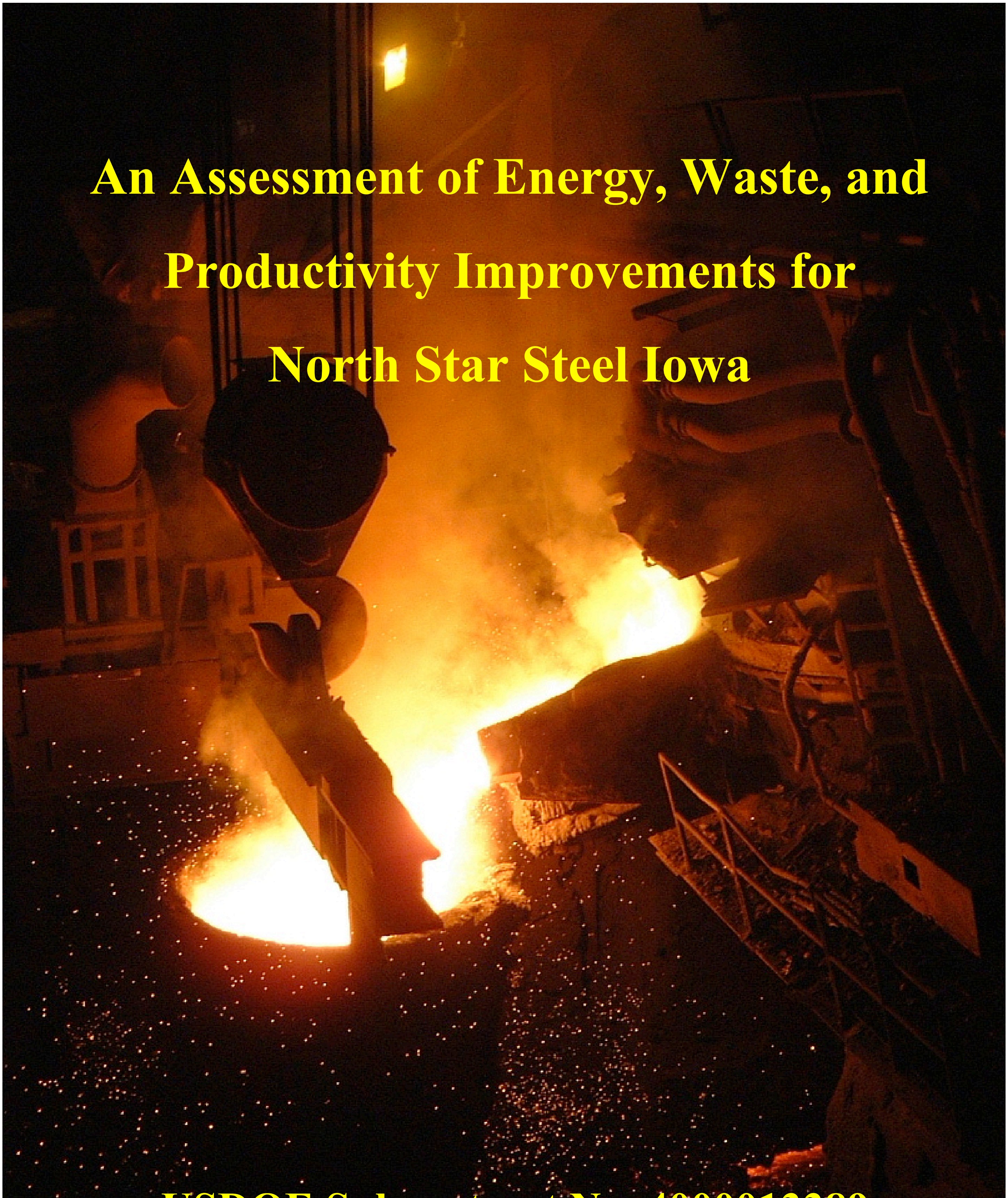

An Assessment of Energy, Waste, and Productivity Improvements for North Star Steel Iowa

USDOE Subcontract No. 4000013389

April 2003

An Assessment of Energy, Waste, and Productivity Improvements for North Star Steel Iowa

Prepared for

Industries of the Future
Plant-Wide Energy Efficiency Opportunity Assessments

UT - Battelle
Oak Ridge National Laboratory
United States Department of Energy – Office of Industrial Technologies

Prepared by:

Rudy Pruszko, Project Manager
Center for Industrial Research and Service, Iowa State University Extension

Clay Crandall, Assistant Project Manager
Center for Industrial Research and Service, Iowa State University Extension

John (Jack) Skelley, Regional Environmental Manager
North Star Steel Iowa

Tom Levad, Engineering Manager
North Star Steel Iowa

Dr. Don Casada, Consulting Engineer
Diagnostic Solutions, LLC

Arvind C. Thekdi, President
E3M, Inc.

Dr. John Stubbles, Steel Industry Consultant

David C. Engle, Technology Manager
Energy Enterprises, Inc.

April 3, 2003

Executive Summary

Overview of the project:

North Star Steel's Wilton, Iowa plant (NSSI) was awarded a subcontract through a competitive process to use Department of Energy/OIT project funding plus required matching funds to examine potential processes and technologies that could save energy, reduce waste, and increase productivity. The plant employed specialized energy use and waste management assessments in five critical areas: 1) EAF dust reduction; 2) motor program; 3) melting and reheat furnace processes; 4) heat recovery; and 5) energy management plan.

North Star Steel believes that the assessment findings and subsequent technical and management solution options will make a considerable impact on the plant's energy efficiency, productivity, and waste reduction improvements. Furthermore, assessment methodology, data, and technical solution options will be shared with North Star Steel's other mills in Beaumont, Texas; Calvert City, KY; Monroe, MI; Duluth, MN; St. Paul, MN; and Delta, OH, where similar assessments and energy/waste reduction improvement methods could be deployed.

Cargill, Inc., parent company of North Star Steel, has a corporate-wide goal to reduce waste by 30% and energy use by 10% by the year 2005. This goal has also been adopted by the North Star Steel plants.

Project Summary

A plant-wide assessment (PWA) process was used to identify a number of projects with the potential to save energy, reduce waste, and increase productivity. These projects are listed in Summary Table 1 along with the associated savings, economic impact, and implementation date for each project area. The Summary Table lists the carbon equivalent units of the potential energy savings for each project with the energy units expressed as fuel (natural gas) and electric energy (coal-based) converted to millions (mm) Btu. Steam is not used in any significant way at North Star Steel. There were no quantifiable environmental impact improvements associated with the projects listed in this report.

The total potential savings from the identified energy projects are presented below. Annual savings per ton of steel produced was based on a yearly production of 300,000 tpy. This includes the energy from the fuel savings added to the electrical savings (using the conversion factor of 1 KWH equals 10,500 Btu).

Annual Potential Savings from Identified PWA Projects			
Projects	mmBtu	Annual Savings $	Annual $/ton steel
TOTAL – NSSI Projects	344,593	$1,720,250	$5.73
TOTAL - All Projects Identified in PWA	409,051	$2,639,960	$8.80

Summary Table 1: Projects Identified During the Plant-wide Energy Assessment								
Project to be Implemented?		Assessment Area / Project Title	Annual Projected Energy Savings			Annual Projected Economic Impact		
Y/N	Date		Fuel (mmBtu) (natural gas)	Electricity (kWh)	Carbon Equivalent Units (tons)	Annual Savings ($)*	Capital Cost ($)	Payback Period (yr)
EAF Dust Reduction								
N	NA	Recycle all dust to EAF				Negligible		
N	NA	Recycle fixed amt. to EAF				Negligible		
N	NA	Process Dust On-site				Negligible		
Motor Program								
Y	2003/04	Motor/Pump East Tower		735,000	221	$32,000	$20,000	0.63
Y	2003/04	Motor/Pump Clean Water		1,341,000	402	$59,000	$35,000	0.59
Y	2003/04	Motor/Pump Mill Water		1,068,000	320	$47,000	$5,000	0.11
Melting and Reheat Furnace Process								
Y	Done	EAF Energy Consumption	(48,000)	19,800,000	5,172	$675,000	$1,800,000	2.67
Y	Done	Reheat Furnace Upgrade**	25,600		397	$341,450	$3,000,000	8.79
N	NA	Tundish Heater-Dryer	1,020		16	$4,590	$45,000	9.80
Y	2005/06	Ladle Heaters	13,500		216	$60,755	$70,000	1.15
N	NA	Billet Preheating	14,080		225	$63,360	$50,000	0.79
Heat Recovery								
Y	2004/05	Reheat Discharge Skid Base	17,600		282	$17,600	$100,000	5.68
Y	2003/04	Reheat O_2 Monitoring & Control	21,333		341	$81,000	$50,000	0.62
Y	2004/05	Higher Combustion Air Preheat Temperature	61,860		990	$278,400	$150,000	0.54
N	NA	Combined Heat/Power	21,412	16,000,000	5,143	$856,350	$2,745,000	3.21
Y	2004/05	Air Compressor Heat Recovery	10,768		172	$48,455	$50,000	1.03
Energy Management Plan								
Y	***	Strategic Utility Metering					80,000	
Y	Done	NSSI Firewatch Program				****		
Y	In progress	Air System Balance				TBD	TBD	
Y	2003/04	Energy Mgmt Plan, Program				TBD	TBD	
Y	2005/06	Fume System- Bender Study				TBD	TBD	
Average Project Payback Period								2.73
Sub Total - Projects Implemented			(22,400)	19,800,000	5,569	$1,091,450	$4,800,000	
Sub Total - Projects for Implementation			126,081	3,144,000	2,960	$628,800	$600,000	
TOTAL - NSSI Projects			103,681	22,944,000	8,529	$1,720,250	$5,400,000	
TOTAL - All Projects Identified in PWA			139,173	38,944,000	13,897	$2,639,960	$8,200,000	

* Annual savings includes additional savings and cost in addition to energy savings.

** Reheat Furnace Upgrade savings are total of energy, production, and other non-energy related benefits per NSSI.

*** Metering to be implemented with other projects as required, not as stand alone capital project.

**** Program used in above freezing weather only. Shown to save up to $3000/day if both rolling and melting operations are shut down for maintenance and/or production reasons.

Company Background

"North Star Steel will create enthusiastic stakeholders by becoming the leading steel company in the world."

Although simple, this statement summarizes our vision to continue to create enthusiasm among our key "stakeholders"-everyone who has an interest in our business: our customers first, our suppliers, our employees, our owners, and the communities in which we work. We will strive to maintain the highest level of enthusiasm with the way we operate our business.

North Star Steel Company (NSS) was founded in October 1965 in St. Paul, MN, and began steel-scrap-recycling operations at the St. Paul mini-mill in 1967. Cargill acquired the company in February 1974. North Star Steel's Wilton Plant was acquired from Iowa Steel in 1975. North Star's operations currently include electric-arc furnace mini-mills in Beaumont, TX; Monroe, MI; St. Paul, MN; and Wilton, IA. NSS also has a steel rolling mill in Calvert City, KY, a grinding-ball plant in Duluth, MN, and a joint venture (North Star/BHP) with BHP Steel of Australia. North Star/BHP operates a 1.5 million ton-per-year, flat-rolled steel mini-mill near Delta, OH.

Since 1974, North Star's annual steel-production capacity has risen from 300,000 tons to its current level of 3.5 million tons, and employment has risen from 600 to over 3,000. Productivity averages less than two worker-hours per ton of steel.

