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AIR POLLUTANT CONTROL TECHNIQUES FOR ELECTRIC ARC FURNACES IN THE IRON AND STEEL FOUNDRY INDUSTRY

by

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3.0 EMISSION CONTROL TECHNIQUES

3.1 INTRODUCTION

Control of emissions from the electric arc furnace (EAF) requires two separate steps:

- Evacuation or containment of fumes
- Removal of particulates from the evacuated exhaust gas.

This section discusses emission control techniques in common use and also discusses control techniques which may be widely used in the near future. Control of fumes from the melting phase of furnace operation is straightforward, and currently practiced at most foundries. Control of fumes from charging and tapping is not widely practiced at existing foundries. Recently, new designs for control of charging and tapping have been installed on several EAF's and appear promising for economical fume control. In addition, several conceptual designs for charging and tapping control have been developed, and are also addressed in this chapter.

3.2 EVACUATION OF MELTING AND REFINING EMISSIONS

Virtually all EAF's in iron and steel foundries collect furnace emissions during melting and refining with one of three basic systems:

- Roof hoods
- Side draft hoods
- Direct furnace evacuation

Selecting the best system for an EAF depends on physical and structural constraints at the foundry and metallurgical requirements of the furnace.

When properly designed and maint·ined, each system can provide efficient capture of melting emissions and direct them to a gas cleaning device (usually a fabric filter). However, there is normally a small leakage of fume from the furnace or furnace evacuation systems. Some fume inevitably escapes through electrode holes, improperly sealed roof rings and slag doors, especially during initial meltdown and oxygen lancing, if used.

Melting contol systems are not designed to collect emissions from charging and tapping. The collection hoods or ducts are attached to the furnace roof and become inoperative during charging (when the roof is removed) and tapping (when the furnace tilts and disconnects from the main exhaust duct). This section discusses basic control equipment for melting and refining emissions with the understanding that variations of each system are often encountered in the field. Later sections within this chapter address control technology for charging and tapping.

3.2.1 Roof Hoods

The roof hood is attached directly to the EAF, completely enclosing the furnace top as illustrated in Figure 3-1. Extensions of the hood may also collect fumes from the pouring spout, and slag or working door. Hood suction maintains a slight draft through electrode holes and through small gaps between the roof ring and furnace top, effectively drawing fumes into the hood. A disadvantage of roof hoods is that access to electrodes and water cooling glands is restricted, making maintenance and repairs more difficult. This problem is partially eliminated by providing access doors on the hood assembly. The full roof hood is the heaviest of the furnace evacuation systems. When retrofitting an EAF, allowances must be made for increased structural loads

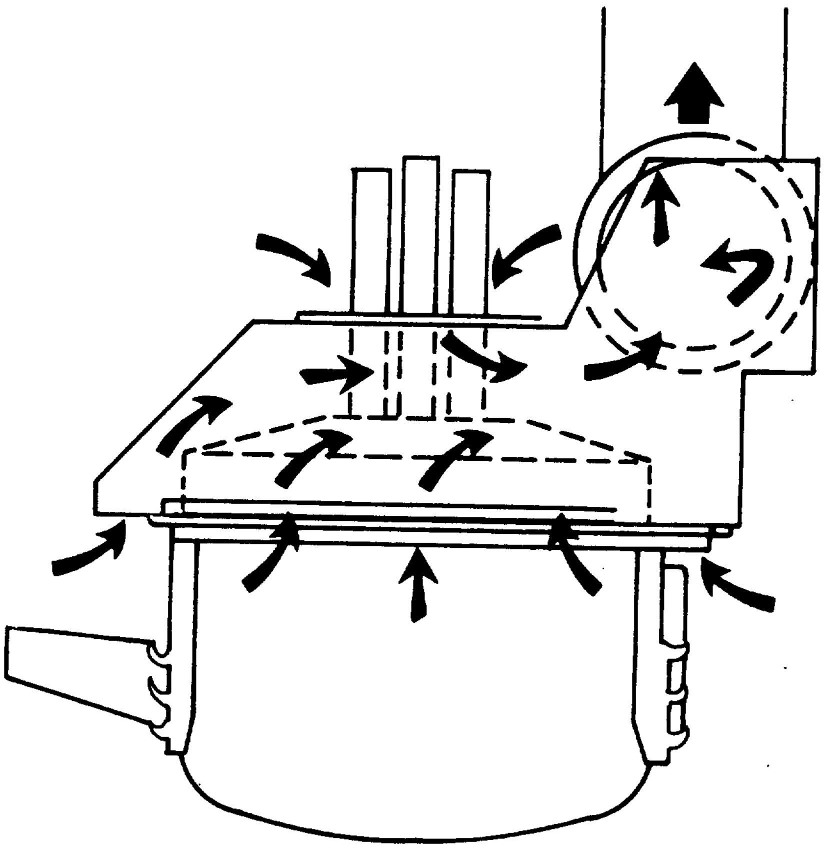

Figure 3-1. Roof hood

on both the furnace roof, base and the mechanisms which remove the roof for charging.

A modification of the roof hood design, called a two-section hood, reduces access and weight problems which may be associated with the full roof hood. This two-section hood has separate subhoods, one located over the electrodes and the other located above the space around the furnace roof gap. Collection efficiency is slightly reduced over that of a full roof hood. The full roof hood can provide most reliable collection of melting and refining emissions as some storage capacity is provided by the hood to contain an instantaneous increase in emissions. As shown in Table 3-1, control efficiency ranges from 95 to 100 percent of melting and refining emissions with 99 percent being a typical, maximum level encountered at foundries. Exhaust flow rates typically range from 7.7 m^3/sec (16,000 acfm) for a 3.9 Mg/hr furnace to about 30.0 m^3/sec (64,000 acfm) for a large, 22.7 Mg/hr furnace. These are about 60 percent of flow rates encountered by side draft hoods of comparable efficiency.[1]

3.2.2 Side Draft Hoods

The side draft hood is the most common of the three fume evacuation systems. It is also mounted on or near the furnace roof as illustrated in Figure 3-2. The hood is designed with one side open for the electrodes so their travel is not restricted. As fumes escape from electrode holes they are drawn into the open side of the hood. Vanes for directing air flow are provided on the ends of the finger ducts. Hoods may also be installed over the pouring spout and slag door to capture fumes which may escape during melting. Larger exhaust volumes are required for side draft as compared to the roof hood since enough suction must be maintained to draw fumes laterally

TABLE 3-1. TYPICAL EXHAUST FLOW RATES AND PARTICULATE REMOVAL EFFICIENCY OF MELTING CONTROL SYSTEMS*

	Typical exhaust flow rate for model furnaces in m^3/sec			Particulate removal efficiency	
	Furnace size			Range	Typical maximum
	3.9 Mg/hr	9.1 Mg/hr	22.7 Mg/hr		
Side draft hood	12.9	19.8	50.00	90-100	99
Roof hood	7.7	11.9	30.0	95-100	99
Direct evacuation	3.2	5.0	12.5	90-100	99

*Data source: Reference 1.

