

**GEORGIA TECH RESEARCH INSTITUTE
ENVIRONMENTAL SCIENCE AND TECHNOLOGY LABORATORY
POLLUTION PREVENTION PROJECT**

Company: Southwire Company
Copper Division
P.O. Box 1000
Carrollton, GA 30119

Contact: Mr. Greg McKibben
Environmental Engineer

Primary Products: Copper Rod

Wastes Generated

Solid Waste

Second-Hand Cardboard

Pallets

Fugitive emissions from low grade lay-down yard

Fugitive emissions of lead in smelter building

The scope of this project includes the following four areas identified by Southwire Copper Division personnel as pollution prevention opportunities:

1. Reduction of the volume of solid waste generated and disposed of in the county landfill. Wood pallets and cardboard boxes makeup a large percentage of Southwire's solid waste stream.
2. Reduction of fugitive dust emissions for the low grade lay-down yard.
3. Reduction of fugitive emissions from furnaces by finding a substitute process to replace the anhydrous ammonia currently used for removing oxygen.
4. Reduce the volumes of gases generated by furnaces by the use of an electric plasma gun (plasma torch) in furnaces. The use of the plasma torch for treatment of furnace dust will also be investigated.

Process Description

Southwire Company is one of the largest producers of copper rod for the development of copper wire. Southwire acquires large amounts of scrap copper from over 100 suppliers around the U.S.. The scrap is received in second-hand boxes, segregated, and stored for input into the process. A large lay-down yard is used to store loose large piles (approx 30

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ft high) of low-grade scrap metal. Southwire converts the impure scrap copper into an interim product called the electrolytic copper anode. This anode is transferred and purified into an electrolytic copper cathode via electro-deposition in an acid bath. The copper cathode then undergoes four processes (melting, casting, rolling, pickling and coiling) to convert the raw copper into a copper wire rod. The copper rod is then converted into copper wire at a separate Southwire facility.

Efforts to Reduce Wastes

Southwire has made considerable progress over the last several years to reduce wastes and clean up the facility. The waste reduction areas considered in this analysis represent a team effort where personnel from all sectors of the plant provided input to generate the final list. This type of input from the working levels is the key to successful implementation of a pollution prevention program.

Recommendations

A detailed assessment of each of the four pollution prevention opportunities was conducted and the results are presented in Appendices 1 through 4. The analyses did not generate any single recommendation that should be immediately implemented, but resulted in a series of options that should be further investigated by Southwire. With the exception of finding a process to replace anhydrous ammonia for removal of oxygen, one of the options identified in the appendices could possibly be implemented in the foreseeable future. It is recognized that a replacement for ammonia will take some additional research on some of the topics identified in the literature search included in Appendix 3.

Attachments

Appendix 1 - SOLID WASTE

Appendix 2 - FUGITIVE DUST EMISSION REDUCTIONS

Appendix 3 - AMMONIA REPLACEMENT LITERATURE SEARCH

Appendix 4 - ASSESSMENT OF PLASMA TORCH FOR PROCESSING COPPER

**APPENDIX 1
SOLID WASTE**

A large percentage of Southwire's solid waste is second-hand cardboard, used to contain low-grade scrap copper components. The next largest solid waste source is used pallets.

Cardboard

Uncontaminated corrugated cardboard can be recycled. Southwire's cardboard contains considerable contaminants which can be power-sprayed clean. Cleaned cardboard can then be dried and stored until enough can be collected to be economically feasible to be shipped to a recycle firm. Money earned from recycling corrugated can easily pay for shipping costs, while the cost of landfilling can also be saved. Recycle firms that accept corrugated cardboard and are in the Carrollton area are provided in the appendix.

Wax-coated cardboard currently cannot be recycled. The only alternative to landfilling is incineration/cogeneration. However, Southwire does not generate enough wax-coated cardboard for this to be feasible.

Used Pallets

Southwire generates pallet waste which formerly contained boxes of low-grade copper components. There are several landfill alternatives for used pallets. Further information is provided.

Rebuild and Reuse - Pallets can be rebuilt and reused for outgoing shipments. Some companies save scrap pallets during fall, winter, and spring, then hire a dedicated summer student to rebuild all pallets for reused throughout the year. Unusable wood from pallets can be denailed and stored for employees' winter fireplace use.

Grind and Sale - Non-usable pallets can be ground into a course material. All metal material should then be magnetically removed. The ground pallets can then be sold as a bedding to cattle and poultry farmers. The Gold Kist Poultry plant in Carrollton is a suggested first contact.

Selective Sale - Pallets which are 48 X 40 4-way can be sold to several companies from \$1.50 - \$3.75 per pallet, depending on the condition. Several companies occasionally purchase different size pallets as well. Pallet companies that purchase pallets are provided in the appendix.

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Bibliography

"Properties of Shredded Wood Pallets", Forest Products Journal, June 1989, pp. 50-54.

"Wooden Pallets: Disposal, Design and Distribution", Material Handling Engineering, October, 1990, pp. 71-75.

