent Loading (btu/hr)	Fuel (btu/hr)	Electrical (kw/hr)	Fuel (btu/hr)	Electrical (kw/hr)	Fuel ($/hr)	Electrical ($/hr)	Total	Fuel ($/hr)	Electrical ($/hr)	Total
9,000	70	0	6,752,115	26	--	--	$50.64	$2.87	$53.51	--	--	--
36,240	100	23,752,800	2,995,412	130	0	170	$22.47	$14.33	$36.80	$0.00	$18.66	$18.66
36,240	300	23,753,800	0	177	0	202	$0.00	$19.45	$19.45	$0.00	$22.20	$22.20
36,240	100	2,628,150	24,121,062	130	1,157,210	170	$180.91	$14.33	$195.24	$8.68	$18.66	$27.34
36,240	300	2,628,150	21,182,687	177	480,105	202	$158.87	$19.45	$178.32	$3.60	$22.20	$25.80
10,000	70	0	--	--	1,433,249	28	--	--	--	$10.75	$3.03	$13.78

Assumptions
- Both the Thermal Recuperative Oxidizer and Regenerative Oxidizer have no Heat Loss to Atmosphere
- The Pressure Drop for the Recup is about 19 Inches Water Column
- The Pressure Drop of the RTO system is about 22 Inches Water Column
- The Fuel Costs $0.75/therm and $0.11 kw/h

Anticipated Return on investment based upon the following estimates:

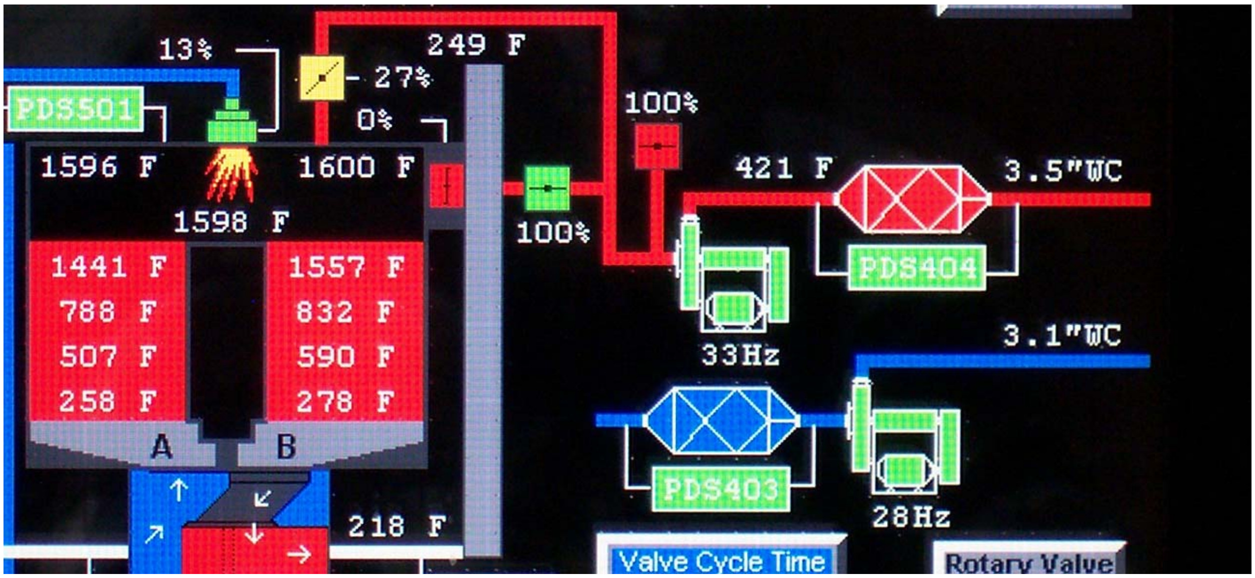
- Increased capacity $ 200,000 (line speed stabilization)
- low gas cost $ 370,000
- present gas cost $ 550,000
- high gas cost $ 735,000

Range of return from $ 570,000 to $ 935,000, the anticipated simple payback is roughly 2 years.

The project plan called for the unit to be installed and operational (no process connections) prior to shutting down the operation to do the complete tie in to the processes, including exhaust fans, t-dampers, duct work, hot air supply including filtration and duct work, cold air supply including filtration and duct work.

