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A RECYCLING PROCESS FOR DEZINCING STEEL SCRAP

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ABSTRACT

In response to the several-fold increase in consumption of galvanized steel in the last decade and the problems associated with refurnacing larger quantities of galvanized steel scrap, a process is being developed to separate and recover the steel and zinc from galvanized ferrous scrap. The zinc is dissolved from the scrap in hot caustic using anodic assistance and is electrowon as dendritic powder. The process is effective for zinc, lead, aluminum, and cadmium removal on loose and baled scrap and on all types of galvanized steel. The process has been pilot tested for batch treatment of 1,000 tons of mostly baled scrap. A pilot plant to continuously treat loose scrap is under construction. Use of degalvanized steel scrap decreases raw materials and environmental compliance costs to steel- and iron-makers, may enable integrated steel producers to recycle furnace dusts to the sinter plant, and may enable EAF production of flat products without use of DRI or pig iron. Recycling the components of galvanized steel scrap saves primary energy, decreases zinc imports, and adds value to the scrap.

INTRODUCTION

Argonne National Laboratory (ANL) and Metal Recovery Industries, Inc. (MRII), in cost-sharing collaboration, have developed an electrolytic process to separate and recover steel and zinc from galvanized steel scrap. This work has been supported by the U.S. Department of Energy. An assessment of available dezincing technology was begun in 1987 that (1) screened process concepts for separating and recovering zinc and steel from galvanized ferrous scrap, (2) selected electrochemical stripping in hot caustic as the most promising process, (3) evaluated the technical and economic feasibility of the selected process on the basis of fundamental electrochemical studies, (4) experimentally verified the technical and economic feasibility of the process in a phased evaluation from bench-scale controlled experiments through batch tests of actual scrap up to six ton lots, and (5) concluded that the process has technical and economic merit and requires larger-scale evaluation in a continuous mode as the final phase of process development. Preliminary economic analysis indicates that the cost of processing ferrous scrap would be about $25 to $50/ton, including credit for the co-product zinc and depending on production volume, form, and zinc content of the scrap. Concentrations of zinc, lead, cadmium, aluminum, and other coating constituents (not nickel) on loose scrap are reduced by a minimum of 98%, with zinc, in particular, reduced to below 0.1%. Removal efficiencies on baled scrap with bulk densities between 60 and 245 pounds per cubic foot range from 70 to 90% with removal effectiveness decreasing with increasing scrap density. About 1,000 tons of galvanized scrap bales have been treated in batch operation at MRII in Hamilton, Ontario. The major portion of this scrap was prepared for an American Iron and Steel Institute (AISI) experimental program to evaluate the degalvanizing process on bales for technical, economic, and environmental viability. A pilot plant for continuous treatment of 40 ton/day of loose scrap is being built by MRII in East Chicago, Indiana, with operation starting in early 1992.

Application of the degalvanizing process to only half of the 10 million tons of galvanized ferrous scrap that will be available in the United States market in the year 2000 is estimated to (1) save 50 x 10^{12} Btu of primary energy per year, (2) reduce raw materials costs to the iron and steel industry by $160 million/yr, (3) create about $336 million/yr in value-added manufacturing; and (4) eliminate the need to import about 80,000 to 160,000 tons of zinc per year at a value of $128-256 million/yr.

DEZINCING PROCESSES ASSESSMENT

The need for dezincing galvanized ferrous scrap to provide "specification-grade" or low residual scrap to the steel industry is not new. However, thermal and chemical dezincing concepts that have been considered prior to this investigation have not had a recovered scrap cost that could compete with the price of pig iron.[1] The concept of anodically promoting the dissolution of zinc from galvanized steel scrap and electrowinning in hot caustic is technically feasible. Operating and capital cost estimates for the process indicate it is cost-effective relative to the alternatives of using pig iron or DRI and is the least costly to the steel industry compared to other processes considered.[2]