Plant and Process Descriptions

North Star Steel's Wilton Plant (NSSI) is a steel mini-mill that uses electric arc furnace (EAF) steelmaking and 100% recycled steel scrap to make steel products. The recycled steel scrap is melted in the electric arc furnace and refined to the correct chemistry by the addition of alloys, carbon, and other additives. The molten steel is tapped into a preheated ladle and transferred to the tundish at the billet caster. From the tundish the molten steel flows into molds making square billets that are cooled, solidified, and cut to length. The billets are stored until needed, then fed into the reheat furnace and brought to a temperature of around 2,200°F. When the correct rolling temperature is reached, the billet is passed through water-cooled roll stands where the steel is formed and shaped into long steel products. The final step involves shearing the steel products into custom lengths, which are bundled together for storage.

NSSI produces structural steel products including flats, angles, channels, rebar, and round-cornered squares. The current annual production is 300,000 tons and the employment at the Wilton plant is 304 workers. In the last three years, energy consumption per shipped ton has averaged 8.69 mmBtu annually. Good mini-mill industry practices range from 7.7mmBtu to 8.7 mmBtu *(Stubbles)*. NSSI's total energy costs were $8.73 million for fiscal year 2000-2001.

Key Elements of the Assessment

A Total Assessment Audit (TAA) was used to evaluate NSSI's five focus areas for energy savings, waste reduction, and improved productivity. TAA methodology is a synergistic and integrated energy, waste, and productivity audit carried out by a team of experts chosen specifically for a particular manufacturing system facility. It was developed by the Iowa Energy Center (IEC) and deployed by the Iowa Manufacturing Extension Partnership (IMEP) under an IEC grant. Both IEC and IMEP, along with MidAmerican Energy Co., are partners in this DOE project. In response to a Request for Proposal (RFP), NSSI submitted an application for

Department of Energy/OIT project funds on Oct. 12, 2000, competing with other industrial companies. NSSI was awarded the USDOE subcontract for this new comprehensive project on Dec. 18, 2000. The plant was also able to obtain matching funds and/or time from MidAmerican Energy Company, IEC, IMEP, the Center for Industrial Research and Service (CIRAS), and the North Star Steel Company for this project.

TAA team members were asked to assess NSSI's chances of achieving its efficiency goal of 10% energy reduction and 30% waste reduction by 2005. The consensus of the team was that a high probability of achieving the goals existed. NSSI and the TAA Team Members identified five areas for improvement based on pre-assessment findings:

- EAF dust reduction
- Motor program
- Melting and reheat process upgrades
- Heat recovery measures
- Overall energy planning

These five areas were more closely scrutinized for ways to cut energy, reduce waste, and improve productivity. In addition to identifying projects to meet these goals, the benefits and costs of possible technological solutions or improvements were also studied. Consultants with expertise in these areas were involved in the process.

The results of the consultant investigations and assessments are contained and summarized in this report. The projects they identified to cut energy use, reduce waste, or improve productivity are listed in the project summary table at the beginning of this report.

Other opportunities for improvement discovered by the consultants during the plant-wide investigation were added to the assessment and are also addressed in this report. In addition, any technologies or solutions evaluated during this assessment and determined not applicable or feasible for NSSI are still mentioned and addressed in this report so that other steel producing companies or divisions of North Star Steel can determine if these technologies would benefit their locations.

Project Descriptions

EAF Dust Reduction

NSSI annually spends about $350,000 to recycle EAF dust at an off-site facility. This figure was compared against the annual capital and operating costs for on-site recycling technologies. There are three basic on-site EAF dust-recycling options for any steel plant:

1. recycle all dust through the EAF
2. recycle a fixed tonnage of dust through the EAF
3. process the dust on-site

<u>Recycle all the dust through the EAF.</u>

As shown in the top line of Fig 1, zinc (Zn) in the recycled material quickly builds to an intolerable level for EAF operation. This creates electrical issues in the furnace and possible surface defect issues ("star cracking") at the caster. Dissolved Zn is rejected when steel solidifies in the mold, and Zn can react with copper to form low melting point brass.

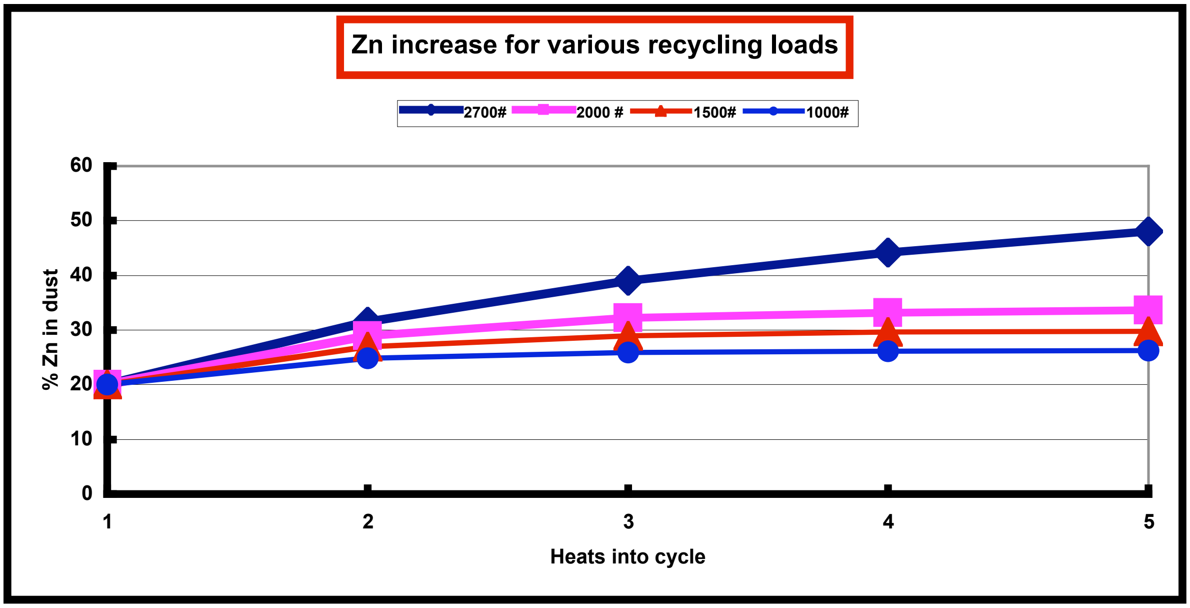

Figure 1. Zinc Build-up in EAF Dust with Recycling

With this recycling approach, some material must be shipped to an external processor every few heats to purge the system of excess Zn. The tonnage of dust shipments is less but the Zn content is higher. Credits for recovered metallic values and lime are difficult to quantify. Energy penalties are also difficult to measure and may be quite severe, although this has not been the experience of other steel plants. Savings depend on the cost of preparing the dust for recycling. This preparation can range from simple "super-sacking" the material "as is," to blending with carbon and either injecting or agglomerating the mix. This 100% recycling approach has been rejected for NSS because of the rapid build-up of Zn in the EAF from the scrap being charged to the EAF.

Recycle a fixed tonnage of dust through the EAF

A subset of the above recycling approach, this option results in some control over the operating zinc level in the EAF but still reduces offsite shipments (Figs. 2 and 3). The advantage over recycling 100% of the EAF dust is that purging is eliminated because an acceptable asymptotic level of Zn can be developed in the EAF atmosphere and maintained. For example, if a constant 2000 lbs of dust/heat were recycled, the Zn would rise to 34% (Fig. 1) and the dust generated per heat would rise to 3500 lbs. (Fig. 2), of which 1500 lbs. would be shipped (as opposed to the present 2700 lbs.) and 2000 lbs. would be recycled. If less dust per heat was recycled, more would be shipped offsite (Fig. 3) and savings would be reduced.

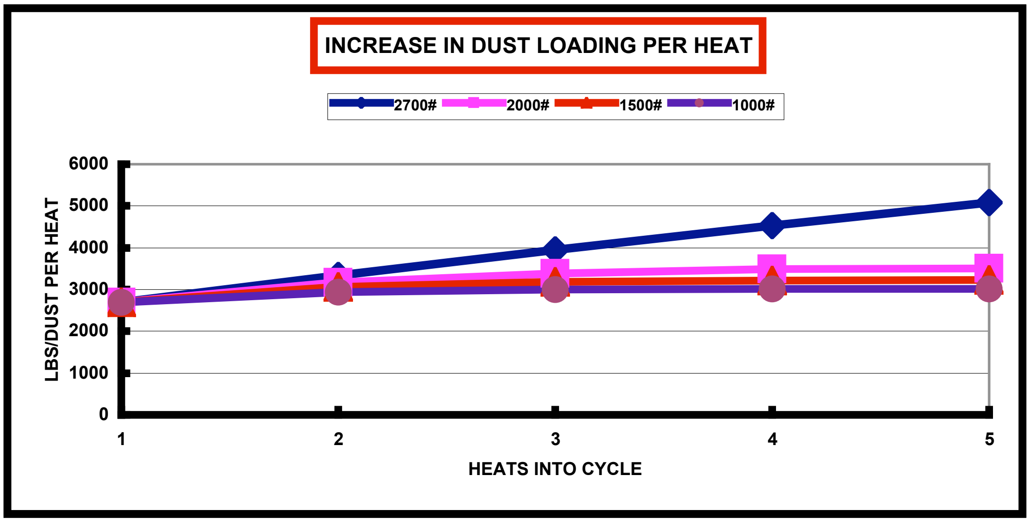

Figure 2. Dust Loading per Heat for Various Recycling Loads

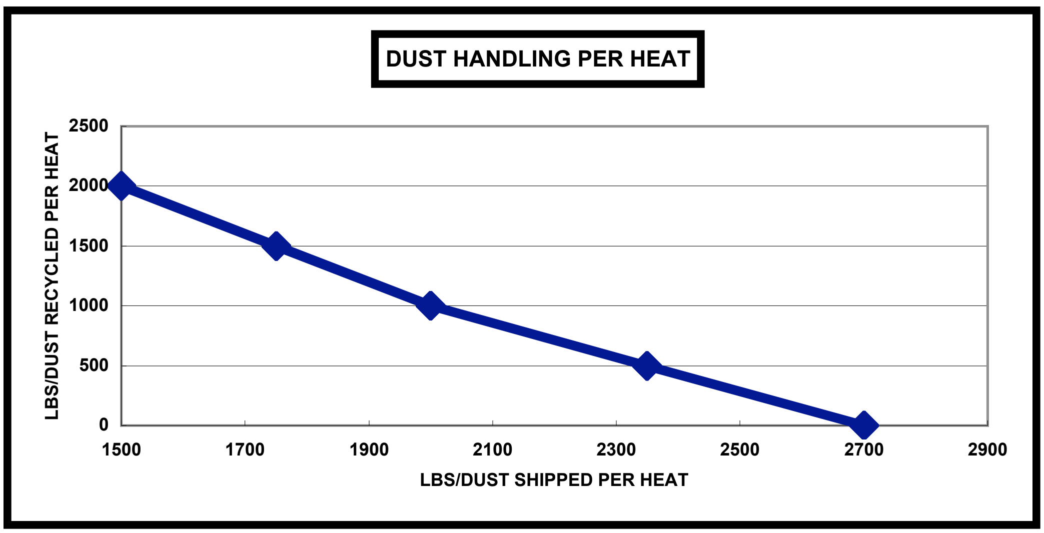

Figure 3. Dust Recycling versus Shipments per Heat

The higher Zn level in the dust is credited at the rate of $1.00/% increase in Zn. In other words, if the present 20% Zn increased to a steady state of 34%, the savings per heat would be $65 instead of the original $51. This would result in a $233,000 annual savings relative to today's shipments, assuming a credit for the higher Zn dust. However, this savings would be reduced by the cost of recycling the dust to the furnace.

