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ASME/US BUREAU OF MINES INVESTIGATIVE PROGRAM ON VITRIFICATION OF COMBUSTION ASH/RESIDUE

— Findings and Conclusions —

HERBERT I. HOLLANDER
Hollander Associates
Wyomissing, Pennsylvania

ARTHUR L. PLUMLEY
ABB Combustion Engineering
Windsor, Connecticut

ROGER S. DE CESARE
U.S. Bureau of Mines
Washington, D.C.

ABSTRACT

Vitrification of the residues from thermal processes into a dense, grainless, amorphous, glasslike material may provide an opportunity to permanently relieve our concerns regarding aquifer contamination and . . . if the vitrified products are utilized, conserves those land areas which are suitable for disposal for those discards for which we have not as yet found a practical use.

This discussion briefly describes and illustrates the implementation of the $1.2 million ASME/BuMines investigative program; the scope and methods followed, equipment systems employed, areas of investigation, findings and conclusions in determining the potential effectiveness of sequentially vitrifying significant quantities of ash/residue from three different types of mass burning municipal solid waste energy recovery facilities, a regional wastewater treatment plant sludge combustor, and air quality control products from a large refuse derived fuel energy recovery facility while utilizing for this purpose a fraction of the electric energy recovered; identifying potential beneficial applications for the resulting products, the environmental implications and projected overall economics.

PERSPECTIVE

In view of ever diminishing and more remote land areas considered suitable for final disposal of materials judged to have no further use and the perception that residues from thermal processes, albeit free of putrescibles, are comprised primarily of inorganics, mineral matter, which may leach, however slightly, and may eventually contaminate aquifers, in addition to stabilization or fixation for land disposal options for utilization are also available.

Conversion of combustion residues of wastes from production and consumption into useful products which might be absorbed into our economy would relieve these environmental concerns and perhaps provide new economic development opportunities.

Vitrification of the residues from thermal processes into a dense, grainless, amorphous, onyx-like material, may provide an opportunity to permanently relieve concerns regarding aquifer contamination, and if the vitrified products are utilized, this process would conserve those land areas which are suitable for disposal for those discards for which we have not as yet found a practical alternate use.

Proof-of-concept melting trials at the Bureau of Mines Rolla Missouri Research Center revealed that the vitrified products from the combined combustion residues from the Chicago NW Waste-to-Energy Facility were amorphous, environmentally benign, as much as 3 times denser than the original residue and had the potential for several beneficial uses, in lieu of burial and potential future liability.

As a consequence, the American Society of Mechanical Engineers Research Committee on Industrial and Municipal Waste commenced in 1986 to plan and solicit sponsorship for a commercial scale demonstration of vitrification technology in an electric arc furnace facility located at the US Bureau of Mines Albany Oregon Research Center (BuMALRC).

US DOE and the New York State Energy Research & Development Authority (NYSERDA) agreed to provide significant funds for this investigation, but only on a cost sharing basis . . . thereby assuring recognition of need for the program by affected users and the technical community.

INTRODUCTION

This program was prompted by public concern regarding potential leachability of combustion residues and the yearning for recycling.

The American Society of Mechanical Engineers Center for Research and Technology Development and the U.S. Bureau of Mines through cooperative agreements that included over 30 government and industry sponsors, conducted over 200 hours of melting tests to vitrify ash/residues from five state-of-the-art municipal waste combustion facilities. Program participants included industry and government researchers, furnace suppliers and operators, academics, solid waste industry professionals, implementing entities, regulatory agencies and private engineering consultants.

The following charts illustrate the diverse interests of the program participants and sponsors which provided objectivity, a broad range of experience, vantage points and concerns. The Program Implementation Diagram illustrates the major roles of participation and the sequence of events.

The residues for this melting program included dry combined grate and air quality control equipment residues from three mass burning waste-to-energy (WTE) plants, dry combined residue from a multiple hearth wastewater treatment plant (WWTP) sludge combustor, and dry acid gas absorber baghouse residues from a modern WTE plant burning refuse derived fuel.

An electric arc melting furnace having water-cooled roof and sidewalls, a modified power supply, furnace feeding and fume emission control systems were constructed at BuMALRC specifically to feed and continuously melt up to one ton/hour of combustion residues and permit the vitrified products to be continuously tapped from the furnace all within stringent environmental requirements. The melting program commenced with short test runs to define operating procedures and culminated in a 100 hour operating campaign in which 54,000 pounds of combustor residues were melted.

In addition to the +6000 analyses conducted by the BuMines laboratories, the ABB-CE laboratories conducted the many TCLP analyses on the residue received and the resulting furnace products; under the direction of Environment Canada, AMTEST extensively characterized the many samples they had taken at various locations in the fume exhaust system; the Oregon DOT conducted analyses on the vitrified products to assess their potential use as road construction aggregate. This extensive data is assembled and correlated in the ASME/BuMines comprehensive report of this program.

ASME RESEARCH SUBCOMMITTEE ON ASH VITRIFICATION

Arthur L. Plumley, Ph.D., Co-Chairman, Executive Consulting Engineer, ABB Combustion Engineering Corp., Windsor, Connecticut

David A. Hoecke, Co-Chairman, President, Enercon Systems, Inc., Elyria, Ohio

Roger S. DeCesare, Environmental Research, U.S. Bureau of Mines, Washington, D.C.

Simon Friedrich, Program Manager, U.S. Department of Energy, Washington, D.C.

