INNOVATIVE EQUIPMENT TO DECOAT SCRAP ALUMINUM

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ABSTRACT

An atmosphere-controlled indirect-fired kiln to remove the organics from scrap aluminum is described. Stein Atkinson Stordy (SAS) has implemented this design philosophy in a packaged system termed IDEX™*. The IDEX system removes organics with little or no use of auxiliary fuel, saving 1,000 Btu per pound of scrap. Further, the scrap is preheated by the IDEX to about 900°F, resulting in a 41 percent energy savings in the melting furnace. The total energy reduction from the kiln and furnace is 56 percent. The conventional system requires 4,000 Btu/lbm to process the scrap, whereas IDEX would eliminate the kiln fuel use and reduce furnace use to 1,770 Btu/lbm. Additionally, there are emission reductions inherent in IDEX that may allow secondary smelters to meet Clean Air Act regulations.

This project demonstrates a unique and successful teaming arrangement between state government and various private companies. The New York State Energy Research and Development Authority (NYSERDA) objectives for collaborative industrial demonstrations include:

- Obtain energy and economic benefits for New York State and the host industrial firm;
- Strive for environmental benefits whenever possible; and
- Support technical demonstrations that can be replicated elsewhere in the State.

To achieve these objectives, NYSERDA demonstration projects include the elements of risk sharing, technical assistance, networking, and technology transfer. The most common project development issues that are addressed and resolved in the formation of a research project are discussed.

COLLABORATIVE R&D

This project demonstrates a uniquely successful and rewarding teaming arrangement between state government and various private companies. As a case study of a NYSERDA industrial partnership, this project exemplifies the objectives defined, the strategies employed, and project development issues.

Objectives

Prior to funding a project, the NYSERDA project management team considers a number of objectives, with an emphasis on energy and economic benefits for New York State and the host industrial firms. had a number of objectives when it funded this project. It was anticipated that significant energy would be saved by using this technology, and that Roth Bros. should realize factor-input cost savings associated with energy, feedstocks, and labor (due to increased melter yield), with an additional savings in waste

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* IDEX™ is a registered trademark and is patented worldwide by SAS.

disposal costs. The State benefits because the project helps keep Roth Bros. competitive and growing in New York, additional jobs are created for local project suppliers and fabricators, such as O'Brien & Gere, and these suppliers are being positioned to compete for business associated with future sales of the IDEX, either in New York or elsewhere in North America.

Environmental benefits for the host were also a significant consideration. If the technology performs as expected, Roth Bros. will benefit from reduced dross and baghouse dust production, and a new means for expanding the aluminum recyclables market will have been demonstrated.

As elaborated in the section on advantages; energy, economic, and environmental benefits appear achievable and sizable.

Strategies

This project is typical in its use of four complementary strategies designed to achieve the stated benefits.

- Risk Sharing. By providing risk-sharing capital, the project reduces financial risks for Roth Bros. The economic analysis shows the near-term risk inherent in large, highly-technical projects. In the first year, the company can expect to lose 1.44 times the IDEX purchase cost, if all goes well. Unforeseen difficulties common with high-tech ventures could push the cost higher. However, NYSERDA absorbs some of that risk by funding the beginning portion of the project. Should the project not perform as anticipated, the host's liability is limited. As the project enters full production, a positive cash flow ensues and the high-risk capital from NYSERDA is no longer needed.
- Technical Assistance. NYSERDA provides objective, expert advice by supplying support for consultants as well as through NYSERDA's project review and management process.
- Networking. NYSERDA maintains a high level of interaction with industrial trade associations, individual companies, and utility representatives and is often able to identify productive working partnerships. Principals at Roth Bros. and Energy Research Co. were familiar with the NYSERDA industrial demonstration program, and our relationship with the local utility enabled it to enlist NYSERDA's support when it sought assistance for Roth Bros., an important customer. Through networking we can identify industrial leaders. In this project, we knew Roth Bros. is highly respected in the secondary aluminum industry. As an industry leader known for technical innovation, their participation attracts the attention of others in the industry, thereby addressing NYSERDA's fourth strategy of technology transfer.
- Technology Transfer. Through the careful selection of partners, the use of networks, and information dissemination, NYSERDA seeks to maximize technology transfer to potential users in New York State.

Project Development

Before these strategies can be implemented and objectives realized, an agreement must be in place. While an agreement is formalized in one or more contracts between members of the partnership, it represents both the beginning of a research project and the end of a project development process. This process is complex, and may not always result in a research project. Implementation issued include timing; organizational compatibility; business terms such as recoupment, liability, indemnification, rights to technical data, and confidentiality; and interpersonal compatibility among the key players that requires mutual respect and trust.