Direct Charging Methods: Chaparral (TXI) "super sacks" a large percentage of its dust, which appears to be the simplest, least expensive approach to the problem. However, according to personnel at this plant, there are hazards associated with this approach. The fine dust is already oxidized so it is not explosive or pyrophoric, but it can react violently with a heel of carbon-rich liquid steel. The recovery of dust and, therefore, iron is likely to be less than with an agglomerate but the zinc build-up is unaffected. Net credits for iron recovery would be lower along with the cost of preparation.

If agglomeration with a binder plus carbon is considered, the costs mount rapidly due to equipment and manpower requirements as well as the need for additional raw materials. Specific information on costs is proprietary information but \$25 to \$50/ton is an optimistic minimum. This means that the net savings for the 2000 lb. recycle load per heat are \$(62 - 37.5) x 3760 heats per year (300,000 tons) or \$92,000 +/- 50,000. The conclusion is that the super sack approach is the most economical but is not as simple as it appears. Additional carbon units must be charged (about 200 #) to avoid soft melts. This additional carbon, along with the dust (~0.5% S), will add 25% to the sulfur load in the charge, assuming scrap at .025% S.

If agglomeration is mandatory, the use of lime plus water as the cement to make small pellets is worth exploring. Unless the green pellets can withstand reasonable handling, they may also need to be placed in super sacks. To maintain the Zn at a high but workable level, it is recommended that 1500 to 2000 lbs. of dust be charged per heat (2700 lbs. is normally generated). There will be fewer offsite shipments but they will be of greater value due to higher Zn concentrations. This assumes that higher Zn values in the dust will bring a lower tolling fee. If the iron recovery offsets increase energy consumption, and the recycling practice does not extend heat time, the savings could be on the order of \$40/heat or \$150,000 annually.

Injection Processes: In Europe, DDS has been injecting mixtures of EAF dust and carbon, which are stored in silos and premixed prior to injection. The system is fully engineered and expensive. No details concerning the EAF performance were cited in the reference paper by DDS.

At Sheerness in the U.K., a similar system is used (CARBOFER) but the setup is unique: dust from one furnace is upgraded in Zn in the second furnace before shipment to a nearby crude ZnO processing facility. This is a fully engineered system operated by Heckett and would be far too costly to contemplate for NSSI with their dust load of only 4000 tons/year.

Process the dust on-site.

The idea is to take the dust and process it pyrometallurgically to a crude ZnO. The material would be contaminated with volatile halides, lead and cadmium oxides, and iron oxide. There is a market for such material but the iron content should be as low as possible because it tends to tie up the Zn as an insoluble ferrite, which reduces the effective value of the crude ZnO. At this time, the value of crude ZnO is set by the LME price for zinc, which has plummeted in recent years to below \$800/metric ton. According to George Obeldobel, president of Big River Zinc, the crude ZnO may fetch 40 to 45% of the LME price. Therefore, one ton of washed product containing 60% Zn (75%ZnO) is worth \$800 x 60% x 42.5% or about \$200.

NSSI annually generates about 4000 tons of EAF dust containing 20% Zn. If 90% were recovered as crude ZnO, the value would be about \$245,000. Valued at a generous \$100/ ton, recovery of reduced iron units from the residue would add another \$100,000. Four processes were considered in this study as potential candidates for installation at NSSI. These were selected from a list of available EAF dust processing technologies provided by the Steel Manufacturers Association, Washington, D.C.

- The INDUTEC process from Engitec Technologies, Srl, Novate Milanese, Italy, is energy intensive and although the idea of generating crude ZnO plus a molten pig iron is very attractive, the amount of iron that could be recovered from both EAF dust and scale is only 6000 tons annually or about 120 tons per week at best. The cost of producing such a low amount of ZnO plus the equipment costs to handle the molten material makes this prohibitive economically for NSSI. Engitec mentioned about \$6 million for a pilot plant installation in the United States. The INDUTEC process has been tested in an industrial scale pilot plant, and plans to build a large commercial plant are underway. Data for the 50,000-ton per year plant suggest it will be a reliable operation, with the following energy consumption quoted per ton of EAF dust.
  - 590 kWh @ 4c/kWh = \$23.60

- 700 scf natural gas @ $2.75 per 1000scf = $1.925
- 3200 scf O2 @ 15c/100 =$4.8
- 350 Lbs C @ 6c/lb = $21

- Another process from Europe, PRIMUS, is also attractive from a process stand-point, however, the pilot plant of Paul Wurth at Arbed would cost at least $2 million to duplicate. This multi-hearth roasting process is charged with coal and iron oxide fines, and can be set up to produce a relatively pure ZnO (from EAF dust) and a pre-reduced solid iron. The sponge iron is contaminated with gangue, but could be either charged hot to an EAF or melted in a duplexing operation to produce pig iron. A 50,000-ton a year plant is being built in Europe at this time.
- Midrex explored the micro-plant idea last year but with the weak scrap market, DRI /HBI products are not competitive and such material is used only in special circumstances (captive plants, need for low metallic residuals). Midrex has abandoned this project for the time being.
- In Mexico, steel plants convert their EAF dust into bricks, which are used for walkways in the plants, among other things. A cold bonding process (Solvent Systems International) using a phosphate to produce shapes from dust and swarf with very high cold strength is available in this country. However, it is unlikely that the U.S. Environmental Protection Agency would approve such a use of EAF dust at this time.

The conclusion is that on-site processing of such small tonnages of dust and mill scale is not economically feasible for NSSI. In general, these technologies require tonnages of 30,000-50,000+ of EAF dust per year to provide economic viability. If the metals markets (Zn, Fe, Pb, Cd) or the relationship with the current recycling vendor changes, this subject should be revisited to determine if technologies or capital costs have changed enough to produce a significant savings and justify the installation of an on-site recycling operation at NSSI.

Motor Program

East Tower Water Pumps

The two vertical turbine pumps used in the East Tower are single-stage Goulds 10 x 16 DHLC, with nameplate performance of 3000 gpm at 70 ft. The 460-volt motors are 100 hp, with full load current of 120.3 amps.

The field data were also used as inputs to the Pumping System Assessment Tool (PSAT) software to provide a comparison between actual performances and an optimal pump and motor combination. Due to a degrading pump head, the results point toward significant energy and cost savings potential. Assuming full-time operation, the potential annual savings for the two pumps are over $32,000. The recommendations are as follows:

1. The drain valves located above the tower basin that discharge directly into it should be closed. To protect against freezing in some operations, it may be necessary to open a drain valve but under all other circumstances, it should remain closed.
2. Confirm the measured head values.
3. If the head measurement made during assessment is confirmed by the suggested measurement near the pump discharge, there is significant pump degradation. While pump repair might be considered, other alternatives should be explored as well. There are a variety of options, including new pump and motor assemblies, but one alternative that might be worth exploring is using the same pump model with a larger impeller (e.g., the 10.43-inch trim shown in the manufacturer's performance curve) accompanied by a 6-pole motor. The potential energy savings would be about 38 kW/pump or 76 kW total, which translates into about $29,000/year (the pump motor size could also be reduced to 40-hp). It might be noted that the use of multiple pumps in this type of application (static head dominated system) is normally

preferable to the use of an adjustable speed drive.

Clean Water Pumps

There are five horizontal split case (double suction) clean water pumps. The pumps are Allis-Chalmers 10x8x17S, with 14.9-inch impellers rated for 2800 gpm at 157 feet of head at 1750 rpm (nameplate). The pump performance curves used for this analysis are based on NSSI curves developed at 1785 rpm. The motors are 4-pole (rated speed = 1780 rpm) 150-hp, with full load current of 169 amps at 460 volts.

The diagram in Figure 4 illustrates the physical layout and the flow splits (not all fittings are shown, and no scaling is used). The measured data were compared with manufacturer performance curve data. The composite pump performance was shown as a bit below the composite pump head-capacity curve. It was noted that all pumps were operating below the pump best efficiency point (BEP).

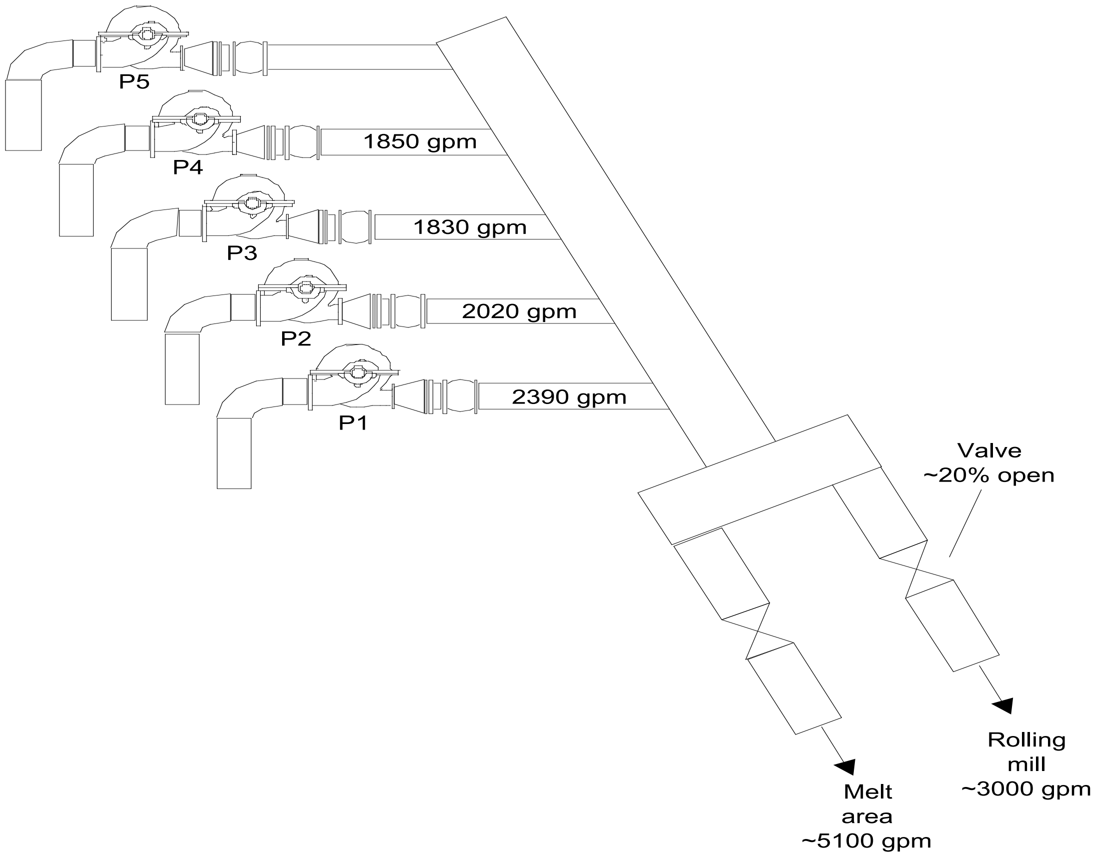

Figure 4. Clean water cooling pump measured flow rates

While pump impeller/wear ring/casing wear may account for part of the observed degradation, the presence of cavitation noise combined with the relatively high vacuum levels in the pump suctions indicate excessive losses across the pump inlet and foot valve. Corroborating this as a source of degraded performance was the relationship between individual pump flow rate and suction pressure. The pump with the lowest suction pressure (pump 3) has the lowest flow rate, while the pump with the highest suction pressure has the highest flow rate. This is consistent with the pump head-capacity curve, since the head would be lower (and the flow rate consequently higher) for the pumps with higher suction pressure. However, the presence of cavitation noise—particularly in the pumps with lower suction pressure —is also an indication that performance would likely be degraded. This suction configuration can contribute to suction problems; some alternatives will be noted in the recommendations section.