Herbert I. Hollander, Consultant, Hollander Associates, Wyomissing, Pennsylvania

Carl D. Kolts, Marketing Manager, UCAR Carbon Company, Inc., Clarksville, Tennessee

J. Kenneth Wittle, Ph.D., Vice President, Electro-Pyrolysis, Inc., Wayne, Pennsylvania

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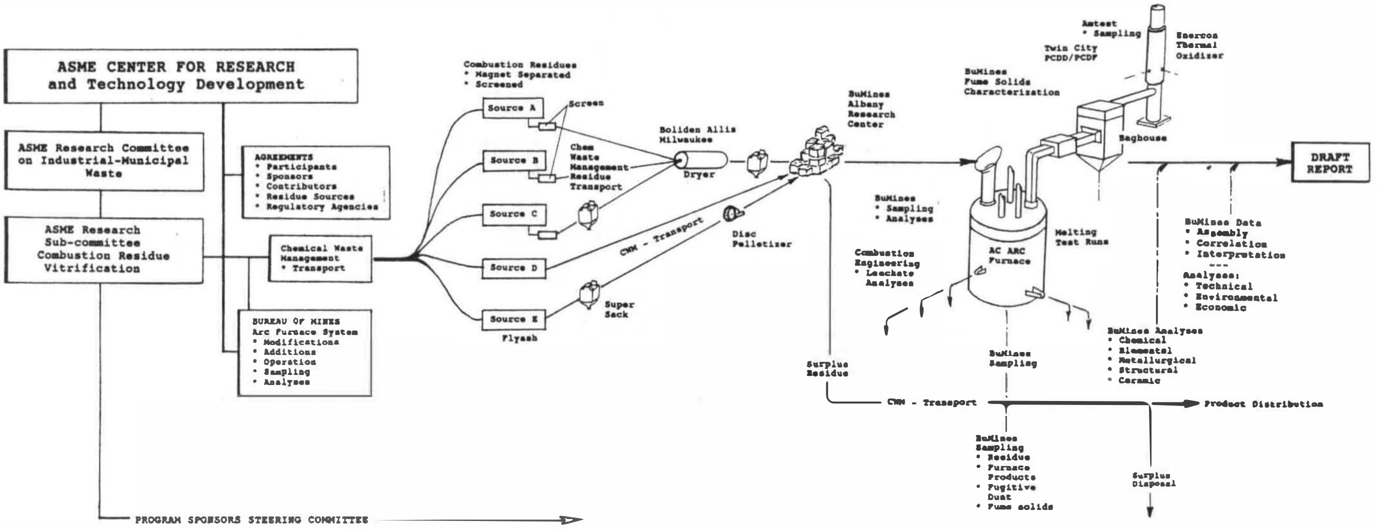

PROGRAM IMPLEMENTATION DIAGRAM

Government & Other Sponsors

ASME's Board of Governors
ASME's Board on Research and Technology Development
ASME's Research Committee on Industrial & Municipal Waste
ASME's Solid Waste Processing Division
Connecticut Resources Recovery Authority
Dutchess County Resource Recovery Agency
Environment Canada
Electric Power Research Inst.
Idaho National Engineering Laboratory
U.S. Federal Highway Administration
Monroe County Division of Pure Waters
National Renewable Energy Laboratory
New York State Energy Research & Development Authority
U.S. Bureau of Mines
U.S. Department of Energy
U.S. Environmental Protection Agency

PROGRAM IMPLEMENTATION FACILITIES AND PROCEDURES

- Combined grate and air quality control equipment residues from different types of state-of-the-art mass burn MSW WTE plants were collected, screened, dried, bagged, and shipped to the melting facility at the BuMines Albany Research Center, Oregon. Particulate emissions from drying each residue were collected in a baghouse and combined with the dried residue product prior to bagging and shipment. Exhaust from the baghouse was also monitored.
- The combined dry residue from a regional wastewater treatment plant sludge combustor, and the dry residue from the dry acid gas absorber of a WTE plant burning RDF were double bagged and shipped directly to the BuMines melting facility.
- The melting facility was comprised of a feed system, electric arc furnace system, fume emissions control system and water cooling tower, Figure 1 — Process System Schematic. The residue feed conveyor system with interim storage and metering bins provided continuous feeding to the furnace of one inch screened residues with densities averaging 80 lbs/cu ft at rates up to 2000 lbs/hr.
- A stationary, sealed, refractory-lined arc melting furnace with a 5 cubic foot hearth, water-cooled walls, roof and air-cooled bottom, was constructed, and an existing 3 phase, 800 kVA power supply was modified to provide the higher voltage anticipated for effectively melting the combustor residues. The furnace was fitted with a water-cooled copper tapping fixture, for continuous tapping of vitrified product. The inventory of molten metal was withdrawn through the lower taphole at the furnace hearth floor — Figure 2. (Plumley — Progress Report 92), (Hartman-BuM RI-9476)
- The emissions control system was designed to accommodate 125 to 250 scfm of furnace exhaust since with a sealed furnace having no air introduced it was difficult

