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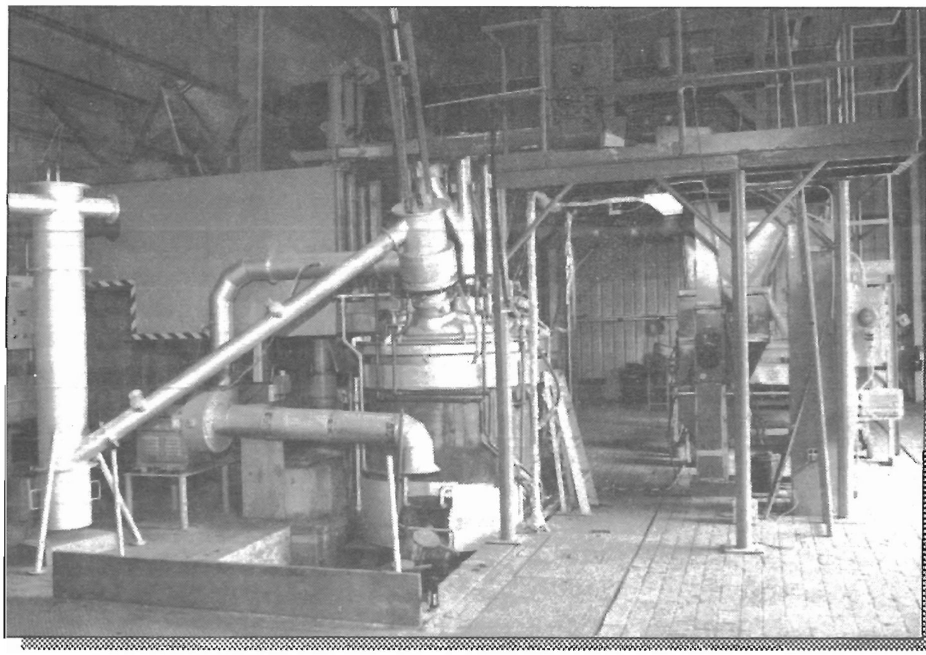
REPORT OF INVESTIGATIONS/1995

Evaluation of the Three-Phase, Electric Arc Melting Furnace for Treatment of Simulated, Thermally Oxidized Radioactive and Mixed Wastes

(In Two Parts)

1. Design Criteria and Description of Integrated Waste Treatment Facility

By L. L. Oden, W. K. O'Connor, P. C. Turner, and A. D. Hartman



UNITED STATES DEPARTMENT OF THE INTERIOR

BUREAU OF MINES

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Cover: Thermal waste treatment facility.

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UNITED STATES DEPARTMENT OF THE INTERIOR
Bruce Babbitt, Secretary

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Rhea L. Graham, Director

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UNIT OF MEASURE ABBREVIATIONS USED IN THIS REPORT

Metric Units

A	ampere	mm	millimeter
cm	centimeter	min	minute
g/cm^3	gram per cubic centimeter	MPa	megapascal
h	hour	MW	megawatt
kg/h	kilogram per hour	Pa	pascal
kV•A	kilovolt ampere	pct	percent
kW	kilowatt	s	second
kW•h	kilowatt hour	t	metric tons
kW•h/mt	kilowatt hour per metric ton	t/h	metric ton per hour
L	liter	V	volt
L/s	liter per second	var	volt x ampere x reactance
m	meter	W	watt
m/s	meter per second	μm	micrometer
m^3	cubic meter	°C	centimeter

U.S. Customary Units

acfm	actual cubic foot per minute	lb	pound
ft	foot	lb/ft^3	pound per cubit foot
ft^3	cubic foot	lb/h	pound per hour
ft/min	foot per minute	psig	pound per square inch, gauge
gal	gallon	scfm	standard cubic foot per minute
gal/min	gallon per minute	st	short ton
hp	horsepower	st/h	short ton per hour
in	inch	°F	degree Fahrenheit
in WC	inch water column		

EVALUATION OF THE THREE-PHASE, ELECTRIC ARC MELTING FURNACE FOR TREATMENT OF SIMULATED, THERMALLY OXIDIZED RADIOACTIVE AND MIXED WASTES

(In Two Parts)

1. Design Criteria and Description of Integrated Waste Treatment Facility

By L. L. Oden, W. K. O'Connor, P. C. Turner, and A. D. Hartman

ABSTRACT

The U.S. Bureau of Mines and the Department of Energy (DOE), through its contractor EG&G Idaho Inc., are collaborating on a multiyear research project to evaluate the applicability of three-phase, electric arc furnace melting technology to vitrify materials simulating low-level radioactive and mixed wastes buried or stored at the Idaho National Engineering Laboratory and other DOE sites. The melter is a sealed, 1-t (1.1-st), three-phase, 800-kV•A electric arc melting furnace with 10.2-cm- (4-in-) diameter graphite electrodes, water-cooled roof and sidewalls, and four water-cooled feed tubes. A water-cooled copper fixture provides for continuous tapping of slag. An instrumented air pollution control system (APCS) with access ports for analysis and a feeder based on screw conveyors and a bucket elevator are dedicated to the facility. Test data are provided by an arc furnace analyzer and by sensors indicating feed rate; slag temperature; and temperature, pressure, and velocity in the APCS. These data are received by a data logger, digitized, and transmitted to a personal computer for storage and display. This unique waste treatment facility is available for public and private use on a cost-sharing basis.

[1]Research chemist.
[2]Chemical engineer.
[3]Supervisory metallurgist.
[4]Chemical engineer.
Albany Research Center, U.S. Bureau of Mines, Albany, OR.

INTRODUCTION

The U.S. Bureau of Mines (USBM) and the Department of Energy (DOE), through its contractor EG&G Idaho Inc., are collaborating on a multiyear research project to evaluate existing three-phase, electric arc furnace melting technology to vitrify simulated mixed wastes and soils contaminated with transuranic (TRU) elements and other hazardous organics and metals listed in the Resource Conservation and Recovery Act (RCRA) that are buried or stored at the Idaho National Engineering Laboratory (INEL) and other DOE sites. Over 57,000 m^3 (+2,000,000 ft^3) of buried waste is located at the Subsurface Disposal Area of the Radioactive Waste Management Complex at INEL, and roughly four times that amount of potentially contaminated soil is intermingled with the original wastes. These buried wastes represent a highly heterogeneous mix of combustible organics, reactive materials, metal oxides, sludges, metals, and contaminated soils. An equal volume of similar waste is located in retrievable above-ground storage at the INEL Transuranic Storage Area. Similar types and quantities of buried and stored wastes exist at DOE's Hanford, WA site.

Commercially available arc melting technology is well developed for industrial pyrometallurgical smelting and melting applications, which routinely process large volumes of heterogeneous materials similar to the buried mixed wastes and soils. Electric arc furnaces are available in many design configurations including direct current and single- and three-phase alternating current systems with multiple electrodes. Furnaces have been successfully operated with power levels to over 100 MW processing over 130 t/h (143 st/h). Sealed furnaces have been built, and furnaces processing materials at very high temperatures 2,000 °C (3,632 °F) operate routinely. The objectives of this research program are to adapt and demonstrate the application of existing arc melting furnace technology to thermal processing of TRU-contaminated mixed wastes and soils, with the ultimate objective of preparing a nonleachable final waste form that is stable over geologic time frames.

The current program, the first year of an anticipated 3-year effort, is directed to processing simulated, thermally oxidized mixed wastes. Simulated, actual, as-retrieved waste mixtures containing combustible materials will be processed during the following years, with the ultimate goal of determining design parameters for a pilot-scale, on-site waste processing facility.

The current research program required significant modification of a melting facility originally constructed to vitrify residues from municipal waste combustion (*1*).[5] This modification consisted of adding water-cooled feed tubes to the existing furnace; altering the air pollution control system (APCS) to cope with condensable fume in the offgas; and adding a data management system to log test parameters electronically characterizing the feed system, the APCS, and the electric furnace. Following is a summary of design criteria and a description of the waste treatment facility. The results of over 80 h of melting experience will be reported later in this series.

DESIGN CRITERIA

The following design criteria were developed to provide a versatile facility for processing a variety of simulated, thermally oxidized, low-level radioactive wastes and other materials for which vitrification melting is a viable method for conversion to a stable waste form.