The system curve reflects (in part) the heavily throttled valve to the rolling mill area. The permanently installed pressure gauges overstate the pressure drop; the upstream and downstream pressures were measured to be 67 psig and 48 psig, respectively, using a test pressure gauge. This differential pressure, adjusted for the difference in elevation of the gauges (~4 ft), equates to a head loss of 48 ft. With a flow rate through the throttled valve of about 3000 gpm, the hydraulic power being dissipated is about 36 fluid hp. Assuming a combined pump and motor efficiency of 75%, the annual energy cost of the frictional loss is about $14,000.

But this significantly understates the potential savings. As will be shown below, if the existing rolling mill section was segregated from the melt furnace load, a total of three pumps (instead of the four currently used) could handle the existing load. The net load reduction would be about 84 kW, which equates to an annual energy saving of about $32,000. Reducing the flow rate to some loads could provide significant additional savings, as will be discussed in the reduction in flow rates section below.

The field data were also used as inputs to the Pumping System Assessment Tool (PSAT) software to provide a comparison between actual performances and an optimal pump and motor combination. The potential savings primarily derive from two sources - degraded pump performance and operation away from the pump's best efficiency point, both of which were noted previously.

Another option that was suggested for consideration during discussions was the potential for separating the discharge header to allow an individual pump or group of pumps to support the individual loads instead of feeding all loads from the common header. The primary indicator that this would be worthy of consideration is the throttled valve that restricts flow to the rolling mill.
If the discharge header were segregated to support the different loads with dedicated pumps, it is likely that three pumps instead of the present four could support the plant requirements. But there is another opportunity that would arise, particularly in the rolling mill portion of the clean water load.

If the flow rate to the rolling mill area was reduced to 2000 gpm, and if that load was handled by one dedicated pump (segregated from the furnace loads), it would be possible to replace the existing 150-hp, 4-pole motor with a 40- or 50-hp, 6-pole motor. The potential savings of this action would be about $27,000 per year (reduction in electric power of about 70 kW). Note that this is in addition to the $32,000 per year savings from reducing the number of operating pumps from 4 to 3. Recommendations are as follows:

1. The existing suction geometry is likely responsible for most or all of the apparent pump degradation. In addition, the losses in the suction reduce the overall flow rate that the system can support. There are two areas that are recommended for plant consideration relative to the clean water pump suction lines:
    a. Replace the existing foot valves with a power-driven priming system. The losses across the foot valves are likely significant. Although a venting system would require a bit more operator attention during startup, it should improve pump performance.
    b. Install bell mouth inlets and remove the suction screens. The bell mouth inlets would reduce the inlet losses and promote improved pump operation.

2. Consider reducing flow rates through some of the system loads. As noted above, doing nothing more than changing the speed and size of the motor would save about $27,000 per year.

3. When the change to the furnace operation is made, consider segregating the discharge header to allow selected pumps to handle segregated system loads. Examples of the effects were discussed previously. As noted, a segregated system would likely allow one pump one of the four pumps to be turned off. The annual savings would be around $32,000.

It should be noted that although these recommendations are discrete, they are also interrelated. For example, segregating the loads and their pumps would allow further optimization efforts, such as flow rate reduction, to be made in a simpler, more cost-effective manner. To illustrate, changing the speed or impeller diameter of one pump dedicated to the rolling mill area could be done if it was segregated from the melt furnace loads. However, this could NOT be done if it remained connected to the common header (the pump operated slower speed or with a trimmed impeller would be dead-headed).

<u>Mill Water Cooling System</u>
The pumps used in the Mill Water Cooling System are Hazelton twin volute; vertical wet pit-type pumps rated for 3000 gpm and 150 ft head at 1190 rpm. The pumps are powered by 200-hp, 460-V motors with a rated full load speed of 1185 rpm, and full load current of 225 amps. Two pumps are normally in operation.

On June 19, 2002, with the plant in normal operation, the discharge pressure was observed to be about 62 psig. The corresponding head (152 ft) suggested an individual pump flow rate of just over 3000 gpm (total flow rate just over 6000 gpm). This flow rate is very near the pump best efficiency point. Motor data was not acquired; however, the pressure downstream of the basket strainer was observed to be 10 psig less than that upstream of the strainer (the pressure drop was minimal on June 18, under low flow conditions).

While the pumps appear to be in reasonably good shape (consistent head and power data), and they normally operate at near the pump best efficiency point, there are nonetheless two opportunities for energy savings in this system.

First, on the aforementioned date, there was approximately a 10-psig pressure drop across the basket strainer located in the discharge header for the mill water-cooling pumps. The strainer is replaced with a clean one when the pressure drop reaches 12 psig. Assuming that the pressure drop across the strainer when clean is 2 psig, the average pressure drop during the life of the strainer would be 7 psig (assuming the strainer clogs in a linear fashion). At a flow rate of 6000 gpm, the 7-psig pressure drop corresponds to a hydraulic power of 24.5 hp. Assuming the pump efficiency of 82%, and a motor efficiency of 94%, the electric power would be 23.7 kW. Assuming continuous operation, this average pressure drop costs over $9,000 per year. Another way of looking at this is that a pressure drop of 7 psig causes a reduction in flow rate of about 1600 gpm with two pumps running.

Second, the flow rates delivered to the rolling mill stands appeared to be significantly more than that needed to maintain the rolls at an acceptable temperature. Discussions with operating staff supported this observation, and both operations and engineering representatives agreed that the flow rates could be significantly reduced without adversely affecting quality (or in some cases, positively impacting quality).

The two observations noted above, head loss across the strainer and apparently excessive flow rate to the rolling mill stands, are synergistic. The high flow rate results in a much greater head loss. Dropping the flow rate in half would drop the head loss by a factor of four.

If a reduction of about 20% in flow rate to all the mill water-cooling loads could be tolerated, a single pump could likely support the system operation. At normal operating flow rates, the electric power for each pump is estimated to be about 110 kW. Turning off one pump would increase the flow rate and operating power of the other pump. The net power savings would be slightly more than 90 kW, which would result in annual savings (assuming constant operation) of $35,000, as indicated by the PSAT software. Note, however, that if operation is reduced to one pump, the pump would be operating beyond its best efficiency point and additional savings, on the order of $12,000 per year, could be achieved by using a pump better suited to that condition.

Another benefit of this type of action would be a reduction in the dirty water return pit pump volume. This system was not evaluated, but any reduction in inflow would obviously allow one of the pumps to be stopped at least part of the time.

The plant staff was encouraged to evaluate the possibility of reducing flow delivered to the rolling mill stands by about 20%. If this appears practical and workable, they should try operating with a single pump. A logical time to check the effects of a single pump operation would be during a maintenance outage. If this is attempted, it is recommended that a clean strainer be used at the time of the test.

Melting and Reheat Furnace Process

<u>EAF Energy Consumption</u>

According to Dr. Fruehan and Associates, melting one ton of pure iron and super-heating it by 100°C, requires a minimum theoretical energy of 1327 MJ, which becomes 1327*.86 or 1.07 mmBtu/ton. However, this is misleading as a target because:

a) other materials besides iron are needed to produce a ton of steel

b) conversion of coal to electricity is only 33% efficient, so the conversion factor from Btu to kWh is not the scientific 3412 but 10,500

c) the melting process is neither adiabatic (no heat losses) nor instantaneous

In a 1998 survey of EAF plants, the energy required to produce one ton of shipments was about 11.3 mmBtu, with the melt shop accounting for the largest share at an estimated 7 mmBtu/ cast ton. This included auxiliary services (bag house, ladle heating etc) and the casting operation. The furnace operation itself was under 6 mmBtu/ tapped ton.

The traditional measure of EAF energy consumption has been kWh/ton but with the increasing use of natural gas, carbon injection, and oxygen for combustion, decarburization, and scrap cutting, this chemical energy input must be recognized. While it is not possible to determine the efficiency of the chemical energy input except with extensive comparative trials, we can convert all chemical inputs into equivalent Btu. The following conversion factors are used by the DOE and are used here.

1 lb carbon (coal, coke)	= 13,000 Btu/lb
1 scf natural gas	= 1,000 Btu
1 scf oxygen	= 179 Btu (electrical energy required to produce).
1 kWh	= 10,500 Btu

The other major development in EAF steel-making has been the use of more powerful transformers and long arcs, which are efficient only when a foamy slag practice is used to envelop the arc, thus minimizing heat losses and arc flare damage.

Energy consumption per ton will always decrease as productivity increases. This is achieved primarily by minimizing power-on time, which depends on the chemical energy input and the efficiency of electrical energy transfer. Power-off time is a function of the efficiency of tapping, scrap charging, the frequency of electrode changing, gunning requirements, and furnace maintenance. These should all be tracked to reduce this time to an average of <20 minutes/heat, with 15 being a good target.

Furnace productivity is also dependent on scrap charging efficiency and caster productivity. The bottleneck must always be identified because the greatest cost savings in any plant is EAF prime productivity.

<u>The MORE' lance system:</u> While not strictly part of this study, this system is very relevant to NSSI energy consumption. It will permit carbon injection to promote slag foaming and thus increase the electrical efficiency of the furnace. Some information on slag foaming is attached from ISS educational material prepared by Jeremy Jones (Nupro Corp -716-773.8726). The carbon in the injected foamy slag material can also react with undershot oxygen, and some of the CO generated will be oxidized to CO_2 to liberate heat (post-combustion). Some of this is recovered by the slag-metal system.

The real cost savings to justify this project is tied to increased furnace productivity, which hopefully is not restrained by scrap charging, casting, or rolling. From an energy perspective, the current and projected energy per cast ton are shown below in terms of Btu/ton. However, it is believed more charge or injected carbon will be required than is contained in the foamy slag material.

	Current	mmBtu/ton	Projected	mmBtu/ton
kWh	461	4.84	395	4.15
Charge C -lbs	36.6	0.48	15	0.41
Foamy slag material (80%C)	8	0.08	16	0.16
SCF oxygen	1096	0.20	1270	0.23
SCF natural gas	55	0.06	224	0.22
TOTAL		5.66		5.17

This indicates an energy savings per ton of 0.5 mmBtu. But if additional productivity is realized, there will be corresponding increases in the absolute energy consumption of the melt shop. This is the national dilemma—the U.S. is projected to use more energy in the future as the population grows and more uses are found for consuming energy. The only reasonable goal is to reduce per capita energy consumption through increased efficiency. The real benefit for NSSI is that more tons will be produced for less cost and the plant will be more competitive.

Relative to other mini-mills, NSSI currently is competitive energy-wise (Fig 5) and will become more so as some of the projects and report recommendations are implemented. One can also see in the figures below (which are not exactly calculated as in Fig. 5), how the mmBtu/ton decreases as the plant output increases with less heat loss/ton at the furnace and better hearth coverage at the rolling mill. This is why a snapshot in time is not a fair assessment of the efficiency of a plant. It will vary with the U.S. economic cycle.