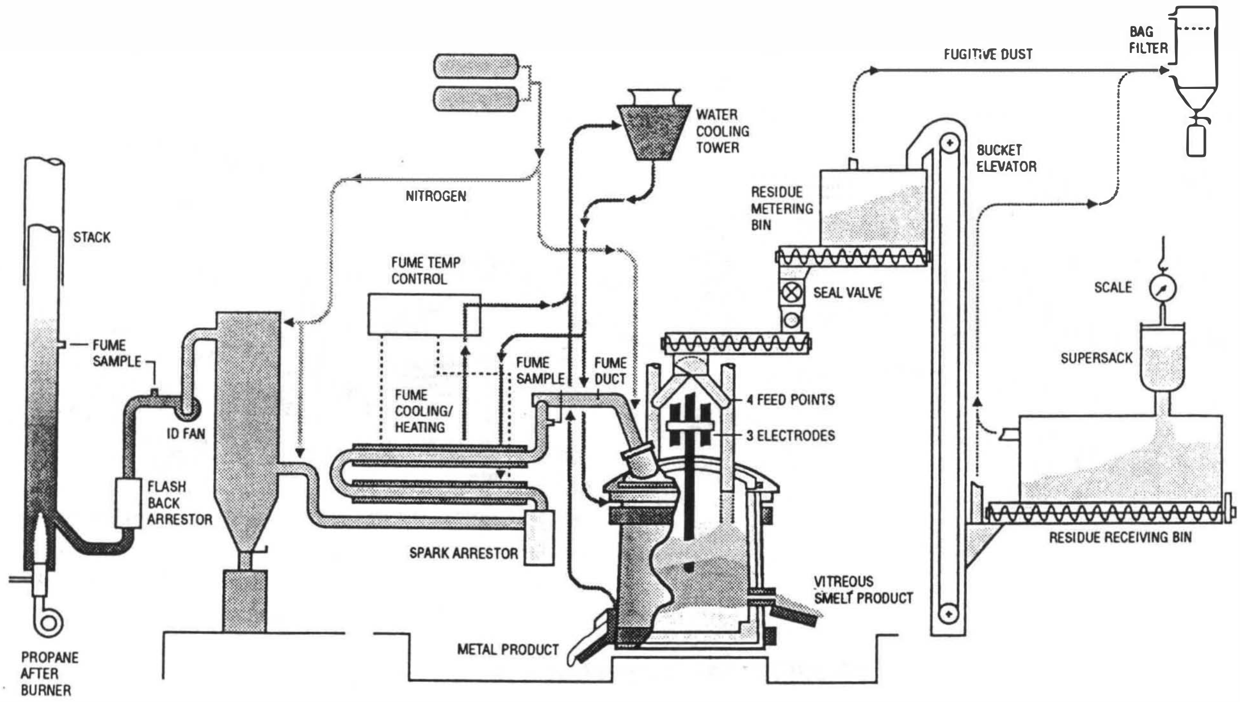

FIG. 1 PROCESS SYSTEM SCHEMATIC

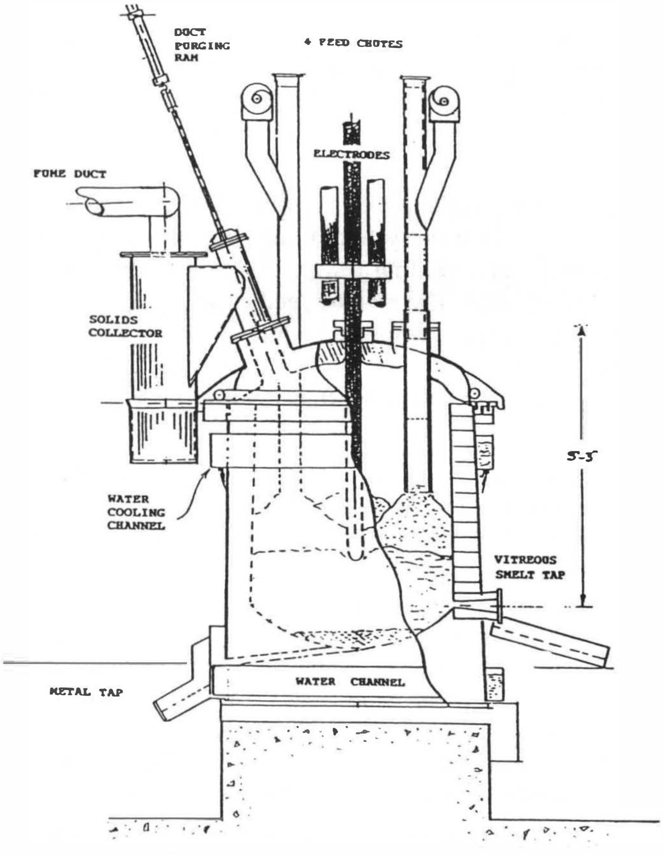

FIG. 2 SPECIAL ELECTRIC ARC FURNACE

to predict the volume of fume to be encountered. The system consisted of a cleanable six inch duct, baghouse, 123,000 Btu/hr heat exchanger to assure exhaust fume temperatures can be held within a prescribed range to protect the baghouse; a lime injection system for acid gas control since some volatilized chloride and sulfur salts were to be expected, and since this facility was adjacent to a high school within the City of Albany, Oregon a thermal-oxidizer system to provide one second residence time at 1800F was incorporated in the stack to assure absolute control of any remaining trace emission constituents of concern.

- To assure safe operation, inerting nitrogen gas was injected into the fume system to limit oxygen concentration below 5% thereby avoiding possible formation of a flammable gas mixture.