Recycling centers which are in the same proximity as Southwire and accept corrugated cardboard:

Austell
Austell Box Board Corp.
3100 Washington Street
Austell, GA 30001
(404) 948-3100

Cartersville
Self Recycling Inc.
168 Cassville Road
Cartersville, GA 30120
(404) 382-2320

Albany
Consolidated Recycling
1178 East Board Avenue
Albany, GA 31705

Dalton
Berry Environmental Technologies
P.O. Box 982
700 North Hamilton Street
Dalton, GA 30722-0982
(404) 278-7677

Atlanta
Goler & Sons
594 Decatur Street
Atlanta, GA 30312
(404) 525-3183

Peachtree City
National Fiber Supply Co.
14 Eastbrook Bend
Peachtree City, GA 30269
(404) 487-2408

Mindis Recycling
1905 Lower Roswell Road NE
Marietta, GA
(404) 973-2312

Southeast Recycling Corporation
565 Western Avenue - Rear
Atlanta, GA 30314
(404) 524-4324

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Companies which purchase 48 X 40 4-way pallets. The price listed is the amount paid per pallet

Douglasville
Hill Top Pallet Inc
5556 Yeager Road
Douglasville, GA
(404) 949-0247
Price: \$1.50

Atlanta
John Jones Pallet Company
705 Constitution Rd SE
Atlanta, GA
(404) 622-6304
Price: \$2.50

Hapeville
Young C. Bowlden, Jr.
983 North Central Ave
Hapeville, GA
(404) 768-2347
Price: \$1.50 - \$3.75

Loganville
C & D Pallet Inc.
Highway 78
Loganville, GA
(404) 466-4589
Price: \$1.50

**APPENDIX 2
FUGITIVE DUST EMISSION REDUCTIONS**

Several alternatives can reduce the fugitive dust emissions from Southwire's low-grade lay-down yard:

Dry Fog - Water can be sprayed using a proprietary device which emits a fog of very fine water droplets. When applied, fugitive dust particles become agglomerated and settle onto the pile. This type of spray system will not actually wet the area since the spray is in essence a fog which will settle on the area of concern. The frequency and amount of application will depend on the climate and amount of fugitive emissions. See the appendix for information concerning vendors.

Contact: Sonic Development Corporation

Foam or Chemical Application - Another alternative is foam or a solution of chemicals and water which is applied to a pile using a spray device. In most cases these types of materials can provide the same suppression as water suppression but with much less application frequency. This combination reduces manpower costs, water usage, and accumulated mud. See the appendix for information concerning vendors of foam and chemical additives.

Contact: DeTer Company, Inc., Johnson March Systems, Inc.

Note: These types of chemical and foam additives should be evaluated before implementation. The components may interfere with Southwire's process and may also be a source of fugitive and stack toxic emissions. Non-toxic additives are the preferred application.

Physical Barrier - A physical barrier could be constructed to provide protection from wind. The barrier must be strategically placed to block the prevalent wind, but not obstruct transient traffic. An example is a fence approximately 3/4 the height of the lay-down pile with a porous cover, much like that used around tennis courts. If situated close enough to the pile, this type of protection can block much of the approaching wind thus substantially reduce fugitive emissions. According to a representative of Johnson March Systems, Inc., a protective barrier, if correct for the circumstance, can provide as good, if not better, dust suppression as water-based systems. This type of approach can also save substantial future material costs.

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Bibliography

“Dust Suppression System Doesn’t Wet Coal”, Power, March 1989, p.104.

“Enclosure, Wet Suppression Will Help Control Dust”, Pit & Quarry, January 1988, pp. 72-74.

“Keeping Down the Dust”, Pit & Quarry, November 1988, pp. 27-29.

Vendor Information

Sonic Development Corp
Parsippany, NJ
(201)882-9288

Johnson March Systems, Inc.
220 Railroad Drive
Ivyland, PA 18974
(215) 364-5425

DeTer Company, Inc.
Burgin, Kentucky 40310
(606) 748-5262

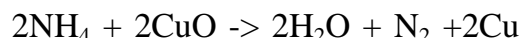
**APPENDIX 3
ASSESSMENT OF METHODS OF OXYGEN REMOVAL
FROM MOLTEN COPPER**

Pollution Prevention Objective

Research of the methods for the removing oxygen from molten copper to replace the ammonia currently used for oxygen removal and a major source of emissions.

Current System

The current system of oxygen removal from molten copper utilizes ammonia to react with the oxygen in the copper and remove the oxygen as a gas. The complete reaction of ammonia and oxygen assuming the oxygen is in the form of copper oxide is as follows:



Since the copper oxide is a solid, one volume of ammonia gas is producing three volumes of gases consisting of 2 volumes of water vapor and one volume of nitrogen dioxide. The large volume of gases emitted from the reaction tends to carry particulates in the form of metals which increases emissions from the process.

The current process has three major drawbacks:

1. the process generates large quantities of gas which carry heavy metals such as lead and chromium into the environment,
2. ammonia is a reportable chemical on the toxic release inventory although the quantities actually released are minimal, and
3. ammonia is an extremely hazardous substance (EHS) which requires additional reporting requirements under SARA Title III and consideration of exposure limits for worker health and safety under OSHA requirements.