SECONDARY ALUMINUM INDUSTRY OVERVIEW

Secondary aluminum smelters process scrap aluminum in reverbatory furnaces and make ingots and sows that typically are sold to die casters. Ultimately, the scrap aluminum is cast into products for:(1) automotive and automotive related products (66 percent), small engines (8 percent), appliances (7 percent), and other (19 percent).

In 1990, total scrap aluminum consumption was 2.9 million tons,(2) about 63 percent of the total aluminum alloy production. There are 12 primary and 34 secondary aluminum processors. Secondary aluminum production, which currently accounts for just under half of the total scrap use, is likely to increase due to an increase in the aluminum used in automobiles. Currently 200 pounds of aluminum is used; by 2000, it is expected to increase to 500 pounds.(1)

Secondary aluminum production consists of the following steps. Most scrap is shredded to a small size and passed by a magnet to remove iron. The scrap then enters a decoating rotary kiln to remove cutting oils, plastic, paint, and other organics. This process minimizes melt loss in the furnace from unwanted metal oxidation and minimizes furnace emissions of smoke and fumes. Some high-priced scrap, clean and oil free, is charged directly into the furnace without pre-processing.

Furnaces and rotary decoating kilns are usually fossil-fired with gas or oil. Typical energy use is 3,000 Btu/lbm in the furnace and 1,000 Btu/lbm in the kiln.

PROBLEM STATEMENT

The decoating kiln is the weak link in the secondary aluminum processing, as it is unnecessarily energy-intensive and produces considerable emissions. Further, conventional decoaters do not recover the energy in the organics on the scrap, thus missing a valuable source of free fuel.

Emissions

Emission of dust, volatile organic compounds (VOC), and NO_X both through the stack as well as openings in the kiln and into the workplace is a serious problem, particularly in light of the Clean Air Act impact on secondary aluminum smelters. Dust arises as a result of the direct-fired nature of decoating kilns. Since the burner flames directly impinge on the scrap, its surface undergoes significant thermal shocking, which produces six to seven percent dust (defined as -20 mesh particles) that must be landfilled.

Because of the large amount of uncontrolled dilution air entering the kiln, it is unlikely an incineration temperature of 1500°F or higher is consistently achieved. Although oil and other organics may vaporize, a large percentage escapes as VOC in vapor form.

Dross Production

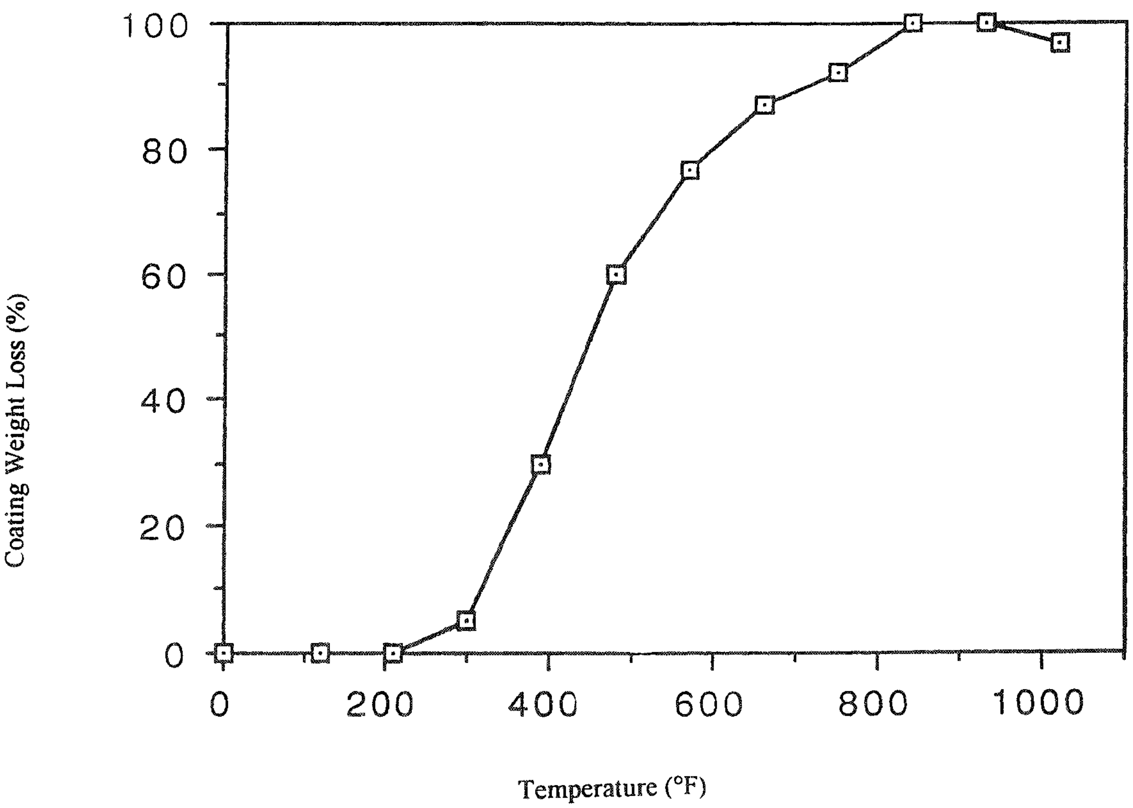
It is possible to overheat scrap in the kiln and, with the amount of oxygen present, an oxide coating is formed. Figure 1 shows this effect as a function of temperature in a limited-oxygen environment. Beyond 1000°F the weight of the metal increases, indicating oxidation has occurred. Since there are no automatic temperature controls in conventional kilns, and since there is considerable oxygen present, scrap oxidation beyond that given in Figure 1 is likely. Visual spot checking of the scrap at a typical secondary smelting plant indicates that scrap oxidation is frequent. After charging into the furnace, the oxidized scrap, along with the aluminum substrate, is removed as dross.