The process is essentially reverse electroplating. Loose or baled galvanized scrap is fed to an electrolytic cell where it is made the anode by being placed in contact with the positive side of a high-current/low-voltage direct-current power supply. The cell (tank) is filled with a warm (70-90°C) water solution of 20-32% sodium hydroxide (NaOH), the electrolyte. The tank is fitted with a metal (e.g., steel sheet) cathode. An electrical potential is applied between the cathode and the scrap. Zinc and other common coating constituents are anodically stripped (dissolved) from the scrap steel surface and simultaneously deposited on the metal cathode. The stripped scrap is conveyed from the tank and water rinsed to minimize loss of NaOH solution that wets the steel. The washed scrap may then be shipped to the steel mill or foundry. Zinc deposited on the cathode is removed and recovered. The pregnant solution from the primary stripping tank may also be sent to a purification circuit and to secondary electrolytic recovery cells for zinc recovery. The washed and mostly zinc solids may be sent to a zinc smelter or used directly. The liquids recovered from washing and filtration are sent to make-up tanks for eventual return to the stripping tank. The process consumes no chemicals other than drag-out make-up losses for treatment of most galvanized products and produces only small quantities of wastes. Treatment of galvanized alloy coatings containing aluminum results in consumption of caustic.

Anodic dissolution of metals with cathodic deposition in the same electrolyte, i.e., one-step active-metal-dissolution/recovery, is common in electroplating practice. Tin and zinc flake pigments were produced early using this process.[3] Anodically promoted detinning in caustic of tinplated scrap has been practised commercially for many years and is directly analogous to the dezincing process reported on here.[4] A Belgian patent has been granted for use of electrolytic dissolution/electrowinning to recover the components of scrap galvanized steel.[5]

Distinct from anodic dissolution processes are studies of recovery of zinc by electrolysis of alkaline or acid solutions derived from leaching of oxidic zinc ores [6,7,8,9] or zinc bearing residuals such as steel making furnace dusts.[10,11,12] These are two-step processes which put metal into solution by chemical leaching followed by electrolytic recovery using inert anodes. The predominant commercial detinning process uses chemical leaching in caustic followed by electrolytic recovery of the tin or precipitation of the stannate; this process has also been practised economically in North America and Europe for many years.

The preliminary assessment of the technical and economic feasibility of the one-step caustic electrolytic dezincing process was favorable. Experimental work was then directed to addressing uncertainties in extending the concept to commercial operation on scrap. These include determining: 1. maximum expected rate of dissolution, 2.

selectiveness for zinc over steel, 3. effectiveness of zinc removal, 4. effects of variation in process conditions such as temperature, caustic concentration, zincate concentration, expected impurities and current density, 5. morphology of zinc deposits, 6. effectiveness on various types of galvanized coatings and 7. performance on various forms of scrap.

EXPERIMENTAL RESULTS

Work was done in three areas: 1. the electrochemical behavior of zinc and steel in hot caustic was explored in the laboratory, 2. small, 2.5 cm (1 in.) diameter, coupons of galvanized steel were stripped, and the zinc was recovered from caustic in a bench-scale stripping cell and 3. batches of sheet, loose and baled galvanized scrap were dezinced, in two stages of scale-up, using anodic dissolution in hot caustic with recovery of clean scrap and electrodeposited zinc. The first stage of scale-up was capable of treating 50 to 150 kg (110 to 330 lb) scrap lots in a 1500 liter (400 gal) tank. In the second stage, loose, sheet, and baled scrap was treated in lots as large as six tons culminating with the 600 ton AISI program. A total of approximately 1,000 tons of galvanized scrap of various forms and coating types were treated.

