NEW METAL RECOVERY SYSTEMS FOR MASS BURN INCINERATORS AND WTE FACILITIES

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ABSTRACT

This paper discusses economic considerations and technologies involved in recovering marketable ferrous metal from bottom ash generated in municipal solid waste (MSW) incineration facilities using mass burn technology. Methods for enhancing the resale value of the metal are reviewed, as well as design techniques for recovering and recycling the free moisture in the bottom ash to reduce ash disposal costs. The economic benefits of metal recovery and water recirculation is illustrated for a 900 TPD waste-to-energy (WTE) facility.

INTRODUCTION

To meet stricter regulatory requirements, the cost of operating incineration facilities has increased, and plant operators are looking for new ways to improve the operating efficiency of these units. An opportunity for savings in plant operating costs and to increase plant revenues is presented by a new generation of ash management systems discussed in this paper. These systems have built-in subsystems for recovering ferrous metal and for cleaning the metal to increase its value for the resale market. In addition, these new ash systems include provisions for draining the water from the bottom ash, recovering the water and recirculating it within the facility. In this way, the recovered water does not leave the plant and the unnecessary cost of transporting the water to the ash landfill is minimized. We have also reviewed methods for maximizing the total recovery of metals, by use of metal shredding to reduce the size of oversized metal pieces for cleaning and increasing the ferrous metal recovery yield.

BEI Associates, Inc., which was formerly Blount Engineers, has designed a number of ash systems for municipal solid waste incineration projects, and this paper is based on our experience in implementing these projects. To illustrate the cost considerations and to explain the thinking process in developing metal recovery projects, we have considered a 900 TPD project located in a heavily industrialized area of the U.S. The processes and parameters cited in the illustrated example of this paper are drawn from two recent project experiences, namely: Grosse Pointes–Clinton Refuse Disposal Authority, Mt. Clemens, Michigan, where an ash management and ferrous metals recovery facility went into operation in April 1991; and Montenay–Islip Inc., Long Island, New York, for whom advanced feasibility studies were conducted.

The project is based on modifying an existing waste-to-energy (WTE) facility where water submerged drag chain conveyors are utilized for removal of bottom ash from the combustion process.

GENERAL DISCUSSION

In a municipal waste incinerator or resource recovery facility of the "mass burn" type, two types of ash streams are present, bottom ash and fly ash. The fly ash is mixed with air quality control system reagents. Bottom ash is generally water quenched and dewatered prior to discharge from the combustion process. The fly ash is typically conveyed in the dry state, conditioned with water and combined with the bottom ash for offsite disposal.

For extracting bottom ash from the incineration process, either a water submerged drag conveyor or a ram type discharger is used. Ram type dischargers are more efficient in dewatering the bottom ash than water submerged drag conveyors. Typical moisture content of ash from a ram discharger system is in the range of 15–20% compared to a 35–45% for drag conveyor applications. Use of ram dischargers is a more modern approach whereas older facilities utilize water submerged drag chain conveyors.

The bottom ash is a material having high variability both in terms of size distribution and chemical characteristics and consists of larger sized pieces called "oversize" and smaller materials and fine ash called "undersize". Both "oversize" and "undersize" contains recoverable and marketable ferrous metal. The quantity of ferrous metal varies from plant to plant and is typically 4–7% of the incoming municipal waste. The ferrous metal is recovered by employing magnetic separation systems. However, in a conventional system, the recovered metal is a low quality scrap metal because of ash adhering to the metal. Enhancement of the value of metal can be achieved by removing the adhering ash.

In addition to the revenues obtained from the sale of ferrous metals, savings are realized from ash disposal costs owing to the removal of metal and water from the ash and a consequent reduction in quantity of ash to be transported and landfilled.

PLANT DESCRIPTION

The facility illustrated in Fig. 1 is a new ash management system, designed to service an existing waste-to-energy plant. The bottom ash is water quenched in existing furnace ash removal conveyors which are wet type drag chain conveyors. The bottom ash is partially dewatered in the drag conveyors and discharged onto a vibrating conveyor, which conveys the materials to a separate fully enclosed ash containment building.

Enhancements are included in the plant system design in order to improve quality of the recovered metals and weight reduction in the ash to be landfilled and hence facility economics are also improved. Using Fig. 1 as reference, the enhancements include the following:

(a) The oversize materials removed by the grizzly are reduced in size by a shredder. This operation, arranged in closed loop with the grizzly size separation, ensures a uniform presentation to the ferrous magnet separator to improve recovery efficiency. Also, ash is removed from the large pieces in the shredding operation.