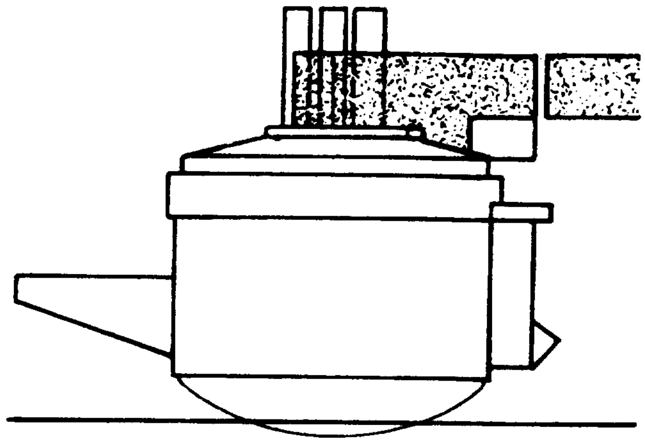

Figure 3-2. Side Draft Hood

into the hood. The larger exhaust flow insures combustion of carbon monoxide and reduces downstream exhaust temperatures. The side draft hood is simpler than a roof hood, places less weight on the furnace and furnace tilting mechanism, and improves access for maintenance of electrodes and cooling glands. To insure effective capture of melting emissions, the furnace roof must be sealed tightly to avoid the escape of fume. This is not a requirement of roof hoods which enclose the entire furnace top.

Retrofitting an existing furnace with a side draft hood generally presents few problems. However, one large, new foundry reported severe deterioration of the finger-like projections which collect fumes from electrode ports. The furnace was directly evacuated, with the side hood designed to catch fugitive emissions from the electrodes. Heavy stainless ductwork was eroded in a matter of weeks, and after many attempts at solving the problem, the company installed a roof hood.[2] However, this is not considered a common problem as many side draft hoods are operating quite satisfactorily on EAF's of all sizes.

Side draft hoods have the greatest exhaust flow rate of the three devices for control of melting and refining emissions. Flow rates range from about 12.9 m^3/sec (27,000 acfm) for a 3.9 Mg/hr furnace to about 50 m^3/sec (106,000 acfm) for the large, 22.7 Mg/hr furnace. These flow rates are typical of nearly recent installations; older, less efficient side draft hoods used lower flows. The maximum collection efficiency expected from a side draft hood is 99 percent, ranging from 90 to about 100.[1]

3.2.3 Direct Furnace Evacuation

Direct evacuation is accomplished through a fourth hole (sometimes termed a "snorkel") in the furnace roof or sidewall, as illustrated in Figure 3-3. A slight negative pressure in the furnace is maintained by a damper in the exhaust duct, which is often automatically controlled by pressure sensors. Furnace fumes are withdrawn through an elbow which is water cooled or refractory lined. Direct evacuation is the most effective method for collecting melting emissions and also results in the lowest exhaust volume. Unlike roof and side draft hoods, direct evacuation requires greater cooling of exhaust gases before entering the gas cleaning device. Cooling is usually accomplished by introducing dilution air, although atomizing water spray chambers, radiant-convection coolers, and air or water cooled duct work may also be used. When exhaust volume is minimized, the gas cleaning device can be of a smaller size and both capital and operating costs are reduced.

While direct evacuation is the most efficient method for collecting melting emissions, it cannot be applied to all EAF's because the internal furnace atmosphere is affected, which in turn influences the chemistry of the melt. The slight, but constant influx of outside air to the furnace cools the slag, makes temperature control difficult and oxidizes carbon in the bath to form

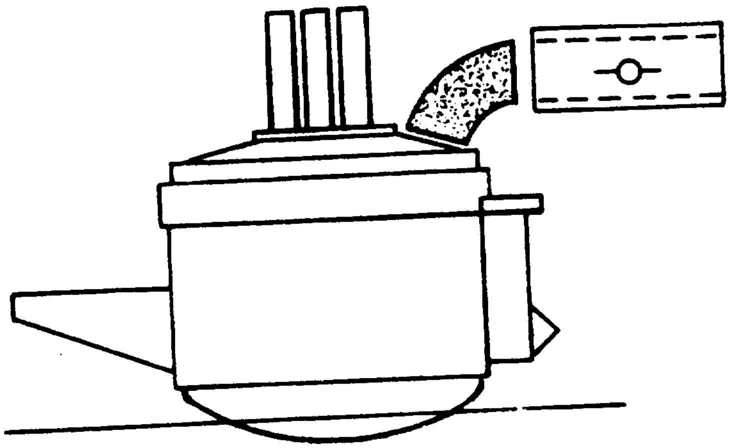

Figure 3-3. Direct Evacuation Through Fourth Hole

carbon monoxide. As a result, direct evacuation systems are least applicable to EAF's which pour high carbon alloys and certain other specialty iron and steel. Direct evacuation is more common with steel making EAF's than with foundry furnaces. It is rarely used, if at all, with iron foundry EAF's.

Formation of excessive carbon monoxide, which can occur with direct evacuation systems, also causes some potential for explosions downstream in the exhaust duct work. This potential problem is usually eliminated by leaving gaps between the furnace and fourth-hole elbow or between the elbow and exhaust duct. This allows introduction of outside air to the exhaust. Because of prevailing high temperatures and excess air, carbon monoxide is readily oxidized to carbon dioxide. Inflow of air also cools the exhaust, reducing deterioration problems in downstream duct work from high temperatures.

Direct evacuation is generally not applicable to iron-producing EAF's because the inflow of fresh air to the furnace causes excessive oxidation of carbon, and it is difficult to maintain adequate carbon in the melt. On small steel furnaces, direct evacuation is not always a viable option because of (1) lack of space for fourth hole in furnace roof and (2) pressure fluctuations in furnace, which are too rapid for automatic control of dampers in the exhaust duct.

The direct evacuation system is probably the device most easily retrofitted to an existing furnace. However, problems reported concerning some EAF's which were retrofitted with direct evacuation include: additional weight on the furnace roof, excessive deterioration of shell refractories and roofs, water cooling problems and clearance problems with roof rotation for charging.

Typically, exhaust flow rates for direct evacuation are 25 percent of those required for comparable fume control with side draft hoods. Table 3-1 shows flow rates ranging from 3.2 m^3/sec (7,000 acfm) for the 3.9 Mg/hr furnace to about 12.5 m^3/sec (26,000 acfm) for the large 22.7 Mg/hr furnace. Because the exhaust gas temperature is considerably greater with direct evacuation systems, compared to side draft hoods, substantial dilution air is normally introduced to cool gases prior to the gas cleaning device (baghouse). Particulate removal efficiency is comparable to side draft hoods, ranging from 90 to 100 percent, with a typical maximum level of 99 percent for well-designed systems.

3.3 EVACUATION OF CHARGING EMISSIONS

EAF's are normally charged by removing the entire roof-electrode-fume hood assembly and dropping scrap into the furnace with drop-bottom charging buckets. As scrap contacts the hot furnace, fumes consisting of hydrocarbon vapors and soot (from entrained oil), iron oxides (from splashing and oxidation of iron), and smoke (from dirt on the scrap) are generated. Charging emissions have traditionally been vented to the atmosphere through roof monitors, since conventional fume collection devices only collect melting emissions. However, because charging and tapping often result in substantial visible emissions, it is becoming more common for regulatory agencies to require control of charging and/or tapping operations.