METHODS AND FINDINGS

- The emissions monitoring program and sampling parameters are illustrated schematically on Figure 3. The program schematic for obtaining analytical samples is illustrated on Figure 4.
- The dried, screened, as-received residues were extensively characterized by BuMALRC to determine physical properties and chemical composition — Table 1 and Table 2. Of particular interest is the broad range in

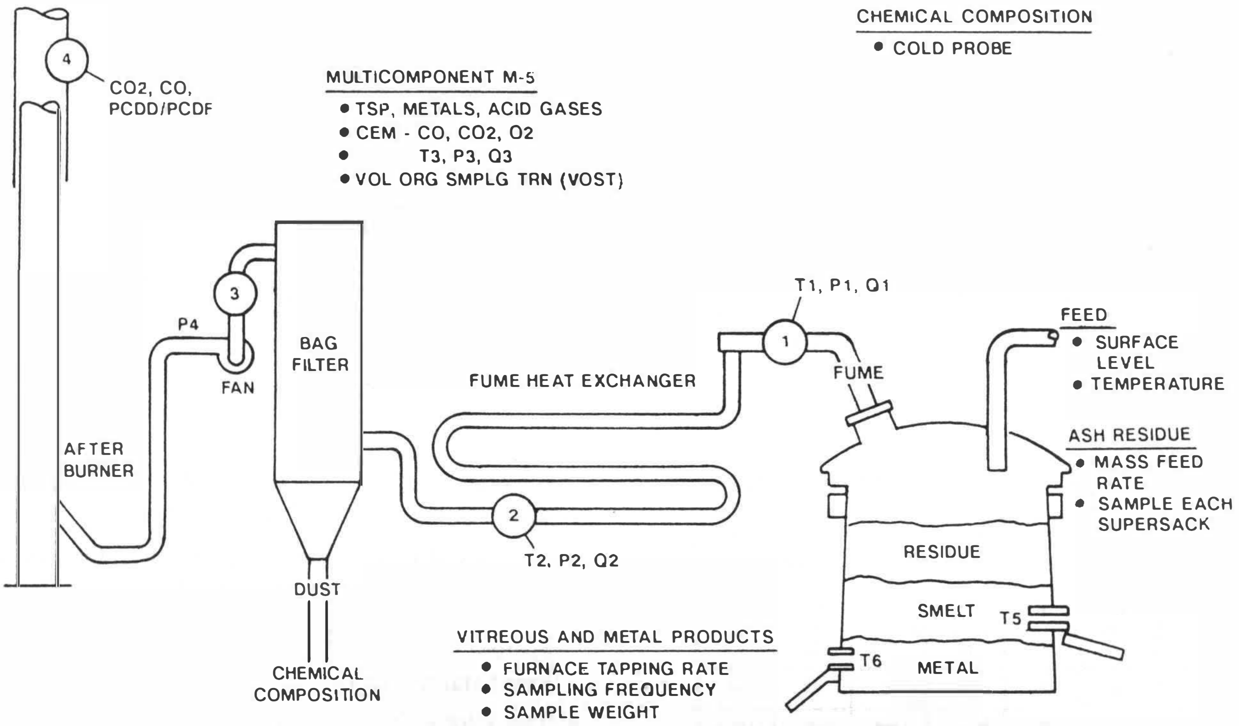

FIG. 3 EMISSIONS MONITORING PROGRAM AND SAMPLING PARAMETERS

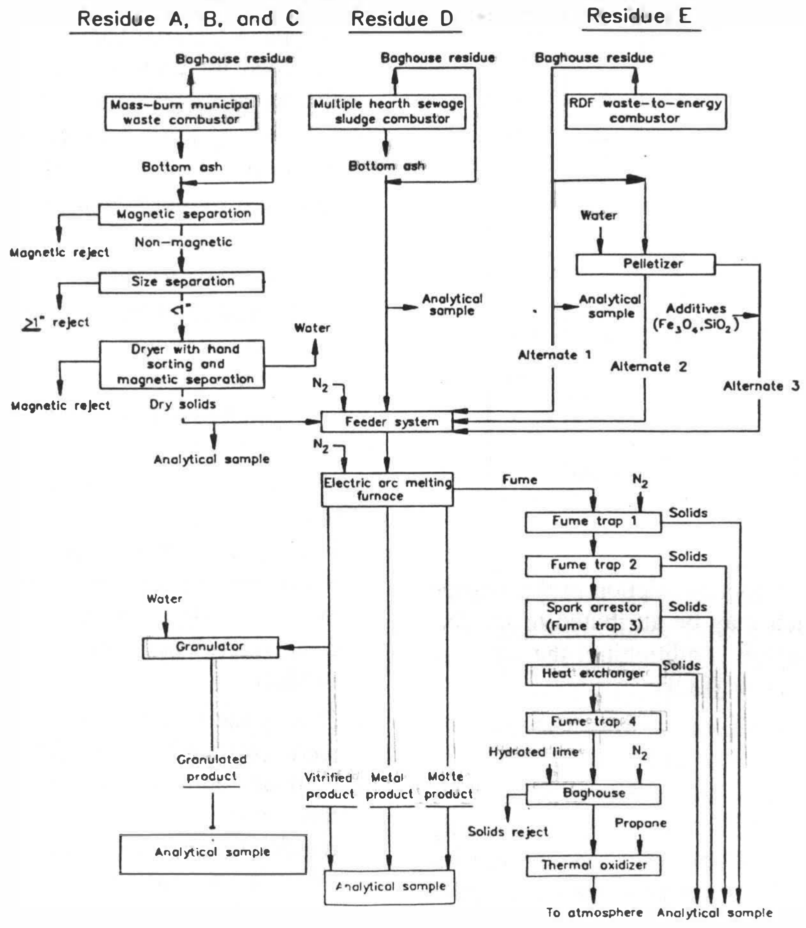

FIG. 4 SCHEMATIC PROGRAM — ANALYTIC SAMPLING

TABLE 1 PHYSICAL PROPERTIES OF RESIDUES*

Residue	Moisture% (1)	LOI% (2)	Magnetic,wt%	Nonmagnetic,wt%	Bulk Density
A	1.54%	5.66	10.2	89.8	1.25 g/cm3 or 78 lb/ft3
B	1.38%	1.44	17.4	82.6	1.74 g/cm3 or 109 lb/ft3
C	0.92%	2.51	12.7	87.3	1.14 g/cm3 or 71 lb/ft3
D	0.42%	0.71	51.9	48.1	0.50 g/cm3 or 31 lb/ft3
E	1.58%	5.22	2.7	97.3	0.65 g/cc/cm3 or 40 lb/ft3