Alternatively, kilns can under-heat the scrap, resulting in inadequate decoating. This leads to oxidation in the furnace and subsequent dross increase. Secondary aluminum smelters produce about 8 percent dross in the furnace

Kiln Energy Use Unnecessarily High

The organics on the scrap entering the decoating kiln have a high heat content as shown in the following analysis of cutting oil:

Figure 1 - Measured Coating Weight Loss



CUTTING OIL ANALYSIS

Contaminants	As Received (%)
Total Moisture	0.10
Carbon	82.74
Hydrogen	11.33
Nitrogen	0.04
Sulfur	2.21
Ash	0.05
Oxygen (diff)	3.53
	100.00
Btu/lbm	18,774

A heating content of 18,774 Btu/lbm of oil was measured and is likely typical of the organics on most oily scrap. Unfortunately, existing decoating kilns cannot make use of this heat because they are designed to use natural-gas-fired burners to run the process. Energy is required to heat the scrap and drive off oil and water. Heat losses also occur through the kiln's walls and in heating the air. Natural gas measurements taken at typical smelters show kiln energy consumption of about 1,000 Btu/lb. Since most scraps contain about 5 percent or more oil or other organics, the need for gas firing could be reduced or eliminated.

SOLUTION

The problems with current decoating technology can be solved by using an indirect-fired controlled atmospheric kiln to decoat borings, turnings, and other scraps. In this design, the scrap is first decoated in a controlled atmosphere with limited oxygen to avoid scrap oil combustion or scrap oxidation. The ensuing volatized organic gases are combusted in an incinerator, apart from the scrap, to destroy the VOC. The heat release from organics combustion drives the decoating process.

The IDEX™ system, shown in Figure 2, consists of three major components:

- Rotating kilns to process scrap;
- Incinerator to destroy organics; and
- Control system and associated hardware.

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 a few minutes.

At 1500°F, gases enter the center tube, flow parallel to the scrap, then reverse direction (flowing counter current) after exiting the center tube. The center tube indirectly heats the scrap and the counterflowing gases to avoid downstream condensation. Organics are vaporized in the kiln.

The kiln removes the coatings from the scrap, without oxidizing the metal, by fixing the oxygen content to aid in decoating but not high enough to combust the organics. Kiln atmosphere and pressure are controlled to prevent organics combustion. The high-temperature gas entering the kiln has 5 percent to 6 percent O_2; air leakage raises this to 8 or 9 percent O_2. A minimum of 4 percent is needed to oxidize any carbon coating on the scrap and a maximum of 10 percent to avoid scrap flaming and fire risk.(3,4) At about 10 percent O_2 content, a blue flame on the scrap is noticed; at 12 percent O_2 the scrap is enveloped in a yellow flame, which is to be avoided as it leads to excessive scrap oxidation.