Electrochemical Studies

The purpose of this work was to determine the fundamental electrochemical behavior of zinc and steel in hot caustic solution. The detailed results of the electrochemical studies have been reported previously.[13] Five types of electrochemical measurements were performed:

1. Current/potential voltammetry (polarization) curves were measured to determine the cathodic, anodic, and passive potential regions of zinc and steel in hot caustic solution,
2. Galvanostatic (constant-current) passivation measurements were carried out to determine the maximum rate of metal dissolution before the onset of passivity,
3. Spontaneous dissolution rates of zinc with evolution of hydrogen were measured for six varieties of galvanized products,
4. Long diffusion path polarization measurements were made under conditions simulating baled scrap geometry and galvanized steel scrap from which different amounts of zinc have been stripped, and
5. Zinc deposition current efficiency was determined by measuring the volume of hydrogen evolved over time during zinc deposition under constant current. The effect of impurities on the cathodic process was investigated for Al^{+3}, Fe^{+3}, Cd^{+2}, and Pb^{+2} ions. Aluminum and lead oxides are soluble in the basic solution; 0.1 M and 0.01 M solutions were used, respectively. Iron and cadmium oxides are practically insoluble; saturated solutions were prepared at

room temperature and they were analyzed by atomic absorption spectroscopy, giving 0.4 and 11 pprn solubility, respectively.

The electrochemical tests were conducted at 70 or 90°C in either 3, 5, 8 or 10 M NaOH with some tests conducted with 0.15, 0.30, 0.45 or 0.60 M ZnO added.

The major results of the electrochemical behavior study are:

1. Zinc is anodically dissolved in hot caustic at maximum current densities about a factor of 1000 greater than for steel. This means that zinc can be selectively removed by anodic promotion from the surface of galvanized steel.
2. The passivation limited current densities for anodic dissolution of zinc in unstirred solution is about 150 mA/cm^2. A typical galvanized coating can then be stripped in a few minutes under ideal conditions. Fluoride (0.025 to 0.075 M), chloride (0.1 and 1.0 M) and sulfate ion (0.15 M) additions had no effect on passivation limited current densities in 90 °C, 5 M NaOH and 0.2 M ZnO.
3. Spontaneous dissolution (without the application of external electrical current) of zinc is thermodynamically possible, but kinetically limited. Dissolution will occur at a measurable rate only if the zinc metal is in electrical contact with another metal that catalyzes the evolution of hydrogen or if a strong oxidizing agent is added as a consumable reagent. Iron, nickel and aluminum will catalyze the dissolution of zinc at practical levels (equivalent to at least 100 mA/cm^2) if the exposed area of the catalytic metal is about the same as that of the zinc. With alloyed zinc coatings, the alloying metal can suffice as the catalytic surface. Practical spontaneous dissolution rates in hot caustic are not obtained when the zinc content of the solution is above 0.1 M.
4. Anodic dissolution of zinc in the end of long, 150 mm (6 in.), narrow 3 mm (0.25 in.) channels proceeds at current densities about a factor of 100 less than for parallel plate, line-of-sight geometries. This suggests that electrolytic stripping of scrap with tortuous paths to the cathode, e.g. baled scrap, will require much longer processing times.
5. Current efficiencies for zinc deposition from hot caustic range from about 80 to 98%. Cathodic current efficiency increases with increasing current density and is strongly affected by choice of cathode material. None of the impurity ions tested (Al^{+3}, Fe^{+3}, Cd^{+2}, and Pb^{+2}) had any measurable effect on the current efficiency. Merrill and Lang observed a decrease in cathodic efficiency when iron was above 5 ppm but the iron was not in solution.[14]

Bench Scale Stripping Tests

Electrolytic stripping of galvanized steel sheet disks was conducted in acid and in caustic solutions. The results of the acid and caustic stripping tests have been reported.[15,13] Caustic solutions were at 90 °C, 5 or 10 M NaOH, and with 0.1 to 0.4 M ZnO added. Stripping tests were run at various constant currents corresponding to a current density range of 40 to 380 mA/cm^2. The exposed stripping area was 5.3 cm^2 (0.8 in^2) and the electrode separation set at 15, 29 and 59 mm (0.6, 1.1 and 2.3 in.) using cylindrical cells of different lengths.