(b) A metals wash screen is provided for the removal of adhering ash from the recovered metals.

(c) Fly ash and by-products from the scrubber/baghouse operations are separately conveyed and introduced into the bottom ash stream, downstream of the ferrous recovery operation. Contamination of the ferrous metals with fly ash is thereby avoided.

(d) The combined bottom and fly ash material is stored in a bunker or on a working floor for a period of time, and water is then allowed to drain out of the ash pile.

Typically the ash management and metals recovery systems are located inside a fully enclosed ash containment building consisting of the following primary systems, with various support services:

(a) Undersize and oversize material separation.
(b) Oversize material reduction in a shredder.
(c) Ferrous metals recovery.
(d) Ferrous metals washing.
(e) Ferrous transport loading.
(f) Fly ash storage and conditioning.
(g) Combined ash storage.
(h) Ash water drainage and recovery.
(i) Ash transport truck loading.

The bottom ash is conveyed from the furnaces by means of existing submerged drag chain conveyors and discharged onto a vibrating conveyor provided with an integral grizzly section. The size separation at this typical facility is selected at 4 in. The "grizzlies" are metal fingers with slots that vary in width from 2 in. to 4 in., which separate material by size, with undersize ash and metals dropping through the slots while oversize material is transported over the vibrating fingers.

The plus 4-in. material is discharged from the grizzly into an intermediate or surge storage area. From the surge pile the oversize material is conveyed either by front end loader or overhead bridge crane with clamshell bucket to a shredder.

The metal shredder selected is a slow speed high torque type requiring low energy use, and is hydraulically driven. The slow speed shredder is capable of shredding white goods, automobile body parts and light metal sections. The shredder has design features that stop the machine to prevent rotor damage when hard-to-shred materials such as engine blocks, axles, I beams, etc. are inadvertently introduced into the shredder. These items are picked out using an overhead jib crane. The shredding system includes a feed hopper, and a