There are four basic techniques applicable for collecting charging emissions:

- Canopy hoods
- Building evacuation
- Furnace enclosures
- Specially designed, "close capture" hoods

Each technique also applies to control of tapping emissions, which is discussed in Section 3.4. Additional techniques are available for control of charging emissions. For example, charging emissions can be reduced by use of clean scrap. Although most foundries currently seek high quality scrap, dirty scrap can be cleaned prior to charging by preheaters or a degreasing process. Conceptual designs for collecting charging emissions include the hooded charge bucket and closed charging systems, althogh these are not in use at domestic foundries.

3.3.1 Canopy Hoods

The canopy hood is the most common device in current use for collecting charging and tapping emissions at foundries. Located above the overhead crane, canopies are normally operated only during charging and tapping, when the melting collection system is inoperative. A typical canopy hood collector is illustrated in Figure 3-4.

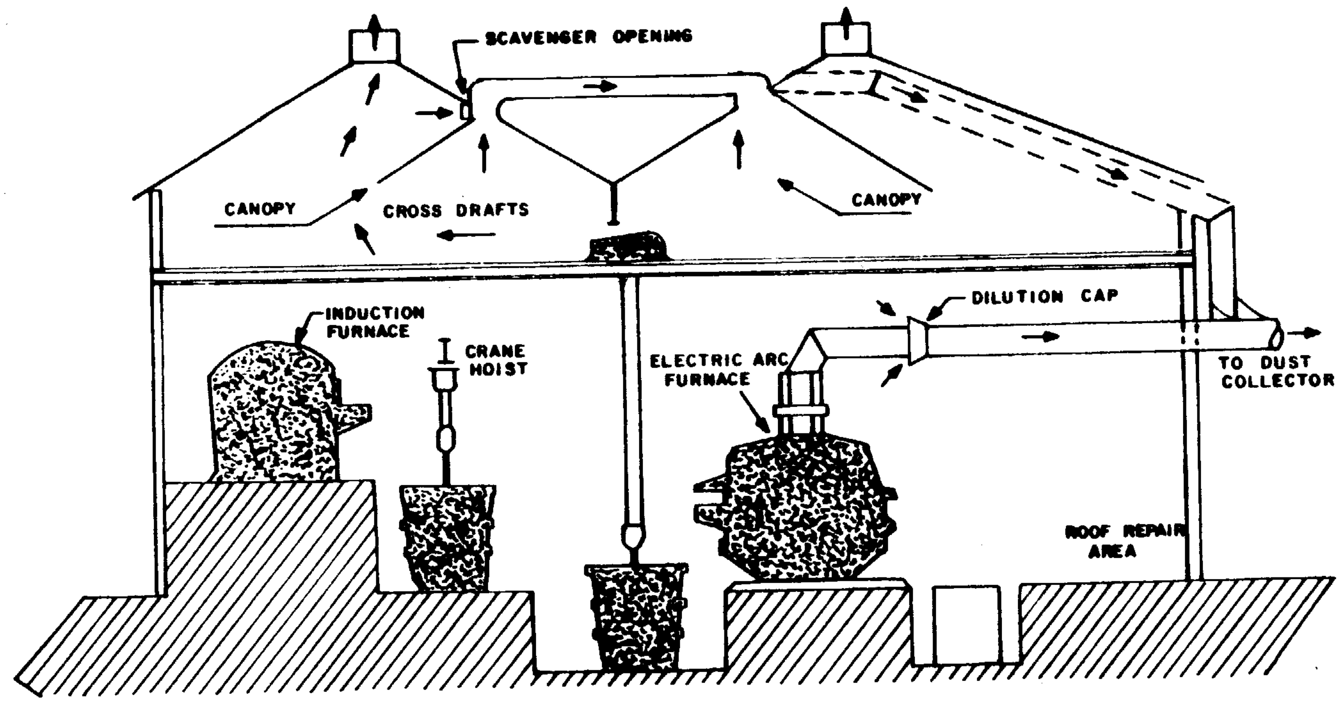

Figure 3-4. Canopy Hood Using Building Roof as Part of the Canopy, Combined with Direct Furnace Evacuation

The configuration and proper location of a canopy is dependent mainly on structural and geometric considerations within the shop. Clearance for overhead cranes and furnace electrodes must be maintained and thus, the most effective position, closely spaced above furnace electrodes, generally cannot be attained. Rather, canopies are either suspended 7 to 13 meters above the furnace, or attached directly to the shop roof. Umbrella-shaped hoods of a diameter larger than the furnace are one design option, while other designs incorporate the foundry roof and side walls. The canopy can be constructed in sections with separate dampers to vary suction exerted by each section. Dampers can then be preset or controlled by an operator to provide a greater suction to areas which receive the most fume.

Because canopies are constructed some distance above the furnace to provide clearance for overhead cranes, exhaust flows must be high to ensure effective capture of fumes. Although thermal currents from the hot furnace help direct fumes upwards to the canopy, flow rates necessary for fume capture are several times greater than that required for control of melting emissions. Consequently, the size and costs of a final gas cleaning device (normally a baghouse) are substantially increased over costs for melting control.

Effective fume capture is not always attained with use of a canopy hood. As the furnace is charged, fumes are sometimes diverted away from the canopy because of impingement on overhead cranes and the charge bucket. Another problem is caused by cross drafts in the shop which have a pronounced, adverse effect on canopy hood collection efficiency. Upward flow of the fume is easily disrupted by drafts from openings along foundry walls and doors, passage of shop vehicles, and even suction hoods which may ventilate other nearby foundry processes. High pressure systems and low humidity tend to allow efficient upward flow of fume to the canopy. However, during periods of low pressure, high humidity, or strong winds, thermal columns above the furnace may not be sufficient to carry fumes directly into the canopy. For small furnaces, a canopy hood is not generally as effective because there is less thermal uplift generated by the smaller furnace.

Several techniques have been used to reduce effects of cross-drafts and improve upwards flow of fumes to the canopy. Many of these techniques are more prevalent at large steel-making EAF's at the steel mill, since emissions are usually greater than at smaller foundry EAF's. At foundries it is common to provide scavenger openings (see Figure 3-4) immediately above the canopy in the exhaust duct work to collect fumes which have escaped and accumulated under the shop roof. Curtain walls constructed of sheet metal have been used to screen sensitive portions of a steel-making furnace area from drafts and improve upward flow of charging and tapping emissions.[3] Another technique recently applied to both foundry[4] and steel-making[5] EAF's is the use of an air curtain. An upwards flow or curtain of air is directed around the furnace to contain and help direct fumes to the canopy. Mobile air curtains have provided an effective method for locating proper positions or counteracting daily variations in cross draft flow patterns at a steel-making shop.[6] Unfortunately, the air curtain often cannot completely overcome the force of cross drafts.