The critical results of the electrolytic stripping tests are:

1. Anodic promotion and chemical dissolution of zinc proceeds at higher rates in room temperature hydrochloric or sulfuric acid than in hot caustic, but those acids are not selective for just the zinc coating.
2. Coupons of electrogalvanized steel with a coating thickness of 0.02 mm (0.0008 in) were typically stripped in 3 to 8 minutes in hot caustic.
3. After stripping, the residual zinc on the steel was typically 0.05 wt%.
4. Anodic current efficiencies were over 100% because of chemical dissolution. Cathodic current densities ranged between 80 and 100%, increasing with current density, for deposition on zinc cathodes.

Scrap Dezincing Trials

Electrolytic stripping test capacity was first scaled-up to a 1500 liter (400 gallon) tank fitted with sheet steel cathodes; a typical batch size of 50 kg of loose or 150 kg of baled scrap could be dezinced. An anode basket for loose or bulk scrap was provided with adjustable side HDPE grid panels to provide 230 to 400 mm (9 to 16 inch) thick thicknesses of loose scrap. Bales of scrap were placed between the cathodes and were self-contained.

Loose scrap with apparent bulk density of 25 to 50 lb/ft^3 with a zinc coating weight of 2.3 -3.3% was stripped in 30 to 65 minutes to 0.002-0.04% residual zinc; power consumption was 0.7 to 1.1 kWh/lb zinc recovered. Bales averaging 85 lb/ft^3 and zinc coating weight of 3.0% were stripped in 4.3 hours to 0.008-0.034% residual zinc; power consumption was 1.5 kWh/lb of zinc recovered. Bales averaging 150 lb/ft^3 and zinc coating weight of 0.4% were stripped in 5 hours to 0.02-0.09% residual zinc; the anodic current efficiency was 28% and the power consumption was 4.5 kWh/lb of zinc recovered. Solution composition for the tests reported here were 5 M NaOH with 0.2 M ZnO added and the electrolyte was maintained at 70-80 °C.

The second stage scale-up in dezincing capability comprised two 20,120 liter (5,300 gal) primary treatment tanks, each able to accommodate six tons of bales. This was in line with a counter-current five-stage washing system for dezinced scrap; the pregnant dezinc solution was sent to an electrowinning cell for zinc recovery. This system was used to dezinc a total of approximately 1,000 tons of galvanized scrap of various types and forms. The 600 ton AISI trial to examine the technical and economic feasibility of dezincing and deleading of industry standard bales was conducted in this facility. A summary of some of the experimental campaigns on loose, sheet and baled scrap follow, including the experimental AISI program.

Approximately 22 tons of loose scrap, in 12 runs, were processed for galvanized coating removal. The scrap was loaded into steel baskets measuring 100x860x640 mm (39x34x25 inches). The average bulk density was 94 lb/ft^3, initial zinc weight was uniformly 2.16%, and the average residual zinc was 0.008%, independent of stripping time between 1 and 26 hours . A four hour test run on one ton of this loose scrap was made without anodic promotion with no significant difference in coating removal effectiveness.

Approximately 15 tons of dealer bundles prepared from heavy galvanized construction sheet scrap were processed for coating removal. The bale dimensions were nominally 100x660x660 mm (44x26x26 inches) with an average bulk density of 107 lb/ft^3 and a zinc weight of 1.53%. Electrolytic treatment for 17 to 26 hours resulted in an average 78% and range of 68-83% zinc removal effectiveness; without anodic promotion and a residence time of 71 hours, the zinc removal effectiveness was 36%.

Approximately 600 pounds of scrap Galvalume sheets with an average thickness of 0.037 inches and a coating of 1.4% zinc and 0.7% aluminum were processed for coating removal by electrolytic stripping. The stripped scrap analyzed 0.003% zinc and aluminum was not detectable.[16]

A total of 31 tons of baled automotive stamping plant scrap nominally 13 x 14 x 16 inches (1.7 ft^3), weighing 270 to 370 pounds with a density of between 120 and 190 lb/ft^3 were processed for removal by electrolytic stripping of the predominantly galvannealed coating. The sheet thickness was mostly 0.028 inch and the zinc coating ranged from 0.2 to 1.1%, averaging 0.6% by weight. The stripped scrap contained residuals of zinc, 0.10%; water, 0.3%; aluminum, 0.006%; sodium, 0.004%; and lead, 0.003%; this was 84% zinc removal effectiveness based on the 0.6% average incoming zinc content.

