Industry-Government Cooperation Leads to Productivity and Energy Improvements

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ABSTRACT

Many plant operations are averse to installing innovative equipment due to the risk of it not working. In addition, innovative equipment that targets energy saving is especially difficult to sell since the value of any possible production losses are much greater than the value of the energy savings. Yet the energy savings can be substantial in some cases, so finding ways make these projects work is important. One way to mitigate the upfront risk is to use government grants to help pay for the installation. Two organizations, the US Department of Energy and the New York State Energy Research and Development Authority have a number of programs that can accomplish this. Another way is to stress other benefits besides energy savings. For instance, production increases and emission reductions are valuable, and sometimes necessary components, to make energy projects go. This paper explores these issues along with two examples of successful energy projects.

Introduction

Industrial innovations have been an engine of change and advancement throughout history. Yet, for all its worth, technology innovation has a remarkably difficult time penetrating into most mature industries. Neal Schwartz, while the plant manager at Wabash Alloys put it, "The discovery of fire was the last great invention in our industry". The problem is that plant managers have always been reluctant to take on a new technology because of the risk of it not working.

And with energy related innovation in industrial settings, the situation is more difficult still. Whenever managers install innovative equipment, they are rolling the dice since any process change designed to save energy risks upsetting production if it doesn't work. Even at current natural gas prices, energy costs make up only a few percent of the product value in most industries. For instance, the energy use for making auto parts from scrap aluminum is about 3000 Btu per pound of product. At $6 per MMBtu for natural gas, this amounts to less than two cents per pound, on a product that sells for 60 cents per pound, or about 3%. Saving a percentage of this energy, at the risk of upsetting production, has a risk to reward ratio of over 100. That is, for each dollar of energy saved, over 100 dollars of production will be at risk. Figure 1 shows this same example as a function of natural gas prices. At today's prices the risk to reward ratio has certainly improved, but not to level even approaching unity. Even at a gas price of $10, the risk still outweighs the reward by a factor of 70.

These problems notwithstanding, one cannot ignore industry's huge energy appetite. According to the US Energy Information Administration, in 1999, industrial energy use accounted for 38% of the total US energy use, or 36.5 quadrillion Btu's costing about $120 billion. See Figure 2. It has more than doubled since 1950, and except for recessions, industrial energy use has increased continually, and is projected to continue chugging along at an increasing pace. Of all the fuels shown, only coal has shown a drop-off. Figure 3 shows the energy use of some of the most intensive industries. Chemicals, refining, paper, and iron and steel show the highest use.

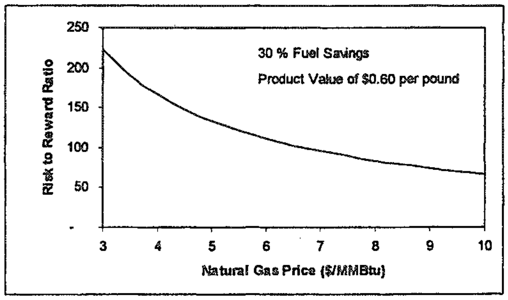

Figure 1. The Effect of Natural Gas Prices on The Risk to Reward of Fuel Savings

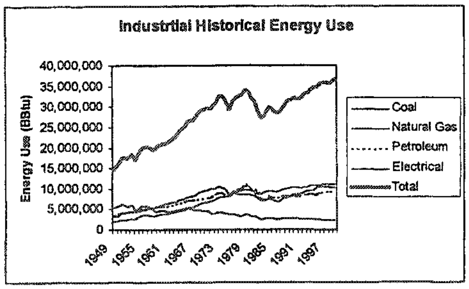

Figure 2. Industrial Historical Energy Use

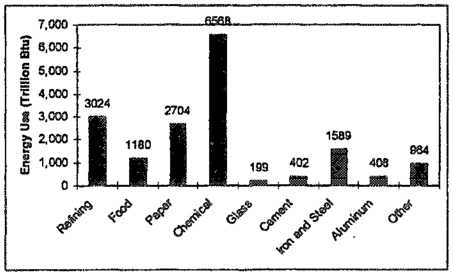

Figure 3. Energy Use of Large Industrials in 1999

Government Funding To Mitigate The Risk

It is worthwhile to provide incentives to industry to reduce their energy use, given their large energy expenditures. The first approach is partnering with government agencies to reduce risk.