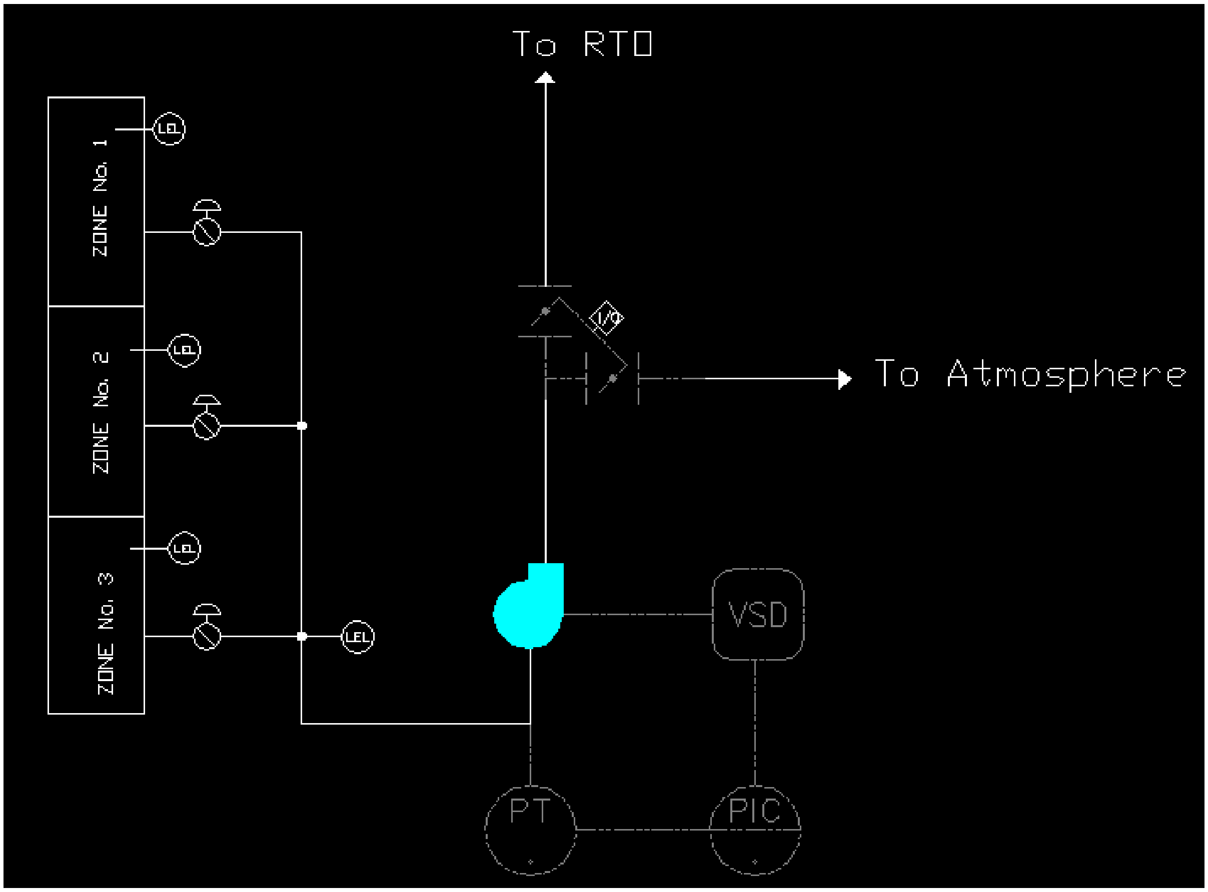
SYSTEM REVIEW

The system was installed with four weeks of prep work prior to a three week plant shutdown for conversion. The heat recovery system, the most critical portion of the unit was designed to use direct RTO exhaust air as the primary heat source and this was then mixed with additional hot air to achieve the process set point for hot air supply. This control scheme requires monitoring of several process variables, and modulation of three separate valves, all with interactions. The safety requirements of this type of system are also critical as all valves must be designed for fail safe operation and many points must be redundantly monitored.