(1) 105^{o} for 12 hr (2) 1000^{o} C for 1 hr

TABLE 2 CHEMICAL COMPOSITION OF RESIDUES

	Residue Concentration, ppm (mg/kg)					
Element	A	B	C	D	E-1	E-2
Ag	16	10	28	217	14	8
As	34	32	40	8	54	31
Ba	809	729	517	1294	544	31076
Br	28	73	86	8	660	376
Cd	26	21	46	24	69	39
Cr	232	324	238	1371	194	111
Hg	6	3	13	<1	20	11
Mo	<50	<50	<50	<50	<50	<50
Ni	259	257	219	404	296	169
Pb	4094	3801	2171	211	1940	1106
Sb	142	105	192	16	405	231
Se	2	<1	1	8	11	6
Sn	257	210	245	<200	200	114
Zn	4160	3142	5900	2209	5203	2966

E-1: Residue E without additives
E-2: Residue E with additives

Each of the values listed for Residues A, B, and C is the arithmetic mean of four individual analyses of bottom ash, combined with the correct percentage of dryer baghouse dust.

bulk density; the high magnetics fraction in the sewage sludge ash/residue which may be attributed to the ferric chloride used for sludge conditioning; the range in residual combustible content (LOI).

- Preliminary melting trials of up to 18 hours were conducted to refine operating procedures.
- Although the dry baghouse dust residues as received from the RDF burning WTE plant was successfully melted during the early melting trials, for the continuous melting campaign they were pelletized to simplify material handling, and iron oxide and silica sand were added to better control thermochemical reactions.
- During the 100 hour melting campaign the five municipal waste combustor residues were melted sequentially to determine the technical and operational feasibility of electric arc melting, and provide vitrified products for beneficial use evaluation.
- The vitrified products were continuously tapped while the slowly accumulated inventory of metal was tapped intermittently from the furnace hearth.
- A typical material balance across the furnace system is provided for each source of residue in Table 3 and is illustrated graphically on Figure 5.
- In general, melting of MWC residues, WWTP sludge combustor residue, as well as the RDF baghouse residue produced five principal products:

Vitreous Product	up to 86%
Metallic Product	up to 7%
Matte Product	up to 2%
Fume Solids	up to 5%
Baghouse and Gas Solids	

- The combined MWC residues and the baghouse residue with iron oxide and silica additions produced dense black glassy vitrified products similar to obsidian or basalt not unlike some forms of volcanic lava. The WWTP sludge combustor residue melted at a lower temperature and produced a predominantly crystalline product
- During the melting test of Residue A the fume solids were collected during the first 8 hours and recycled gradually into the system residue receiving bin to enhance mixing with the fresh feedstock. The combination residue and recycled fume solids were melted during the following 8 hour period.
- The chemical composition of the furnace products, including vitrified material, interface surface metal sulfide (matte), metal, and fume exhaust solids, are provided in

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*Tables 1–10 were abstracted from Ash Vitrification Main Report.

TABLE 3 MATERIAL BALANCE OVER ELECTRIC ARC MELTING FURNACE

	Residue A		Residue B		Residue C		Residue D		Residue E*	
Product	Wt, lb	Wt, %	Wt, lb	Wt, %	Wt, lb	Wt, %	Wt, lb	Wt, %	Wt, lb	Wt, %
Vit. Prod.	20261	78.0	6067	83.4	3717	68.7	11478	86.4	897	86.3
Metal	1622	6.2	357	4.9	382	7.1	93	0.7	0.0	0.0
Matte	186	0.7	64	0.9	118	2.2	22	0.2	0.0	0.0
Fume Traps	661	2.5	129	1.8	239	4.4	108	0.8	90	8.7
Baghouse	2497	9.6	479	6.6	727	13.4	1388	10.4	0.0	0.0
Exhaust Gas	751	2.9	182	2.5	225	4.2	199	1.5	52	5.0
Total	25978	100.0	72782	100.0	5408	100.0	13288	100.0	103.9	100.0

* with additives (mill scale and silica sand)

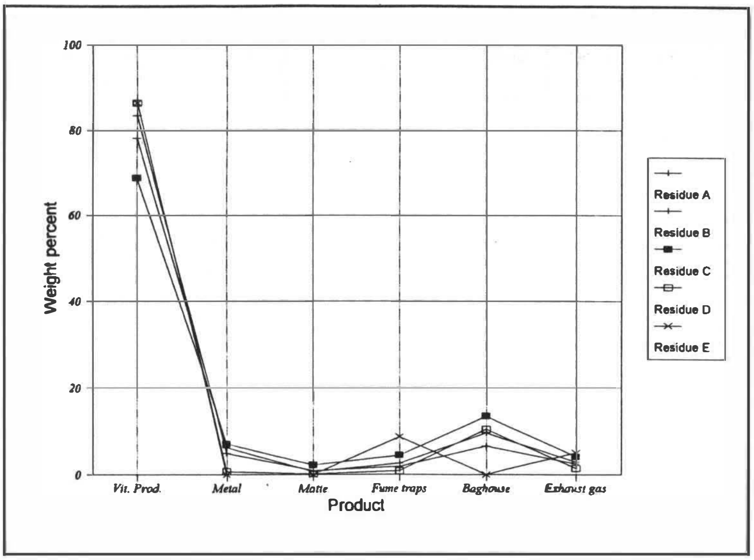


FIG. 5 MATERIAL BALANCE OVER ELECTRIC ARC MELTING FURNACE

Table 4 without recycled fume solids, and in Table 5 with recycled fume solids.