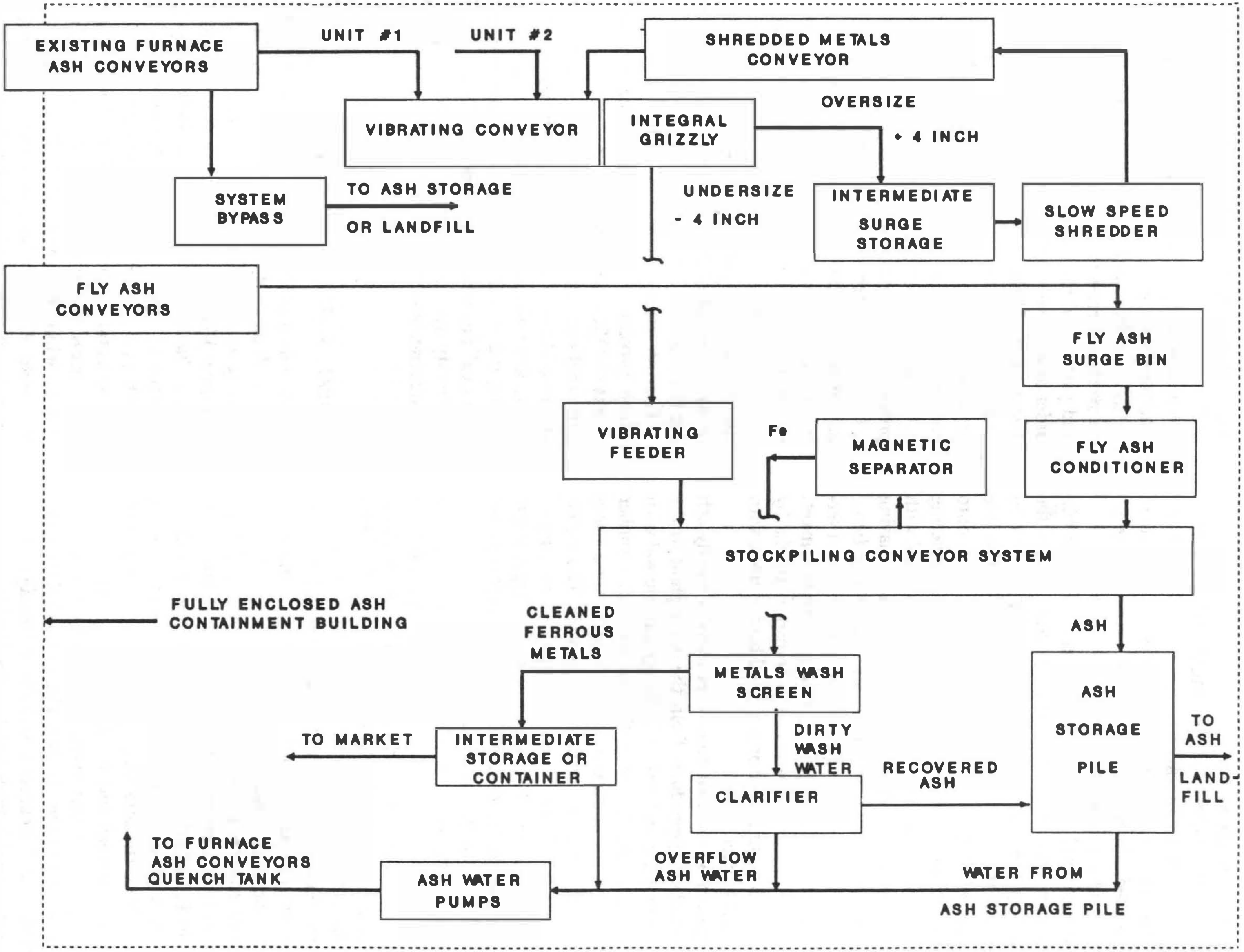

FIG. 1 SIMPLIFIED FLOW DIAGRAM

metal pan conveyor for returning the shredded metal to the residue vibrating conveyor. The shredded metal is then removed by the magnetic separation process and cleaned in the screen.

The minus 4-in. material passing though the grizzly is discharged to a vibrating feeder, which then feeds the material onto a stockpiling belt conveyor. The benefit of using a feeder is to protect the belt from damage by sharp metallic pieces.

Ferrous metal is recovered by means of a high efficiency belt type magnetic separator located over the stockpiling belt conveyor head pulley. The preferred arrangement is for the magnet to be installed in-line with the belt. The recovered metal is gravity fed onto a special wash screen system to remove the adhering ash from the metal. The wash screen is horizontal with the vibrating screen deck in two stepped panels having ¼-in. diameter round openings, and with spray bars/nozzles at the leading edge of each panel. Cleaned ferrous metals discharge directly into a separate bunker. The metals are then loaded onto transport trucks by either a front end loader or overhead bridge crane with clamshell bucket.

A system of enclosed conveyors transfer the fly ash and scrubber by-products from the main plant to the independent ash and residue building for disposal with the bottom ash. Typically the fly ash and scrubber by-products are conveyed in a dry bulk state using either drag conveyors or screw conveyors. These conveyors are totally enclosed. Pneumatic conveying of these materials is discouraged due to the hygroscopic nature of the materials as well as due to higher power requirements for pneumatic conveyors.

An ash surge bin is provided with a dust collector, a bin activator and ash conditioner. The bin receives fly ash and scrubber by-products from the (drag chain) conveyor and feeds the material at a controlled rate into the conditioning system. Conditioned ash is discharged via a screw conveyor and combined with the bottom ash downstream of the magnetic separation station on the stockpiling belt conveyor.

Water from the stockpile is drained via sloped flooring and floor trenches into a water collection sump. The stockpiled ash filters the entrained water and the water is relatively clear in the sump. The dirty water, washed from the screening operation, has a high percentage of fine ash and fine metals. Therefore, the system includes a clarifier to remove the solids which settle rather rapidly in the clarifier. The clarified clear water overflows and discharges into the floor drainage system. The ash material settles in the clarifier and is then conveyed by the clarifier drag conveyor to the ash storage area where it is combined with the bottom ash.

A heavy duty slurry type pump is utilized to transfer the water back to the gravity tank of the existing water submerged drag chain conveyors. This recycling of water eliminates discharges of water from the plant facility.

The combined ash materials, bottom ash, fly ash and clarifier discharge, are stockpiled either on a floor area by use of a front end loader or in a bunker by use of an overhead crane with clam shell bucket. Intermediate and partitioned material storage areas are provided in order to segregate the clean metal for the resale market. The capacity of the storage areas are sized for a minimum of 3 days of the production capacity for each material. The handling of the materials in bunkers with remotely operated heavy duty overhead travelling crane with hydraulically operated clamshell bucket provides a cleaner and more manageable operation than a front end loader. The materials are stockpiled for a day or two to allow water to drain out, and then the ash is loaded into trucks by the same equipment used for storage. A truck scale is provided to accomplish precise weighing of trucks before they leave the facility site. A loading hopper is provided to contain materials being loaded into trucks and spillage is prevented during the loading operation.