The Federal Government provides research money to private industry for varied reasons and in FY 2001 has earmarked $45 billion for civilian research. For industrial users, DOE is worth reviewing. DOE is a cabinet level agency and has a FY 2001 research budget of $4 billion. Within DOE is the Office of Industrial Technologies (OIT), headed by Denise Swink, which focuses on industrial projects that reduce energy and pollution or promote renewable energy. OIT's FY 2001 budget is $184 million, most of which is spent on the "Industries of the Future"; those industries that account for 75% of industry's energy use. Currently nine industries are identified (Agriculture, Forest Products, Mining, Aluminum, Glass, Petroleum, Chemicals, Metal Casting, and Steel) with others being added.

Three programs within OIT are of immediate interest. The first is their NICE[3] program which funds first-of-a-kind demonstrations of innovative technologies. Lisa Barnett runs this program, and provides grants of up to $500,000. As in all of their programs, OIT expects an equal match from the recipients, either in cash or in project services.

After the first demonstration, and if you meet OIT's criteria, it is possible to get funding for a second demonstration through its "Emerging Technology Deployment" program which offers up to $600,000.

The third is OIT's "Plant Assessments", headed by Eric Lightner. This program offers up to $100,000 for assessments on ways of improving plant energy, emissions, and productivity. Visit OIT's website (www.oit.doe.gov) for details on these and many other programs and resources.

Not to be outdone, various state governments offer funding for industrial projects somewhat similar to DOE. Probably the largest is the New York State Energy Research and Development Authority (NYSERDA). With an R&D budget of $35 million, they provide grants up to $250,000 for NY State companies to demonstrate technologies and lesser amounts for plant assessments. In addition, NYSERDA has a substantial Demand Side Management Program, which has recently been enlarged by Governor Pataki in response to the California electric power crises. NYSERDA's web site is www.nyserda.org.

Productivity Gains To Complement Energy Savings

The second approach we take is to develop equipment that has benefits beyond energy reduction. Production improvements and emissions reductions are two winning combinations. We have conducted a number of projects which use these techniques. A presentation of two of these projects, from the aluminum processing industry follow.

The Secondary Aluminum Sector

The secondary aluminum industry cycle (which processes and recycles scrap aluminum) is illustrated in Figure 4. Starting as discarded scrap, aluminum is collected by scrap dealers and sent to a processing plant. The scrap is pre-processed to remove organics, water, ferrous metals, and other impurities. The scrap is also sized in a shredder. Next the scrap is melted in a reverberatory furnace and alloyed to customer's specifications. The resulting ingots are shipped to a die caster where they are again melted and then poured into a die. These die cast parts are shipped to a manufacturer and assembled into a final product, such as an automobile. The auto is sold to a customer and eventually discarded to repeat the cycle.

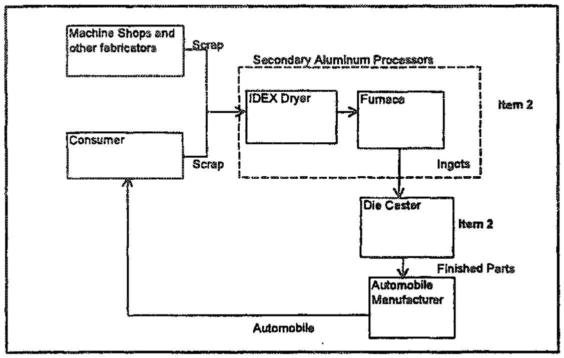

Figure 4. Schematic of Aluminum Life Cycle

Total United States scrap aluminum consumption in 1997 was 8,126 million pounds (Aluminum Association, 1997). This represents 37% of the total aluminum supply. Other sources include primary production (36%) and imports (28%). There are 12 primary and 34 secondary aluminum processors in the United States.

For the secondary aluminum sector (item 1 in Figure 4) the furnaces and decoating kilns used are fossil fired. Typical energy usage is 3000 Btu/lbm in the furnace and 1000 Btu/lbm in the kiln. For the secondary market, total annual gas kiln consumption in the United States is about eight trillion Btu and the furnace gas use is about 24 trillion Btu.

The metal casting industry (item 2 in Figure 4) melts and casts ingots from the secondary producers. In 1996, the U.S. metal casting industry produced castings with a value exceeding $29.3 billion, and employed nearly 217,000 people which. The major portion of the industry is producing gray iron and ductile iron castings for automotive and heavy equipment industries. The industry expends 15% to 25% of its production costs on energy for a total annual energy use of 0.25 quads.

Decoating Kiln Demonstration at Roth Bros.