Method of Assessment

The process of removal of oxygen from copper of any molten metal is a complicated process and is not easily analyzed. Many of the current techniques were established years ago, and there is reluctance to modify these methods since the quality of the product produced meets production standards. Any change in the process should be carefully evaluated before implementation since changes in quality could be disastrous. A systematic process of

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literature research, laboratory evaluation, bench scale evaluation, and pilot scale evaluation should first be conducted. The first step in this evaluation is to review the research currently being conducted on the technology of the removal of oxygen from molten metal and, specifically, molten copper.

The Library of the Georgia Institute of Technology was utilized for a computerized literature search of processes for the problem. This literature review is essential in determining which technologies have been investigated and are currently being studied to prevent investigating a technology that has proven to be ineffective or those that have the potential to solve a problem but need additional research.

After discussions with representatives from several of the database sources, the Library identified the "key words" that should be used in the search of the databases. Key words have different uses in different data bases. Many data bases use key words in a "wild card" format which means that if the "key word" appears any place in the citation including the title and abstract even the authors name or publisher) a citation will appear in the database search. As a result, the search will be complete but many citations will not appear to be relevant to the topic.

A search was conducted of several data bases using copper wire(s), copper wiremaking, copper rod(s), or copper (base) alloys for the copper and the stem words *deoxidiz* and *deoxygenat* for the oxygen removal process. The following data bases were accessed as a part of the search process:

METADEX	-	A metals and metallurgy database
COMPENDEX	-	A general engineering database
CASEARCH	-	Chemical Abstracts Search
ASTI	-	Applied Science & Technology Index
ENGI	-	Engineering Index Monthly/Compendex Plus
INSP	-	A index of engineering journal articles
TRND	-	Trade and Industry Index

The search identified a total of 223 citations using the key words and stem words previously discussed. The output from the search has been reviewed and 14 citations appear to have data or information related to the problem. The following is a summary of the citations found in each of the databases.

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<u>Database</u>	<u>Total Citations</u>	<u>Applicable Citations</u>
METADEx	40	3
COMPENDEX	13	1
CASEARCH	52	5
ASTI	1	0
ENGI	72	5
INSP	24	0
TRND	21	0
Totals	223	14

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The complete computer output has been provided to the Southwire Copper Division under a separate cover. The following is a review of the 15 citations applicable to the problem:

METADEX - Bydalek¹ reported laboratory studies using carbide as a refining agent: The study reported good deoxidizing and desulfuring of the castings. The citation indicates the paper is written in Polish, but translations can usually be obtained. Pimenov and Gofenshefer² conducted laboratory studies to generate a mathematical model for the melting process. Their research indicated that finer fraction and larger flux layer contribute to a significant decrease in the amount of the dissolved oxygen in the melt. A translation of this paper was found in the ENGI database. The final citation in this database was an article³ that discussed the use of boron for deoxidation.

COMPENDEX - The only applicable citation identified in the database was a paper by Dompas and Lockyer⁴ which describes the development of a probe for monitoring of the oxygen content of molten copper. Since this paper is almost 20 years old, it is likely that newer technology is available.

CASESEARCH - Arakida and Kiyomiya⁵ have a British patent for a production process for low-oxygen copper wire. The data in the citation is limited but it appears that the process involves specific controls of the reducing gas atmosphere to control the oxygen content of the product. Another paper by Bydalek⁶ appears to discuss some of the same work as reference 1. Unfortunately, the second paper is also in a foreign language. However, it may be worthwhile to contact the author since this appears to be an area of interest. It appears that Mr. Bydalek can be reached through the Polish Academy of Sciences, 00-901 Warsaw, P. O. 24, Palace of Culture and Science, Poland. Nanda and Geiger⁷ investigated the kinetics of oxygen removal by carbon monoxide. A patent by Froulard and Galey⁸ describes processes for removal of oxygen using hydrogen and nitrogen, and a second patent by Associated Electrical Industries' uses hydrogen for the same process.

ENGI - Nagai *et al.*¹⁰ describe a vacuum system for removal of oxygen from molten copper. The citation indicates that a system has been installed in a fully continuous casting plant. An English translation of Pimenov and Gofenshefer¹¹ (Reference Number 2) was found in this database. Sudavtsova *et al.*¹² studied the effect of lithium, boron, magnesium, and yttrium on the activity of liquid copper and concluded that the elements could be used for deoxidation. Correlations were drawn between the deoxidizing features of the elements. Selenium as a deoxidizing agent was investigated by Seetharaman and Staffansson,¹³ and phosphorous was studied by Razavi-Zadeh and Miramadi.¹⁴

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Summary

The research in the United States in methods of removing oxygen from copper seems to ten to twenty years old. However, research in other countries is much more current, probably driven by environmental problems. Several of these technologies might have potential for the elimination of the use of ammonia.