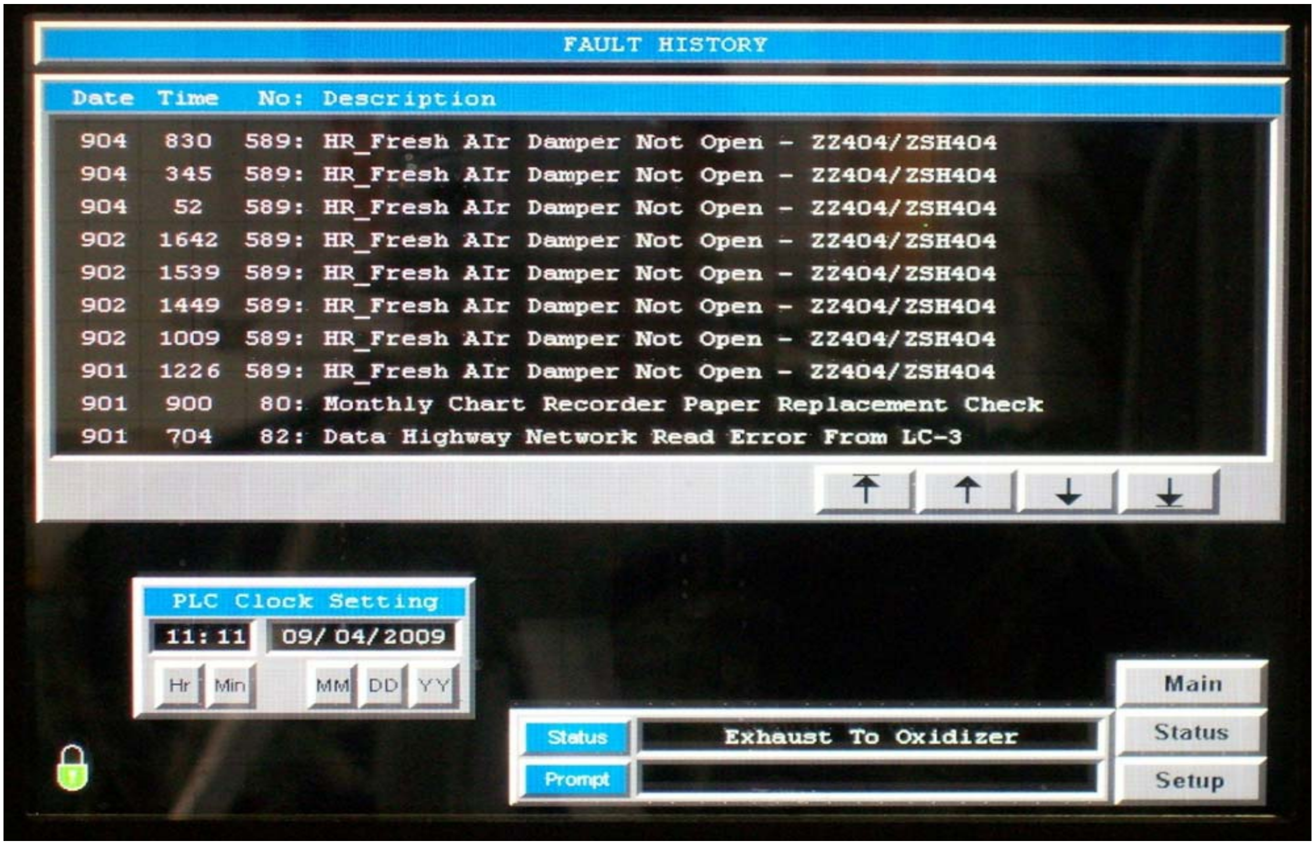
With the advanced control systems, several additional features were added to the RTO system, the first are on the heat recovery system;

- Prior to the ovens demand for heat, the hot air fan has already been running at a very low speed with just stack air, this provides an initial warm up of the duct and equipment.
- When a line comes on and requests heat, the initial temperature set point is higher than the planned set point, this provides an initial heat surge to reduce heat up times.
- The temperature set points for the lines that are running are examined, and based upon this, the heat recovery is set to one of three temperatures, high, medium or low. This results in the least amount of energy being used.



The second area of benefit is the exhaust systems for the individual lines, these coupled with T-dampers provide flexibility to the operation.