A demonstration of an advanced decoater was conducted at Roth Bros. (now Wabash Alloys) of East Syracuse, NY (item 1 in Figure 4). The project was funded by NYSERDA and DOE's NICE^3 program. Roth Bros. buys three different types of scrap: turnings and borings, clips, and direct charge. Turnings and borings, and clips must be pre-processed before being charged into the furnace due to their contaminated nature - typically they contain various amounts of oil, moisture, paint, lacquer, and solid organics (rubber, plastic, etc.). For Roth Bros., the average measured moisture content of the scrap is about 10%, but the range is from 1% to 68 %. For turnings, nearly half of the scrap had a moisture content from 10 to 20%, and 21% of the scrap had over 20% moisture. Tests on a limited set of samples showed the oil to be one part in three of the total moisture.

It is necessary to remove the organics to minimize dross production and gaseous emissions. Dross is aluminum that has oxidized and so has no commercial value. Dross reduces the furnace production, typically by 5 to 10%. Gaseous emissions are produced form the organics in the form of smoke or unburned hydrocarbons.

The Roth furnace is an open-hearth reverberatory furnace, 125,000-lbm capacity. Most scrap is fed into the open-hearth charge well and is immersed into the liquid bath where it is melted. Four gas-fired burners are used, each rated at 5 MMBtu/hr. During charging, the burners fire at 20 MMBtu/hr, the melt temperature is about 1400°F, and the flue gas is about 2200°F.

The problem of removing the variable oils and other organic coatings was solved by employing an innovative concept; an indirect-fired controlled atmospheric kiln. In this concept, the scrap is first decoated in a controlled atmosphere with limited oxygen so as to avoid scrap oil combustion or scrap oxidation. The gases are then combusted in an incinerator, apart from the scrap, to destroy the VOCs. The heat release from this oil combustion is used to drive the decoating process.

Stein Atkinson Stordy (SAS) has implemented this design in a packaged system termed IDEX™. A schematic of the IDEX™ is shown in Figure 5. It consists of three major components: a rotating kiln to process the scrap, an incinerator to destroy the organics, and a control system and associated hardware.

The scrap enters the rotary kiln through an airlock. The combination of kiln rotation and internal baffles disperses the scrap throughout the kiln volume. Scrap residence time is about 20 minutes.

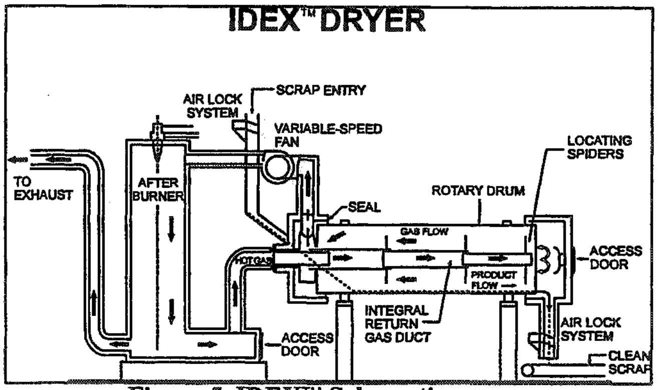

Figure 5. IDEX™ Schematic

Gases at 1500°F enter the center tube, flow parallel to the scrap, and then, after exiting the center tube, reverse direction (flowing counter current). The center tube indirectly heats the scrap. Due to the heat from the gases, the organics are vaporized but because the oxygen in the kiln is kept below the lower flammability limits of the organics, no combustion takes place in the kiln. The high temperature gas entering the kiln has 5% to 6% O_2 and air leakage raises this to 8 or 9% O_2. A minimum of 4% oxygen is needed to oxidize any carbon coating on the scrap, and a maximum of 10% to avoid scrap flaming and fire risk (Haney and Jenkins 1990 and Lannon 1986).

The gases from the kiln are passed to an incinerator that elevates the temperature to 1500°F. The organic vapors combust in this environment, which releases heat and destroys the VOCs. Part of the gases are vented and part are recirculated back to the kiln via a fan. The recirculated gases provide the heat to drive the kiln heating and vaporization processes.

The IDEX™ installation was completed in January 1997, and underwent a series of shakedown tests and modifications. It now has been commercially operating for over four years. It operates 24 hours per day and processes about 10,000 pounds per hour. It is fed a number of different scrap types including used beverage cans, borings, turnings, frag (fragmented automobiles) and others.