References

1. Bydalek, A, "Interaction of Active Calcium Compounds with Copper and Its Alloys in Liquid Form," *10th Reporting Meeting of the Polish Academy of the Sciences, Division IV Metallurgy Committee, 1981-1984, Papers, Volume II*, Kozubnik, Poland, (1984).
2. Pimenov, A. M. and Gofenshefer, L. I., "Deoxidizing Capacity of Carbon-Containing Covering Fluxes During Copper Melting," *Liteinoe Proizvod (3)*, (1989)
3. "A Specially Processed Boron Deoxidized Copper Developed for Electrical Conductors," *Wire Wire Prod Vol 42 No. 6*, p 982 (1967)
4. Dompas, J. M. and Lockyer, P. C., "Oxygen Control in Liquid Copper by the Oxycel," *Metallurgical Technologies Vol 3 No. 10*, pp. 2594-2604, (1972)
5. Arakida, Y and Kiyomiya, S., "Manufacturing a Low-Oxygen Copper Wire," *United Kingdom Patent No. GB 2041411*.
6. Bydalek, A, "Studies on Copper and Copper Alloy Refining Using Calcium Carbide," *Neue Huette, Vol. 22, No. 12*, pp. 663-665, (1977).
7. Nanda, C.R. and Geiger, G. H., "Kinetics of Deoxidification of Copper and Copper Alloys by Carbon Monoxide," *Metallurgy Transactions Vol 2 No. 4*, pp. 1101-1106, (1971).
8. Froulard, J. and Galey, J., "Deoxidization and Degasification of Copper and Its Alloys," *French Patent No. 1552137*.
9. Associated Electrical Industries, "Deoxidizing of Copper and Its Alloys," *Netherlands Patent No. 6607251*.

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10. Nagai, Y., *et al.*, "Mass Spectrometric Observation of Vacuum Treated Oxygen Free Copper," *Proceedings of the 11th International Vacuum Conference and 7th International Conference on Solid Surfaces*, Cologne, Germany, (1990).
11. Pimenov, A. M. and Gofenshefer, L. I., "Deoxidizing Capacity of Carbon-Containing Covering Fluxes During Copper Melting," *Soviet Castings Technology No. 3*, (1989)
12. Sudavtsova, V. S., *et al.*, "Effect of Lithium, Boron, Magnesium, and Yttrium on the Activity of Liquid Copper," *Melts Vol.1 No.2*, pp. 111-114, (1988).
13. Seetharaman, S. and Staffansson, L., "Effect of Selenium on the Activity of Oxygen in Dilute Liquid Copper Alloys," *Scandinavian Journal of Metallurgy Vol 17 No. 3*, pp. 127-130, (1988).
14. Razavi-Zadeh, H. and Miramadi, T. S., "Deoxidizing Copper with CaB," *Journal of Metallurgy Vol. 39 No. 2*, pp. 42-47, (1987)

**APPENDIX 4
ASSESSMENT OF PLASMA TORCH FOR PROCESSING COPPER**

Pollution Prevention Objective

Research and evaluate methods to reduce gas volumes generated in the processing of copper and increase the efficiency of the current control equipment. The project would include the suitability of an electric plasma gun (plasma torch) for processing copper.

Project Description

Plasma technology is used in numerous situations in the metals fabrication industry. These include blast furnaces, smelting, and other applications. Plasma is a physical state of matter obtained by ionizing a gas. A plasma consists of positively charged ions and negatively charged free electrons, but remains electrically neutral. However, the fact that a plasma is ionized makes the plasma an electrical conductor.¹

A plasma transfers electrical energy to another material. A plasma torch works in a transferred and non-transferred arc mode. In the transferred arc mode, one of the electrodes is attached to the torch and the other is attached to the material being heated. This mode is typically used when the material being heated is a conductor such as copper. In the non-transferred arc mode both electrodes are attached to the torch. This mode is used when the material being heated is not a conductor such as municipal solid waste. The gas used for the plasma gas can be selected to establish an oxidizing, neutral, or reducing environment.

An initial review of the operations at the Copper Division of Southwire (CDS) indicated the possible use of the technology in the blast furnace, Hoboken converter, anode holding furnace, Maertz furnace, the melting of cathodes in the rod mill, and/or the treatment of dust from any of the furnaces. After discussion with CDS personnel, it was decided to analyze the use of plasma technology in the anode holding furnace and the treatment of dust from the anode holding furnace. The analysis of the plasma torch for the anode holding furnace was conducted on a Lotus 123 spreadsheet. The seven tables presented in this analysis are part of the same spreadsheet. Therefore, the analysis can be easily modified to reflect changes in factors that were estimated to conduct the analysis or evaluate alternative factors such as the currently low cost of natural gas. A copy of the spreadsheet will be provided to CDS.

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Anode Holding Furnace Assessment

The anode holding furnace assessment will evaluate the replacement of the oxygen blown natural gas burners in the current furnace with plasma torches. The operating parameters for the holding furnace are presented in Table 1. The current system has one 7-million Btu per hour, two 2-million Btu per hour, and one 4-million Btu per hour burners in the system. This analysis combines all four burners into one 15-million Btu per hour system. It is recognized that the actual replacement could involve any of the burners and could be phased to evaluate the impact of a single torch before further investment. The plasma torch for this application would be operated in the transfer arc mode.