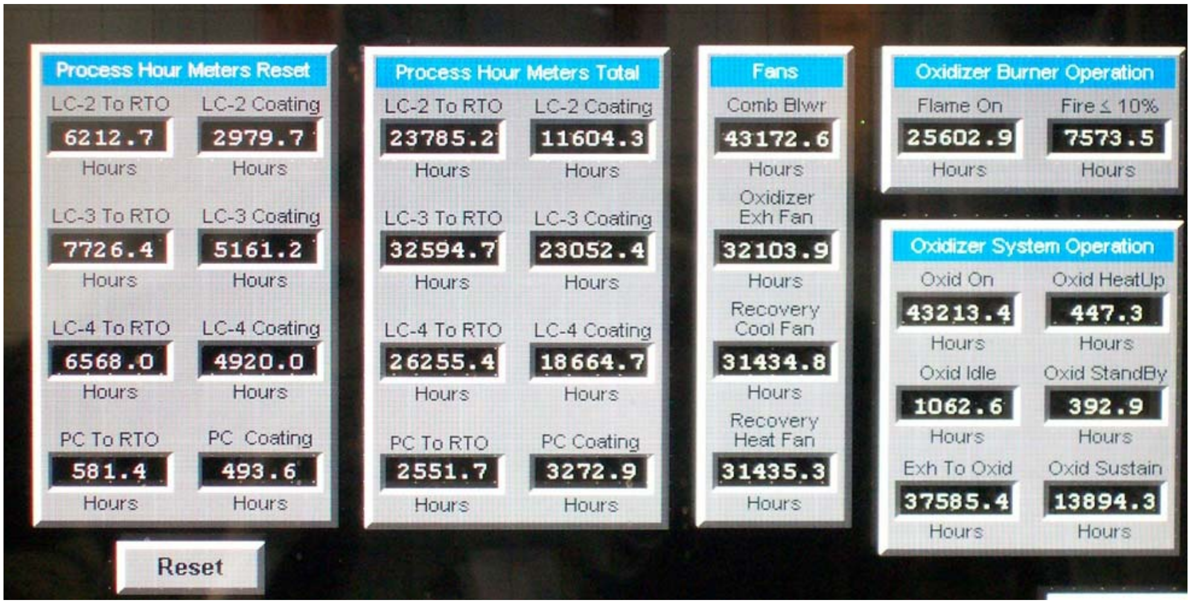
- The t-damper is configured so that exhaust can be vented to atmosphere and the line can be run without coating. This can provide significant reduction in air loading requirements for the RTO.
- Variable speed fan with pressure controls allows for the pressure to be adjusted based upon the solvent loading of the machine. Again, providing a reduction in demand for the RTO and allowing enriching the air streams and achieving self sustain in a more timely fashion.
- Variable speed fans also allow the fans to be lowered when the ovens are on and the machine is not running. This idle mode represents nearly 40% of the total time the coating lines are directing the exhaust to the RTO.
- With the additional capacity of both the unit, and the separate control fans, line speeds have been increased with no safety risk, and in fact lines do not run as close to the LEL alarm points any longer.



The third benefit is advanced diagnostics.

Fault history provides a time stamped alarm point, with description. The alarm number relates directly to the address in the programmable controller, streamlining troubleshooting of shutdowns and other alarms. This provides more timely diagnose and correction of problems.

Status line: This provides a simple indication of what is happening and the state of the RTO.

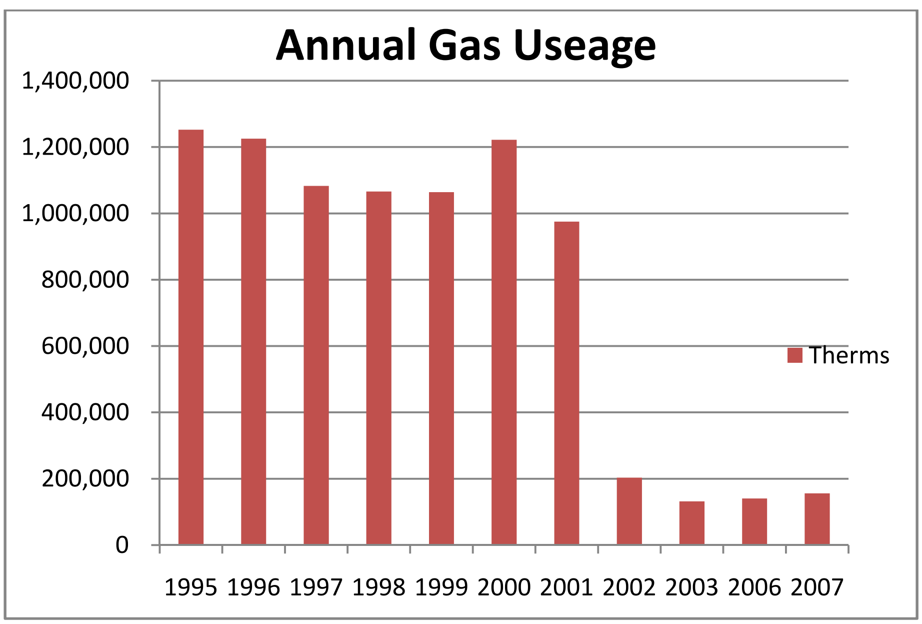


An additional benefit is process and equipment monitoring.