Feed System:

1. 1 t/h (2,200 lb/h) continuous feed rate of material having a bulk density of 1.28 g/cm³ (80 lb/ft³).
2. Capability to convey material passing a 12.7-mm (1/2-in) screen.
3. Air lock within the feed system to minimize air ingress into the furnace.

Electric Arc Melting Furnace and Power Supply:

1. Voltage to the furnace measured at the electrodes phase-to-phase in the 240- to 350-V range at full load amperage in the 2,000- to 2,500-A range. (The power supply is unchanged from reference 1.)
2. Furnace sealed to minimize air ingress.
3. Melt rate up to 1 t/h (2,200 lb/h) of material having an enthalpy requirement of 725 kW•h/t.
4. Open arc, submerged arc, or intermediate modes of operation.
5. Hearth volume below the slag taphole approximately 0.14 m³ (5 ft³).
6. Options to tap slag intermittently or continuously.
7. Intermittent tapping of metal and the facility to empty the furnace through the bottom of the hearth.
8. Feed material supplied uniformly within the furnace through four ports in the roof.
9. Four water-cooled feed tubes extending through ports in the roof to within 0.46 m (18 in) of the molten pool to minimize dust generation within the furnace and particle entrainment with the offgas.
10. Pressure sensor within the furnace.

[5]Italic numbers in parentheses refer to items in the list of references at the end of this report.

11. Electronic arc furnace analyzer to provide continuous indication of electrical parameters.

APCS:

1. Water-cooled duct through the furnace roof to prevent the accumulation of physically strong accretions.
2. Air quench of furnace exhaust gases immediately upon exiting the furnace roof by injection of room-temperature air.
3. Mechanical scraper to clear accretions from the water-cooled and air-quench sections of the duct.
4. Fume traps within the APCS to provide increased offgas residence time and to collect particulate and condensed fume solids.
5. Heat exchanger in the APCS to maintain the temperature of the exhaust gas above the dew point but below the destruction temperature of filter media in the baghouse.
6. Baghouse rated to remove >99 pct of particulate greater than 0.3 μm at a total flow rate of 950 L/s (2,000 acfm).
7. High-efficiency particulate air (HEPA) filter unit at the APCS outlet rated to remove 99.98 pct of particulate >0.3 μm at flow rates to 472 L/s (1,000 acfm) at 249-Pa (1-in-WC) pressure drop.
8. Electrical sensors within the APCS to provide temperature, pressure, and velocity profiles.

Data Management System:

1. Electronic logging of electrical parameters for analyzing demand and power consumption of the electric furnace.
2. Electronic logging of temperature, pressure, and velocity data from sensors within the APCS.
3. Electronic logging of feed rate.
4. Electronic logging of slag temperature during continuous tapping.
5. Electronic logging of furnace sidewall and bottom temperature.
6. Computer storage and video display of all process data.

DESCRIPTION OF WASTE TREATMENT FACILITY

The integrated facility comprises four primary components: feed system, three-phase electric arc melting furnace and power supply, APCS, and data management system. Many elements of the arc melting furnace and the APCS are unique, and the facility as a whole constitutes the state-of-the-art integrated waste processing facility shown schematically in figure 1.

FEED SYSTEM

The feed system is serviced by a motorized barrel lift and/or an overhead crane. Materials to be melted can be transferred directly into the 2.8 m^3 (100 ft^3) receiving bin or mixed with additives in a two-barrel-capacity hopper, which then is transferred by overhead crane to the receiving bin. Twin tapered, counter-rotating, 30.48-cm- (12-in-) diameter screws in the base of the receiving bin discharge material to a bucket elevator, which lifts the material 5.2 m (17 ft) to a 0.28-m^3 (10-ft^3) metering bin. The height of material in the metering bin is controlled by a sonic level indicator with high and low set points. Calibrated twin, counter-rotating, 15.24-cm- (6-in-) diameter screws in the base of the metering bin feed through a rotary air lock into a 15.24-cm- (6-in-) diameter splitter screw, which feeds two 15.24-cm- (6-in-) diameter delivery screws. Each delivery screw discharges into the furnace through a pneumatically activated diverter gate, which changes position at 6-s intervals to divide and route the feed to two separate ports in the furnace roof. Feed is thereby admitted uniformly into the furnace through four ports in the roof.

Fugitive dust liberated during operation of the feed system and by dumping of the hopper and/or barrels is collected in a dedicated baghouse through a system of ducts connected to the receiving bin, bucket elevator, and metering bin. In practice, the quantity of fugitive dust collected is subtracted from the weight of material placed in the receiving bin.

The height of material in the furnace under one of the charge ports is determined manually by lowering a weight suspended on a 1.6-mm- (1/16-in-) diameter, stranded stainless steel cable in the manner of a plumb bob. The feed system, rated to deliver up to 1 t/h (2,200 lb/h) of minus 12.7-mm (1/2-in) screened and dried material with a bulk density of approximately 1.28 g/cm^3 (80 lb/ft^3), is operated manually or controlled automatically by a programmable controller. A detailed description of the feed system is provided by the operations manual (*2*). The receiving bin and charge hopper are shown in figure 2.

Feed materials enter the furnace roof through four water-cooled tubes that extend through the roof to within 0.46 m (18 in) of the molten pool to minimize turbulence and dust generation within the furnace. These tubes, with their design shown in figure 3, are double-walled, carbon steel structures 122 cm (48 in) long by 21.91-cm (8.625-in) outside diameter (OD) by 13.97-cm (5.5-in) inside

Figure 1

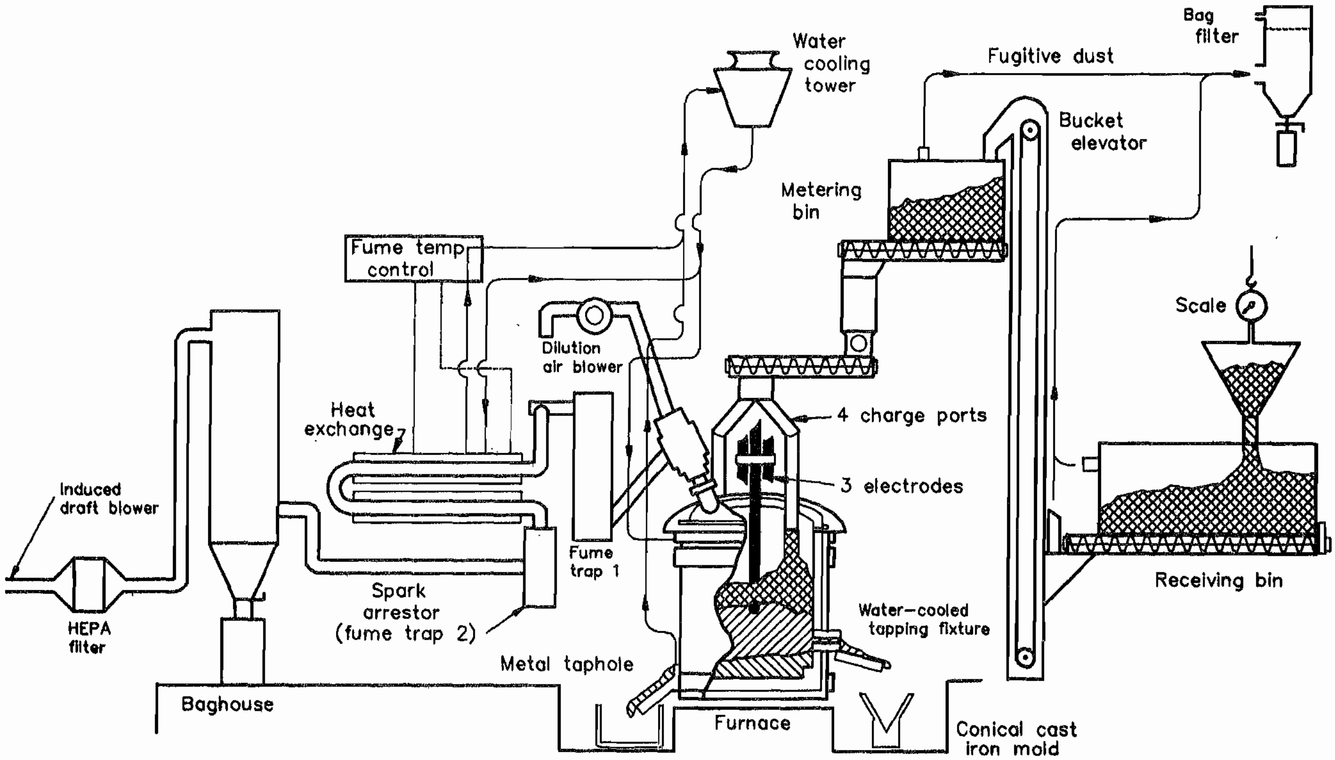


Diagram of integrated waste processing facility.

diameter (ID). The annular water jacket is divided lengthwise by spacers to form six water passages, each of which is supplied by a nominal 6.35-mm (1/4-in) copper tube that extends to within 12.7 mm (1/2-in) of the bottom of the passage. Cooling water is supplied to the feed tubes in the range of 1.21 to 1.51 L/s (20 to 25 gal/min).