Control of cross-drafts often involves reworking shop ventilation systems. For example, an exhaust hood of a pouring line adjacent to a furnace may create a negative pressure which impedes upwards flow of fume from the furnace. At many foundries, the scrap handling area is adjacent to the furnace and has large doors which open to the atmosphere. Influence of outside winds on canopy efficiency must be reduced by closing these and other openings in the foundry walls.

Particulate collection and removal efficiency attainable with canopy hoods were evaluated during a research and development program conducted by a large British steel company.[7] Canopy hood size and exhaust flow rates were optimized in the development program, and it was determined that 90 to 100 percent of charging and tapping emissions were collected under optimum conditions. However, during periods of strong prevailing winds outside the shop, up to 30 percent of charging and tapping emissions drifted away from the canopy. To control the influence of cross-drafts deflecting the rising plume, vertical sheeting was installed over the entire length of a four-furnace melt shop, roof vents were blocked off, and doors fitted on large openings in the shop wall.

Table 3-2 summarizes exhaust flow rates and particulate removal efficiencies for canopy hoods and other control techniques for charging (and tapping) emissions. Exhaust requirements for canopies are high, ranging from about 65 m^3/sec (140,000 acfm) for a 6.9 Mg/hr furnace to 81 m^3/sec (172,000 acfm) for the large 22.7 Mg/hr furnace. Larger furnaces require proportionally less flow than the smaller because of the benefits of thermal uplift provided by the larger heat source. Flowrates shown are averages of typical values since the physical layout of a particular foundry dictates canopy location and size, and also flowrates. Collection efficiency of the canopy is listed at 80 to 90 percent; with 80 percent considered a typical level because of potential for fume deflection by cross-winds. Efficiency can be much lower for improperly designed canopies, especially in shops which do not control cross-drafts.

TABLE 3-2. TYPICAL EXHAUST FLOW RATES AND PARTICULATE REMOVAL EFFICIENCY OF CHARGING AND TAPPING CONTROL DEVICES AT MODEL FOUNDRIES

	Typical exhaust flow rate for model furnaces in m^3/sec			Particulate removal efficiency (percent)	
	Model furnace size				
	3.9 Mg/hr	9.1 Mg/hr	22.7 Mg/hr	Range	Typical maximum
Canopy hoods, charge and tap[1,7]	65.1	73.2	81.0	80-90	80*
Building evacuation, charge and tap[1,8]	81.0	91.5	101	95-100	99
Furnace enclosure charge[1]	22.8	25.6	28.3	95-100	99
tap				90-95	90
Close capture hoods charge[1]	12.9	19.8	50.0	60-90	80
tap				60-90	80†
Ladle pit enclosure, tap only[1]	12.9	19.8	50.0	90-100	99

*Collection efficiency substantially reduced if cross-drafts are present in shop.

†Tapping efficiency considerably reduced with increasing alloy additions to ladle; i.e., at steel furnaces.

Retrofitting an existing furnace with canopy hoods sometimes requires extensive structural modifications. Trusswork and roof beams must often be relocated, reconstructed and/or strengthened to accommodate the canopy and exhaust duct work. In some shops, there may not be enough clearance between the crane and the roof, or the roof configuration itself may not be adaptable to a canopy installation. Also, space must be provided for the baghouse which will necessarily be of a large size to handle the high exhaust volume.

3.3.2 Complete Building Evacuation

Several large iron foundries operate ventilation systems which completely evacuate the shop, exhausting fumes from charging, tapping and other foundry operations to a gas cleaning device.[4,9] Building evacuation systems are similar to canopy hoods but operate at greater flow rates, exhausting fumes which accumulate under the shop roof. Factors which influence installation of building evacuation over other systems for control of charging and tapping emissions are:

- Insufficient space, or structural limitations to use of a canopy-hood
- Need to collect other fugitive or miscellaneous emissions
- A roof configuration well suited to complete evacuation. Often, the roof can be modified to serve as a collection hood, as shown previously in Figure 3-4
- Desire to exhaust the entire foundry internal atmosphere to reduce pollutant concentration for reasons of industrial hygiene and also to reduce heat stress.

Major considerations in design of a building evacuation system are control of air flow patterns through the building and maintenance of an effective flow rate. Ideally, floor level air inlets surround sources of heat and the fumes are exhausted to a central outlet located overhead in the shop roof. However, compromises in the ideal situation are usually necessary because of structural and shop operational constraints. Excessive turbulence and dead zones must be avoided to ensure proper removal of fumes. Flow control is enhanced by isolating emission sources with partitions constructed to provide maximum feasible containment without interferring with foundry operations. These concepts are illustrated in Figure 3-5.

Air velocity through inlet openings of the building must be adequate to induce flow through proper locations of the shop. Louvers or vertical traveling adjustable doors are sometimes used as inlet openings through building external walls. Air outlets in the roof can be designed to avoid the necessity for large evacuation hoods, relying on the building roof truss area or plenum as a fume reservoir and collection chamber.

The volume of air typically withdrawn for building evacuation systems is difficult to generalize because each foundry is of a different size and building configuration. To maintain a clean internal atmosphere, about five air changes per hour is a typical design factor at steel mills.[10] Data developed for steel-making, EAF shops shows that typical building evacuation systems evacuate about 25 percent more air than an efficient canopy hood. This criterion was used for flow rates summarized in Table 3-2, 81 m^3/sec (170,000 acfm) for the small 3.9 Mg/hr furnace, ranging to 101 m^3/sec (214,000 acfm) for the large 22.7 Mg/hr furnace. Particulate collection efficiency is listed in Table 3-2 as typically 99 percent, ranging from 95 to 100 percent, in recognition of the fact that a few small openings may exist through which some emissions escape.

How many ACFM per Sq. ft. of Bldg?