The decoating process takes place in two stages.(3,5) In the first stage, 300°F to 750°F, the water, oil, and other volatiles are vaporized. In the second stage, 900°F to 1000°F, the non-volatile carbon residue on the

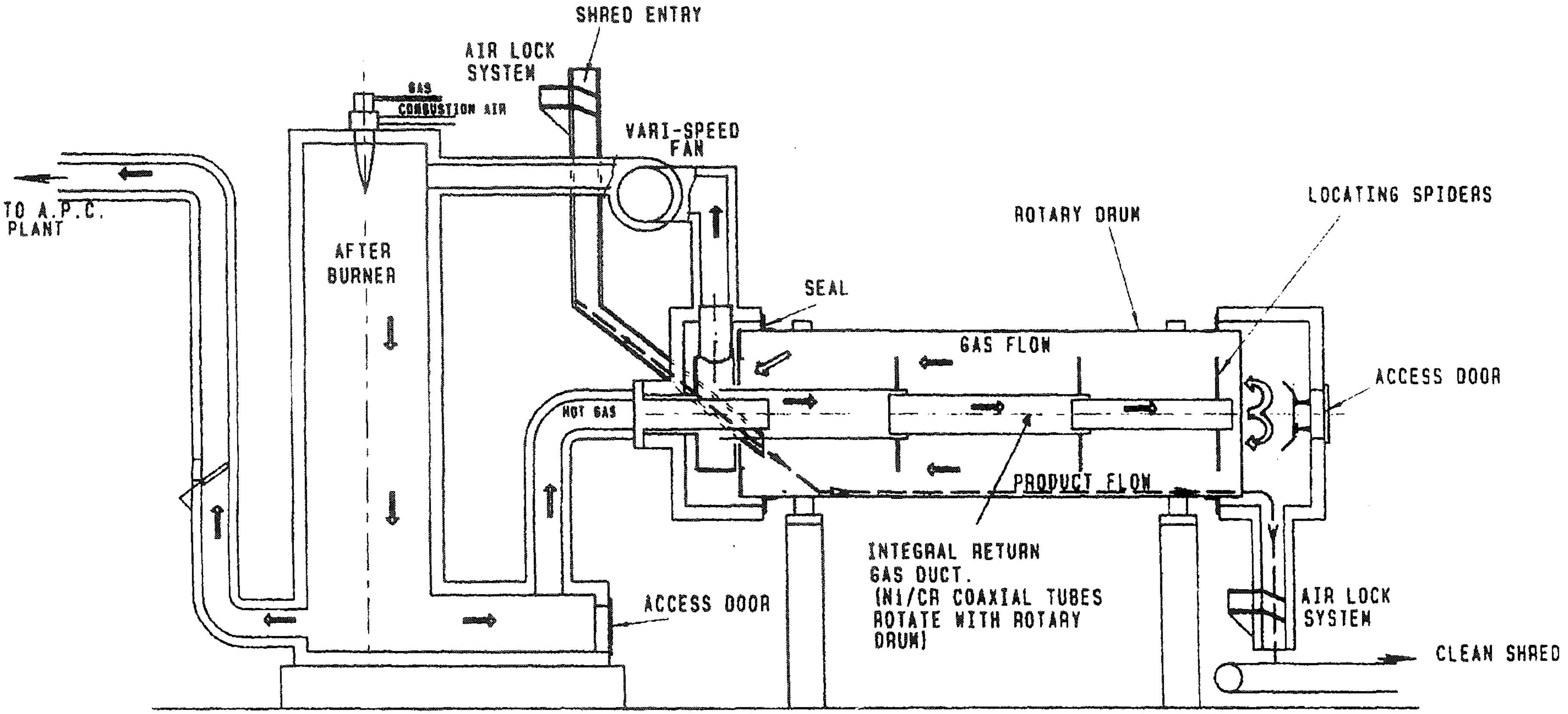


Figure 2

①
'IDEX' DECOATER/DRYER
RATED AT 0.5 TO 5 TON/HR
(THROUGHPUT DEPENDS ON MATERIAL SPECIFATION)

THIS DRAWING DOES NOT FORM PART OF ANY CONTRACT AND IS INTENDED AS A GUIDE ONLY. DIMENSIONS GIVEN ARE APPROXIMATE AND DETAILS SHOWN ARE NOT BINDING.

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scrap is removed by oxidation - oxygen combines with the carbon to produce CO_2 and CO. Hence, the need for a minimum 4 percent O_2 in the kiln.

The gases from the kiln are passed to an incinerator with an oil or natural-gas burner. The burner elevates the temperature to 1500°F and additional air flows in. Organic vapors combust in this environment, releasing heat and destroying the VOC. Part of the gases are vented and part are recirculated back to the kiln by a recirculation fan. During steady-state operation, the heat is carried away in the incinerator exit gas; a small portion is lost through the walls. Heat for the kiln is provided by the portion of incinerator gas that is not bypassed and, to a lesser degree, by carbon oxidation in the kiln. Since the scrap is indirectly heated, dust formation from direct flame impingement does not occur.