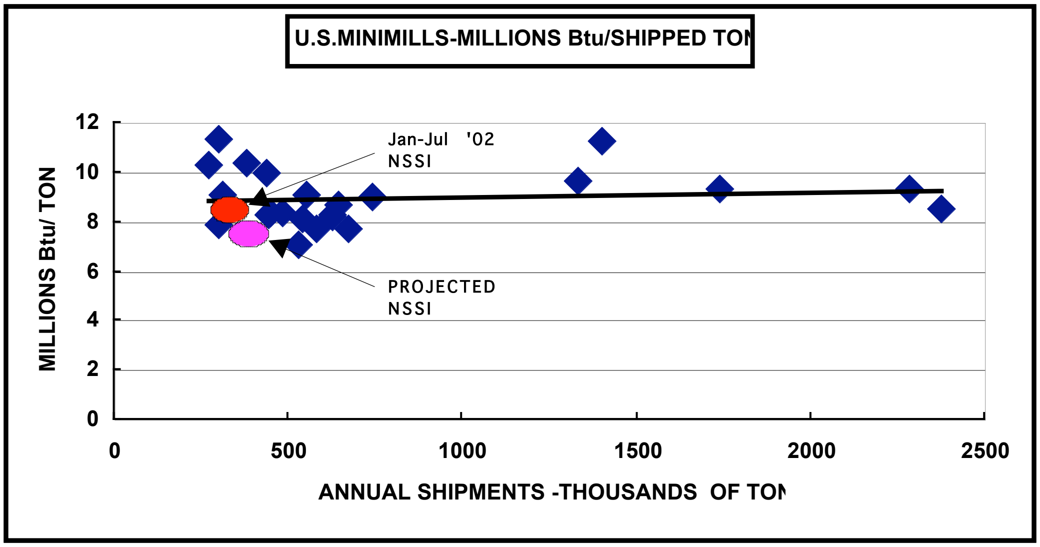

Figure 5. Energy per Shipped Ton- NSSI Actual and Projected

Feb 99-Jan 00	328,000 tons charged to RM : 7.8 mmBtu/ton
Feb 00-Jan 01	305,000 tons charged to RM : 8.1 mmBtu/ton
Feb 01-Jan 02	228,000 tons charged to RM : 8.3 mmBtu/ton
June 02	27,990 tons charged to RM : 7.7 mmBtu/ton (336,000 tons annualized)

If charging scrap is a bottleneck, an increase in magnet size and power may reduce the lifts per bucket. This was needed at Charter Steel. If the tundish becomes the bottleneck, it should be investigated to determine if its size could be increased.

Casting speeds are a function of chemistry, mold water-cooling, and machine metallurgical length. In recent years, a number of mills have explored the use of longer molds (e.g. Nucor-Kankakee, the former Birmingham Steel facility) and molds of different designs to increase casting speeds by 10% without major capital expenditures. Resources like Don Lorento of Accumold can be contacted (519-228-6601) for information on what the industry has found and what he would advise if casting capacity becomes an issue.

<u>Upgrade of the Reheat Furnace</u> North Star Steel Iowa Division Rolling Mill has implemented the Phase II upgrade of the reheat furnace and controls during the plant shutdown in late November-early December 2002. Phase II revisions to the existing billet re-heat furnace included:

1. Adding a bottom pre-heat zone (6 Ultra Low NO_X burners), a top pre-heat zone (6 Ultra Low NO_X burners), and replacement of the 4 heat zone burners with lower capacity Ultra Low NO_X burners.
2. Installation of a new level I and level II control system.
3. Replacement of existing natural draft stack with an ejector stack.
4. Relocation of all furnace controls to the charge end of the furnace in a new pulpit.
5. Relocation of the rougher controls to the main pulpit.

The upgrade will result in the following benefits:

1. reduced cost of finished product through lower BTU rates and less staffing
2. improved product quality through uniform heating of the billets, which will minimize decarburization, cambered bars, and rolled in scale
3. return to historic production levels of 320,000 plus tons while maintaining the current rolling

cycle

4. lower NO_X emissions (revised burner configuration will reduce by approximately 50%)
5. improved BTU rates will help the plant achieve the corporate goal of 10% reduction in energy by 2005. Our current fuel rate is 1.43 mmBtu's per ton. Bricmont guaranteed a 1.28 mmBtu/ton energy usage rate when operating the furnace across a consistent 90 TPH rate.

Expected Savings

- Fuel savings: It is expected that an average fuel saving of 0.08 mm Btu/ton will be achieved for the production rate of 320,000 tpy production. The energy savings will be 320,000*0.08 = 25,600 mm Btu/year.
- Energy cost savings: At a fuel cost of $3.75 per mm Btu, the annual savings will be 25,600*$3.75 = $96,000 per year.
- Labor cost savings: Relocating the pulpit controls to the charge end of the furnace will eliminate the need for a Heater Helper on each crew. This will save labor cost equal to $60,000 x 4 heater helpers = $240,000/yr.
- Benefits will also be derived from improved product quality (decarborization, camber, surface, etc) and improved furnace refractory life.
- Savings due to reduction in scrap: It is expected that a total of 25 tons scraped for camber during a fiscal year could be recovered due to these furnace modifications. Savings resulting from the reduction of scrap steel can be estimated by accounting for scrap reduction at an average selling price of $283, less the scrap value of $65. The savings are equal to 25*($283-$65) = $5,450 per year.
- Total savings are estimated to be the sum of all above savings or $341,450 per year.

Additional benefits will be derived from increased production and associated profit potential. It is estimated that the modifications will allow 20 turns operation vs. current practice of 15 turns. The project cost was $3,000,000. Based on this, the payback period is equal to $341,450/$3,000,000 or 8.79 years. The actual payback period will be shorter than this estimate since this estimate does not include the economic benefits related to increased profits generated from more efficient reheat furnace and rolling operations.

<u>Installation of Recuperators for Ladle and Tundish Heating Systems:</u>

NSSI uses gas-fired burners to preheat ladles. The plant has two ladle heating stations, which are used to preheat three ladles to approximately 1600°F. The exhaust gases from the burners are discharged out in the open air. The East side ladle preheater uses two direct-fired burners with ambient temperature air. Each burner has a firing capacity of 4 mmBtu/hr. At this time, the burners' flue gas heat is not recovered and is discharged directly into the building where they rise to the ceiling level and mix with the fumes from the EAF. This additional volume causes serious problems with the concentration of smoke in the melt area.

The West side ladle heater uses two regenerative "Twin-Bed" burners that are designed to recover heat by using a regenerator bed attached to each of the burners. These burners are designed to get very high heat recovery and their total firing capacity is approximately 4 mmBtu/hr. However we were told that the burners are not operated in the regenerative mode and are fired in the "cold-air" mode. This means the heat recovery system is not functional. It is recommended that NSS install a recuperative heat exchanger to recover part of the exhaust gases to preheat combustion air. The collection method requires modifying the air preheating system for the ladles (See Figure 6). It will be necessary to provide suction on the collector header and a means to account for pressure drop (expected to be 0.3 inch water column) with use of an exhaust fan. The exhaust fan offers an additional advantage of eliminating the hot exhaust gases rising to above the charge crane level of the EAF.

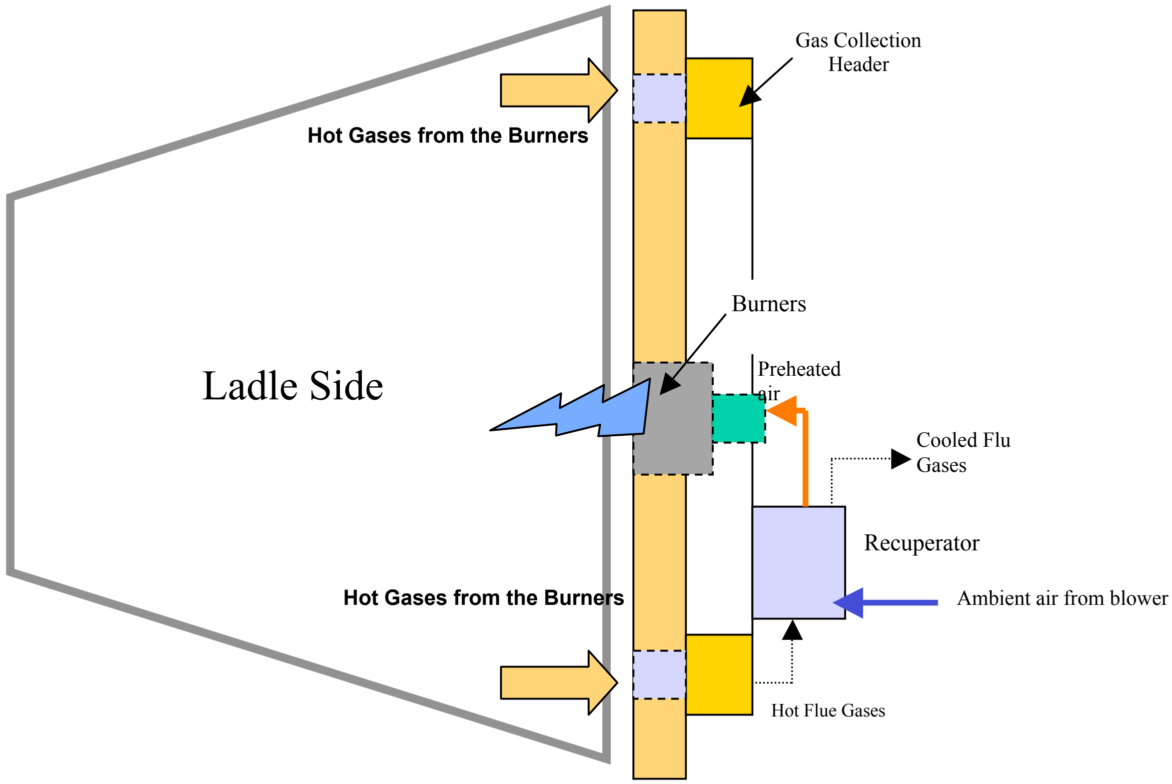

Figure 6. Schematic of the proposed air preheating system for the ladles

A simple calculator developed by E3M, Inc. is used to calculate estimated fuel savings and annual dollar savings with the use of preheated combustion air. Figure 7 gives the results of savings calculations for one of the practically applicable case for ladle heaters at NSS.

Combustion Parameters	Current	New
Furnace flue gas temp. (F)	1,600	1,600
Combustion air temperature(F)	100	899
Fuel Consumption (MM BTU/Hr	6.00	4.31
Fuel Savings (%)		28.1%
No. of Operating Hours	8000	
Cost of Fuel ($/mm BTU)	$4.50	
Annual Savings ($/year)		$60,755

Figure 7. Calculations for savings resulting from combustion air preheating. (Ladle Heaters)

It is assumed that the flue gas temperature is 1600 F and the use of a recuperator will result in air preheating to 1000°F. This will result in fuel savings of 28% or $60,755 at a gas cost of $4.50 per million Btu. At this time, a detailed design of the system cannot be finalized. However based on past experience with similar installations, it is expected that the total installation cost be $30,000 to $40,000. Allowing for the higher cost and the cost of the recuperator, the total project cost is expected to be approximately $70,000. (A quotation was obtained from Exothermic, Inc., a major supplier of recuperators used for combustion air preheating.) The predicted savings, based on the current gas cost of $4.50 per million Btu, is $60,755 per year.

The simple payback period = Cost of installation/annual savings
= $70,000/$60,755
= 1.15 years or 13.8 months.