The maximum permitted annual operation of 1,900 hours is the current air permit limit and was provided by CDS. The energy costs of \$1.30 per million Btu for natural gas and \$0.035 per kilowatt hour and the cost of oxygen of \$0.23 per 100 cubic feet were also provided by CDS. The cost of anhydrous ammonia of \$145 per ton was obtained from the Chemical Marketing Reporter.² The air pollution control operating cost of \$980,000 per year, the processing rate of 58 tons per hour, and the maximum temperature of 2,180°F were provided by CDS.

Table 1. Operating Parameters for Holding Furnace		
Burner No. 1	7.0	million Btu per hour
Burner No. 2	2.0	million Btu per hour
Burner No. 3	2.0	million Btu per hour
Burner No. 4	4.0	million Btu per hour
Furnace Operation	1,900	hours per year
Natural Gas Cost	\$1.30	per million Btu
Oxygen Cost	\$0.23	per 100 cubic feet
Electricity Cost	\$0.035	per kWh
Ammonia Cost	\$145	per ton
Air Pollution Control Cost	\$988,000	per year
Processing Rate	58	tons per hour
Maximum Operating Temperature	2,180	degrees F

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The physical constants used in the computations are presented in Table 2. The densities and molecular weights were obtained from Crane.³ The oxygen composition of air by volume and the anhydrous ammonia specific volume were obtained from Hawley's⁴. The water density of water was also obtained from Crane³.

The assumptions for the current operation of the holding furnace are presented in Table 3. These were used in the analysis of the current system and the analysis of the current system fired with a plasma torch. The first assumption is the efficiency of the current burners in the transfer of input energy in the form of natural gas into the copper. The factor is not used in the analysis of the current system, but used to size the plasma torch for the modified system.

Table 2. Physical Constants		
Air Density	0.07528	pounds per cubic foot
Methane Density	0.04163	pounds per cubic foot
Oxygen Density	0.08305	pounds per cubic foot
Carbon Dioxide Density	0.11420	pounds per cubic foot
Water Vapor Density	0.03731	pounds per cubic foot
Nitrogen Dioxide Density	0.07274	pounds per cubic foot
Ammonia Density	0.04420	pounds per cubic foot
Methane Molecular Weight	16	
Oxygen Molecular Weight	32	
Nitrogen Molecular Weight	28	
Carbon Dioxide Molecular Weight	44	
Water Vapor Molecular Weight	18	
Ammonia Molecular Weight	17	
Percent Oxygen in Air by Volume	20.95%	
Water Density	8	pounds per gallon
Anhydrous Ammonia Specific Volume	1	

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Burner Efficiency	50.0%	
Percent Pure Oxygen to Burners	30.0%	
Percent of Pollution Control Cost Attributed to Holding Furnace Operation	30.0%	
Natural Gas Heating Value	1,000	Btu per cubic foot

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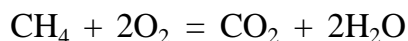
The 50% estimate is based on discussions with other engineers who are familiar with the operation of oxygen fired natural gas burners and data in Industrial Furnaces.⁵ The actual computation of the burner efficiency is complicated and involves the computation of a number of factors. These factors, as outlined in Chapter 5 of Industrial Furnaces', include:

- o Heat losses through the wall of the furnace,
- o Gas leakage through the wall of the furnace,
- o Heat loss by radiation through openings,
- o Heat loss by gases escaping around doors,
- o Sensible heat carried out of the furnace by products of combustion, and
- o Heat loss by incomplete combustion.

The second factor is the percentage of pure oxygen in the combustion air supplied to the burners. This factor was provided by CDS personnel and is used to compute the annual amount of pure oxygen purchased for economic computations. The annual cost for operation of the total air pollution control system of \$988,000 was supplied by CDS'. However, this cost includes the control of emissions from other sources such as the blast furnace and the Hoboken converter. The 30% factor is an estimate of the cost of the total air emissions contributed by the anode holding furnace. The last factor of 1,000 Btu per cubic foot is a typical value for the energy content of natural gas.

The analysis of the current operation of the holding furnace using the four oxygen enhanced natural gas burners is presented in Table 4. The energy input to the burners is computed by multiplying the total energy input to the four burners in Btu per hour by the number of operating hours per year. The energy input to the copper is computed by multiplying the energy input to the burners by the burner efficiency. As previously discussed, this value is used to size the plasma torch in the analysis presented in Table 6. The natural gas required in cubic feet is computed by dividing the energy input to burners by the heating value of the natural gas and this value is converted to pounds by multiplying the amount in cubic feet by the density of natural gas (methane) by the density shown in Table 2.