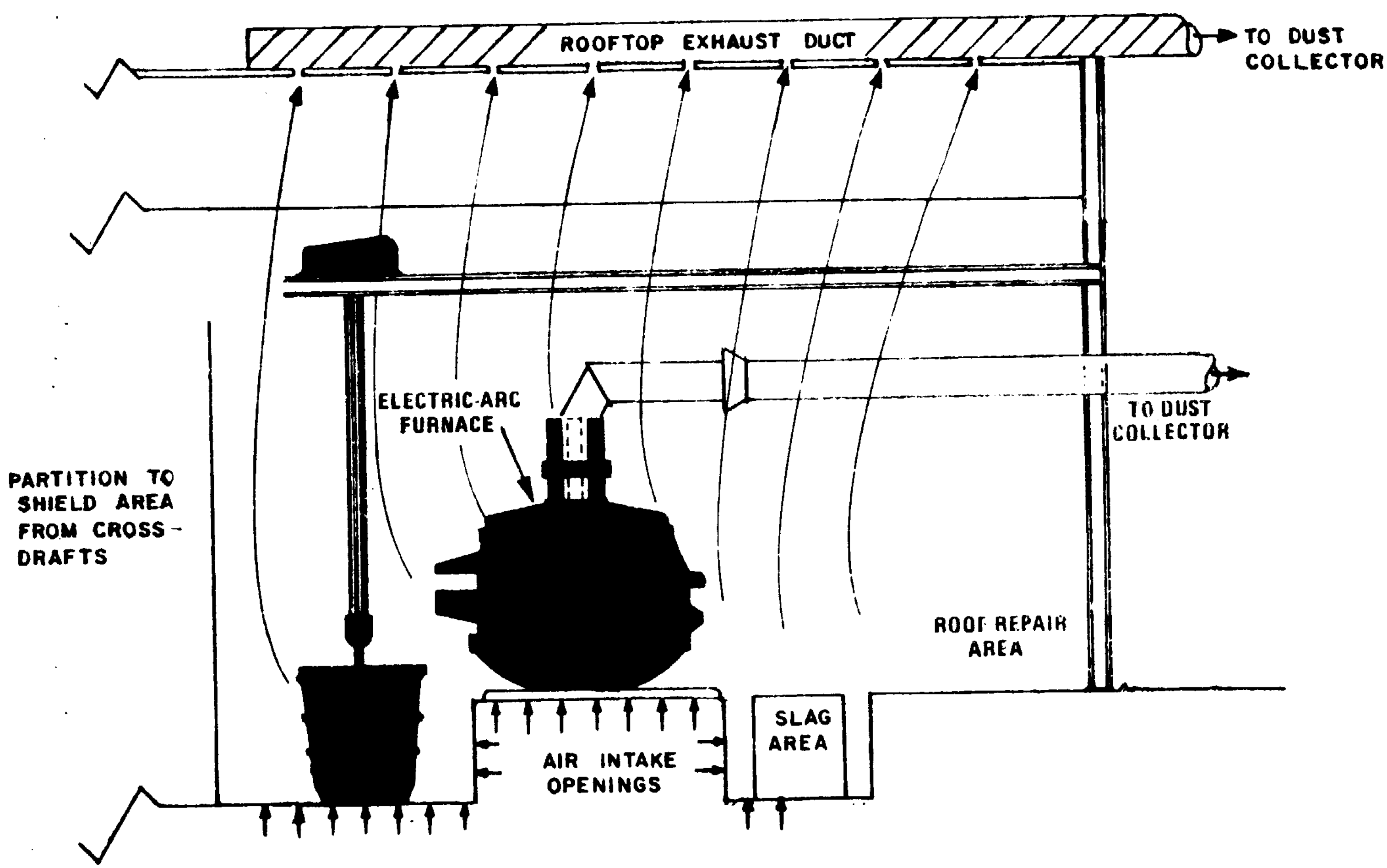

Figure 3-5. Design Aspects of Building Evacuation System

There is a trend towards enclosing roof monitor vents to contain charging, tapping and other fugitive emissions and avoid violation of visible emission codes. A multiple, manifold-type exhaust system ducts contained fumes to the gas cleaning device, normally a baghouse. These systems are not designed as complete building evacuation systems, but are intended to simply remove fumes which accumulate under the shop roof. In this manner, charging, tapping and other fugitive furnace emissions are eliminated at an exhaust flow rate somewhat less than complete building evacuation systems since the exhaust flow rate is only adequate to remove accumulated fumes, not to evacuate the entire building. Although most emissions are collected and removed, a small amount will often escape the foundry through open windows and doors. The new Michigan casting facility of Ford Motor Company[11] is an example of this type of charging (and tapping)control.

3.3.3 Furnace Enclosure

A metal shell which completely encloses the furnace and tapping area can effectively capture emissions from melting, charging, and tapping. A large exhaust duct or hood near the enclosure top removes charging and melting emissions while a separate, local hood contains tapping fumes. Tapping fumes are collected by diverting exhaust flow from the enclosure to a local hood adjacent to the ladle. Several pairs of sliding doors allow entry of the charge bucket by conventional crane, and also provide for slagging, chemical addition and oxygen lancing.

The first domestic application of the shell enclosure concept began operation in 1976 on two 60-ton capacity steel-making EAF's at the Lone Star Steel Company, Lone Star, Texas. The furnaces are part of a new melt shop and each furnace was enclosed as an economical alternative to canopy hoods for control of charging and tapping emissions. Furnace enclosures have not yet been installed in foundries.

Furnace enclosures collect charging and tapping emissions with an air volume 30 to 40 percent of that required by an efficient canopy hood, considerably reducing both capital and operating costs for exhaust duct work, fans and gas cleaning device. These savings are partially offset by the greater capital cost of the enclosure, compared to canopy hoods or building evacuation. Major factors which reduce effectiveness of a canopy hood, namely, cross-drafts and diversion of fumes by the crane, are eliminated with a shell enclosure. As a secondary benefit, furnace noise is somewhat reduced outside the enclosure.

Figure 3-6 shows the basic design at Lone Star Steel Co., and pertinent design parameters are summarized in Table 3-3. Constructed of riveted steel plates, each enclosure is a cube with a domed or rounded top measuring 44 feet on edge. The enclosures contain the minimum volume which provides clearance for furnace roof removal during charging and for furnace electrodes when tilted for a tap. Pneumatic cylinders operate large vertical doors on the front of the enclosure, and an electric motor operates a segmental, horizontal, cable-guided top door to allow furnace charging by conventional crane. Smaller vertical doors at rear of enclosure allow access for oxygen lancing, slagging and chemical additions.

When charging, the crane operator has a line of sight to the furnace through the top enclosure doors. Final positioning of the charge bucket is aided by radio contact with a worker inside the enclosure. When a charge is dropped into the furnace, the front, charge doors are closed but the top, horizontal door remains open. A fan-type air curtain directs fumes past the