- As is common in such demonstration programs, for one reason or another frequent unscheduled interruptions were experienced. Consequently the actual steady state test runs on each residue were quite short. Establishing and maintaining furnace equilibrium on each residue for more than relatively short periods was very difficult. Nevertheless the furnace was forgiving, yielding relatively uniform melt products in spite of the erratic conditions encountered.
- The electric power required to melt the residues was influenced significantly by mechanical/operational factors. Periods of furnace down time, slowing feeding rates yet keeping the furnace at temperature, and thermochemical reactions within the furnace increased the power consumption. During periods of uninterrupted (though not necessarily steady-state) operations, the operating power ranged from 616 to 1040 kWh/ton. (This variation is believed to result largely from intermittent furnace operation encountered and the non-equilibrium thermal conditions experienced prior to the measurement.) The project furnace designer estimates that at a residue feed rate of 1300 pounds per hour an optimally designed furnace system of this size and type could reduce power consumption to as low as 500 kWh/ton under normal continuous operation for most types of combustion residues. This rate of power usage would range from 1/3 to 1/5 of that which can be produced from the energy recovered from burning the amount of municipal waste corresponding to the amount of residue being vitrified.
- A typical characteristic plot of furnace power input is illustrated on Figure 6.

TABLE 4 COMPOSITION OF FURNACE FEED AND PRODUCTS RESIDUE A WITHOUT RECYCLE OF FUME SOLIDS

Element	Feed	Vit. Prod.	Metal	Matte	Fume
Ag	16	2	30	2580	132
As	34	1	388	18	127
Ba	809	1089	27	333	389
Br	28	<0.6	NA	NA	2191
Cd	26	3	48	16	354
Cr	232	703	1088	6293	146
Hg	6	1	1.5	<1	6
Mo	<50	<50	384	<50	<50
Ni	259	25	4454	805	74
Pb	4094	53	156	42100	50414
Sb	142	2	NA	1700	782
Se	2	<1	220	69	11
Sn	257	<200	NA	NA	3039
Zn	4160	584	634	5300	95528

Concentration, ppm (mg/kg)

Weighted mean concentration (Appendix A.3)
NA: Not Analyzed

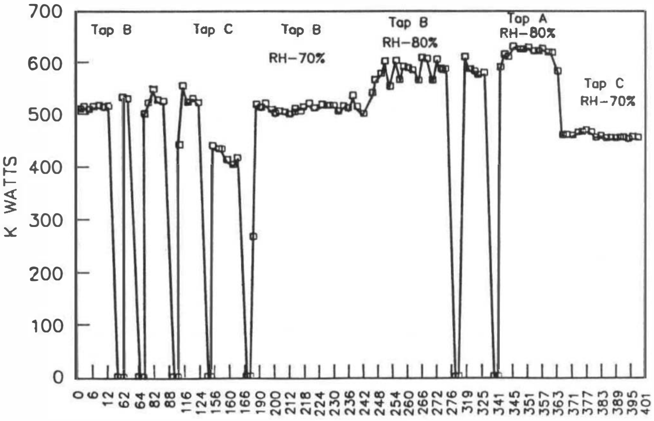
TABLE 5 COMPOSITION OF FURNACE FEED AND PRODUCTS RESIDUE A WITH RECYCLE OF FUME SOLIDS

Element	Feed	Vit. Prod.	Metal	Matte	Fume
Ag	18	2	38	117	14
As	1	421	25	112	54
Ba	804	1125	28	263	280
Br	56	<0.6	NA	NA	2397
Cd	30	2	49	16	539
Cr	231	533	1151	9842	92
Hg	6	<1	<1	<1	8
Mo	<50	<50	293	<50	<50
Ni	257	18	4051	570	47
Pb	4696	32	452	27100	69301
Sb	150	1	NA	1090	800
Se	2	<1	244	37	14
Sn	293	<200	NA	NA	2840
Zn	5348	488	466	5800	164539

Units in ppm (mg/kg)

Weighted mean concentration (Appendix A.3)
NA: Not Analyzed

- To assess environmental implications, the products from the electric furnace were tested in accordance with EPA's TCLP and a summary is provided in Table 6. The leaching potential of the vitrified products and metals were below the EPA limit for each of the eight regulated metals.
- A summary of parametric emission data on furnace fume for each residue are provided in Table 7.
- TCLP specified extracts of the small quantity of fume solids in most cases exceeded the TCLP limit for lead (Pb) and cadmium (Cd) — Table 8. Although the weight percent of fume solids were quite small, if the metals therein were to be further concentrated, these solids may then have potential as a source of raw material for recovery of Pb, Cd, and possibly zinc (Zn) and tin (Sn) or otherwise, dispose of them in accord with applicable regulations.
- Under the circumstances encountered, no attempt was made to identify and employ additives which might enhance absorption of these metal oxides into the furnace products. This activity should be included in future vitrification investigative programs.
- Thermal oxidizer-stack emissions were controlled to meet current regulatory requirements and were monitored for acid gases, metals, and dioxins. Mercury emissions were measured at the residue dryer baghouse outlet, dried residue furnace feed, at furnace fume baghouse outlet, and in all resulting furnace products. The environmental significance of the measured values is ultimately determined by the local regulatory agency.