ELECTRIC ARC MELTING FURNACE AND POWER SUPPLY

Furnace Description

The furnace—a refractory-lined steel shell with water-cooled sidewalls, partially water-cooled roof, and air-cooled bottom—is unchanged from reference 1. Reference 1 provided a vertical cross-section schematic of the furnace shell and roof showing upper and lower water trough placement, air plenum for bottom cooling, taphole locations, launder, and placement of the furnace with respect to floor level; and a top view schematic of the furnace roof showing the placement of feed ports, offgas outlet port, inspection port, and electrode ports.

Tapping metal and draining the furnace is done through the 3.81-cm- (1-1/2-in-) diameter hole in the bottom center of the hearth that was built into the furnace lining during construction. The water-cooled, slag-tapping fixture is grouted in place with the MgO ramming mix. This tapping fixture is a welded, double-walled copper structure 15.24 cm (6 in) in diameter by 25.4 cm (10 in) long with a 2.54-cm- (1-in-) diameter central hole designed to permit continuous tapping of slag at rates up to 1 t/h (2,200 lb/h).

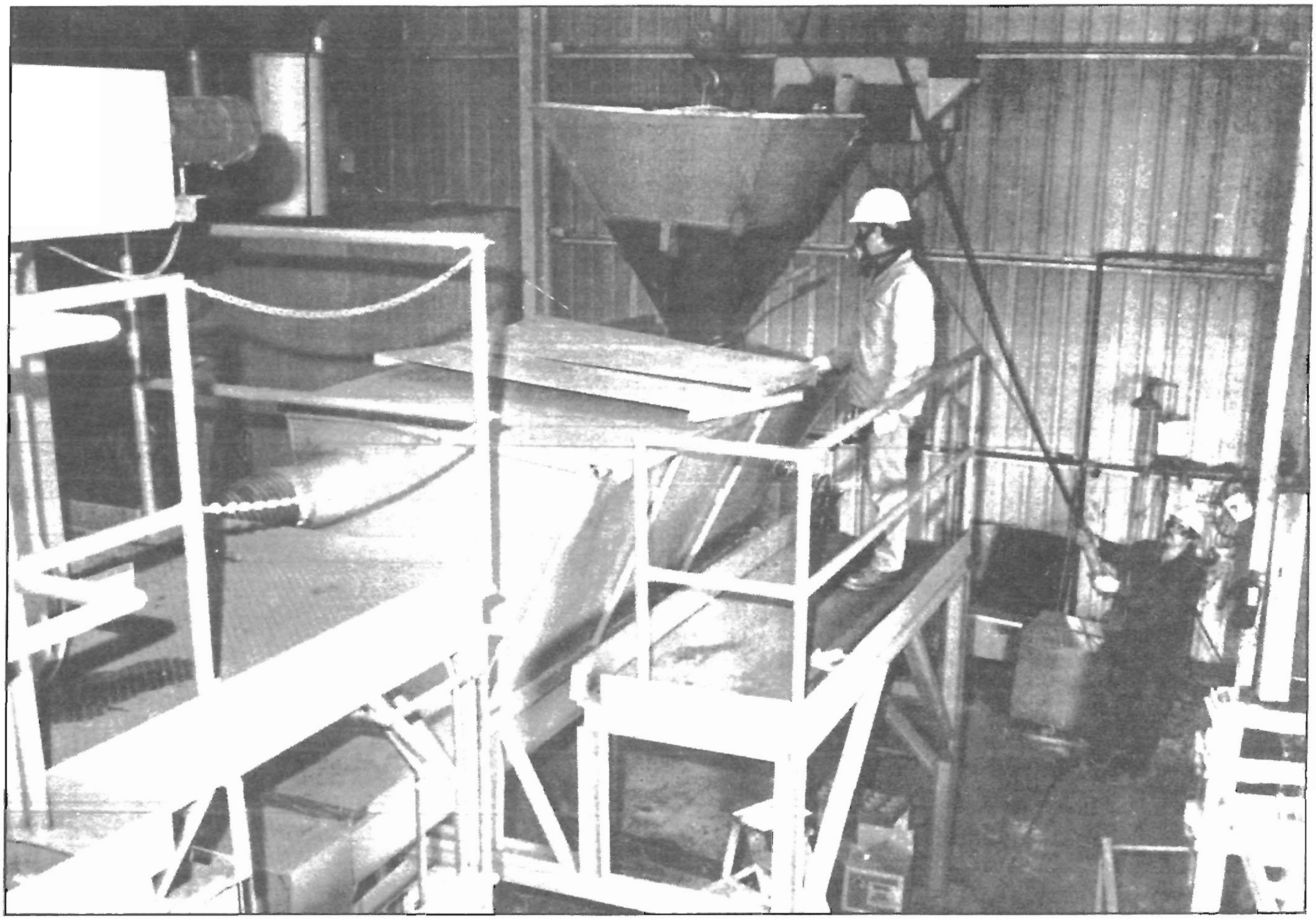
The conceptual design and engineering drawings[6] for the modified furnace; including refractory selection and placement, cooling-water needs, voltage and power requirements, water-cooled, slag-tapping fixture, and general furnace operating procedures; were provided by Lectromelt Corp.[7]

Figure 4 is a photograph of the domed, carbon steel roof taken from the metering-bin platform. The electrodes, electrode arms, three central electrode ports, and graphite electrodes are clearly visible. The feed delivery screws and feed downcomers are on the right and left sides of the figure. At the lower right, the cable-pulley

[6]Private communication from H. F. Davis, Jr., consulting metallurgical engineer, 1992.

[7]Reference to specific tradenames or manufacturers does not imply endorsement by the U.S. Bureau of Mines.

Figure 2



Receiving bin and charge hopper.

support for the plumb bob is visible. The water-cooled feed tubes, each with a 21.91-cm (8.625-in) OD, enter the four charging ports in the roof, but only the top portions containing the plumbing are visible in the photograph.