600 tons of baled, galvanized steel produced from sheet steel and coil ends generated directly from steel mills were processed for dezincing. The source and form of this scrap were as provided in a multiple company cost-shared research program coordinated by the AISI Task Force on Recycling of Galvanized Steel Scrap. The dezinced scrap was used in a melting trial conducted at LTV Steel, Indiana Harbor Works, to determine the effect on environmental performance of BOF operations.

Three dezincing campaigns were conducted for the AISI program: 1. 186 tons of bales with no added lead content were treated for 24 hours, 2. 305 tons of bales with no added lead content were treated for 36 hours, and 3. 144 tons of bales with lead added as Terneplate were treated for 24 hours. On average, the bales were 24 in. x 24 in. x 31 in., weighing 1600 lb with an apparent bulk density of 155 lb/ft^3. Using the dezincing performance data generated from the solution mass balances, the zinc removal for the regular and leaded bales processed for 24 hours were quite similar, at 1.53% and 1.49% respectively. For the regular bales treated for 36 hours, the zinc removal was marginally higher at 1.61%. Based on the average zinc content of the incoming scrap of 2.0%, the dezincing performance is 76% for the 24 hour bales and 81% for the 36 hour bales. The additional zinc removal observed for the 36 hour treatment is not likely to be economically justified.

Approximately 6.6 tons of impure zinc metal powder was produced from the 600 tons of galvanized scrap treated for the AISI. Purification tests were performed in the laboratory, and to a limited extent, in the pilot plant. Iron, lead, copper and nickel in caustic solution can be readily controlled by cementation with zinc dust; tin and antimony were not significantly affected by cementation. Evaluation of the different grades of zinc powder produced will be required by the potential users to determine suitability. The high surface area and high reactivity of the zinc powder makes it desirable for chemical production, fertilizers, animal micro-nutrients, or as a zinc supply for inert anode zinc electroplating systems, but may result in excessive loss to oxide if used for melting.

The zinc metal collected from the electrowinning system was a dendritic, non-adherent powder with a surface area typically over 3 m^2/g. The purity varied from 77 to 95% by weight, on an "as produced" basis, with the degree of oxidation the largest variable. Washing and drying of freshly produced electrodeposited zinc under non-oxidizing atmosphere produced zinc powder with an analysis of 97% zinc and 1.8% oxygen.

Sludge was generated from the dezincing and washing systems at a combined rate of 2.25 lb (dry weight) per ton of mill scrap. This material contains iron, zinc, lead and other heavy metals which would require that it be classified as and disposed of as a hazardous waste. From dezincing solution analysis, aluminum was present in the baled scrap at a level of 0.25%. Laboratory tests indicate that the solution may be treated with calcium hydroxide to precipitate the aluminum. Aluminum sludge would be generated at a rate of 25 lb per ton of scrap; it is not hazardous and might be used to aluminize cement. No quantities of oil or grease were collected from the dezincing system during the AISI trials.

The bales of galvanized steel prepared for this trial should be considered as some of the most difficult to dezinc. This is due to the fact that they were made exclusively with sheet steel and coil ends; some bales were wrapped with sheet. There were no "through holes" present to allow solution to pass to the center of the bale, as would be the case if stamping plant scrap had been used. Also, steel generated from a stamping plant or shredder would be bent and produce wrinkles in the scrap when baled, allowing solution to travel more freely within the bale. For the bales prepared for this trial, the smooth sheets tended to laminate when baled, which restricted movement in the bale. Most of the steel surfaces were wetted due to capillary action of the dezincing solution; however, diffusion of zinc ions and movement of the wash water between these sheets is limited.