* Chart provided courtesy of UCAR Carbon Co. Inc.

FIG. 6 TYPICAL FURNACE POWER INPUT CHARACTERISTIC

TABLE 6 RESIDUE AND VITRIFIED PRODUCT LEACHING ANALYSES—TCLP (ppm)

Parameter	Residue A Vitrified	Sludge Residue D As Recvd.	Sludge Residue D Vitrified	Flyash Residue E As Recvd.	Flyash Residue E Vitrified	U.S. EPA Critern
Arsenic	0.09	<0.09	<0.09	<0.09	<0.09	5.0
Barium	0.4	0.08	0.08	1.6	0.3	100
Cadmium	0.007	<0.007	0.001	0.06	0.007	1.0
Chromium	<0.02	0.02	0.02	0.06	0.1	5.0
Lead	0.3	0.3	0.04	8.2	0.1	5.0
Mercury	0.0005	<0.003	0.0003	0.008	0.008	0.20
Selenium	<0.07	<0.07	0.07	<0.07	0.07	1.0
Silver	<0.01	0.01	0.01	0.07	0.01	5.0

* Residue A - Modern Mass Burn WTE Plant
* Residue D - Regional WWTP Sewage Sludge Incinerator
* Residue E - Modern RDF WTE Plant: Flyash + AQC Deposits

TABLE 7 FUME SOLIDS LEACHING ANALYSES—TCLP (ppm)

Constituent	EPA Limit*	Residue A*** Conc.**	Residue A*** TCLP*	Residue B Conc.**	Residue B TCLP*	Residue C Conc.**	Residue C TCLP*	Residue D Conc.**	Residue D TCLP*	Residue E*** Conc.**	Residue E*** TCLP*
Arsenic	5.0	117	<0.1	166	<0.1	106	0.4	68	0.6	174	0.3
Barium	100.0	314	<0.1	271	1.1	273	0.08	1088	<0.1	289	0.2
Cadmium	1.0	482	16	451	8	195	0.9	207	1.4	636	4.2
Chromium	5.0	109	<0.01	155	<0.1	193	<0.1	1047	0.3	229	<0.1
Lead	0.2	63483	200.00	73923	75.00	14138	13.00	3616	8.60	58058	28.00
Mercury	1.0	7	0.001	13	0.001	2	<0.001	4	<0.001	18	0.002
Selenium	1.0	13	<0.1	13	<0.1	7	<0.1	136	0.1	30	0.1
Silver	5.0	122	<0.1	69	<0.1	122	<0.1	225	<0.1	203	<0.1

* Concentration, ppm

** Weighted mean concentration, ppm

*** Residue A with and without fume recyle

**** Residue E without additives

TABLE 8 SUMMARY OF PARAMETRIC EMISSION DATA ON FURNACE FUME

Constituent	Mass emission rate, lb/hr Baghouse inlet HCl (mean)	Baghouse inlet $S0_2$	Baghouse outlet prior to thermal oxidizer Particulate (mean)	Baghouse outlet prior to thermal oxidizer HCl (mean)	Baghouse outlet prior to thermal oxidizer $S0_2$	Baghouse outlet prior to thermal oxidizer C0*
Residue D	0.037	NA	0.001	0.002	0.17->1.89	7.3-14.7
Residue A	0.002	NA	0.003	0.007	0.27->0.67	<4.7-20.7
Residue A with fume solids recyle	0.008	NA	0.001	0.003	>0.36->0.82	<1.4-<25.1
Residue B	0.683	0.52	0.001	0.0004	>0.56->1.2	<7.4-9.7
Residue C	0.045	NA	0.001	0.002	0.07-0.24	>37-37.2
Residue E with additives	2.21	NA	0.007	1.64	0.21	17.0

NA: Not Analyzed
*After Thermal oxidizer, C0~02 ppm during steady state operating period

TABLE 9 ASTM AGGREGATE TESTING DATA

Residue	Unit Weight (lb/ft3)	Sodium Loss Coarse	Sulfate (percent) Fine	Course Spec. Gravity		Fine Spec. Gravity		Abrasive Wear (Percent)	Potential Quantity Sc*	Reactivity Quantity Rc**	Sand Equivalent (percent)
				Bulk (lb/ft3)	Absorption (percent)	Bulk (lb/ft3)	Absorption (percent)				
A	89.0	1.5	1.9	168.72	0.30	166.22	0.87	42.2	28	74	92
B	99.0	0.5	1.8	182.46	0.22	180.59	0.60	35.9	22	37	95
C	88.0	0.4	1.1	163.09	0.48	164.97	0.77	38.5	16	65	95
D	102.8	0.3	1.3	190.59	0.27	188.71	0.58	41.9	56	69	93
E	90.2	0.8	1.2	174.34	0.26	174.97	0.36	39.6	7	110	95

* Dissolved silica, millimoles/liter
** Reduction in alkalinity, millimoles/liter
Coarse aggregate: plus 0.87 inches (+4 mesh)
Fine aggregate: 0.187 x 0.029 inches (4 x 200 mesh)

Prepared:
Oregon Department of Transportation Laboratories

Additional Notes
(1) Quantity of material crushed and tested:
20kg sample per residue source

(2) Specific molds from which samples were taken:
Residue A - Mold AV-9
Residue B - Mold BV-4
Residue C - Mold CV-5
Residue D - Mold DV-7
Residue E - Mold EV-1

(3) Equipment used to crush the samples:
7-inch jaw crusher. Two passes

The Oregon DOT Laboratories subjected the vitrified products to the appropriate ASTM tests for aggregate in Portland cement or asphaltic concretes which indicated they may be suitable even for the wearing course for roadways — Table 9.