- Process monitoring gives an accurate record of the time that machines are on line and coating.
- Hours of service are tracked.
- Unit performance in terms of time at low fire and self sustain.

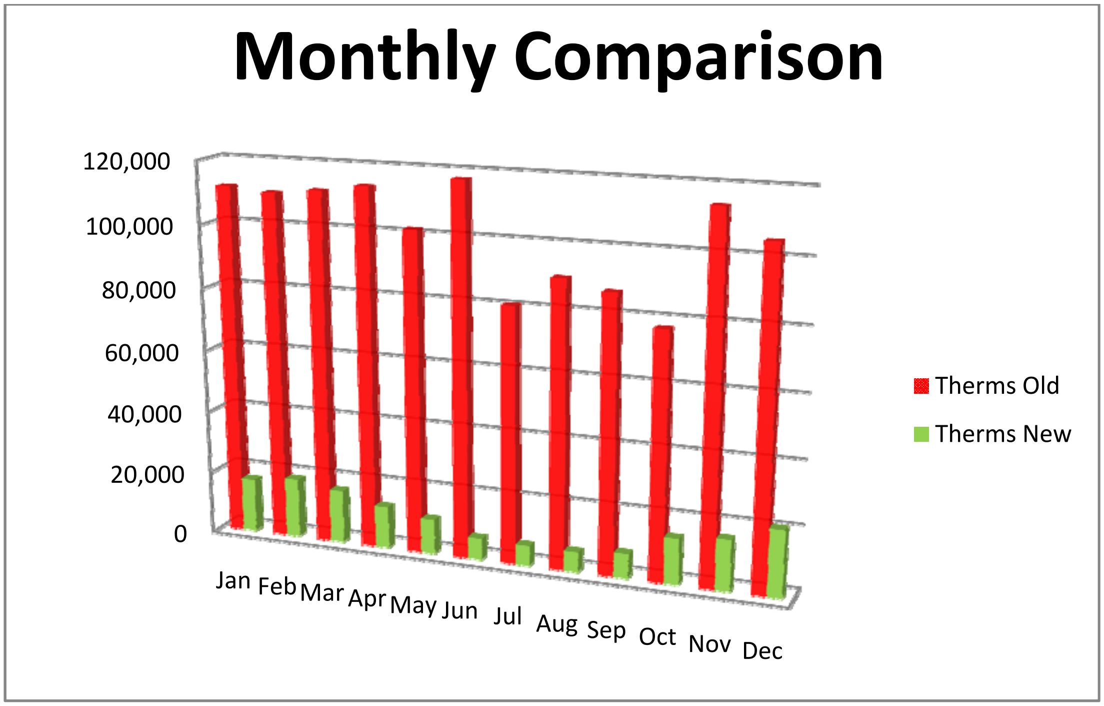
SAVINGS & PAYBACK

The primary reason for the installation of the unit was the increasing cost of natural gas. Madico does not separately meter the gas to the Thermal Oxidizer, so building utilities are confounded in the gas usage data. The gas consumption for the facility ran at roughly 1,200,000 therms annually with the CE Preheater. Gas Consumption for the facility now is roughly 140,000 therms annually.



Gas prices for the past year have been $1.39 per therm. This translates to annual savings of **$ 1,516,600**, this is more than the cost of the entire project. In fact, even with significantly lower gas prices at the time of the installation, the unit paid for itself in ~1.5 years, far above the original analysis predicted.

With the lower gas consumption, the actual use for HVAC and other areas can be more closely determined than in the past.



An examination by month shows that the total load for the facility is less than 20,000 therms, and the RTO accounts for well under 50% of this based upon summer month performance. This provides direction for further cost and energy savings in the future.

Summary

Through clear goals and objective, careful planning, expert process analysis, and project management, the replacement of older systems with new units, utilizing heat recovery offer exceptional payback.