PROCESS ECONOMICS

The cost of electrolytic hot caustic processing of galvanized steel scrap for dezincing is estimated to be about $25 to $50/ton, including credit for the co-product zinc and depending on production volume, form, and zinc content of the scrap. The processing time, rectification requirements and power consumption for the removal of zinc from galvanized steel are variables which are greatly dependent on the physical form of the scrap and, to a lesser extent, on the type of galvanized steel to be processed. The type of galvanized steel affects the rate and completeness of coating removal and the associated processing time, anodic current efficiencies, rectification and power costs. Alloy coatings of zinc such as galvanneal, galvalume and zinc/iron all react relatively faster in the hot caustic process because of spontaneous chemical dissolution of zinc. Relatively pure hot dipped or electrogalvanized zinc coatings react slower to hot caustic unless an oxidizing agent or anodic promotion is provided. Zinc-nickel coatings tend to be the most resistant to the hot caustic process as the nickel is essentially inert and hinders access of the caustic solution to the zinc.

The physical form of the scrap is the most significant variable to the dezincing process. Estimates based on batch processing indicate that relatively small pieces of uncoated, loose scrap can be processed continuously in less than three hours, with high zinc removal efficiencies, and with relatively small plant area. Dezincing of baled scrap encounters the problems of solution contact with the zinc, solution removal and washing of the bale (even more difficult than solution contact), the lack of any distinct current density in the center of the bale, the inability to physically dislodge protective coatings from the internal scrap surfaces, and the collection of gas bubbles within the bale which subsequently displaces dezincing solution reducing process efficiency. The need to dezinc baled scrap is a genuine need, however, and can be accomplished to a varying degree at varying costs. The main variables to performance and cost of dezincing bales are the size of the bale, the tightness of the bale, the physical nature and size of the scrap used in the bales, (i.e. full sheets vs. stamping plant refuse) which directly affect the porosity of the bale, and the presence of protective coatings (some of which may be dissolved over time in the hot, alkaline solution, while other coatings may, in fact, act as gasketing material). The dezincing process time for bales can range from 6 to 24 hours, depending on the variables identified above. Even though most baled scrap will have a greater bulk density than loose scrap, the longer process residence time means that a larger dezincing facility would be required for baled as compared to loose scrap.

BENEFITS OF DEZINCING FERROUS SCRAP

The constituents of galvanized coatings in the scrap charge impose environmental compliance, yield, nuisance, and opportunity cost penalties on iron- and steel-making. Zinc-coated scrap increases the volume and cost of baghouse dust disposal. Cost penalties in excess of $60/ton of galvanized scrap consumed have been estimated by some integrated BOF shops for disposal of dusts that do not pass the TCLP test or lead. For operations with wet gas scrubbers, zinc concentrations in waste water are exceeding the limit for discharge. Waste water treatment is estimated by the AISI to increase costs by $1 to $3/ton liquid steel. Use of degalvanized steel scrap in BOF operations offers the strong potential for delisting dry dusts as hazardous, avoiding treatment to decrease zinc concentration of waste water and enabling recycling of ferrous dusts to the sinter plant. In EAF operations, zinc fuming on charging, tapping and casting is troublesome. Aside from environmental concerns in BOF and EAF steelmaking, problems are operational rather than metallurgical with anecdotal evidence indicating that zinc contributes to high porosity in billets and to breakthroughs in continuous casting operations. In foundries, galvanized scrap also causes operating problems, such as: 1. zinc fuming when charging and pouring, 2. furnace shaft size reductions due to zinc oxide accretions, 3. recuperator inefficiencies due to oxide coatings on the checkerwork and 4. increased porosity in castings. Use of a specification grade scrap may enable the founder to use some quantities of lower cost scrap feeds such as post consumer tin-coated steel cans. The effect on iron foundry practice of increased tin levels from use of such scrap are presently under investigation in a program underway by Waupaca Foundry in Wisconsin.