The ash management facility has several features which protect the environment. The movement of trucks and the loading of ash and metals into the transport trucks are completely contained inside the building. In addition, truck washing facilities are provided.

The ash management facility has flexibility for operating the system with built-in bypass arrangements at critical material transfer points. This ensures that the facility systems are functional during equipment maintenance periods.

FERROUS METAL MARKET

The selling price of ferrous metal scrap to the end user (such as steel mills and foundries) is determined by using as a guideline the published metal prices in *American Metal Market Prices* and other publications such as *Business Week*. For June 1991, the published price for #1 grade ferrous metal scrap was $95 per gross ton (of 2240 lb) or $85 per short ton (of 2000 lb). For the metal scrap generated from the waste incineration process, the quality of metal is #2 grade or less and the selling price is typically 15–20% less than the #1 grade. We have also discovered in discussions with a number of scrap dealers both in Michigan and in the New York area that the cleanliness of the metal scrap is of prime importance, particularly in regard to the adhering ash. Theoretically, the metal scrap generated from the MSW combuster, which is cleaned to the extent that there is no adhering ash, can be sold to the end user as a #2 grade metal at a range of $75–80/gross ton by the scrap dealer. Thus the price of the incineration produced ferrous metals would be in the range of $50–60/short ton at the MSW plant. To illustrate the economic justification, we have used a selling price of $50/short ton for recovered ferrous metal to the scrap dealer, F.O.B. facility site.

ECONOMIC JUSTIFICATION

The financial analysis is based on capital cost projections and reasonable assumptions made for the ash stream compositions, plant availability, cost for hauling and landfilling, operating and maintenance expenses, metal recovery factors and interest rate.

Thus economic justification for an improved MSW combustion plant ash handling and processing facility may be realized from the following sources:

(a) Revenues from recovered ferrous metals marketed at a high value, in the range of $50–60/short ton.

(b) Cost savings from reduced quantities of ash, reduced by the weight of metals recovered (in the order of 4–7%) and reduced by the amount of water drained from the ash stockpile (in the order of 5%). These costs savings result in:

(1) Reduction in hauling costs to the landfill.
(2) Reduction in ash landfill tipping fees.

The combined savings may be in the order of $70–120/ton.

Cost savings in MSW combustion plant operations may also be realized where the ash is continuously loaded into trucks or containers. That is, ash truck loading (and possible hauling) operations would change from a 24 hr, 7 day/week operation to a day shift and 5 day/week operation. The savings may be as much as the cost of five tractor-trailers plus five operators, depending upon the plant operations.

It should be noted that community recycling programs may influence economic justification factors for an ash management facility. Curb-size collection of tin cans will result in a small decrease in ferrous metals quantities. A mechanical/manual separation of combined delivered solid waste at a front-end material recycling facility may significantly reduce ferrous metals in the ash.

Two methods are used to evaluate the economic viability of a project over a 20-year economic analysis period.

(a) NPV (Net Present Value)—which is the sum of all cash outflows and inflows discounted at the cost of capital. Positive NPV indicates an economic incentive to proceed with the investment.

(b) IRR (Internal Rate of Return)—which is the discount rate that equals the present value of the future stream of cash inflows with the initial investment cost. If the IRR is above the cost of obtaining the capital, the project is economically justified.

Data used for the evaluation is summarized as follows:

(1)	Projected Capital Cost.	$6,000,000
(2)	Projected Yearly Operating and Maintenance Cost.	$500,000 Escalation 3%
(3)	MSW incinerated per day.	900 tons
(4)	Plant operating hours/per year (365 days at 24 hr/day).	8760 hr
(5)	Plant availability.	85%
(6)	Ash transportation costs to landfill.	$10/ton (1991) Escalation 5%
(7)	Ash landfilling costs.	$50/ton (1991) Escalation 5%
(8)	Selling price of clean ferrous metal.	$50 per ton (1991) Escalation 3%
(9)	Financial evaluation period.	20 years
(10)	Debt interest rate.	8%
(11)	Bottom ash content in waste stream inclusive of ferrous metal.	25%; equivalent—0.25 ton/ton of MSW
(12)	Ferrous content in waste stream.	6%; equivalent—0.06 ton/ton of MSW (Sensitivities analyzed for 4% and 5% also)
(13)	Ferrous metal recovery rate utilizing shredding system.	90%
(14)	Water added in drag conveyors.	40% of bottom ash; equivalent 0.4 × 0.25 ton/ton of MSW or 0.10 ton/ton of MSW