To eliminate mixing with the EAF fume inside the Melt Shop, exhaust gases will be discharged at 1000°F outside the shop. The discharge will occur at a rate of 1333 scfm or 3900 acfm. An exhaust fan of approximately 5000 acfm capacity rated at 800°F. is suggested to discharge these gases. The cost of this unit is not included because it is not required for the energy savings. However, this exhaust fan offers beneficial effects for removing heat from the Melt Shop to reduce competition with the fume collection system. (See Bender Corporation Melt Shop Ventilation Study in Energy Management Program section)

The West side ladle already has regenerative burners for air preheating. However, we were told that they are not operated in the regenerative mode due to several problems related to maintenance of the bed and the controls. We suggest modifying the system to solve the maintenance problems or installing a recuperator with use of both burners in the preheated air mode at all times. The burners are apparently designed for high temperature operation and can be de-rated to get total capacity of 6 to 7 million Btu/hour. With the recuperator and hot air piping, it is very likely that the existing burners can be used.

In addition to the two ladle heaters, the plant uses a tundish dryer to cure and preheat the tundish. Two North American burners are used for this heater unit. It is assumed these burners have a heat supply capacity of 1 _ mmBtu/hr. each or a total of 3 mmBtu/hr. We were informed that the Tundish heater is operated at 2300°F. However, it is very likely that during the dry-out part of the cycle, the flue gas temperature is much less than 2300°F. It is assumed that for a 24-hour cycle the average flue gas temperature is 1600°F and the average firing rate is 2 mmBtu/hr. The recuperator cost for this system is estimated based on the information obtained for the larger unit discussed above. The estimated cost is almost _ or $15,000. The installation cost including burners, piping etc. is assumed to be approximately $30,000 with total cost as $45,000. The energy savings are calculated by using the calculator (See Figure 8)

Combustion Parameters	Current	New
Furnace flue gas temp. (F)	1,600	**1,600**
Combustion air temperature (F)	100	**800**
Fuel consumption (mmBtu/hr)	2	**1.49**
Fuel savings (%)		**25.5%**
No. of operating hours	2000	
Cost of fuel ($/Million Btu)	$ 4.50	
Annual savings ($/year)		**$ 4,590**

Figure 8. Calculations for savings resulting from combustion air preheating. (Tundish heart-dryer)

The simple payback period = Cost of installation/annual savings
= $45,000/$4,590
= 9.80 years

Installing a combustion air preheater (recuperator) offers a payback period of 9.8 years. These calculations are based on the budgetary prices and estimated cost of installation with gas price of $4.50 per million Btu.

Billet Preheating

In cases such as reheat furnaces, large amounts of high temperature gases are available and can be used to preheat work charged into the furnace. Figures 9 and 10 show potential benefits of charge preheating by using furnace flue gases. The estimates are based on the available data from reputable furnace suppliers such as Bricmont, who is responsible for rebuilding the North Star furnace.

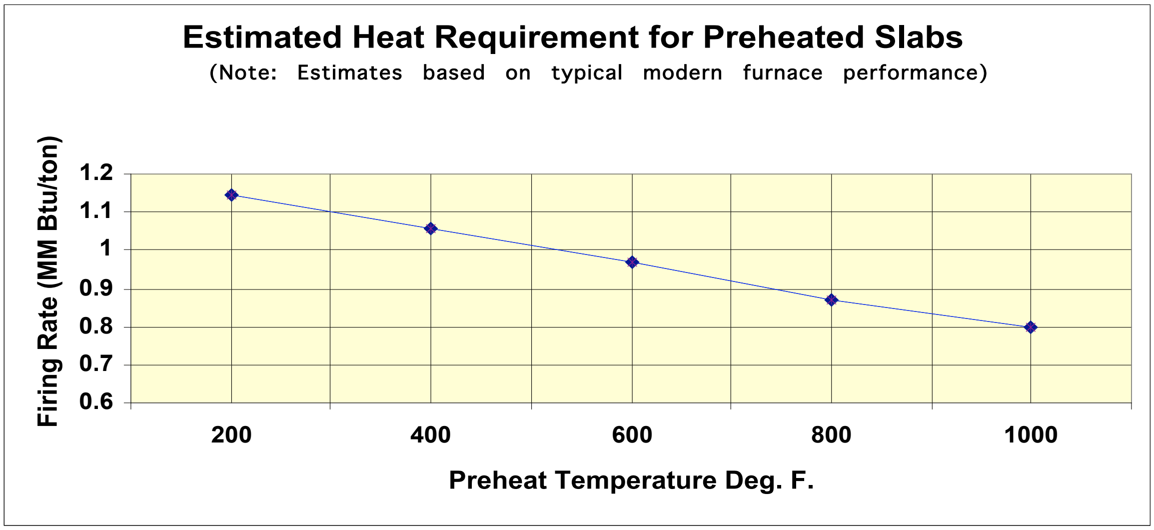

Figure 9. Estimated heat requirement for preheated slabs in a typical modern reheat furnace

Draft inch w.c. 0.05	Flow cfh/in^2 302.25	
Air Infiltration – cf/h		43,523
Heat Required (net) to Heat Air - Btu/hr		992,336
Available Heat - %		62.89
Gross Heat Required - Btu/hr		1,577,982
Fuel Cost - $/mm Btu		$ 4.50
Number of Hours Operated - per Year		8,000
Cost of Fuel Wasted - $ per Year		$ 56,807
Temperature of Flue Gases - °F		1,200
Opening Size Area - ft^2		1

Figure 10. Estimate of cost of fuel wasted due to air infiltration

Figures 9 and 10 indicate that charge preheating to a moderate temperature of 800°F to 1000°F could result in savings of 32 to 32.5%. The variety of products at NSSI makes it difficult to charge 100% of the charge as preheated charge. The cost of changes required to allow hot charging depends on many factors, such as method of charge handling, distance between the casting machine and the reheat furnace, slab surface temperature etc.

Our best estimate for costs associated with a relatively small percentage of hot charging is from

$50,000 to $100,000, when it is not necessary to make extensive changes in the slab or billet handling system. Assuming 10% hot charging, the payback period varies from 5 to 10 months. For 5% hot charging, the payback period varies from 10 to 20 months. The cost considerations would perhaps be quite different when a very large percentage of material is hot charged and the charge temperature is in excess of 1000°F.

Note: Due to the current scheduling requirements, marketing conditions, in addition to radical plant and operational changes necessary to implement Billet Reheating, NSSI will not be pursuing this project.

Heat Recovery

Reheat Discharge Skid Base

The current reheat furnace design includes a water-cooled section at the discharge end for the skids. This results in skid marks that, indirectly, require over heating of the bars prior to hot rolling by maintaining higher zone temperature. The effect of higher zone temperature is two-fold: (1) increased energy consumption, and (2) higher scale formation for the bars. During our visit we noticed unusually thick scales had formed on the bars as they were being discharged.

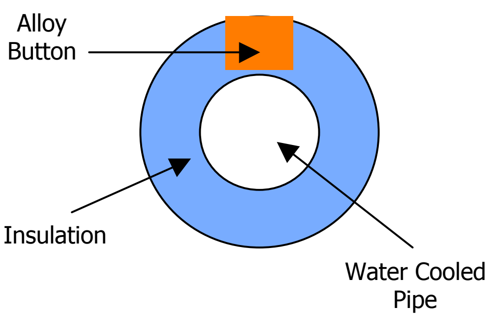

Figure 11. Skid Base Design

Two design revisions are recommended: lower the position of the water-cooling and install insulation with a button to support the bars as they are discharged (See Figure 11).

The design would allow NSSI to reduce the final temperature of the billets by as much as 25°F since there will be no need to overheat to compensate for the cold spots at skid mark. In addition, the furnace zone temperature and, correspondingly the exhaust gas temperature, could be reduced at least 25°F. It is expected that this reduction in exhaust gas temperature will result in an equal amount of flue gas temperature drop from the furnace.

During our visit, the furnace heating zone temperature was 2460°F and the soak zone temperature was 2225°F with the billet dropout temperature at 2175°F. By installing this system, the soak zone temperature (and the heating zone temperature) could be reduced to 2200°F with a change in available heat of approximately 1% for flue gases downstream of the recuperator. This will represent a fuel savings of 1.1 mmBtu/hr or $39,600 per year. The savings resulting from the 25°F reduction in steel temperature is approximately 1% of the heat input or, once again, 1.1 mmBtu/hr for an additional savings of $39,600 per year. Additional savings from reduced scale formation and associated metal losses are calculated based on several assumptions. The current level of scale is 3500 tons per year. Based on production level of 300,000 to 350,000 tons per year reheating, it represents 1% of the furnace production. It is assumed that lower furnace temperatures would result in a reduction of 5% of the scale currently produced or additional steel shipping of 175 tons per year. At a value of $250 per ton at this stage of production, the savings are estimated to be $43,750. Cost of scale handling is not considered here.

The total savings that can be attributed to this change is $122,950. It is estimated that such a change may cost approximately $75,000 to $100,000. Hence, the payback period can be in the range of 7.5 to 10 months. A payback period of 10 months is reported for this recommendation.

Oxygen (O_2) monitoring and O_2 control system

The flue gas oxygen reading was not available for the record during our visit. We were told that the burners were calibrated for 10% excess air that will give approximately 2% O_2 in flue gases for a tight furnace. The burner flame was observed using an opening in the furnace wall on the charge end and looked very "rich" in fuel (yellow, long, and bushy). It is unlikely that the air-fuel ratio was correct (i.e. 10% excess air) and a large amount of air was leaking in the furnace. We believe that the furnace was operated at a negative pressure, resulting in leakage of ambient air into the furnace at the charge end.

In view of this, we have analyzed the economic impact of excess oxygen in flue gases (1900 F.) for the reheat furnace operating at the current operating conditions. The following figures give results of analysis for two cases.

	Furnace Flue Gas Temperature	Oxygen in flue Gases	Excess Air	Combustion Air Temperature	Available Heat	Fuel Savings
	Deg. F.	%	%	Deg. F.	% of gross Heating Value	%
Base Case	1900	3	**15.6**	450	**49.99**	**0.0%**
Case 1	1900	2	**9.6**	450	**51.71**	**3.3%**

Item	**Number**	**Units**	**Comment**
Fuel Cost	$4.50	Per Million Btu	
Firing Rate	80	mm Btu/hr	Average value
Operating hours/year	8000	Hours	20 turns/wk, 50 wks.
% Savings	3.3%		See above
Fuel savings	21,375	mm Btu/year	
Savings	$96,187.00	$/year	
Cost of O_2 monitoring & control	$50,000.00		Capital Cost
Maintenance Cost/year	$15,000.00	$/year	
Avg. annual savings	$81,187.00	$/year	
Simple payback period	7.39	Months	

Figure 12. Payback period analysis for effect of reducing O_2 from 3% to 2%

In one case (Figure 12) the oxygen is reduced from 3% to 2%, resulting in annual savings of approximately $96,000 per year in fuel and an overall average annual savings of $81,187 after deducting the maintenance cost of $15,000. We recommend that the O_2 monitoring and control be given attention to improve energy efficiency and reduce the scale on the bars.

Higher Temperature Combustion Air Preheating for Reheat furnace

The reheat furnace has been modified to improve its performance. The modified furnace uses the current recuperator but has significant changes in the firing system of the furnace. During our visit we reviewed the drawings and other information given by the supplier (Bricmont, Inc). The suggested changes will certainly improve furnace performance and reduce fuel consumption from the current value of approximately 1.4 mm Btu/ton to 1.28 mmBtu/ton. However, the preheated air temperature will be at approximately 600°F. We suggest that NSSI consider increasing the air preheat level to 900°F. This will increase overall efficiency and reduce energy consumption by approximately 10%. This will result in an estimated annual savings in excess of $250,000. The following description gives details of the analysis.