- Other apparent uses include aggregate for flowable construction fill, road ice control, walkway or garden tiles, roofing granules, grit for air blast cleaning, and high temperature mineral wool insulation and possibly other uses. As with natural aggregate uncovered storage should be acceptable since there should be little concern regarding rainwater run-off contamination.
- Although only a small weight percent of the total . . . the "matte" fraction may have some value to metal refiners and smelters by virtue of its copper and precious metal content.
- Accumulated ingots of the ferrous fraction may be considered as a scrap resource by foundrys or minimills or municipally specified for use in non-stress applications such as fence posts, tree grates, bench or table supports, counter weights, stanchions etc.
- The cost projections in the BuMines estimate summarized in Table 10, are based upon wet residues having 20% moisture, and on installation of adjacent stand-alone electric furnace equipment systems each having independent air quality controls. Assuming an electric power cost of 5 cents/kWh, depending on system capacity, the calculated owning and operating costs range from $98/residue ton for a plant processing 350 tpd of MWC residue to $175/residue ton for a plant processing 60 tpd of residue.
- These costs when expressed as additional tipping fees for MSW delivered to the WTE plant could range from $10/ton MSW to $45/ton MSW. No allowance is included for landfill cost avoidance or possible substitution value/revenue received for products having beneficial use. The extent of front-end and back-end recycling as well as other methods for calculating cost of capital may also alter these cost projections.

TABLE 10 GENERIC ECONOMIC ESTIMATES

Plant capacity--dry residue (Residue at 20 pct H_2O)	300 TPD ~350 TPD	150 TPD ~175 TPD	50 TPD ~60 TPD
Total Capital Costs	$31,513,000	$17,335,900	$10,930,200
Operating Costs ($/dried st):			
Raw materials	$7.22	$7.22	$7.26
Utilities:			
Electricity ($0.051/kWh)	42.32	42.80	44.59
Water and gas	10.24	9.82	10.53
Direct labor	7.11	11.50	26.39
Plant Maintenance:			
Labor	6.89	8.12	16.21
Materials	5.74	6.77	13.51
Depreciation (20-year life)	15.36	16.91	32.18
Other costs (see Appendix D, Table 2) ..	20.97	26.61	55.10
Operating cost/dry ton	$115.85	$129.75	$205.77
Cost/ton residue at 20 pct H_2O	98.47	110.29	174.90
Cost/ton MSW at combustion plant 10 to 25 pct residue	10.00-25.00	11.00-28.00	18.00-45.00
Additional costs	*	*	*
Additional credits	*	*	*
*Insert applicable costs/credits.			

CONCLUSIONS

- For commercial implementation for a specific residue it would be prudent to conduct a continuous 24 hour/day melting test program for three to five days to ascertain specific furnace performance and thereby obtain sufficient definitive reproducible information for establishing the parametric data basis for design, operation, regulatory requirements and realistic cost projections.

- The ASME/BuMines Investigative Program on Vitrification of Combustion Ash/Residue, conducted in response to public concern regarding potential leachability and the desire to maximize recycling/reuse, demonstrated that vitrification by electric arc furnace melting is technically and operationally feasible for significantly decreasing the volume and leachability of municipal waste combustor residues and can provide new materials which have potential beneficial use in lieu of burial.
- The peer reviewed comprehensive report of this ASME/Bureau of Mines program should be available early Summer 1994.

Inquiries should be addressed to:

Howard E. Clark, Ph.D. — Director
Center for Research and Technology Development
AMERICAN SOCIETY OF MECHANICAL ENGINEERS
1828 L Street N.W., Suite 906
Washington, DC 20036
202/785 – 3756 Fax 202/429 – 9417

Note

The objectives of this investigative program were to demonstrate on a commercial scale the technical, operational and environmental feasibility of utilizing electrotechnology to consecutively vitrify combustor ash/residues from multiple sources to produce new, dense, benign materials having potential uses . . . in lieu of burial.

The American Society of Mechanical Engineers, the US Bureau of Mines, NYSERDA, USDOE, EPRI, EPA, Environment Canada and other Sponsors of this investigative program recognize that there are many methods and systems which may accomplish the same objectives as the system employed in this program. Therefore, ASME/BuMines and the Sponsors make no representations, endorsements, expressed or implied, advocate or recommend a particular method or system for this purpose.

REFERENCES

Plumley, A. L., R. S. DeCesare and H. Hollander, 1992, ASME/Bureau of Mines Vitrification of Residue From Municipal Waste Combustion — A Progress Report — presented at the International Power Generation Conference, Atlanta, GA, Oct 18–22, 1992

Hartman A. D., L. L.Oden, J. C. White, 1993, Facility for Melting Residues From Combustion: Design Criteria and Description of Equipment, US Dept of Interior, Bureau of Mines RI-9476

Hollander, H., A. L. Plumley, R. S. DeCesare, 1993, ASME/Bureau of Mines Investigative Program on Vitrification of Combustion Ash/Residue presented at the Third International Conference and Seminar on Municipal Waste Combustion, Williamsburg, VA March 93

Hollander, H., A. L. Plumley, R. S. DeCesare, 1993, ASME/Bureau of Mines Investigative Program on Vitrification of Combustion Ash/Residue — Status Report, presented at the Ninth International Conference on Solid Waste Management, University of Pennsylvania, Philadelphia, PA, November 1993