(15) Water recycled.	50% of total water in bottom ash i.e. 0.5 × 0.10 ton/ton of MSW or 0.05 ton/ton of MSW

(Assumption: 50% reduction in water going to landfill compared with an ash system not utilizing water recirculation system)

The data was analyzed for the selected ferrous metal content sensitivities utilizing a computer based financial model using the following equations and the escalation factors:

(a) MSW (TPY).	MSW (TPD) × 365 (DPY) × Plant Availability (%)
(b) Ferrous Material Recovered (TPY).	MSW (TPY) × Ferrous Metal in MSW (%) × Ferrous Metal Recovery Rate (%)
(c) Ferrous Metal Revenues per year.	Ferrous Metal (TPY) × Selling Price Clean Metal (dollars per ton)
(d) Ash Reduction to Landfill (TPY).	MSW (TPY) × [Reduction Water (%) + Reduction Ferrous Metal (%)]
(e) Yearly Savings realized in Ash Transportation Costs.	Ash Reduction to Landfill (TPY) × Ash Transportation Costs to Landfill (dollars per ton)
(f) Yearly Savings realized in Ash Landfilling Costs.	Ash Reduction to Landfill (TPY) × Ash Landfilling Costs (dollars per ton)
(g) Net Yearly Savings realized.	Yearly Saving in Transportation Costs + Yearly Savings in Landfilling Costs.
(h) Net Yearly Benefits realized from the Metal Recovery and Water Recirculation Operations.	(Ferrous Metal Revenues + Net Savings) − Operating Costs (O&M)

TABLE 1

	FERROUS METAL CONTENT		
	4%	5%	6%
Financial Analysis Period	20 Years	20 Years	20 Years
Investment ($ million)	$6.0 M	$6.0 M	$6.0 M
Plant Availability	85%	85%	85%
Ferrous Recovery	90%	90%	90%
MSW incinerated per year (tons)	279,225	279,225	279,225
Water recirculated (as % of incoming waste)	5%	5%	5%
*Ferrous metal recovered per year (tons)	10,052	12,565	15,078
*Revenues from ferrous metal sales per year	$502,600	$628,250	$753,900
*Water not sent to landfill per year (tons)	13,961	13,961	13,961
*Transportation Savings from water not sent to landfill per year	$139,610	$139,610	$139,610
*Transporation Savings from ferrous metal not sent to landfill per year	$100,520	$125,650	$150,780
*Landfilling savings from ferrous metal and water not sent to landfill	$1,200,650	$1,326,300	$1,451,950
*Net annual savings (ferrous metal plus water)	$1,943,380	$2,219,810	$2,496,240
*O&M annual costs	$500,000	$500,000	$500,000
*Net annual benefit (Revenues + Savings - O&M Cost)	$1,443,380	$1,719,810	$1,996,240
NPV (Net Present Worth in millions)	$15.8 M	$19.6 M	$23.5 M
IRR (Internal Rate of Return)	29.9%	34.7%	39.5%

*Given for first year of full operation only for illustrative purposes; assumed 1991.

CONCLUSION

Incorporating enhancements to improve the quality and value of ferrous metals recovered from ash management facilities, with reduction in the volume of ash required to be landfilled, may be justified economically in mass burn plants located near industrial areas.

The illustrated economic benefits realized indicate positive Net Present Value (NPV) and attractive Internal Rates of Return (IRR). IRR may be in the order of 30% to 40% with a payback period in the order of 3½ to less than 3 years, depending on the amount of ferrous metals present in the waste stream. The illustrated ash facility configuration and related costs are based on experience factors.

In addition, a self contained ash management facility is environmentally superior. Prior to implementation of a program such as we have illustrated, we recommend that a thorough evaluation be undertaken to include factors unique to a given location, such as: landfilling costs, ferrous metal content in the MSW, transportation to market, the type of present ash extraction and fly ash handling systems.

REFERENCES

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SI UNIT CONVERSION FACTORS

APPENDIX A ENGINEERING UNITS

Physical Quantity	English Unit		SI Units
Mass	Pound: 1 lb	=	0.45359 kg
	Ton or short ton: 1 ton	=	907.18 kg
	Gross ton: 1.12 ton	=	1016.04 kg

APPENDIX B ABBREVIATIONS

Abbreviation	Description
TPY	Tons per year
TPD	Tons per day
DPY	Days per year

Key Words: Bottom Ash; Fly Ash; Municipal Solid Waste (MSW); Ferrous Metal Recovery; Mass-Burn Incineration; Waste-to-Energy (WTE)