The next part of the analysis computes the oxygen from air and pure oxygen required for the natural gas burners. The computation is based on the reaction of natural gas (methane) and oxygen at the stoichiometric condition, i.e., without excess air or pure oxygen. The following is the reaction and stoichiometric mass balance for the reaction:



$$16 \text{ lb} + 2 \times 32 \text{ lb} = 44 \text{ lb} + 2 \times 18 \text{ lb}$$

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The reaction of one mole of methane and two moles of oxygen generate one mole of carbon dioxide and two moles of water vapor. On a mass basis, 16 pounds of methane and 64 pounds of oxygen (2 moles x 32 lb per mole) generate 44 pounds of carbon dioxide and 36 pounds of water vapor. The multiplication of the amount of the methane (in pounds) by the ratio of the mass of oxygen to mass of methane in the above equation are used to compute the oxygen required.

Table 4. Computation of Current Operation of Holding Furnace		
Energy Input to Burners	28,500	million Btu per year
Energy Input to Copper	14,250	million Btu per year
Natural Gas Required	28.5	million cubic feet per year
Natural Gas Required	1,186,455	pounds per year
Oxygen Required	4,745,820	pounds per year
Oxygen in Combustion Gas	37.09	pounds per 1,000 cubic feet
Combustion Oxygen Required	127.94	million cubic feet per year
Pure Oxygen Required	38.38	million cubic feet per year
Air Required	427.48	million cubic feet per year
Nitrogen Produced	337.92	million cubic feet per year
Carbon Dioxide Produced	3,262,751	pounds per year
Water Vapor Produced	2,669,524	pounds per year
Combustion Gases Produced	5,932,275	pounds per year
Carbon Dioxide Produced	28.57	million cubic feet per year
Water Vapor Produced	71.54	million cubic feet per year
Combustion Gases Produced	438.04	million cubic feet per year
Ammonia Used	3.0	gallons per minute
Ammonia Used	342,000	gallons per year
Ammonia Used	2,195,676	pounds per year
Oxygen Removed	3,099,778	pounds per year
Nitrogen Gas from Ammonia	1,808,204	pounds per year
Water Vapor from Ammonia	3,487,251	pounds per year
Total Gas from Ammonia	5,295,454	pounds per year
Nitrogen Gas from Ammonia	24.86	million cubic feet per year
Water Vapor from Ammonia	93.45	million cubic feet per year
Total Gas from Ammonia	118.31	million cubic feet per year
Total Furnace Gases	556.35	million cubic feet per year

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The combustion oxygen required accounts for the oxygen naturally occurring in air and the pure oxygen supplied to the natural gas burner. The following equation is used to compute the oxygen in the combustion gas:

$$\text{oxygen in combustion gas} = \frac{\text{percent pure oxygen} + (1 - \text{percent pure oxygen}) \times \text{percent oxygen in air}}{\text{percent oxygen in air}}$$

The values computed are on a volumetric basis, since the percent of pure oxygen in the total combustion air is typically volumetric. The percent oxygen in the combustion gas is multiplied by the density of oxygen to determine the density of the oxygen in the combustion air in pounds per cubic foot. The value computed is then multiplied by 1,000 to convert to pounds per 1,000 cubic feet (a more readable number).

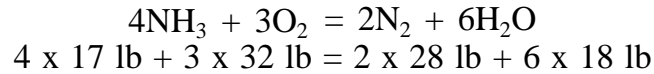
The oxygen required is divided by the oxygen in the combustion gas to determine the combustion oxygen required. The pure oxygen required is computed by multiplying the combustion oxygen required by the percent of pure oxygen from Table 3, and the value is later use in the economic analysis. The air required is computed by multiplying the combustion oxygen required by the difference between the combustion required and the pure oxygen required and dividing the percent of oxygen naturally occurring in air. The nitrogen produced is calculated by multiplying the air required by the percent of nitrogen in air, i.e., 100% minus the oxygen concentration by volume. The nitrogen in the air is one of the gases contributing to the load on the air pollution control system.

The next part of the analysis determines the other gases produced by the burner system from the combustion of methane. The volume of these gases will later be compared with the volume of the gases produced from the plasma torch and used to compute the savings that are achievable with the plasma torch. The computation is based on the stoichiometric mass of carbon dioxide and water vapor produced from the reaction of methane and oxygen that was previously discussed. The amount of gases in pounds produced is determined using the stoichiometric mass balance where 16 pounds of methane produce 44 pounds of carbon dioxide and 36 pounds of water vapor. The total combustion gases produced is the sum of the carbon dioxide and water vapor from combustion. The amount of carbon dioxide and water vapor produced is converted to gas volume using the densities in Table 2. The combustion gases produced in million cubic feet produced is the sum of the volumes of carbon dioxide, water vapor, and nitrogen from the system.

Ammonia is also added to the anode' holding furnace to remove oxygen from the copper. The estimate of 3 gallons per minutes was provided by CDS. The ammonia flow rate was converted to gallons per year by multiplying the gallons per minute by the operating hours per year and converted to pounds per year using the constants in Table 2.