The cost for a new recuperator is $90,000, plus or minus 10%. The following calculations are based on $90,000 as the cost number. Based on prior experience, it is estimated that installation costs could vary from $25,000 to $50,000. A number of different approaches are taken to see the sensitivity of cost figures on the payback periods for use of a higher performance recuperator. Additional assumptions are: average firing rate for the furnace, 80 mmBtu/hour; yearly operating time for the furnace, 8000 hrs per year; and gas cost, $4.50 per mmBtu.

The following Figure 13 gives a summary of payback calculations that assume that a new recuperator will be used and installed in the existing space. No credit is used for value of the current recuperator. The incremental installation cost is estimated to be $60,000 for changes in air ductwork, burner ratings etc. The installation cost needs to be confirmed. For this case the payback period is approximately 7 months.

Item	Number	Units	Comment
Fuel Cost	$4.50	Per Million Btu	
Firing Rate	80	mm Btu/hr	Average value
Operating hours/year	8000	Hours	20 turns/wk, 50 wks.
% Savings	9.7%		See above
Fuel saving	61,860	mm Btu/year	
Savings	$278,369.00	$/year	
Cost of recuperator	$90,000.00		Cost of NEW recuperator
Installation cost (assumed)	$60,000.00		Piping upgrade etc.
Simple payback period	**6.47**	**Months**	

Figure 13. Payback Calculations Based on Total Cost of New Recuperator

<u>Use of Combined Heat and Power (CHP) for Reheat Furnaces</u>
The reheat furnace at NSS is the single largest user of natural gas in the plant. It consumes, on an average, 80 mmBtu/hr and costs approximately $360 per hour to operate. At this rate, assuming 20 turns operation per week for 50 weeks per year, the fuel cost is estimated to be $2.88 million per year.

Recently, a combined heat and power (CHP) system was proposed for the steel industry to produce electric power while supplying necessary heat to the reheating furnaces. Use of this scheme can be very beneficial to NSSI and other plants. This is especially important in areas where power costs increase substantially during certain times of the year. The system consists of a number of burners that use natural gas as fuel and preheated air for combustion of natural gas in several zones of the furnace. The combustion air is preheated to approximately 660°F. by using a recuperator and the total firing rate is approximately 110 mmBtu/hr. at the rated capacity of 90 tons/hr. The overall efficiency of the furnace, accounting for all losses, is approximately 57%.

The CHP system uses turbine exhaust gases to supply oxygen or air to the furnace burners, and it replaces the conventional source of air supplied from a combustion air blower. Exhaust gases from a gas turbine contain relatively high (15% to 19%) oxygen as volume or mass percentage. These gases can be considered as a source of oxygen for combustion of natural gas in the reheat furnaces. A detailed analysis was carried out to determine the appropriate size of the turbine that can deliver the required heat input for the reheat furnace. Based on this analysis it was determined that a 2 MW GE turbine would be the best match. The turbine operating characteristics are shown in Figure 1 where KWe is Kilowatt electricity. The electricity produced in terms of KWH will be equal to (KWwe rating) x (number of hours per year). For example if the KWe rating for he turbine is 2 MWe and the number of hours per year is 8000 then the total KWh savings would be = 2000*8000= 16 million KWH.

The combustion system would be adjusted to maintain 2% excess oxygen (in the conventional combustion system) in the furnace exhaust gases. The furnace should be designed with an "unfired load preheat" or "booster" heating zone that would reduce the gas temperature to approximately 1100°F (See Figure 14). This type of high heat recovery furnace design is common in many newer installations.

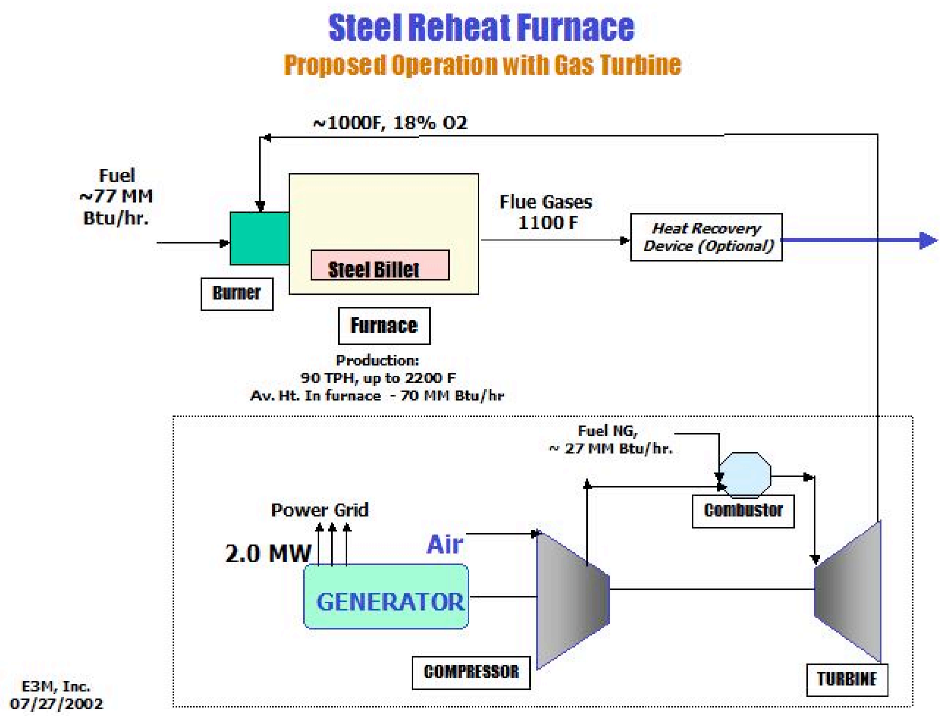

Figure 14. The proposed CHP system Application at as applied to NSSI plant reheat furnace

It should be noted that the current furnace design (new) would discharge flue gases at 1660°F and it will be necessary to have a longer furnace length for the preheat section. However, it will eliminate use of the recuperator. The economics of this system were analyzed in detail. The results of energy requirements are shown in Figure 15. It should be noted that the proposed system uses approximately the same amount of natural gas as used in the rebuilt reheat furnace. However the system also produces 2 MW power that can be used for the plant.

Combined DG System		
Electric power produced	Kwe	2,000
Heat input for the turbine plus reheat furnace	***Million Btu/hr***	***104.45***
Air flow to the turbine	#S/hr	87,317
Exhaust gases from the turbine	#S/hr	87,318
Net heat into the reheat furnace	Million Btu/hr	70.17
Exhaust gases from the DG system (reheat furnace)	#S/hr	92,081
Summary		
Electric power produced	**Kwe**	**2,000**
Heat input for the integrated DG system	**Million Btu/hr**	**104.45**
Heat consumed by independent operation of the reheat furnace with purchased power	**Million Btu/hr**	**107.12**
Heat savings resulting from the use of combined DG-reheat furnace system	**Million Btu/hr**	**2.68**

Figure 15. Summary of the CHP system Energy Requirements for the Reheat Furnace

The turbine cost and associated engineering and installation costs were obtained from personal contact with turbine suppliers and engineering contractors (See Figure 16). The additional costs for the furnace are net costs after accounting (cost deduction) for not using the recuperator, combustion air blower etc.

Based on GE Aero Products GE2 Turbine Generator				
Cost Elements	**Kwe capacity-generated**	**Per Kwe**	**% of equipment cost**	
Turbine-Gen set	2000	$ 1,000.00		$ 2,000,000
Heat recovery device cost (See Below)				$ 120,000
Total hardware related cost				$ 2,120,000
Engineering			15%	$ 300,000
Installation incl. Interconnect			15%	$ 300,000
Other costs		$ 25,000.00		$ 25,000
Total project cost				$ 2,745,000
Net cost for the project				**$ 2,745,000**
Additional Cost for use of turbine exhaust gases into the reheat furnace				
Conventional process heater retrofit component cost		$ 100,000.00		$ 100,00
Installation etc.			20%	$ 20,000
Other costs		$ -		$ -
Total cost – for retrofit				$ 1,200,000
Avoided cost of electricity Cents/Kwh	5.00			
Fuel (natural gas) cost $/mm Btu	5.00			

Figure 16. Cost Summary for the Reheat Furnace CHP System Application

Figure 17 shows the expected payback period. It is assumed that the turbine will operate for 8000 hours per year and the furnace will be operated for an average of 7200 hours at full load conditions. An operating and maintenance cost of $40,000 per year is assumed for the turbine.

Summary of Revenue, Savings and Costs	
Hours of operation for the turbine – per year	8,000
Hours of operation for the heater – per year	7,200
Avoided electricity cost – per year	$ 800,000
Fuel (Nat. Gas) savings (avoided cost) for the heater and turbine operation – per year	$ 96,354
Other operating cost	$ (40,000)
Simple payback period - years	**3.21**

Figure 17. Calculations of Simple Payback Period

In summary, use of a CHP system for a reheat furnace offers several advantages as well as a reasonable payback period when the electric cost is in the range of 4 cents per KWh and higher. NSS management should seriously consider this option for new installations, particularly at locations where the power cost is expected to be volatile during the summer period.

Note: NSSI has elected not to pursue this project as the CHP competes for space with the larger recuperator project and use of the Reheat Furnace gases. NSSI believes the larger recuperator and increasing the preheat gas temperatures to have a better ROI than the CHP project.

<u>Compressed Air Heat Recovery Potential Opportunities</u>: Waste heat can be recovered from an air compressor and used for water heating, space heating, or a combination of both. The maximum energy recoverable would be 94% of the total input energy from an enclosed oil cooled screw compressor. The heat recovered from oil for hot water can be 72% of the total input. (V. Ganesh, "Waste Heat Recovery," Plant Services, July, 1993)

Because NSSI has open compressors, we could assume that 72% of the available energy can be used to produce hot water and the remaining 22% has the potential for space heating. Of the amount available for space heating, a portion (100,000 BTU/Hr) must remain to heat the compressor room. However, when the potential for water heating was examined, the savings has a limit due to the number of employees and lack of hot water applications.

Quincy Compressor suggests that NSSI convert the water cooling units on the QS-1000 compressors to air cooled units and then recover the energy from the cooling units for space heating. They estimated that this could be accomplished for $5,000 - $7,000 per compressor.

According to Kaeser Compressor Company, a 200 HP oil cooled compressor has a potential recoverable heat of 407,109 BTH/Hr for water heating (1271 gal/hr to 158 F) or 560,967 BTU/Hr for space heating. Water heating is accomplished through a plate-type heat exchanger and can be easily retrofitted to any hot water system. Space heating would be either a hot water heat exchanger with ducting or direct-ducted air blowers.

Air Services Company (Bensenville, IL) a Comp-Air distributor, offers air-cooled conversion packages and water heating heat exchangers to fit all manufacturers compressors. They offered a budgetary quote of $7,000 for equipment to convert to air cooled to take advantage of space heating. They also quoted water-heating equipment at $4,000 per compressor. Air Services also suggested alternative combinations based on the individual site.

Maximum effective benefit for water heating: In order to estimate the amount of water heating that could be effectively used, we considered 350 employees each using 20 gallons of heated water per day maximum. This would mean a 7,000-gallon per day requirement that could easily be provided with current heat exchanger technology. The BTU savings for this replacement is calculated on a straight BTU conversion for 100 deg F heat up:

7,000 gal/day x 8.3391 lbs/gal x 100 °F x 1 BTU/lb-°F x 340 days/year = 1,984.7 mmBTU's/ year

Since this energy will be replacing natural gas generated water heating which is 60% efficient, the actual savings will be:

1,984.7 mmBTU/0.6 = 3,307.8 mmBTU's per year

This would require the use of 60% of the energy from only one 200 HP compressor. Because of the distance to the locker room (approximately 350 feet), some amount of heating above the 100°F pick up may be required. An additional 50°F pick up would put the utilization at 90% of one compressor.