The savings in raw materials costs to the iron and steel industry in using high-quality recovered scrap depends on the marginal costs of alternatives to each segment of the industry. For the foundry segment, use of scrap low carbon steels (0.1% C) requires adding carbon to bring the melt chemistry to about 3.8% C: this carbon addition is estimated to cost about $23/ton of scrap consumed based on 90% carbon recovery and a price for carbon of $0.28/lb. The cost of pig-iron ranges from $175-275/ton, depending on quality and quantity. Using $150/ton as the cost of low-residual dezinced scrap ($110 + $40/ton for dezincing), the mid-point raw materials cost savings in use of degalvanized scrap is then $51 million at a market penetration of 1.0 million tons/yr of scrap consumed. For the integrated BOF segment, marginal costs vary with the operation, but they are taken at an average of $175/ton of material (hot metal, DRI, and galvanized scrap) charged to the furnace, which yields a raw materials reduction cost of $71.25 million/yr at a market penetration of 2.85 million tons per year. For the EAF segment, the marginal cost alternative is taken as DRI at $182/ton (a selling price for DRI is taken at $160/ton and adjusted for the 85% yield of DRI relative to a 97% yield of hot metal per ton of clean scrap) which yields a raw materials reduction cost for this segment of $20.2 million/yr at a market penetration of 630,000 tons/yr. Thus, the total raw materials costs reduction to the iron and steel industry is $142 million/yr at a market penetration of 4.48 million ton/yr of black scrap recovered from galvanized scrap.

For each ton of pig iron or DRI that is replaced by a ton of clean black scrap, about 11 million Btu are conserved. This is about 70% of the primary energy that would otherwise be required to produce one ton of hot metal from primary ore or via DRI. In the long term, the scrap market will be burdened by about 10 million tons/yr of galvanized scrap, depending on the recovery rate of obsolete scrap. If this scrap could be cost-effectively stripped of the zinc coating, the underlying steel would be equivalent to the highest-quality scrap available in today's market. In the absence of a process for removing the zinc, scrap exports will increase, and domestic production of steel will require more pig-iron or DRI to replace the lost scrap. Because the primary problems associated with the use of low-quality scrap are derived from environmental regulations that affect the costs of disposing of the residuals resulting from low-quality scrap, it is more likely that the scrap will be exported to countries that do not have environmentally imposed costs. The long-term net effect could be a loss in domestic steel production. If the 10 million ton/yr of galvanized scrap were treated and provided as a substitute for pig-iron, about 100 trillion Btu per year would be conserved. However, if the scrap were exported (at a price of about $75/ton) and finished steel products were imported (at a price of about $450/ton) to make up for a decrease in domestic production, the impact on the federal trade deficit would amount to $2.6 to $3.8 billion/yr -- an increase of 10 to 20% above the current U.S. federal trade deficit.

CONCLUSIONS

Although a number of alternative technologies for responding to the increase in coated scrap have been considered in the recent past, such as induction melting, high-temperature preheating, chemical leaching, and even substitution of ferrous scrap by direct reduced iron, none of these alternatives appear as cost-effective as dezincing with an anodically promoted process in hot caustic. The process can treat effectively all common forms of loose and baled galvanized scrap and is the most advanced option for dealing with the increase in galvanized ferrous scrap. The low carbon steels normally specified for automotive body use and which are under the galvanized coatings have specified limits on carbon, manganese, phosphorus and sulfur. These steels, without the galvanized coating, are an ideal scrap feed to iron and steel furnaces. This scrap provides the necessary quality and also cost savings, in most cases, over the use of pig iron and may enable the use of other lower cost scrap by dilution. Environmental compliance costs may be reduced if the lead content of furnace dusts and the zinc content of waste waters can be sufficiently controlled through use of low-residual scrap.