LABORATORY TEST RESULTS

Tests were conducted at SAS's laboratory to confirm the analytical predictions of IDEX performance. Figure 3 shows the laboratory IDEX used for the testing. The laboratory-scale IDEX is 18 feet 4 inches long, with a kiln diameter of 3 feet 7 inches. The full-scale IDEX is 35 feet long with a diameter of 7.5 feet. The laboratory-scale IDEX is at one-quarter scale, based on cross-sectional area.

Scrap used during the tests consisted of automobile engines shredded to 1 inch to 4 inches. The scrap was spiked with insulated wire and cable, foam, and plastics to a contaminate level of about 2 to 5 percent by weight.

Measurements were taken of kiln temperatures, afterburner temperature, O2 at the kiln exit, drum rotation, scrap charge weight, NOx, SOx, HCl, O2, CO, VOC, and particulates.

Table 1 lists recorded data taken during the test. The oxygen content is shown to be between 12 and 14 percent, at times it was observed to be at 15 percent (not recorded) whereas the design values are 9 to 12 percent. The higher oxygen content would lead to improved processing and possibly scrap oxidation as well, although no oxidation was observed.

Emissions were fairly low throughout the test. A comparison to the measurements and emission claims previously made by SAS is shown in Table 1. The measured NOx was lower then that claimed by SAS, and the CO and VOC met New York State environmental regulations. The particulates and HCl were higher than originally indicated by SAS. The particulate measurements were made upstream of the baghouse, and it is expected that the baghouse would adequately remove them. This is confirmed, as there were no visible emissions from the stack indicating the particulate loading past the baghouse was low.

The HCl was high due to the wire and cable insulation. HCl removal by the afterburner used in this test would not be expected, though HCl can be removed by lime scrubbing systems.

Kiln and afterburner temperatures are shown in Figure 4. The afterburner temperature stayed fairly constant at just over 1500°F. Kiln outlet temperature exhibited a slight decline, starting at 1,015°F and ending up at 988°F. Similarly, the inlet temperature started at 806°F and declined to 759°F. The outlet temperature was lower and the inlet temperature higher than the design values for the full-scale IDEX.