Production, energy, and emission data measurements were taken on the IDEX™. Even with the IDEX only feeding 20% of the furnace throughput, one furnace had an increase in yield that amounts to 294,000 pounds annually for a gross revenue increase of $176,400 per year. If fed 100% it would be 1,176,000 pounds annually worth over $750,000 per year. The IDEX energy savings, compared to a conventional decoater is worth about $185,000. Details follow.

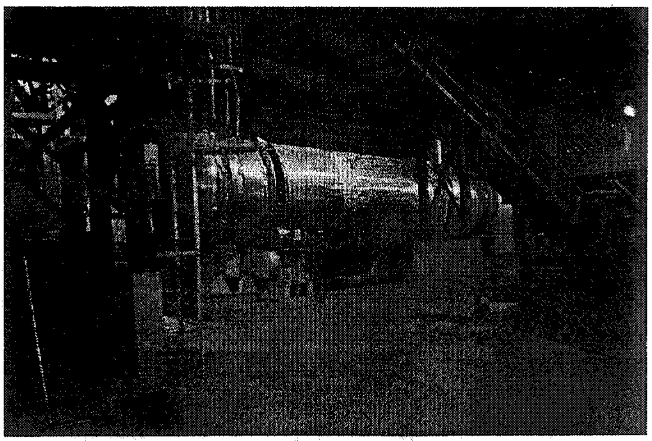

Figure 6. IDEX™ Installed at Roth Bros.

In May 1998, energy measurements were taken while the IDEX™ was running at Roth Bros. At That point the IDEX™ had been running for eight months and was performing to specifications. Natural gas flow was measured using a North American orifice plate and recorded every 5 to 10 minutes. Metal throughput was measured into and then out of the IDEX™, the difference being the organics and water that were removed.

As operated by Roth Bros., the IDEX™ had an excess of air infiltration. It was necessary to operate the IDEX™ at a negative pressure to avoid hot gases entering the work place. The result of the air ingress was that the IDEX™ operated at an oxygen level of about 10 to 11%, much higher than needed to remove the residual carbon from the organics removal.

Figure 7 shows the measured energy use of the IDEX™. The specific energy use vs. scrap inlet feed rate is plotted. At low throughputs the energy use was quite high, but then was reduced as the throughput increased. A low of 450 Btu/lbm was achieved, which is less than ½ that of conventional dryers.

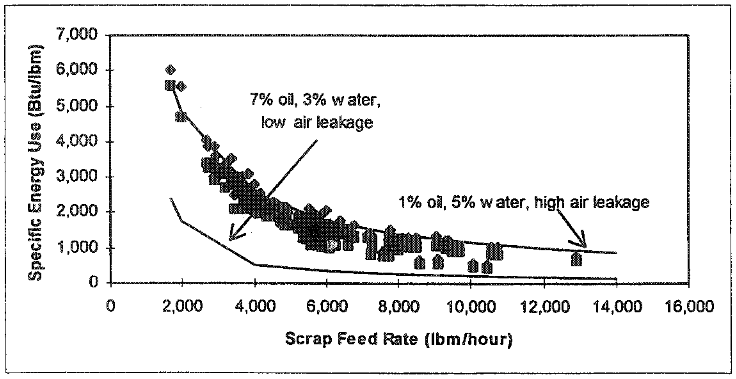

Figure 7. Measured Energy Use of the IDEX™

The scrap aluminum exiting the IDEX™ is at an elevated temperature due to the heating of the metal to drive off the organics and water. To measure this temperature, a sample of the processed scrap was poured into a drum instrumented with thermocouples.

The preheat temperature averaged 628 F. This preheated scrap can now be fed into the furnace providing additional energy savings. The furnace energy savings, using the measured preheat temperature of 628 F, was between 12% and 30%, or roughly 370 Btu/lbm. Hence the total energy savings from the IDEX™, including the kiln and furnace savings was 1,370 Btu/lbm. Applying these results to the total secondary metal produced yields a potential energy savings of 3 trillion Btu annually.

Since the scrap processed by the IDEX™ is cleaner than that from conventional dryers, its subsequent feed into a furnace should reduce dross production. An attempt was made to measure this effect. However, two obstacles arose:

- Due to production scheduling issues, Roth mixes the scrap from all of its dryers, prior to feeding into a furnace. Hence, it is not possible to isolate the effect of the IDEX™ in the absence of other scraps.
- Only 20% of Roth's scrap are processed by the IDEX™, making it difficult to discern the IDEX™ effect.