Large quantities of loose prompt and baled dealer bundles and mill scrap have been dezinced successfully in batch operations using the primary steps of the electrolytic caustic process; however, the process systems must be developed and demonstrated in sustained continuous operation. The process has not been demonstrated on galvanized obsolete scrap, which will constitute 40-50% of the total U.S. supply of galvanized scrap in the next decade and beyond. The process has technical and economic merit and requires larger-scale evaluation in a continuous mode to attract industry investment and confidence in the process for commercialization. Completion of the development effort and its extension to continuous treatment of galvanized prompt and obsolete scrap will be accomplished by operation of a pilot plant now under construction and scheduled for start of operations in Spring of 1992.

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REFERENCES

1. O. F. Angeles, Jr. and E.F. Petras, "Dezincing of Galvanized Sheet Steel Scrap, A Scoping Study," Center for Metal Production Report 86-1F, October 1986.

2. F. J. Dudek, E. J. Daniels and W.A. Morgan, "Benefits of Recycling Galvanized Steel Scrap for Recovery of High-Quality Steel and Zinc Metal," Proc. of the Conf. "Minerals, Metals and the Environment," The Institution of Mining and Metallurgy, Manchester, England, Feb. 4-6, 1992.

3. F. Geltsharp, "Note on the Electrolytic Recovery of Tin," Trans. Faraday Society, 1, 111-117(1905).

4. E.P. Westerdijk, "New detinning plant for tinplate scrap of the Netherlands Detinning Plant (Hoogovens Group)," Leewarden, Iron and Steelmaking, 14(3), 139-141(1987).

5. Centre D'Etude Et De Documentation De L"Environnement (C.E.B.E.D.E.A.U.), Belgian Patent 892,897, "Process and Apparatus for the Recovery of the Components of Galvanized Steel," Oct. 19, 1982.

6. C.T. Baroch, R.V. Hilliard, and R.S. Lang, "The Caustic Electrolytic-Zinc Process," J. Electrochem. Soc., 100(4), 165-172 (1953).

7. J.H. Meisenhelder, A.P. Brown, R.O. Loutfy and N.P. Yao, "An Evaluation of the Alkaline Electrolysis of Zinc," Argonne National Laboratory Report ANL/OEMP-81-2 (1981).

8. D.W. Kappes, "Zinc Recovery by Caustic Leaching," Presented to the AIME Annual Meeting, Phoenix, Jan. 28, 1988.

9. R.L. Meek, "An Alkaline Process for Electrolytic Zinc," Proc. of the Extractive Metallurgy Div. Symp., Cleveland, OH, Dec. 2-3, 1968, T.A. Henrie, D.H. Baker, Jr., Eds., AIME, New York, NY, 306-319 (1969).

10. F.D. Pooley et al, British Patent 1,600,287, "Heavy Metal Recovery from Flue Dusts," Oct. 14, 1981, Assigned to University College Cardiff .

11. University College Cardiff, British Patent 1,568,362, "Heavy Metal Recovery in Ferrous Metal Production Processes," May 29, 1980.

12. W.P.C. Duyvesteyn and R.F. Hogsett, U.S. Patent 4,610,722, "Process for Metal Recovery from Steel Plant Dust," Sept. 9, 1986, Assigned to AMAX, Inc..

13. F. J. Dudek et al, "Electrolytic Separation and Recovery in Caustic of Steel and Zinc from Galvanized Steel Scrap," Separation Science and Technology, 25(13-15)2109-2131 (1990).

14. C.C. Merrill and R.S. Lang, "Experimental Caustic Leaching of Oxidized Zinc Ores and Minerals and the Recovery of Zinc from Leach Solutions," Bureau of Mines Report 6576(1964).

15. S. Zaromb, A.V. Fraioli, E.J. Daniels, G.V. Queen, and R.M. Bozen, "$ZnCl_2$-HCl Plating Baths for Stripping and Recovery of Zinc from Galvanized Iron Scrap," presented at the 173rd Meeting of the Electrochemical Society, Chicago, IL, Oct. 1988.

16. Metal Recovery Industries, Inc., "Dezincing of Scrap Galvalume Steel Sheets," Internal Report, Feb. 25, 1991.

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