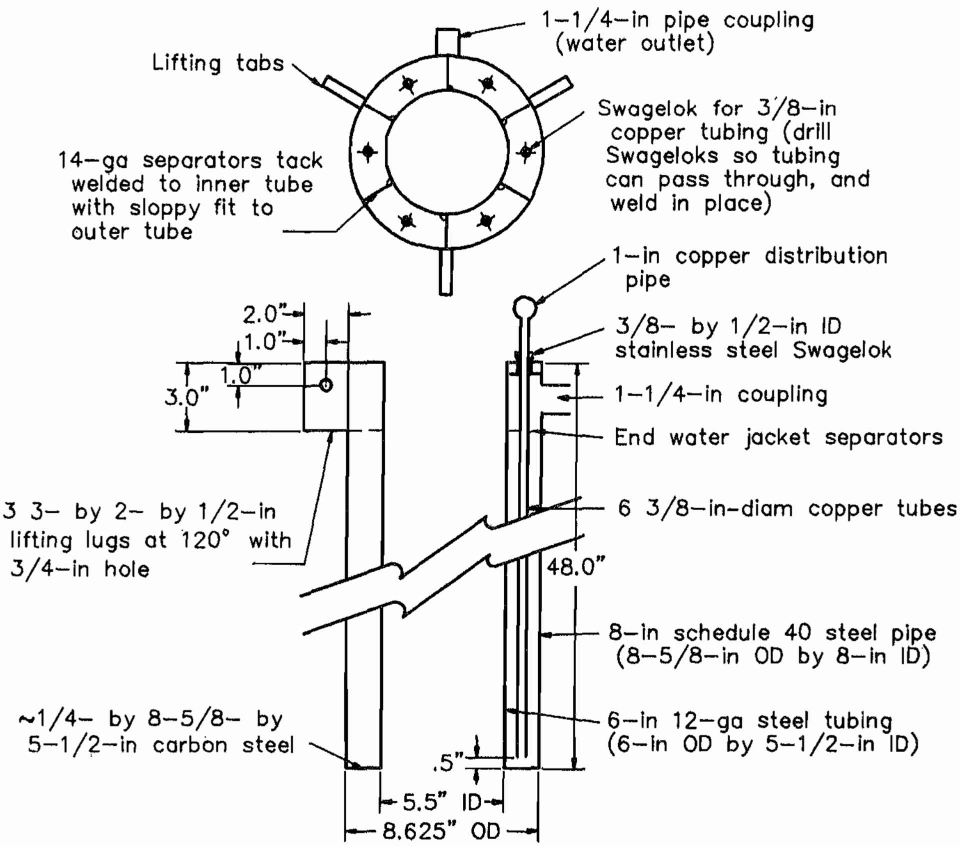
Furnace Refractories

Refractory placement within the furnace shell is unchanged from reference 1, except that the roof refractory, 10.2 cm (4 in) of NARPHOS 85P plastic refractory (85 pct alumina), was removed from the exhaust gas port to accommodate the water-cooled section of duct. Roof refractory was also removed around the feed ports and replaced to fit closely to the OD of the water-cooled feed tubes. The annular space between each vertical roof extension and feed tube is packed with Fiberfrax mullite fiber rope to minimize gas leakage. The two-part, ceramic electrode seals are unchanged from reference 1.

Furnace and Transformer Cooling

The water-cooling tower (*3*); cold and warm water sumps; circulation pumps; and water-cooling circuits to the furnace shell, furnace roof, slag tapping fixture, slag launder, metal taphole collar, transformer, and electrode arms, cables, and clamps; are unchanged from reference 1. Additional water circuits, monitored by indicating flow meters and dial thermocouples, were installed or modified to service the water-cooled section of the APCS duct, feed tubes, and slag-tapping fixture. Water circuitry to provide city water for emergency cooling in case of power failure is unchanged from reference 1. Figure 5 is a circuit diagram for the modified cooling system indicating maximum anticipated flow rates, and figure 6 shows the furnace and the location of the flowmeters and plumbing as it originates from the delivery pipes below floor level.

Figure 3



Design drawing for water-cooled feed tubes (measurements are in U.S. customary units, ["] = inch and ga = gauge).

Power Supply

The power supply, comprising a three-phase, 800-kV•A transformer with a series-connected, single-phase, 250-kV•A transformer in each phase, is unchanged from reference 1. The electrical line drawing from the substation to the electric furnace is reproduced in figure 7 for the convenience of the reader. The secondary open-circuit voltages are reproduced in table 1.

Table 1.—Power supply characteristics

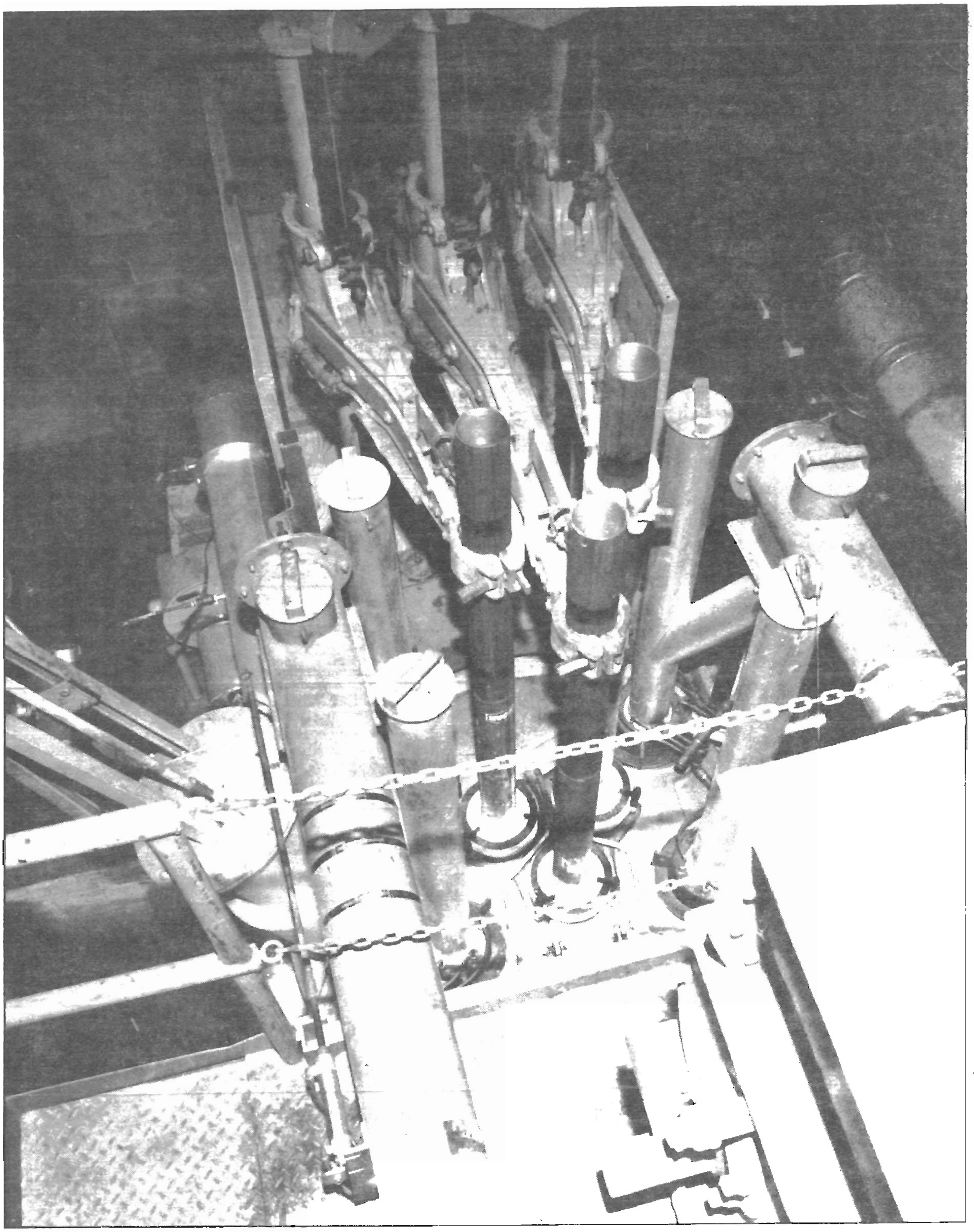
Tap	Phase-to-phase, V	Phase-to-ground, V
A	352	192
B	304	168
C	256	145
D	239	134

The power supply is a constant-voltage supply providing regulation of 3 to 5 pct of the mean from open circuit to full load. The maximum output of the power supply is 2,080 A. Power can be increased for a given transformer tap position by increasing the rheostat positions. A rheostat for each phase, working through the electrode positioning circuit for that phase, adjusts the electrode position to decrease the arc length or even to submerge the electrode in the melt, thereby providing increased current. Power to the furnace is a function of the voltage (transformer tap), current (electrode position as determined by rheostat setting), and resistivity of the slag. A rheostat controls each electrode, thereby providing a means to balance the power.