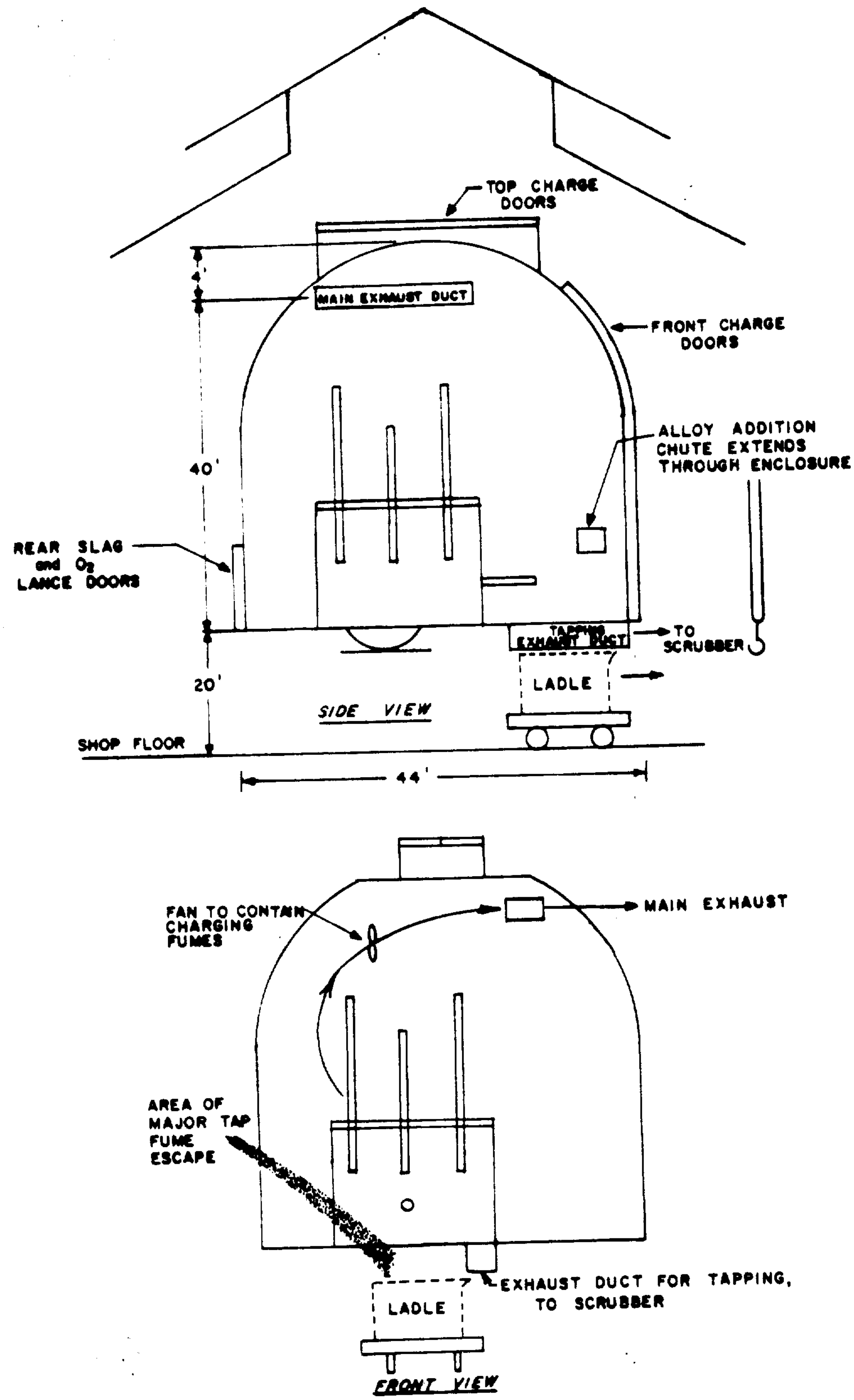

Figure 3-6. Sketch of Furnace Enclosure Design at Lone Star Steel Co.

TABLE 3-3. DESIGN DATA FOR LONE STAR STEEL COMPANY FURNACE ENCLOSURE[12]

I. Steel-Making Facilities

Two 60 ton Whiting EAF's, each enclosed in 114,000 cu ft enclosure. Enclosures measure 44 feet on edge; furnaces are 20 feet above ground level. Average 2-1/2 hours per heat.

II. Gas Flow Rate, per Enclosure

Charge, melt, refine and tap
35 to 42 m^3/sec
(75,000 to 90,000 afcm)

III. Exhaust Gas Temperatures

A. Charge, melt and refine
80°C (175°F)

B. Tap
120°C (250°F)

IV. Dust Concentration Measured by Lone Star Steel Co. (EPA Method 5)

A. Inlet to Steam-Hydro Scrubber
1.0 gr/scf

B. Outlet from Steam-Hydro Scrubber
0.0045 gr/scf

V. Suction Required

Inlet to scrubber units
7.5 in. w.g.

VI. Capital Cost

A. Enclosures, ducting, and auxiliary equipment, excluding gas cleaning device, $900,000 per enclosure

B. Steam-Hydro gas cleaning units only: $200,000 per enclosure.*

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*Utilized existing waste heat boiler and slurry treatment facilities.

open top doors to the exhaust duct. During melting, doors are closed and fumes are exhausted from the enclosure by a large rectangular exhaust duct located 1.2m (4 ft) below the enclosure top, above the furnace. Between 75,000 and 90,000 afcm is withdrawn from each enclosure by suction developed by Lone Star's proprietary Steam-Hydro scrubber which cleans furnace exhaust. Slagging, chemical additions and oxygen lancing are conducted through a third set of doors at the furnace rear. The furnace is tapped in a ladle which is placed on a rail car by the overhead crane, then rolled into position under the enclosure. Tapping fumes are collected by diverting flow from the main exhaust duct to a hood which is adjacent to the ladle. Both furnaces and enclosures rest on a platform about 6.3m (20 ft) above the melt shop floor. This provides room for the tapping ladle car and also provides air flow from underneath the furnaces to effectively carry fumes to the main exhaust duct.

Lone Star Steel has encountered no major problems in using the enclosures. Almost all charging emissions are contained by the enclosure and exhausted from the shop. Presently, only clean, in-plant steel scrap is used as charge. Lone Star has run trial heats charging No. 2 bundles (autobodies processed through a compactor). Because of combustion of contaminating oil and organic matter, flames from the hot furnace reached to the top of the enclosure. Lone Star indicated that the trial runs showed additional enclosure height would be necessary if dirty scrap were to be used routinely. When clean scrap is charged, roughly 95 to 99 percent of charging emissions appear to be collected. This estimate is based on observations of engineers who visited the plant on behalf of EPA, and on statements of plant engineers, and the local air pollution control agency.[12]

Melting emissions are also effectively contained by the enclosures. When viewing the enclosure interior during melting, fumes appear to flow directly upwards in a column towards the exhaust duct near the top. The space around the inside perimeter of the enclosure is relatively free from fume, as the rising column does not fill the entire enclosure. Flames and fumes violently escape furnace electrode holes during melting. The absence of visible emissions from the top of the enclosure suggests that almost 100 percent of melting emissions are captured. Opening of rear enclosure doors for oxygen lancing or slagging did not noticeably affect the uniform flow of melting fumes upwards to the exhaust duct.[12]

Fumes generating during tapping appear considerably greater in magnitude than charging emissions. A tap lasts 6 to 8 minutes. Alloys are continously added to the ladle through a special chute extending through the enclosure side. Tapping fumes are drawn laterally into a rectangular side draft hood adjacent to the ladle top. Most fume was drawn into the hood, as the entire 75,000 to 90,000 cfm exhaust rate is diverted from the enclosure to the tap hood, and capture velocity is quite high. Roughly, 10 percent of tapping fumes escape collection, exiting the enclosure primarily through the alloy addition chute, and to a lesser degree, through enclosure doors. Fumes escaping the alloy addition chute dissipate substantially by the time they reach the melt shop roof. Lone Star's smoke observers have read opacity of fumes escaping the roof monitors ranging from 0 to 40 percent during tapping, averaging about 8 percent.[12]

Another steel-making EAF enclosure was scheduled for operation in Europe in 1977. This system, shown in Figure 3-7, is offered by the Krupp Co. It relies on an enclosure somewhat larger than at Lone Star Steel. A direct roof