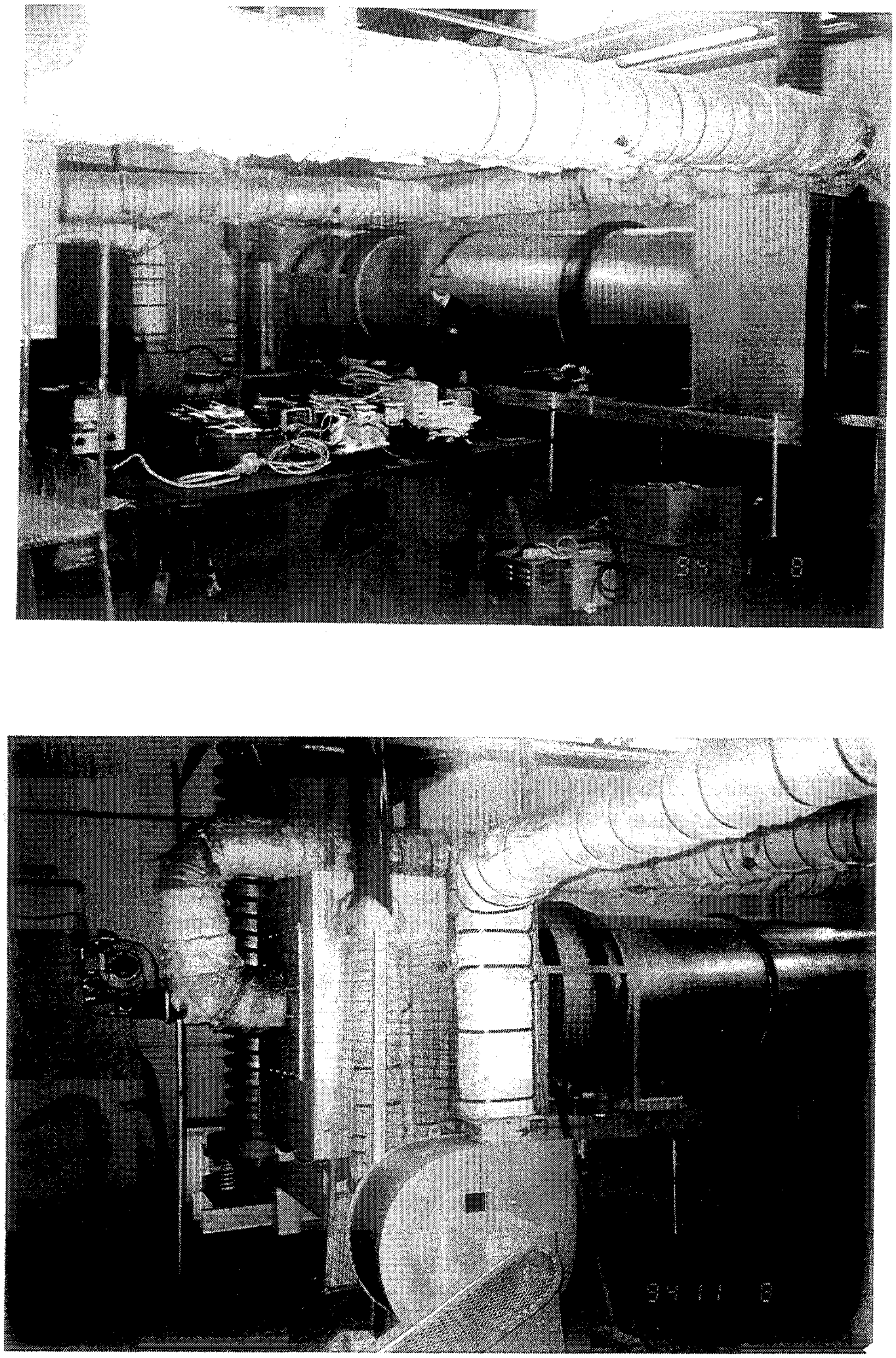


Figure 3 - Laboratory IDEX

Figure 4 - IDEX Tempeatures

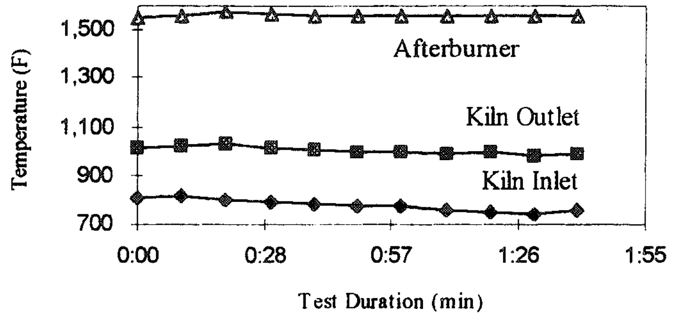


Table 1 - Data From Laboratory Testing

Time	Duration	Temp Kiln Inlet (C)	Temp Kiln Inlet (F)	Temp Kiln Outlet (C)	Temp Kiln Outlet (F)	Temp After Burner (C)	Temp After Burner (F)	Drum RPM	Scrap Weight (kg)	Cumulative Weight (kg)	Scrap Mass Flow (pph)	% O2 Kiln outlet
2:45	0	430	806	546	1,015	843	1,550	2.5		0		14.0
2:55	0:10	433	812	550	1,022	850	1,562	2.5	1	1	13	12.0
3:05	0:20	426	799	555	1,031	855	1,571	3.0	5	6	66	12.2
3:15	0:30	422	792	544	1,011	851	1,564	3.5	29	35	383	14.0
3:25	0:40	417	783	539	1,002	847	1,557	3.5	47	82	621	13.5
3:35	0:50	413	776	536	997	848	1,559	3.5	42	124	555	13.0
3:45	1:00	410	770	536	997	849	1,560	3.5	42	166	555	13.5
3:55	1:10	403	758	533	992	848	1,559	3.5	46	212	608	13.0
4:05	1:20	400	752	535	995	850	1,562	3.5	41	253	542	13.5
4:15	1:30	395	743	527	981	848	1,559	3.5	55	308	727	13.4
4:25	1:40	404	759	531	988	848	1,559	3.5	53	361	700	13.8
4:35	1:50											

Emissions as measured by an Independent Laboratory

	mg/m^3	gm/hr	lb/hr	SAS Claim After Neutralization and the Baghouse lb/hr
Particulate	450	155.3	0.3420	0.19
NO2	76	26.2	0.0578	0.66
SO2	21	7.2	0.0160	-
CO	4	1.4	0.0030	0
VOC	1	0.3	0.0008	0
HCl	352	121.4	0.2675	0.025

The scrap flowrate ramped up for about the first 35 minutes, then was somewhat erratic, ranging from 550 pph to 727 pph. Scrap residence time during the test runs was 23 minutes, slightly longer than the design value of 10 to 20 minutes in the full-scale IDEX.

Visual observations of the scrap showed that all of the organics; including wire and cable insulation, and loose foam and plastic; were completely removed with no metal oxidation apparent.