AIR POLLUTION CONTROL SYSTEM

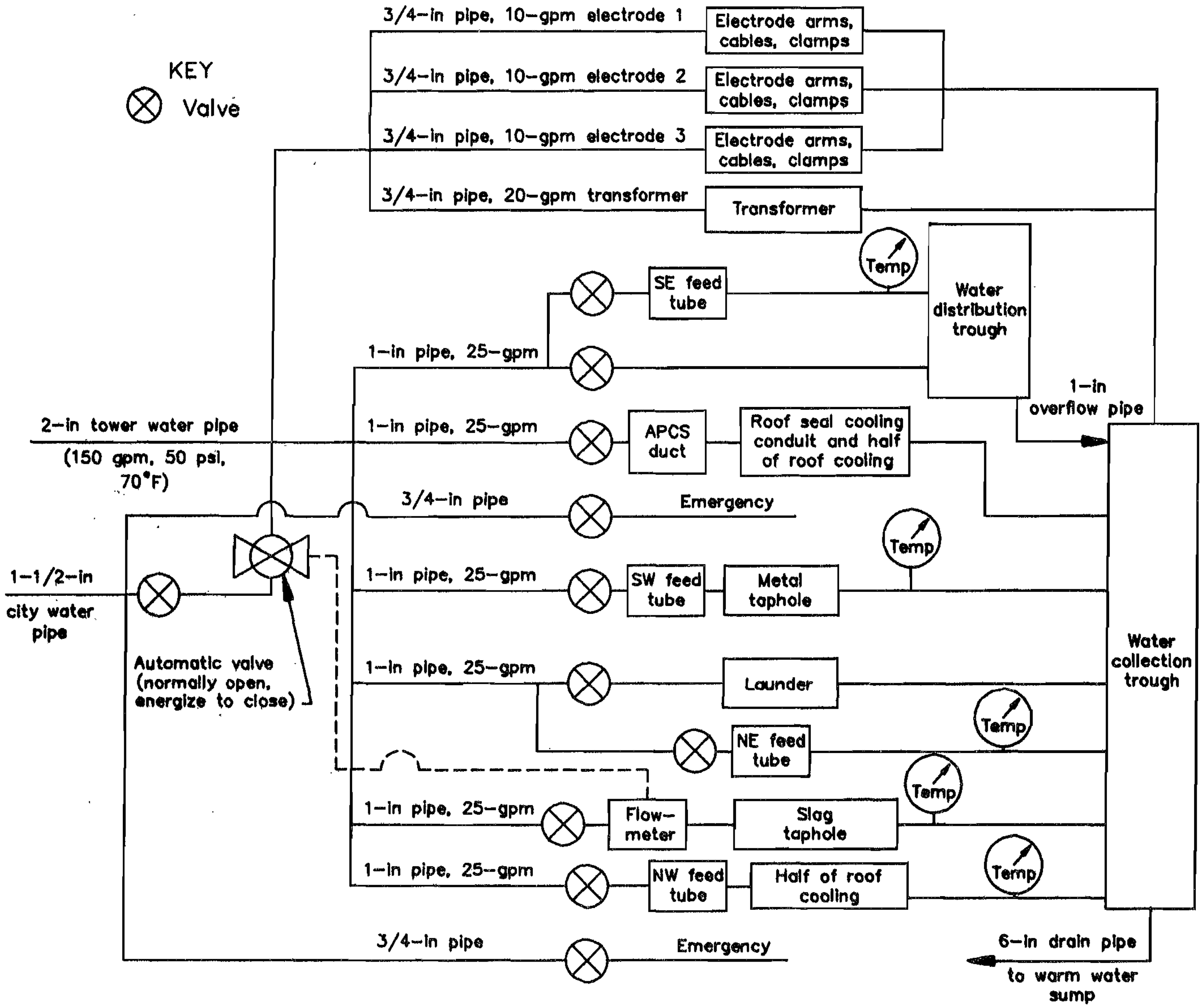
The APCS, shown schematically in figure 1, is designed to minimize fouling by condensates within the furnace exhaust gas. The method selected was to cool the exhaust gas immediately upon exiting the furnace by injecting air into the APCS. For this option to be successful, condensable vapors within the exhaust gas must condense

Figure 4



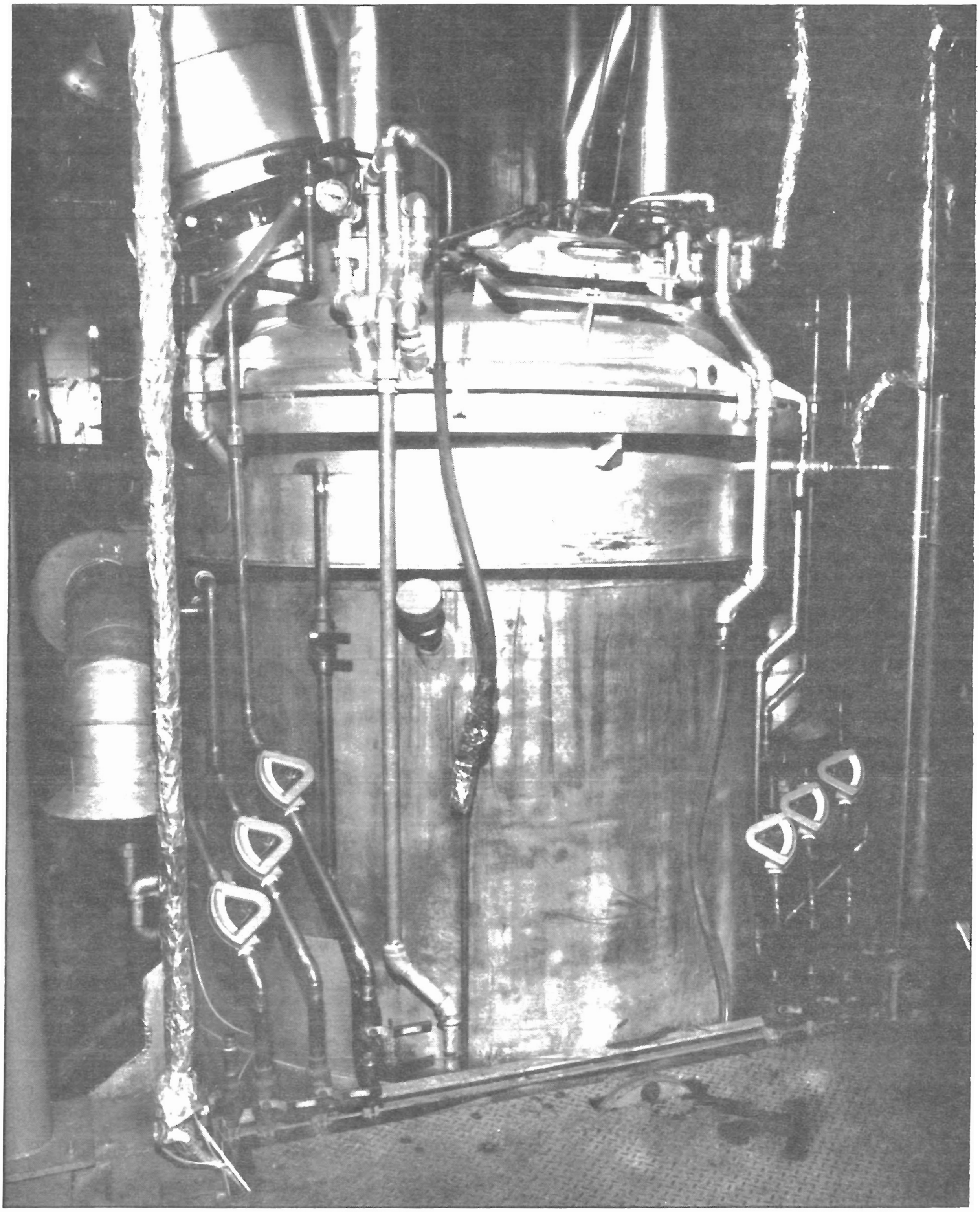
Furnace roof.