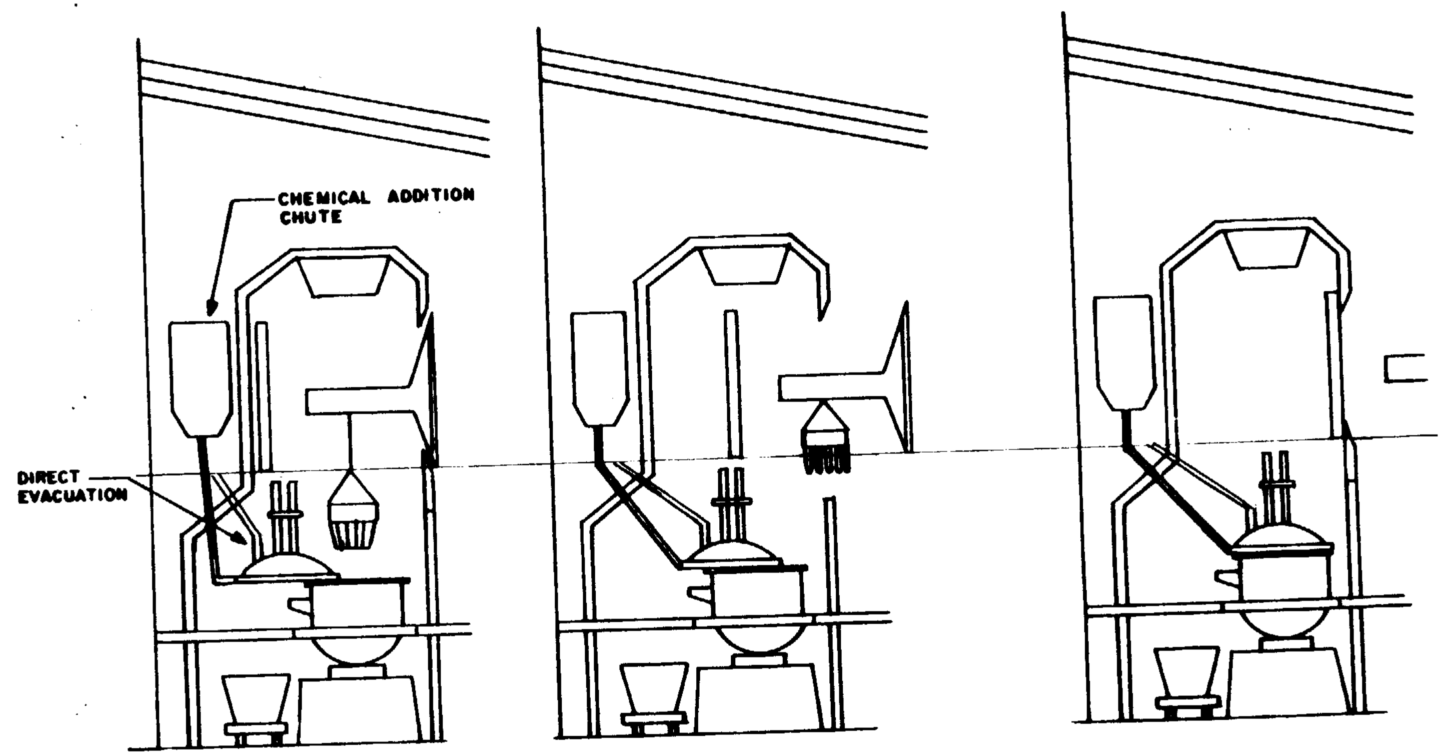

Figure 3-7. Krupp Furnace, Sequence of Events During Charging

evacuation tap supplements fume control during melting. Instead of sliding doors, a section of the enclosure side wall moves horizontally to allow passage of a specially-designed charging crane. The crane is designed with a section which seals the enclosure during charging (see Figure 3-7). Procedures for tapping and alloy additions are similar to methods used at Lone Star. Available data indicates that the enclosure volume for a 128 megagram (140 ton) steel EAF is 11,000 m^3 and enclosure exhaust rate is 135 m^3/s (290,000 afcm) during charging and tapping and 105 m^3/s (226,000 acfm) during melting. No other details are readily available on the Krupp design.

While the enclosure concept appears to be a very effective method for capturing furnace emissions with minimum exhaust volume, it would either be difficult to retrofit this technology to existing furnaces or the effectiveness of the system would be reduced for several reasons:

- Lack of adequate space at existing furnaces may preclude installation of the enclosure, which is larger than the furnace. Adjacent walls, furnaces or foundry process equipment would, in many cases, interfere with enclosure placement.
- At most foundries, the furnace rests on the shop floor and the tapping pit is located below grade. Tapping pits may be too small to accommodate the rail car necessary for carryin the ladle under the enclosure.
- Where existing furnaces rest on the shop floor, airflow through the bottom of the enclosure cannot be optimized as in the case of Lone Star Steel where the furnaces are 6 meters above the shop floor.

- Location and configuration of charging cranes may not be amenable to operating around and within the enclosure.
- Slagging, alloy addition and oxygen lancing procedures must be somewhat modified with use of an enclosure, but this is of minor importance.

3.3.4 Close Capture Hoods

The "close capture" concept for controlling charging, melting and tapping emissions, as supplied by the Hawley Manufacturing Company, is illustrated in Figure 3-8.[13] Melting and refining emissions are evacuated by a circular hood which completely encompasses the electrodes, unlike conventional side draft hoods which are open on one side. This allows improved collection of fumes with minimum exhaust volumes. Capture of charging emissions is accomplished by an annular hood which encompasses the furnace roof ring during charging. The charging hood is designed to rotate onto the furnace during a charge, and then rotate back to the furnace side during melting. Charging fumes are withdrawn radially through slots in the inner hood circumference; the slots serve to increase capture velocity and improve fume collection. When charging, dampers in the exhaust duct work divert the exhaust flow from the circular hoods to the charge hood.

Tapping emissions are collected by enclosing the tap spout with an inverted u-shaped hood which is exhausted through one of the vertical sides. When charging or tapping, dampers divert most of the exhaust flow from the electrode hood to the charge or tapping hoods. A telescoping joint allows the electrode hoods to withdraw a moderate amount of fume from the furnace during tapping, supplementing the tapping hood exhaust. The tap hood only encloses the furnace tap spout and a portion of the ladle, as opposed to