Maximum effective benefit from space heating: Using Kaeser's estimate of 560,967 BTUs/Hr available from each 200 HP compressor for potential space heating, assuming a maximum of three compressors running at one time, utilizing one compressor for hot water heating, and allowing for 100,000 BTUs/Hr for heat in the compressor room, NSSI will have 1,021,934 BTUs/Hr available for space heating. The initial optimum location for space heating would be the Roll Shop. It is located approximately 100 feet from the Air Compressor Room. Based on the cost to retrofit with the existing heating system, this location offers the potential to save:

1,021,934 BTUs/Hr x 730 Hr/month x 6 months/yr x 1/.60 (Natural Gas efficiency) = 7,460.1 mmBTUs/yr

Annual Projected Economic Impact: Heat recovery from the combined projects assuming a three-compressor operation is 10,767.9 mmBtu/year. Based on the cost of Natural Gas ($4.50/mmBtu), the Annual Savings would be $48,455.00. Based on an equipment cost of $20,000 to modify the compressors cooling circuits and assuming an installation cost with piping, ductwork, and insulation of $30,000. The project has a potential of a 1.03 yr payback.

Energy Management Plan

Strategic Utility Metering

NSSI has in place an energy consumption allocation report. It utilizes utility company meters and two plant sub-meters as well as some engineered factors to track energy consumption in the plant to three cost accounts for each utility. The plant "value metering" is approximately 72 percent. The concept of value metering is the percentage of the utility bill that can be verified by downstream meters. This is important to cost allocation, project justification, and energy conservation accountability. Engineered factors can be used for 10 to 15% of the metering, but they need to be reviewed annually.

Areas identified that should be further addressed by strategic metering are:

- Industrial gases, nitrogen and oxygen. There should be a system audit and supply review now that the More' injector system is in service. There may be a large cost savings available to NSSI.
- A metering review recommends the installation of electric power meters for the Rolling Mill, Air Compressor Room, and Bag House.

- Additional natural gas and compressed air meters should be evaluated for the Melt Shop, Caster, Rolling Mill and More' injector system.
- Metering and utilities cost distributions: Electric load logging meters and strategically placed natural gas, air, and water pressure/flow meters should be installed to help the Asset Reliability group more accurately and precisely track some of the critical areas for their performance and reliability analyses.

<u>NSSI Firewatch Energy Savings Program</u>
The Firewatch Energy Savings spreadsheet was developed by NSSI's Maintenance Reliability Group. It is a 26-column spreadsheet tool in Microsoft Excel. The first five columns are handed out to the Firewatch Electrician and Millwright as a guide for shutdown and startup of plant equipment. The columns include a number of energy-related items (such as pumps, doors, lights, compressors, and valves), a 48-hour cost to operate the specific item, item description, and boxes to check the item off and back on. The costs were added to encourage participation and show the value of the energy conservation program.

The balance of the columns identify (when available) for each unit:

- Controller, switch, breaker, or valve location
- Breaker, switch, or valve number
- Breaker box, panel board, valve, switch, motor, or equipment number
- Type of switch, breaker, or valve
- Power supply, HP, Volts, and amps
- Power factor
- Calculated watts consumed
- Costs per hour, day, and total
- Identify candidates for additional savings

The Firewatch checklist covers five specific areas: (1) Finish End Mechanical Shutdown, (2) Rolling Mill Electrical Shutdown, (3) Rolling Mill Mechanical Shutdown, (4) Melt Shop Electrical Shutdown, and (5) Melt Shop Mechanical Shutdown. In each of the areas, items are identified to be turned off, checked for cold weather operation, verified operation, checked for leaks, and etc. It is used every time a shutdown will be 48 hours or longer. This proactive effort is an example of excellent people dedicated to keeping their plant safe, cost competitive, and energy efficient. It should be used at all of the North Star Steel locations as a guideline.

<u>North Star Steel Iowa Energy Management Program</u>: An energy management program was developed for NSSI during the PWA. The components and major sections of the program are presented below. Due to the length and detail of the actual program, this brief summary is all that is presented here.

Component 1: Commitment and Accountability

- Energy Policy Statement

Component 2: Clearly Defined Baseline for Measurement Energy Consumption

- Down Day Consumption
- Plant Total Consumption
- Base Production Data
- Energy Consumption Target

Component 3: Impact of each PWA section on plant

Component 4: Training and Awareness Program for Employees

- Energy Awareness Program

Air System Balance
During the Energy Management Plan Plant Utility Survey, a number of air system imbalances were discovered. Currently, a series of electric data loggers, air pressure, and air flow data is being gathered to identify and quantify these imbalances. Anticipated savings or capital costs to correct these imbalances are to-be-determined.

Fume System - Bender Corporation Melt Shop Ventilation Study
The Bender Corporation, Beverly Hills, CA, completed an evaluation of the melt shop ventilation and emissions control optimization using a fluid dynamic model. The goal was to eliminate the in-plant haze and excessively warm conditions due to operations.

Fume accumulation causes the haze and heat creates the inversion layer. The point where the haze layer begins was the measurement of improvement in the various model tests. At 461,000 ACFM of airflow, the haze layer started at the top of the shop's large doors (approximately equal to the slag door on the furnace). At 690,000 ACFM of airflow, the haze layer was at the furnace roofline. At 920,000 ACFM it was at the transformer vault roofline. It was apparent that the waste heat from the ladle heaters affected the movement of the fumes and the man-cooling fans for the Caster operators would draw the fumes down and across the Caster.

A specific test was run to determine the effect of the temperature gradient. All heat sources were removed and the Caster man-cooling fans were turned off. The heat sources removed were the ladle and tundish preheaters and dryers, heat from the Caster run out, and radiation heat loads (i.e. hot ladles and slag). At 461,000 ACFM, the fume rose faster and straighter because of cooler air. Bender felt that the fume load based on the haze layer was equivalent to 1,500,000 ACFM exhaust flow. Bender concluded that turning off the heat sources is equivalent to increasing the size of the exhaust system. The heat sources in the plant have a significant influence on the emission dispersement in the melt shop. Bender feels that the heat problem will cause a need for increased emission control capacity regardless of changes made to the canopies.

Subsequent tests were made using combinations of scavenging at different levels on the east and west sides of the canopy, removing the caster canopy, installing wind walls at the truck doors, alternative man-cooling at the Caster, with and without Caster run out heat, and a variety of wall and canopy modifications to increase suction.

Bender's primary recommendations were:

- Remove waste heat from ladle and tundish preheating and drying from the building.
- Move the scrap bucket scale to the east.
- Install a wind wall to the west of the melt shop.
- Install better local man-cooling at the Caster.
- Remove sheeting from the Caster canopy.
- Increase height of the slagging area enclosure.
- Remove EAF canopy hood sheeting from the top of the hood.

The project, water model video, and report clearly identify waste heat as a major contributor to inversion and haze level. Arvind Thekdi recommended recuperation for the ladle heaters and tundish heater. His report shows an energy savings (melt shop heat source reduction) of 4,090 mmBtu/year for the Tundish Heater-Dryer and 13,500 mmBtu/year for the Ladle Heaters. When the Ladle and Tundish recuperator projects are considered for installation, the impact(s) to the melt shop ventilation and haze layer should also be included.

Additional Energy Savings and Remarks

<u>Fluff Processing</u>

At the NSSI plant, approximately 5% of the scrap charged in the arc melting furnaces is recovered as fluff. This material consists of mostly organics including plastic derived residues. At the production rate of 300,000 tons per year, fluff production can be 15,000 tons per year. Nominal heating value for fluff can vary from 10,000 Btu/lb to as high as 20,000 Btu/lb. Assuming an average heating value of 15,000 Btu/lb, the fluff material has a potential heat value of 15000*2000*15000 = 450*10^9 or 450,000 mmBtu. It is clear that not all of this heat can be recovered and used effectively for the plant. The actual amount of heat that can be used depends on several factors such as the processing method, amount of energy required for the energy conversion process, and the form in which the heat is available for use in the plant. However, even at a conversion efficiency of 50%, the heat has an economic value of approximately $1 million per year when the final form energy can replace use of natural gas for the plant. Additional savings will be realized in cost of disposing of this material.

Tom Levad–NSSI has conducted research on the extrusion of fluff to produce a consistent size for handling purposes. It is believed that a combination of fluff extrusion methodology for consistent handling and one or more recovery technologies listed below would provide an economical alternative to fluff disposal.

1. Gasification of the material after it has been formed into a uniform shape such as pallets. The gasification process will have to be carried out very carefully since it is very likely that the material has a wide range of melting and vaporizing temperature.
2. Using fluff as an additive to other fuels used by industrial processes, such as coal used in cement kilns. Obviously the economic value of the material will be greatly reduced when used in this form.
3. Using the material as an additive to other "plastic" like materials during manufacturing of non-critical parts such as plastic wood. The chemical and physical properties and their uniformity when added to the mixture becomes an important issue
4. Using the material as filler for producing mixed products, such as roofing tar, road-paving material etc.

We have not investigated the research application of fluff extrusion and recovery. It is recommended that NSSI or other parties working with USDOE consider investigating one or more of these possible options under a separate project.

Replication Plan

The plan for replication of these findings and results is as follows:

- For internal distribution to North Star Steel: This report and all study data shall be copied electronically to the General Managers and Environmental Managers at North Star Steel's other mills in Beaumont, TX; Calvert City, KY; Monroe, MI; Duluth, MN; St. Paul, MN; and Delta, OH.
- For internal Parent company distribution (Cargill, Inc.): This report and study data shall be provided to the Cargill Environmental Health and Safety Department for distribution company wide through the Resource Efficiency program.
- For the steel mini-mill industry: This report shall be made available through the Steel Manufacturer's Association for member use.

Supporting Team Member Companies, Organizations and Point-of-Contact Information

- North Star Steel Company – Wilton Plant
  Division of Cargill Steel
  Highway 38 & Greens Road
  P.O Box 3002
  Wilton, IA 52778-3002
  563-732-4550
- MidAmerican Energy Company
  Richard Walker – RCWalker@midamerican.com
  Austin Henry – AKHenry@midamerican.com
- Iowa Energy Center – Administered by Iowa State University
  William Haman—Industrial Program Manager
  (515) 294-4710; whaman@energy.iastate.edu
- Iowa Manufacturing Extension Partnership – A program of Iowa State University Extension
  Willem Bakker – Director
  (515) 965-7125; wbakker@imep.org
  Ilene Deckert – Account Manager
  (319) 336-3317; IDeckert@imep.org
- Center for Industrial Research and Service (CIRAS) – A program of Iowa State University Extension
  Ron Cox – Director
  (515) 294-3420; rcox@ciras.iastate.edu
  Rudy Pruszko – Sr. Project Manager
  (563) 556-5110; rpruszko@ciras.iastate.edu
  Clay Crandall – Industrial Specialist
  (712) 366-7070; ccrandall@ciras.iastate.edu
- Diagnostic Solutions, LLC
  Dr. Don Casada – Consulting Engineer
  (865) 938-0965; mailto:doncasada@icx.net
- E3M, Inc.
  Arvind C. Thekdi – President
  (240) 715-4333; mailto:athekdi@e3minc.com
- Dr. John Stubbles – Steel Industry Consultant
  (513) 398-9926; mailto:john_stubbles@msn.com
- Energy Enterprises, Inc.
  David C. Engle – Technology Manager
  (630) 416-8921; mailto:dc_engle@yahoo.com

Other Supporting Participants

Steel Manufacturer's Association
Washington, DC