Figure 5



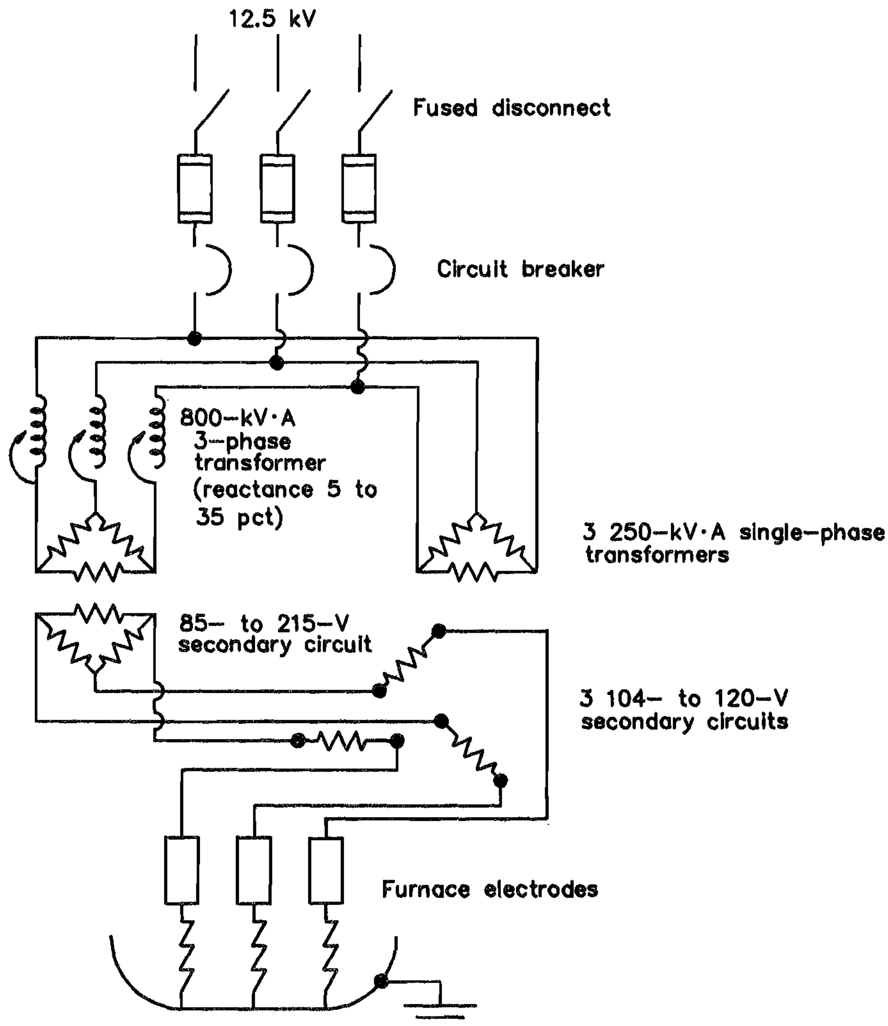
Cooling water circuit diagram (measurements are in U.S. customary units, gpm = gal/min).

Figure 6



Furnace, plumbing, and flowmeters.

Figure 7



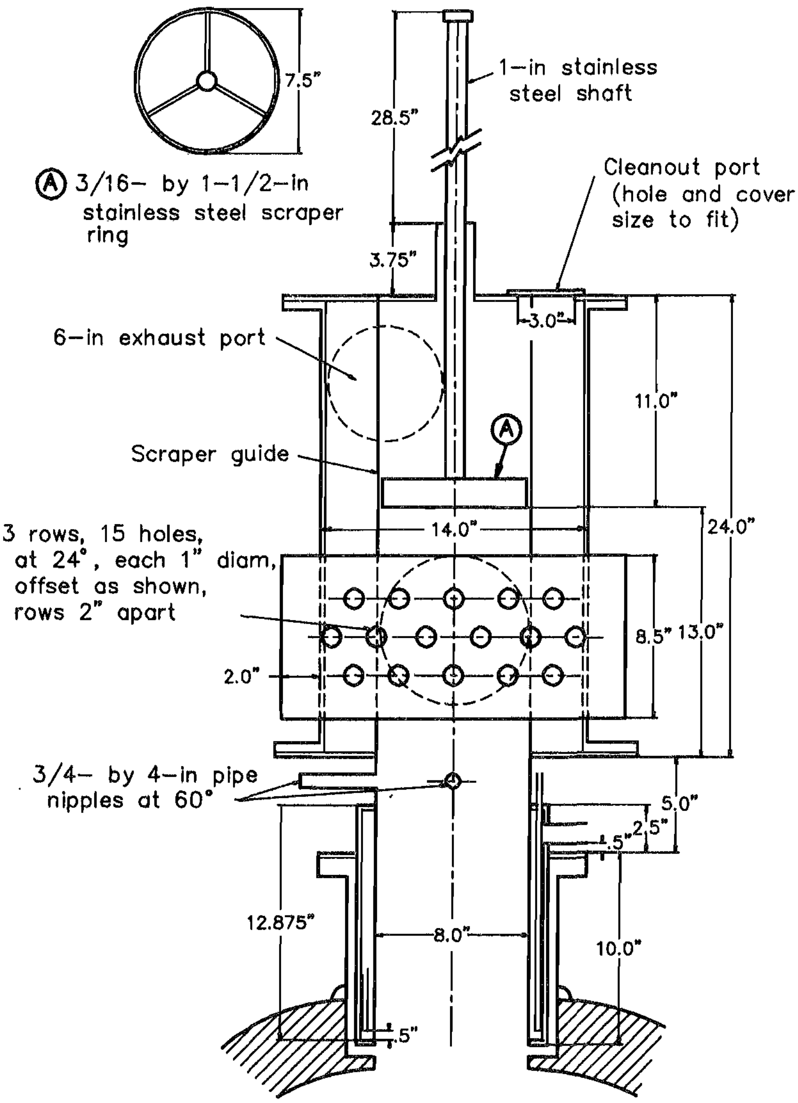
Line drawing for electric arc melting furnace power supply.

quickly to liquid droplets, which then must solidify to form particles that remain entrained within the remaining gas stream. Quenching air is obtained from above the slag and metal tapholes by a 3,730-W (5-hp) blower and duct system, thereby improving air quality within the building. Dampers in these ducts are adjusted to remove air over the slag taphole while tapping slag, and to collect air over the metal taphole while tapping metal or draining the hearth.

Exhaust gases exit the roof of the furnace through a 33-cm- (13-in-) long, 20.3-cm- (8-in-) ID, water-cooled duct that connects to a short section 6.35 cm (2.5 in) long containing two 1.90- by 10.2-cm (3/4- by 4-in) pipe nipples for access. The short section connects to a jacketed wind box into which quenching air is injected in a 5:1 ratio of quenching air to exhaust gas. A circular scraper blade, driven by a pneumatic cylinder fastened at the top of the wind box, is designed to clear accumulations of particulate and condensed fume solids within the wind box and the water-cooled section of duct. The air pollution control duct has a nominal 15.24-cm (6-in) ID, excluding the water-cooled section, fume traps, baghouse, and HEPA filter. The design drawing of the quenching air inlet system is shown in figure 8.

Cooled gases, condensed fume, and entrained particulate solids exit the wind box into a 2.74-m- (9-ft-) long section of duct containing four 7.62-cm- (3-in-) diameter by 10.16-cm- (4-in-) long pipe nipples that provide access for exhaust-gas analysis. That duct then enters tangentially into a quasi-cyclone settling chamber, 34.3-cm (13.5-in) ID by 2.29 m (90 in) long (fume trap 1), that allows large particles to disengage from the gas flow. Accumulated