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The reaction products from the addition of ammonia are based on the following reaction and stoichiometric mass balance for the reaction:



One of the advantages of a plasma torch is that the plasma gas can be selected to create an oxidizing, neutral, or reducing atmosphere. This analysis will assume that methane is selected as the plasma gas to create a reducing atmosphere, and that ammonia will be eliminated from the system. Therefore, the next step in the analysis is to compute the amount of oxygen removed to determine the amount of methane required in the plasma torch analysis. This computation is based on 68 (4 x 17) pounds of ammonia removing 96 (3 x 32) pounds of oxygen from the copper.

The next part of the analysis determined the amount of gases produced from the reaction in a similar manner to the computation to the products and is similar to the computation for the combustion products from the burner. The amounts in pounds are converted to volumes using the conversion factors in Table 2, and the total gas from ammonia is computed. The volume of gases from ammonia is added to the volume of gases from combustion to compute the total of 556 million cubic feet per year.

The economics of the current operation of the anode holding furnace are presented in Table 5. The cost for natural gas, pure oxygen, and ammonia are computed by multiplying the quantities consumed in Table 4 by the unit costs in Table 1. The air pollution operation costs are computed using the 30% factor for the operation of the total system as previously discussed. The estimated total operating cost for the current system is \$580,915.

Table 5. Economics of Current Operation of Holding Furnace	
Natural Gas Cost	\$37,050
Pure Oxygen Cost	\$88,278
Ammonia Cost	\$159,187
Air Pollution Operation Cost	\$296,400
Subtotal Operating Cost	\$580,915

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The assumptions for the plasma torch operation of the anode holding furnace are presented in Table 6. The plasma torch efficiency of 90% is based on estimates presented in ARC' for a plasma torch operated in the transferred arc mode which is typically used for heating of conducting materials such as copper. The assumption to the operational cost of the air pollution control system was previously discussed.

Table 6. Assumptions For Plasma Torch Operation of Holding Furnace	
Plasma Torch Efficiency	90.0%
Percent of Pollution Control Cost Attributed to Holding Furnace Operation	30.0%

The analysis of the plasma torch operation of the anode holding furnace is presented in Table 7. The energy input to the copper was computed in Table 5 based on an assumed transfer of heat from the natural gas burners to the copper. The energy input to the copper is divided by the torch efficiency to obtain the energy input to the torch. The energy input to the torch is divided by the annual hours of operation to obtain the torch power in million Btu per hour. This value is divided by 3,413 Btu per hour to obtain the torch power in megawatts (MW). The total torch power for the system would be 2.44 MW. As previously discussed, the system would probably consist of several smaller torches, but the total torch system was used for comparison purposes. The torch power is multiplied by the annual hours of operation to obtain the annual torch energy requirement in megawatt-hours.

The oxygen removed in the existing anode holding furnace using ammonia was computed in Table 6. The reaction is the same as for the natural gas burner where 16 pounds of methane react with 64 (2 x 32) pounds of oxygen. The amount of methane in pounds required for reduction is computed and converted to cubic feet using the constants in Table 2. The methane consumption is converted to cubic feet per hour by dividing by the annual operation and finally to cubic meters per hour. ARC' indicates plasma gas flows vary from to 15 to 1,500 cubic meters per hour. Since the 277 cubic meters per hour for this system is within this range, it appears to be a reasonable number for a first estimation.

The remainder of the analysis computes the carbon dioxide and water vapor generated from the reaction of methane and oxygen. The computation is first made in pounds and converted to million cubic feet per hour using the densities in Table 2. The final

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computation if the total gas flow in cubic feet per hour from the anode holding furnace heated with a plasma torch to the air pollution control system. It should be noted that the 65 million cubic feet per year is significantly less than the 556 million cubic feet per year from the current system.

The economic analysis of the plasma torch operation of the anode holding furnace is presented in Table 8. The natural gas and electricity costs are computed by multiplying the consumption computed in Table 7 by the unit costs in Table 1. The air pollution operation cost is computed by multiplying the cost shown in Table 6 by the ratio of the gases produced by the plasma system to those produced by the current system. The total operating cost of the plasma torch system is estimated to be \$221,405 representing a \$359,509 annual savings over the existing system.

Energy Input Required to Copper	14,250	million Btu per year
Energy Input to Torch	15,833	million Btu per year
Torch Power	8.33	million Btu per hour
Torch Power	2.44	MW
Torch Energy Requirement	4,639	MW hours
Oxygen Removed	3,099,778	pounds per year
Plasma Gas Required as Natural Gas	774,945	pounds per year
Plasma Gas Required as Natural Gas	18.62	
Plasma Gas Required as Natural Gas	9,797	cubic feet per hour
Plasma Gas Required as Natural Gas	277	cubic meters per hour
Natural Gas Required	18.62	million cubic feet per year
Natural Gas Required	774,945	pounds per year
Carbon Dioxide Produced	2,131,098	pounds per year
Water Vapor Produced	1,743,625	pounds per year
Combustion Gases Produced	3,874,723	pounds per year
Carbon Dioxide Produced	18.66	million cubic feet per year
Water Vapor Produced	46.73	million cubic feet per year
Combustion Gases Produced	65.39	million cubic feet per year

An estimated capital cost for a plasma torch system is \$1,000 per kilowatt. The 2.44 MW system will cost an estimated \$2,241,441. The system will payback in 6.8 years representing a 14.7% return on investment. The torch(s) could be installed in the existing anode holding furnace with a change in the refractory material. The torch electrodes have a service of 200 to 500 hours depending on the plasma gas used. A cost for replacement of electrodes was not included in the analysis.