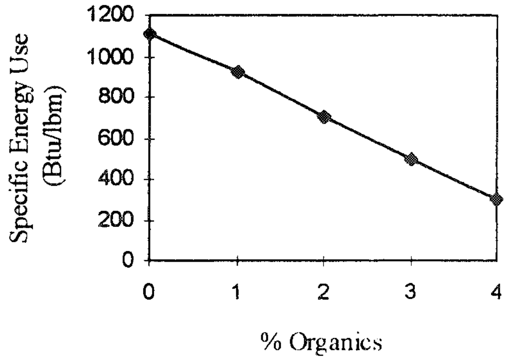
ADVANTAGES

Significant advantages of this equipment compared to conventional equipment include: energy reduction, emissions reduction, production increase, and baghouse dust reduction.

Energy Reduction

Figure 5 shows measured energy use of the kiln as the organics content is varied. As the organics level rises, the fuel required decreases. At about 7 percent organics, the process is auto-thermic: no fuel is needed.

Figure 5 - Measured Energy Usage



Further, the scrap exiting the kiln is preheated to about 900°F. If the scrap is fed directly into the furnace, the energy savings would be:

$$\frac{C_p(T_p-T_o)}{C_p(T_s-T_o)+hv}$$

where

C_p = specific heat of scrap (.22 Btu/lbm°F)
T_p = scrap preheat temperature
T_o = ambient temperature (70°F)
T_s = scrap processing temperature (1400°F)
hv = heat of fusion (157 Btu/lbm)

There are two components to the total energy savings. One component is the preheated scrap, at a temperature of 900°F. This scrap is fed into the furnace, resulting in a 41 percent energy savings for a furnace specific fuel use of 1,770 Btu/lbm, compared to the current 3,000 Btu/lb. The second component is the use of scrap organics to drive the IDEX process, eliminating the need for fuel to decoat the scrap. The combined energy savings from both components could be as high as 2,230 Btu/lbm for a total reduction of 56 percent.

Emissions

The Clean Air Act effect on the secondary aluminum industry is being debated and will be settled in about four years. A survey will be undertaken on 12 percent of the secondary aluminum smelters and the best available control technologies will be mandated. It is not likely that current delacquering equipment will meet the new standards although the proposed unit might. A major goal of this program is to test emission characteristics, both before and after the new installation, to determine improvements.

Emission measurements of the laboratory-scale IDEX are shown in Table 1. NO_2, SO_2, CO, and VOC are quite low. Reductions in CO_2 emissions would be expected in direct proportion to the reduction in firing rate.

Production Increase

Smelters typically lose about 8 percent of their furnace melt as dross. Some of this loss is attributable to the poor decoating process, though how much is speculative. Assuming 1 percent of the 8 percent could be prevented, the savings for a smelter with an annual production of 100 million pounds would be:

$$(0.01)(100 \text{ million lbm/year})(\$0.60)/\text{lbm} = \$600{,}000$$

Further, dust creation in the current kilns of 6 to 7 percent could be avoided with the proposed technology. This is production valued at $0.60 per pound, for a total production gross revenue increase of $3.1 million (700 pph of dust). Additionally, landfilling costs would be avoided for an additional $260,000 savings.

Scrap Purchases

The smelters may be able to process lower grade scrap not currently possible. For example, aluminum foil (such as candy wrappers) undergoes significant oxidation in conventional kilns since the foil is so thin. The IDEX demonstration at SAS showed that foil could be readily decoated with no oxidation.

ECONOMIC ANALYSIS

A version of life-cycle-costing termed cost-of-ownership(6) is being used to evaluate the economics of IDEX installation. In this model, the total costs of owning and operating a piece of equipment are identified in a pyramidal fashion with the most easily identified costs at the apex and the costs most difficult to quantify at the base. For example, the purchase price would be at the apex and the cost of equipment obsolescence would be part of the base. Costs with varying degrees of certainty would be located at different elevations in the pyramid. The placement of costs in the pyramid is up to the individual, and depends on the information available and the experience the company has with the type of equipment under consideration.

The cost-of-ownership analysis was modified by including the time-value of money via net present value (NPV) calculations in 1995 dollars. Costs have been normalized by the IDEX purchase price to allow further comparisons and protect confidential information.

Tables 2 through 4 show IDEX costs and, for comparison, those of an existing dryer at a typical secondary smelter facility. The assumptions used are given in Table 2. Escalation factors are not used since the future value of aluminum, the biggest driver in the analysis, is entirely speculative.

Individual costs and the year incurred are given in Table 3. Back-up spreadsheets (not shown) are linked to the items in this box. The largest cost is IDEX installation, which is 2.4 times higher than the purchase price. This cost is, of course, site specific. In this case, the cost of a new building to house the IDEX was affected by the need for pilings, as indicated by soil samples. Labor costs are low, only 0.29 of the purchase price. Since labor costs are incurred each year, their cumulative affect over 10 years, using an 8 percent discount rate, is 1.95, which exceeds the purchase price, though not the installation cost.