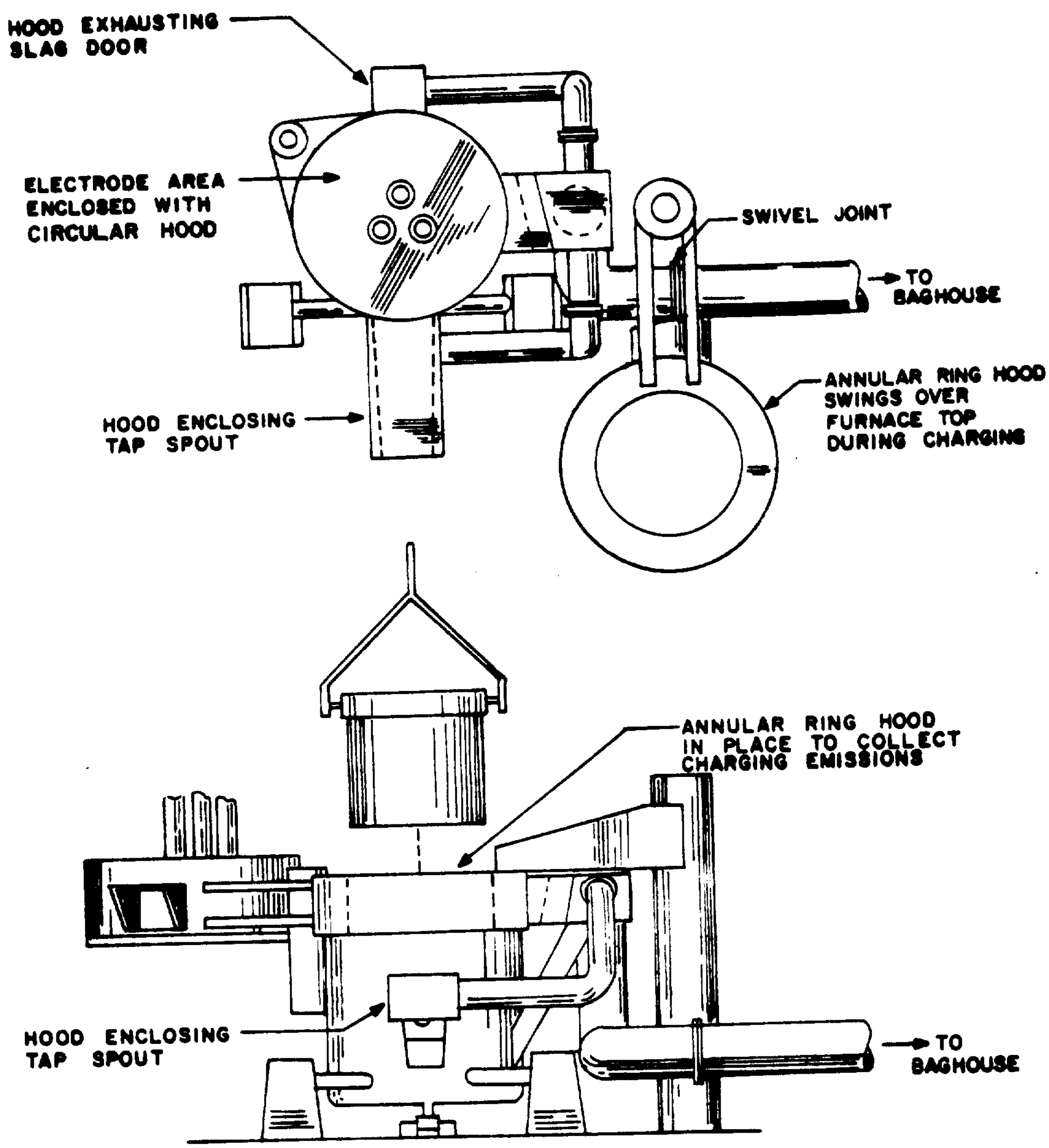

Figure 3-8. Hawley Close Capture Hoods

other designs (furnace enclosure, ladle pit enclosure) which enclose the entire ladle for more complete fume containment. A small, separate hood is also provided for the slag door.

The advantage of the close capture design is that control of charging and tapping are provided at an exhaust flow rate much less than for canopy hoods or furnace enclosures. This significantly reduces the quantity of exhaust gas delivered to the particulate control device, thus reducing costs of gas cleaning. Also, the close capture hoods are simpler and considerably less expensive to install than a furnace enclosure or canopy hood. The disadvantage is the complete control of charging and tapping may not always be provided because the charge/tap hoods do not completely enclose emission sources.

Exhaust flow rates of the close capture design are comparable to those used with conventional side draft hoods. For example, a 3.9 Mg/hr model furnace would require about 12.9 m^3/sec (27,400 acfm) for the close capture hoods, contrasting sharply with 65 m^3/sec for canopy hoods and 23 m^3/sec for a furnace enclosure. The manufacturer guarantees total particulate removals of 100 percent for melting and 80 percent for charging and tapping (of iron). However, these efficiencies have not been verified by EPA. As alloys are added to the ladle (i.e., steel foundries), tapping control efficiency is expected to be substantially reduced. Control of backcharging is also likely to be less than 80 percent.

The close capture design is applicable to most new foundries where the furnace area can be designed to accomodate the hoods. The close capture design has recently been applied to several foundries. At one particular steel foundry, visited by representatives of EPA,[14] there was not enough clearrance between the furnace and the transformer room wall to allow employment of the annular charging ring. In this retrofit case, only a partial charging hood could be used, mounted to the furnace shell to partially encompass charging emissions. Collection efficiency of charging emissions was observed to be substantially lower than that expected from the complete charging hood. Many existing foundries will likely have similar space restrictions which limit control options such as the Hawley design (and also furnace enclosures, and certain other options).

3.3.5 Control of Charging Emissions by Use of Clean Scrap

Charging clean scrap to an EAF substantially reduces charging emissions. When dirty scrap contacts a hot furnace, oil and other volatile impurities combust, releasing dense clouds of soot and smoke. Oily scrap can also cause premature roof failure around electrode ports, damage dust evacuation hooding and ducts and also clog or "blind" a fabric filter control device. Use of dirty, substandard scrap has been estimated to increase overall furnace emissions by up to 100 percent - although quantitative test data for charging emissions are generally not available.[15] Contact with several state and local air pollution agencies indicated that quite often, foundries are required to use a clean scrap to control charging emissions.[16] For example, the Los Angeles County Air Pollution control district issues operating permits to furnaces which use clean scrap as the method to control charging emissions. No visible emissions are detected at roof vents above the furnace during charging.

3.3.6 Preheating or Degreasing Scrap to Reduce Charging Emissions

Charge preheaters are standard equipment on induction furnaces for cleaning the charge, removing water, and avoiding operating problems of charging dirty scrap. Few preheaters are used in EAF foundries although they have been used overseas as a method for producing clean scrap for reduction of charging emissions on electric arc furnaces in foundries.

The most efficient preheater is the conveyor type which applies a fossil fuel flame to the scrap under a fume collection hood. The conveyor typically discharges clean, hot scrap to a charge bucket although a few systems have been designed to charge directly to the induction furnace.[17,18] Preheating in a special charge-preheat bucket has been used but does not result in uniform preheating. Ultra hot, intense flame jets must be directed into the scrap for certain periods to heat the entire charge, increasing the danger of over-oxidation of thin pieces of scrap. Excessively oxidized scrap requires considerably more energy for melting.

Some preheaters are designed with a secondary combustion chamber which acts as an afterburner for controlling emissions from the preheater. One manufacturer of preheaters for induction furnaces reports that air pollution codes of Los Angeles County are met by a local facility using this type of preheater. Emission data for preheaters is not readily available.[17]

Preheaters used for induction furnaces reportedly reduce overall power costs for melting because the preheaters more efficiently heat the metal, and costs for fossil fuel have traditionally been less than electricity. Net energy savings with preheaters have been quoted on the order of 75 kWh per ton of metal,[17,18] compared to normal melt requirements of about 500 kWh/ton.

Application of preheaters to EAF's will likely be severely limited by fuel shortages. Natural gas supplies to industry were severely reduced this past year, and many industries expect shortages throughout the next few years. Other gases, such as producer gas, if available, could be used also.

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