Nonetheless, data was collected on furnace dross both before and immediately after the IDEX™ came on-line. Table 1 summarizes the before and after results of feeding 20% of the furnace feedstock from the IDEX™. The IDEX™ resulted in a dross reduction of 0.7 percentage points for furnace 6 and 0.4 percentage points for furnace 8. Considering that only 20% of the feedstock was from the IDEX™, this was a significant reduction. It is expected that the dross reduction would be higher if the IDEX™ feed represented a higher percentage of the furnace feed. Even at only 20% feed, furnace 6 has an increase in yield that amounts to 294,000 pounds annually for a gross revenue increase of $176,400 per year.

Table 1. Furnace Dross Summary

	Furnace 6			**Furnace 8**		
	Pre IDEX™	**Post IDEX™**	**Diff.**	**Pre IDEX™**	**Post IDEX™**	**Diff.**
Average	8.2%	7.5%	**0.7%**	6.8%	6.4%	**0.4%**
Standard Deviation	0.61%	0.59%		0.42%	0.35%	
Average Range (95.5 % Confid. Level)	7.9% to 8.5%	7.3% to 7.8%	0.1% to 1.2%	6.6% to 7.0%	6.2% to 6.5%	0.1% to 0.8%

In addition, an experiment was performed to visually determine the smoke and particulate emission reductions resulting from using the IDEX™. Two loads of scrap, about 2,000 pounds each, were fed into the furnace. The first load went through Roth's conventional decoater. Immediately following that load, a second load was fed into the furnace that had been processed through the IDEX™. When the first load was fed (Figure 8), flames were observed which originated from the organics that had not been completely removed. Hence, not only were smoke and particulate emissions occurring, but product charge was also being lost.

When scrap aluminum processed through the IDEX™ was fed into the furnace (Figure 9), only a small amount of flame was noticed, which was the residual flame from the previous charge. Hence, the IDEX™ eliminated the flames in the charge well, thus greatly reducing or eliminating the smoke and particulate emissions, and increasing the product throughput.

Emission measurements taken with the IDEX™ are shown in Table 2and Table 3. NOx, SO_2, VOC, and particulates were measured on three separate runs and averaged as shown in the tables. NOx, SO_2, VOC, and particulates were 19%, 2%, 2%, and 6% respectively of New York State's Department of Environmental Conservation standards.

Table 2. Summary of Emission Data from Roth Bros. IDEX™

Run ID	Date	SO_2 (pph)	SO_2 (% of Stand.)	NOx (pph)	NOx (% of Stand.)	VOC (pph)	VOC (% of Stand.)
1	8/5/97	0.2	2	1.61	18	0.18	2
2	8/5/97	0.18	2	1.77	20	0.15	2
3	8/6/97	0.23	3	1.65	18	0.23	3
Avg.		0.2	2	1.68	19	0.19	2
Stand		9.0		9.0		9.0	

Table 3. Summary of Particulate Emissions (Standard is 15 TPY)

Run ID	Date	Conc. (gr/dscf)	Rate (pph)	% of Stand.
1	8/5/97	0.0015	0.31	9
2	8/5/97	0.0009	0.19	6
3	8/5/97	0.0007	0.15	4
Avg.		0.0010	0.22	6

This project demonstrated the value of government funding in buying down the risk so that an industrial user will install innovative technology. The emission measurements showed the IDEX™ to meet the proposed EPA Clean Air Standards and the existing New York State regulations. The IDEX™ had a significant effect on furnace dross production. Reductions of 0.4 to 0.5 percentage points were measured with only 20% of the feedstock coming from the IDEX™. It is predicted that operations that use higher percentages of IDEX™ feed into the furnace will result in greater reductions of dross. These advantages, along with the government funding, drove management's approval of the project.

Lexington Die Casting

As a second project, funded by NYSERDA, involves the demonstration of a stack melter at Lexington Die Casting in Lakewood, NY. We began this project by first conducting a comprehensive plant assessment. One of several recommendations from the assessment was to install a stack melter that could process the ingots and in-house scrap for their subsequent die casting operation. The stack melter would reduce their energy use, but would also allow them to increase production.

Lexington uses reverbatory furnaces to melt the aluminum. One is shown in Figure 10. Clean scrap metal is charged into the furnace and is melted by a natural gas fired burner. The furnace firing rate is 4 MMBtu/hr and the furnace produces 60,000 pounds of product per week at a yield of 92%. The specific energy use of the furnace is 3,000 Btu/lbm for a thermal efficiency of 19 %.