Figure 8

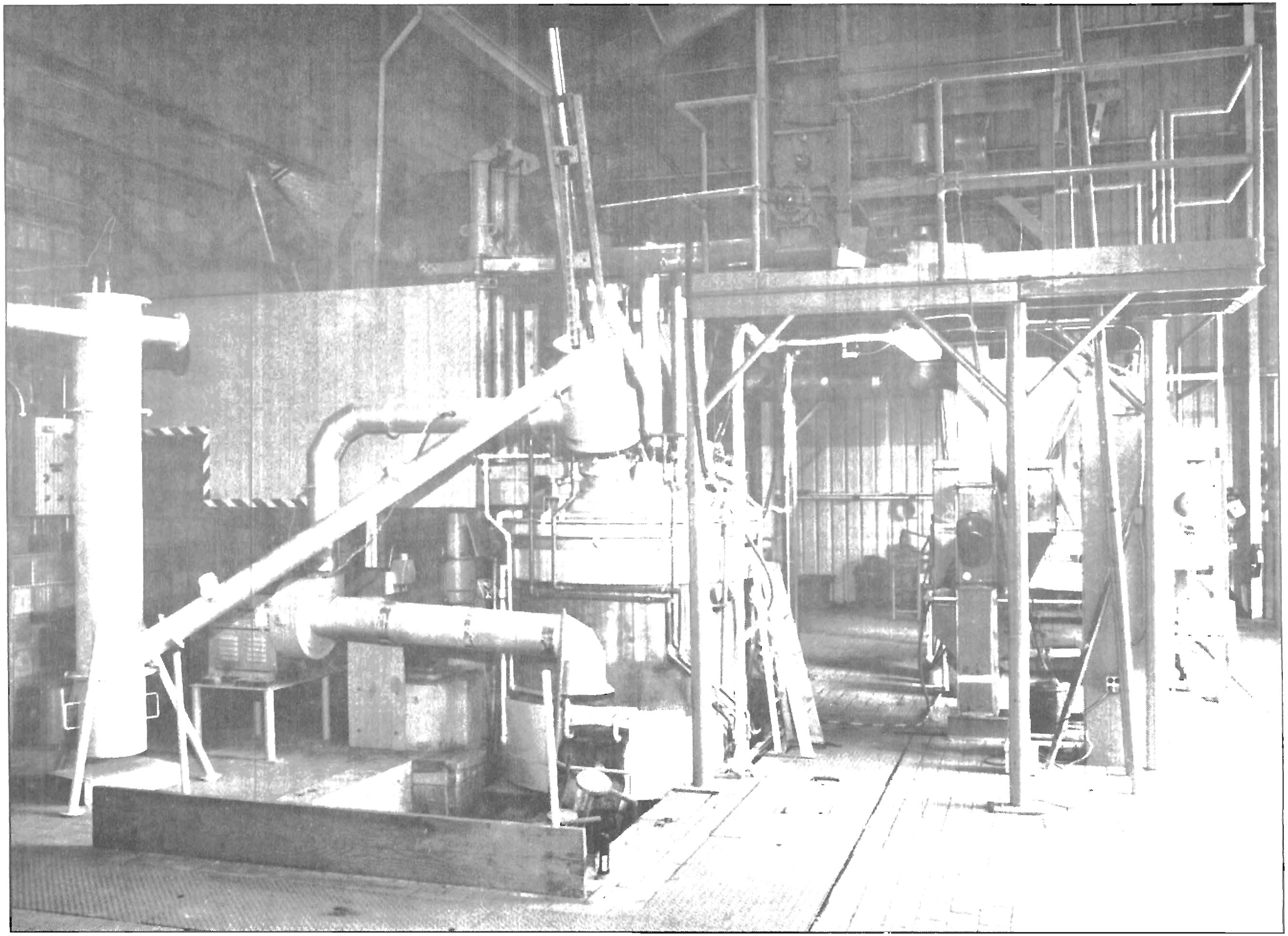


Design drawing for quenching air inlet system (measurements are in U.S. customary units, ["] = inch).

particles are collected within a removable pot on the bottom of the cylinder. Figure 9 is a view of the furnace and the APCS within the building showing the water-cooled section of the APCS, wind box, pneumatic cylinder, analysis duct, fume trap 1, and quenching air blower and duct.

The remaining particulate and gases that exit fume trap 1 enter a 12.2-m (40-ft) long by 15.2-cm (6-in) ID water-jacketed, double-pipe heat exchanger that either heats the cool gas during start-up of the furnace or cools the hot gas during continuous operation to deliver gas in the temperature range of 120 to 204 °C (248 to 399 °F) to the baghouse. Hot or cold water for the heat exchanger is provided by a SuperTrol temperature control unit (*4*). The SuperTrol, which is rated at 36 kW, provides 7.26 L/s (120 gal/min) of water at 82 to 120 °C (179 to 248 °F) to the heat exchanger for heating or cooling. The heat exchanger exits to fume trap 2, which is a large tank (0.76-m (30-in) diameter by 1.22 m (48 in) high), to capture hot particles. A 2.54-m- (10-ft-) long horizontal pipe suitable for conducting gas analysis connects fume trap 2 to the baghouse, which contains 47 11.4-cm- (4.5-in-) diameter by 2.54-m- (10-ft-) long Gortex-membrane, Teflon polytetra-fluoroethylene-coated fiberglass bags rated to remove 99.98 pct of particulate greater than 0.3 µm at flow rates to 950 L/s (2,000 acfm). Bags are shaken with a back pulse of 0.7-MPa (100-psig) air at 3-s intervals. The baghouse is ducted to a HEPA filter also rated to remove 99.98 pct of particulate greater than 0.3 µm at 470 L/s (1,000 acfm) with 249-Pa (1-in-WC) pressure drop. A 7,460-W (10-hp) variable-speed induced draft fan,

Figure 9



Furnace and air pollution control system within the building.

located after the HEPA filter, discharges the clean gases through a stack into the atmosphere. The APCS outside of the building is shown in figure 10. The double-pipe heat exchanger is the black horizontal pipe in the figure extending from near the building to beyond the baghouse through a 180° elbow and back to fume trap 2 near the building.

The estimated gas evolution rate during melting of the simulated mixed wastes, as calculated from the compositions of the simulated mixed wastes and anticipated feed rates, ranged from 9.4 to 42 L/s (20 to 90 scfm). Assuming a maximum offgas temperature of 400 °C (752 °F), the offgas volume then ranges from 21 to 94 L/s (45 to 200 acfm). If the quenching air flow is 235 L/s (500 acfm), then the temperature in the duct will range from about 170 to 195 °C (338 to 383 °F), which is within the safe operating range of the filter medium in the baghouse. Test plans suggest setting the speed of the quenching air blower to midrange and then adjusting a damper at the outlet of the blower to provide about 235 L/s (500 acfm) in the quenching air duct. Minor adjustment of blower speed then serves to fine-tune the flow. The speed of the induced draft blower with inlet open is separately set to midrange. The duct is reconnected, and a damper in the outlet is adjusted to provide the approximate desired pressure in the furnace. The induced draft blower then is adjusted to provide negative pressure in the furnace ranging from 25 to 125 Pa (-0.1 to -0.5 in WC). The anticipated volume of gas reporting to the baghouse—the sum of the quenching air and exhaust gas from the furnace—is 283 to 448 L/s (600 to 950 acfm). Gas velocity in the 15.24-cm- (6-in-) diameter air pollution control duct is expected to be in the range of 20 to 24 m/s (3,900 to 4,700 ft/min), which is adequate to keep most particles in suspension.

DATA MANAGEMENT SYSTEM

Basic information required to evaluate the performance of the feed system, the electric arc melting furnace, and the APCS are recorded electronically or manually throughout a melting campaign.

Arc Furnace Analyzer and Electronic Data Logger

Electrical parameters for analyzing demand and consumption of the three-phase, electric furnace are continuously monitored by a True RMS Power and Demand Analyzer model 3950, which records root mean square (rms) voltage, rms current (A), apparent power (VA), active power (kW), reactive power (var), power factor, and total energy (kW•h). These values for each phase are integrated over 1-min intervals, and the integral values are stored by the instrument. Four channels (V, A, kW, and kW•h) are transmitted to a data logger; which receives 17 additional inputs from the calibrated feed screws, continuous-indicating optical pyrometer monitoring slag temperature, and sensors located throughout the APCS; applies a linear scaling factor to each input as needed, and transmits the calculated values to a personal computer (PC) at intervals of 1 min for display and storage. A hard copy is printed at 5-min intervals. The following data are recorded electronically, where temperatures are degree Celsius, and the remaining measurements are given in U.S. customary units.

Channel	*Factor*
0	Feed rate, lb/h
1	T_1 — temperature of air within quenching air duct
2	T_2 — temperature of furnace offgas exit
3	T_3 — temperature of exhaust gas in fume trap 1
4	T_4 — temperature of exhaust gas before baghouse
5	T_5 — temperature of exhaust gas after baghouse
6	T_6 — temperature within furnace near upper sidewall
7	T_7 — temperature of furnace hearth
8	T_8 — temperature of steel furnace shell bottom
9	T_9 — temperature of slag at taphole by optical pyrometer
10	P_1 — pressure within furnace near upper sidewall
11	P_2 — pressure within fume trap 1
12	P_3 — pressure in APCS before baghouse
13	P_4 — pressure in APCS after baghouse
14	P_5 — differential pressure over HEPA filter
15	V_1 — data logger conversion to flow rate in quenching air duct from hot-wire anemometer velocity probe (maximum temperature for anemometer is 93 °C).
16	V_2 — differential pressure over pitot tube in APCS after baghouse (manual conversion to flow is required)
17	Electrode phase-to-ground voltage, V
18	Electrode phase-to-phase current, A
19	Furnace power, kW
20	Furnace Energy, kW•h

Manual Data Logs

Data also are recorded manually on the appropriate log during a melting campaign, as listed below.

Receiving Bin Log:

This record contains the date, time, and weight of all materials entering the receiving bin.