The advantage of IDEX is the materials value of the recovered fines and dross, being 11.53 and 4.58 respectively over 10 years. Each is larger than the installed cost.

Existing dryer costs also are shown. The biggest liability probably will be the need to install pollution control equipment once the Clean Air Act regulations are enacted. However, this is a lower pyramid cost and is unknown.

Table 2 - Assumptions Used in the Normalized Cost-of-Ownership Analysis

Natural Gas Cost	$	2.5	per MMBtu
Electricity Cost	$	0.07	per kWhr
Discount Rate		8%	
Scrap Value	$	0.60	per pound
IDEX Throughput		10,000	pph
Existing Dryer Throughput		10,000	pph
Use of IDEX		100%	
Use of Existing Dryer		100%	
Burdened Labor Rate	$	15	per hour
Total Fines Loss		6%	
Fines Recovery in IDEX		3%	
Total Dross Loss		8%	
Dross Recovery due to IDEX		1%	

Table 3 - Costs

ITEM	YEAR COST IS INCURRE	IDEX	IDEX 10 YEAR NPV* COST	EXISTING DRYER
IDEX Purchase Price	1995	(1.00)	(1.00)	-
Installed Cost	1995	(2.41)	(2.41)	-
Maintenance	All Years			
Labor Cost				-
Parts Cost				-
Operation	All Years			
Labor Costs		(0.29)	(1.92)	(0.29)
Electricity		(0.08)	(0.54)	(0.08)
Natural Gas		(0.06)	(0.40)	(0.24)
Training Costs	1995	(0.01)	(0.01)	-
Technical Cost Factors	1997			
Air Emission Costs				Unknown
Material Waste Recovery	All Years			
Fines		1.72	11.53	-
Dross		0.68	4.58	-

Table 4 - NPV* Costs

CUMULATIVE COSTS (1995 Dollars)	IDEX	DRYER	COST ADVANTAGE OF IDEX**
Year 1 NPV	(1.44)	(0.61)	(0.84)
Year 2 NPV	0.25	(1.12)	1.37
Year 3 NPV	1.81	(1.61)	3.42
Year 4 NPV	3.26	(2.05)	5.32
Year 5 NPV	4.61	(2.46)	7.07
Year 6 NPV	5.85	(2.84)	8.70
Year 7 NPV	7.00	(3.20)	10.20
Year 8 NPV	8.07	(3.53)	11.59
Year 9 NPV	9.06	(3.83)	12.88
Year 10 NPV	9.97	(4.11)	14.08

* NPV = Net Present Value

** IDEX benefit plus dryer cost avoidance

Table 4 shows cumulative costs of the IDEX and the existing dryer. After 10 years, the IDEX shows a positive value of almost 10 times its cost; continued use of the existing dryer costs four times that of the IDEX. Over 10 years, the advantage of purchasing the IDEX is a factor of 14. The cost of emission-control equipment that will be needed on the existing dryer, and will increase the economic advantage by an additional multiple.

The payback can be determined by examining the cost difference of the two alternatives. Payback occurs in less than two years (1.37 benefit at year two).

PARTICIPANTS

The following are participants in this on-going program:

- New York State Energy Research and Development Authority (NYSERDA), Albany, NY. A major program sponsor interested in funding technology development for New York State-based industries.
- Energy Research Co., Annandale, NJ. Responsible for program management, engineering review, equipment evaluation, and testing.
- Roth Bros. Smelting, East Syracuse, NY. A program sponsor and host site for IDEX installation and testing. Roth Bros. is a secondary aluminum smelter.
- O'Brien and Gere, Syracuse, NY. Responsible for fabricating and installing IDEX at Roth Bros.
- Stein Atkinson Stordy, England. Responsible for providing the IDEX design and overall fabrication and construction management.
- Gillespie+Powers, Inc., St. Louis, MO. Responsible for commercializing IDEX in the U.S.

CONCLUSIONS

IDEX offers a substantial improvement over existing dryers for the secondary aluminum industry and should result in substantial cost savings, production improvements, and emission abatement.

During lab testing, IDEX decoated difficult solid organics. There was no visible evidence of processed scrap oxidation. However, the laboratory-scale IDEX was operated at a lower throughput, with higher oxygen content, and longer residence time than the full-scale unit, which could result in optimistic performance comparisons. Nonetheless, the laboratory-scale IDEX is an excellent representation of the potential of the full-scale IDEX.

The cost analysis shows less than a two year payback and a 10-year NPV value to the owner of 14 times the original purchase price.

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