Figure 8. Charge Well After Feeding Scrap from a Conventional Dryer

Figure 9. Charge Well Using Feed from the IDEX

Figure 10. Lexington's Reverbatory Furnace

Table 4 shows the energy use break-out for the furnace. Most of the energy is lost in the flue gases. This is not surprising, since the furnace transfers heat to the load radiatively, rather than convectively, requiring a high gas temperature. The exiting flue gas temperature is 2200 F, typical of reverbatory furnaces.

Table 4. Energy Use Break-Out of a Typical Reverbatory Furnace

	Specific Fuel Use (Btu/lbm)	(%)
Heat into scrap	560	19%
Heat into Flue gases	1,562	52%
Wall and Holding losses	878	29%
Total	3,000	100%

An innovative Stack Melter has been installed for demonstration at Lexington as shown schematically in Figure 11. A photograph is shown in Figure 12. In this concept, a 3 foot diameter refractory tube, 7 feet high is used. Scrap aluminum, mostly ingots but also in-house scrap, is fed to the top of the melter and pile to the level shown. A burner fires through the charge, which melts the lower portion and preheats the upper portion. As the lower portion is melted, it is drawn out and the upper preheated charge falls to a lower level where it in turn melts.

The throughput is 2500 pounds per hour at a burner firing rate of 4 MMBtu/hr, yielding a maximum specific energy use of 1,600 Btu/lbm. Measurements show the actual energy use to be about 1250 Btu/lbm. Compared to a conventional furnace of 3,000 Btu/lbm, this results in a 58% energy savings. This energy savings is brought about primarily because the flue gases preheat the charge and the gas temperature is dropped to under 1000 F.

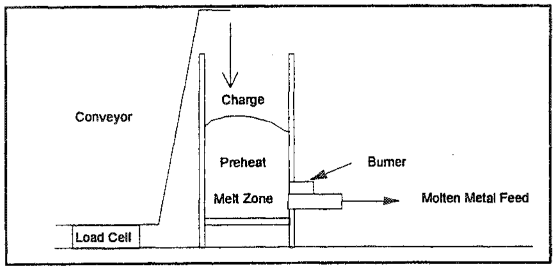

Figure 11. Stack Melter

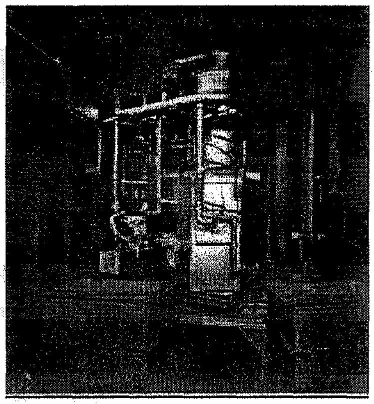

Figure 12 . Stack Melter Installed at Lexington

The Stack Melter is situated between two furnaces which are now used as holding furnaces. The Stack Melter can be rotated between each of the furnaces allowing it to feed either one. This provides an operational advantage to Lexington, since they can process several alloys through the Stack Melter, and can allow one reverbatory furnace to idle and still maintain the Stack Melter's production as it feeds the alternate furnace.

During shakedown testing, the Stack Melter was operated at high fire and NOx measurements were taken, as shown in Table 5. A portable North American analyzer was used. The NO, averaged over 5 test runs, was 8.2 ppm at 3% O_2 and that of CO was 5.4 ppm at 3% O_2.

Table 5. Emission Measurements

	Run #1	Run #2	Run #3	Run #4	Run #5
NO (ppm)	11	8	8	6	6
CO (ppm)	2	14	1	12	2
O_2 (%)	10.3	0.2	1.9	1.5	1.8
CO @ 3% O_2	3	12	0	11	1
NO @ 3% O_2	18	6	7	5	5

This demonstration also showed the power of government funding to overcome the risk aversion of plant managers. The energy use of the Stack Melter was only1,250 Btu/lbm. This results in an energy reduction of 48 % compared to conventional furnaces, or 11,732

MMBtu annually. At Lexington's gas price of $4.7/MMBtu, that results in an annual cost savings of $55,137. The emissions were quite low. NOx is expected to be low due to the low flue temperature. Also, all gaseous emissions would be reduced by 58%, compared to conventional furnaces, due to the reduction in firing rate. If Lexington keeps its firing rate fixed, than a production increase of 58% would occur.

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