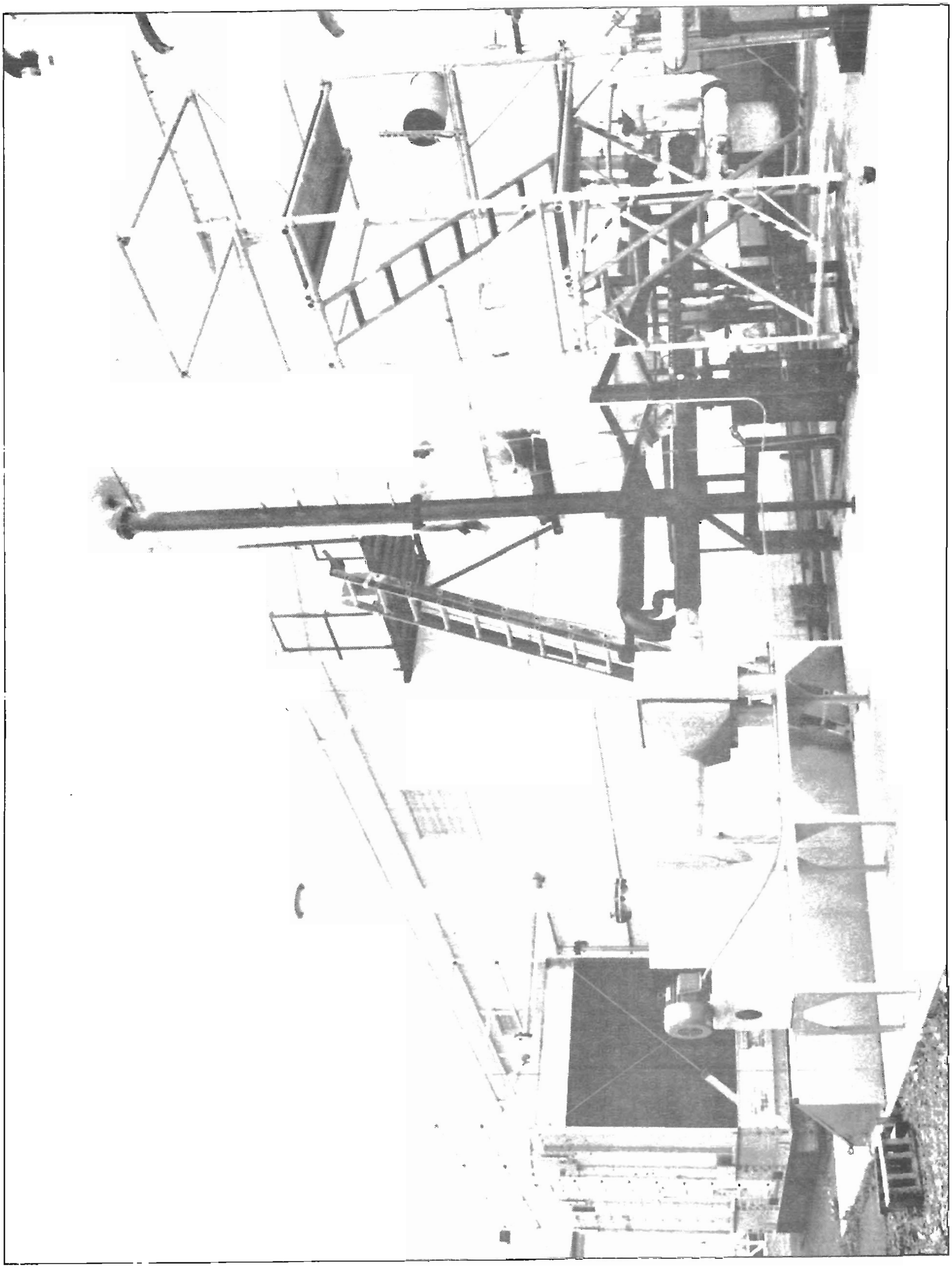
Feeder Log:

Feed rate, the depth of unmelted material in the furnace (cold top height), slag temperature, and other furnace and process parameters are recorded on this log by the feeder operator.

Furnace Run Data Sheet:

Pertinent power supply and furnace information are recorded on this log by the furnace operator.

Figure 10



Air pollution control system outside the building.

Test Log:

This record, kept by the test supervisor, lists the depth from thermocouple port to hearth at the beginning and at irregular intervals during each melting test to ascertain the viscosity of the slag and the presence of dense unmelted material (usually metal) on the hearth. The transformer tap and rheostat settings are recorded from the control panel at 30-min intervals, and the following additional information important to successfully conducting a melting test are recorded at the same frequency from the PC display. This practice assures that all operators are continuously aware of operating conditions during a melting test. Redundant logging provides an additional opportunity to recognize and correct process irregularities before they become significant problems.

Channel	*Factor*
2	T_2 — temperature of furnace offgas exit
4	T_4 — temperature of exhaust gas before baghouse
7	T_7 — temperature of furnace hearth
8	T_8 — temperature of steel furnace shell bottom
12	P_3 — pressure in APCS before baghouse
13	P_4 — pressure in APCS after baghouse
14	P_5 — differential pressure over HEPA filter
15	V_1 — data logger conversion to flow rate in quenching air duct
16	V_2 — flow rate in APCS after baghouse
19	furnace power, kW

Slag and Metal Products Log:

The date and time collected and the weight of all slag and metal recovered from the furnace are recorded on this log. An identification tag is prepared for slag from the slag taphole (conical slag molds) and the metal taphole (ladle and conical molds).

APCS Residue Log:

This record contains the date and time collected, and the weight of all residues recovered from the fume traps and the baghouse. These materials are stored in 19-L (5-gal) buckets and labeled with the date, time, and preassigned sample identification number from the log.

Electrode Log:

This record contains the weight and length of each electrode segment and the date and time placed in service. Electrode consumption is calculated from the total electrode consumption over a given melting campaign and the fraction of total power used for each material melted.

SUMMARY

Design criteria and a description are provided for a waste treatment facility to vitrify materials chemically and physically similar to low-level radioactive and mixed wastes buried or stored at INEL and other DOE sites. The facility consists of a feeder based upon screw conveyors and bucket elevator, 1-t (1.1-st) melting furnace with an 800-kV•A power supply, an instrumented APCS with access ports for analysis, and a data management system. The furnace is a sealed, three-phase, refractory-lined, electric arc melting furnace with 10-cm (4-in) graphite electrodes and water-cooled roof, sidewalls, feed tubes, and copper fixture for continuous tapping of slag. The APCS comprises a water-cooled section of duct through the furnace roof, a 3,730-W (5-hp) blower and ducting to inject quenching air into the APCS duct immediately upon exiting the furnace, a double-pipe heat exchanger to adjust exhaust gas temperature, a baghouse, a HEPA filter, and a 7.960-W (10-hp) induced draft blower. Electrical parameters for analyzing demand and consumption by the electric furnace are monitored continuously by an arc furnace analyzer, which measures rms voltage, rms current (A), apparent power (VA), active power (kW), reactive power (var), power factor, and total energy (kW•h). Four channels (V, A, kW, and kW•h) are transmitted to a data logger, which also receives 17 additional inputs from sensors throughout the system, including feed rate, slag temperature, and temperature, pressure, and velocity within the APCS. The data logger applies a linear scaling factor to each input as needed, and transmits the calculated values to a PC at intervals of 1 min for display and storage. A hard copy is printed at 5-min intervals. This facility is available for both public and private use on a cost-sharing basis.

REFERENCES

1. Hartman, A. D, L. L. Oden, and J. C. White. Facility for Melting Residues From Municipal Waste Combustion: Design Criteria and Description of Equipment, USBM RI 9476, 1993, 10 pp.

2. Miles, T. R. (Consulting Design Engineers, 5475 SW Arrowwood Lane, Portland, OR 97225-1323). Feed System Operations Manual 1991-1992; available upon request from L. L. Oden, U.S. Bureau of Mines, 1450 Queen Ave., SW, Albany, OR 97321-2198.

3. Marley Cooling Tower Co. (P.O. Box 2912, Mission, KS 66201). Marley Manual, series NC and NC Modular Steel Double-Flow Cooling Towers, publication OM-NC1-A, Aug. 1991, 12 p.

4. Enercon Systems Inc. (300 Huron St., Elyria, OH 44035-4829). Ash Vitrification Project Fume Temperature Control and Incinerator Operating and Maintenance Manual, Model MC1-36120-D. E.S.I. Project D-1853 and D-1856, Sept. 1991, 128 pp.