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Conclusions

The use of plasma technology for the anode holding furnace will significantly reduce the volume of gases from the furnace. This reduction in gas volume should also significantly reduce the lead emissions from the system. The technology has the potential for use on other furnaces at the facility. However, it is suggested that installation in the anode holding furnace be accomplished first to verify system operation and allow plant personnel to become familiar with plasma technology.

The payback shown for this analysis, while positive, might be considered marginal at this time. However, there a number of other factors that should be considered that could significantly improve the economics of the plasma torch system. These factors include:

- o the cost of disposal of residues from the air pollution control system (if not included in the operating cost already),
- o increased operation efficiency of the furnace due to better temperature control achievable with the plasma torch, and
- o the possibility of more annual hours of operation due to the reduction in emissions from the system.

This preliminary assessment has demonstrated a sufficiently acceptable return on investment to warrant an further, more detailed analysis of plasma technology.

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Table 8. Economics of Plasma Torch Operation of Holding Furnace		
Natural Gas Cost	\$24,200	
Electricity Cost	\$162,369	
Air Pollution Operation Cost	\$34,836	
Subtotal	\$221,405	
Savings	\$359,509	
Plasma Torch Cost	\$1,000	per kW
Total Plasma Torch Cost	\$2,441,645	
Simple Payback	6.8	years
Return on Investment	14.7%	

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Assessment of the treatment of dust from the blast furnace and converter

The treatment and disposal of dust from the metals processing industry is a problem for all sectors of the industry. A process for recovery of metals from this dust was described by ARC'. The process is based on the PLASMADUST process developed by SKF Plasma Technologies AB, P.O. Box 44, S-182 11 Danderyd, Sweden. The company has designed, built, and is operating the SCANDUST facility that can process 77,000 tons of dust per year at Landskrona, Sweden. This facility uses three 7-MW plasma torches for processing the dust. The SKF torch operates in the non-transferred arc mode. However, another system could be operated in the transferred arc mode resulting in an increase in efficiency.

The process injects dust, coal powder, and slag formers into a low shaft furnace. Practically all the metal oxides in the feed material are instantaneously reduced when these enter the reaction zone in the shaft furnace. The zinc and lead oxides are also reduced as these enter the reaction zone. The metals are then vaporized, removed from the shaft furnace with the off-gas, and recovered by condensation outside the furnace. Lead is used to cool and dissolve the zinc metal produced. The zinc-containing lead is continuously pumped from the condenser to a cooling launder with immersed cooling coils. When the lead is cooled, a zinc layer is formed and removed in a separate furnace. The zinc produced is considered to be of Prime Western Grade. The waste material from the process is no longer considered hazardous although the results of toxicity characteristic leaching procedure

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(TCLP) is not mentioned in the report.¹ Energy can also be recovered from the export gases and cooling water to improve the efficiency of operation.

The plant is used for processing electric arc furnace (EAF) dust from the production of carbon and stainless steel. Table 9 provides a comparison of the zinc and lead content from the CDS blast furnace and converter and from the SCANDUST facility. The data on copper dust was provided by CDS and the SKF data from ARC'. The CDS data was from several different dates and the data indicated is the range for these dates.

Table 9. Comparison of CDS and SKF Dust			
	CDS Blast Furnace Dust Analysis	CDS Converter Dust Analysis	SKF EAF Carbon Steel Dust Analysis
Zinc Oxide	35.15 - 59.86%	26.59 - 52.56%	25 - 30%
Lead Oxide	15.74 - 30.52%	13.88 - 27.84%	2 - 6%

The zinc concentrations in the CDS dusts are higher than the SKF EAF dust. This should result in the production of more zinc and improve the economics over the SKF EAF system. However, the concentration of lead is significantly higher which could reduce zinc recovery or require modifications in the process. Tests will be required with a bench-scale system to determine recovery efficiencies.

Table 10 provides a summary of the energy and feed requirements for the SKF plant from ARC'. As previously discussed, standard refractories can be used in these systems and the plasma torch electrodes last from 200 - 500 hours depending on the plasma gas.

Table 10. Energy and Feedstock Inputs for SKF Plant for Carbon Steel EAF Dust	
Electric Energy For Plasma Torches	1,814 kWh per ton of dust
Coal	220 pounds per ton of dust
Coke	240 pounds per ton of dust
Energy Recovery from Export Gas and Cooling Water	1,100 - 1,400 kWh

The cost estimate for the 77,000 ton per year plant is 30 to 40 million dollars.

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Conclusions

The data on treatment of dust, particularly from copper operations, is not complete. However, it appears that the potential exists for the development of a system using plasma technology. Additional research on a bench-scale system is warranted.