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Review of Standards of Performance for Electric Arc Furnaces in Steel Industry

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Emission Standards and Engineering Division

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U.S. ENVIRONMENTAL PROTECTION AGENCY
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1.0 INTRODUCTION

Section 111 of the Clean Air Act, "Standards of Performance for New Stationary Sources," requires that "The Administrator shall, at least every four years, review and, if appropriate, revise such standards following the procedure required by this subsection for promulgation of such standards."

The purpose of this study is to review the current new source performance standards (NSPS) for electric arc furnaces (EAF's) in the steel industry and to assess the need for revision on the basis of developments that either have occurred or are expected to occur in the near future. This report addresses the following issues:

1. Utilization of EAF's in the steel industry.
2. Review of the best demonstrated control technology for emission control.
3. Review of existing and new control technology since promulgation.
4. Review of EAF's that are exempt from the standard.
5. Review of problems related to compliance with NSPS.
6. Analysis of available EAF particulate and visible emission test results.

Based on the information developed in this study, specific recommendations are made for changes in the current NSPS.

2.0 SUMMARY

Control technology for EAF shops has been improved and refined since the promulgation of the original NSPS. Fugitive emission control technology, especially for charging and tapping emissions, has been developed, and furnace emissions can be captured more effectively. These improvements afford a more stringent control of visible emissions than required by the present NSPS. Some compliance test problems have developed in enforcing the visible emission portion of the NSPS.

2.1 LATEST CONTROL TECHNOLOGY FOR ELECTRIC ARC FURNACE SHOPS

There are several control technologies that EAF shops can use, but only a few recent options are available that can be considered best demonstrated control technology for both process and fugitive emissions. The combination of direct shell evacuation, canopy hoods, fugitive dust pickup system, and a closed roof appears to be the most overall efficient system. Another commonly used system includes a canopy hood, fugitive dust pickup system, and a closed roof. Total enclosure of the furnace, a new concept since the NSPS was promulgated in 1974, can potentially capture all process and fugitive emissions (charging and tapping). Since these emissions do not mingle with other shop emissions, enforcement issues are reduced (See Section 5.3). Partial or semi-furnace enclosure is another concept which encloses the furnace by four walls with the top open, so that a crane can reach the furnace area. The walls, acting as a "stack", force the emissions to rise from the furnace into the overhead canopy hoods. The EAF shop itself can also have a closed roof.

One European system preheats the scrap feed with the hot furnace gases while scrap is fed continuously to the furnaces. This system offers the advantage of confining the charging emissions to the preheater (ducted to a control device) and thus permits a simple collection system. The scrap size for this system must be controlled. Only one U.S. plant (foundry) uses this type of system. The systems previously described usually have baghouses as the control devices. The one furnace enclosure system used in the U.S. uses a proprietary scrubber system, but a baghouse could be used effectively on this system.

2.2 RATIONALE FOR REVIEW OF NEW SOURCE PERFORMANCE STANDARDS FOR ELECTRIC ARC FURNACES

The rationale of the current NSPS that closed roofs, building evacuation, and limited control for tapping or fugitive emissions was too costly and energy intensive, or that technology was not developed may not be valid today. Regulations currently being developed by some local agencies appear to be more stringent than the NSPS. Also, more stringent control (than required by NSPS) may be necessary to prevent significant deterioration of the air quality or to meet off-set policies in specific areas. The technology trend is toward the use of sealed roofs, canopy hoods, and a fugitive dust pickup system. Control technology developed and demonstrated for fugitive emissions mainly from tapping and charging is the major improvement in controlling visible emissions. Although only one official NSPS compliance test has been carried out since promulgation of NSPS, some unofficial test data indicate that emissions from certain new furnaces are below the NSPS for particulates and visible emissions.[1-4]

2.3 INCLUSIONS AND EXEMPTIONS IN REVISED NSPS

A speciality type furnace known as the argon-oxygen decarbonization (AOD) furnace should be included in the NSPS because this furnace is a significant source of particulate and visible emissions. Although AOD furnaces are not electric furnaces, they are an integral part of an EAF shop and should, therefore, be considered for inclusion under an EAF standard. This change may require alternation of the definition of the affected facility portion of the NSPS.

Several other speciality electric arc furnaces used in the industry should officially be listed as exempt from the NSPS. Electric arc furnaces using prereduced pellets should also be reviewed in detail to determine whether their exempt status should be continued. These findings indicate revision of the current NSPS should be considered.

2.4 REFERENCES FOR SECTION 2.0

1. Region IV, 1977. Memo dated February 28, 1977 to Drew Trenholm, ESED from Bruce Miller, Region IV.

2. Blair and Martin, 1978. EAF Fume Control at Lone Star Steel Company, Lone Star, Texas.

3. Reinke, J.M., 1976. Letter dated November 1, 1976 to Mr. Michael Maillard. Wayne County Department of Health, Air Pollution Control Division. Detroit, Michigan.

4. Adams, J.I., 1978. Letter dated September 20, 1978 to Mr. John E. McGrogan, P.E., Department of Environmental Resources, Bureau of Air Quality. Wernersville, Pennsylvania.

3.0 ELECTRIC ARC FURNACES IN STEEL INDUSTRY

3.1 General

Major sources of air pollution in the steel industry are the basic oxygen process, electric arc, and open hearth steel production furnaces; blast furnaces; and coke and sintering plants (Figure 3-1). All will emit large quantities of air pollutants (primarily particulate matter) if not properly controlled. The first standards of performance for electric arc furnaces were promulgated in October 1974. This review was conducted to determine whether existing standards for electric arc furnaces should be revised as required in Section 111(b) of the Clean Air Act as amended August 1977.

Standards for the basic oxygen process furnace (BOPF) were developed before those for the electric arc furnace (EAF) because the BOPF was projected to experience the greatest share of the future growth in steel production. Electric arc furnaces will also participate in the growth because of the increased use of scrap to produce steel. These projected growth rates result from increased demand for steel, replacement of obsolete steel producing furnaces, and higher energy costs. Figure 3-2 shows trends for the past 15 years in the production of steel from these three types of furnaces.[1]

A BOPF can produce steel at a greater rate than the other types of furnaces. Since the BOPF has no exterior source of heat, it must be operated in conjunction with a blast furnace. Because the BOPF requires a high percentage of molten pig iron as part of the charge, the amount of steel scrap that can be recycled by the BOPF shops is limited. In contrast the EAF is very attractive because it can accept a charge that is all scrap.

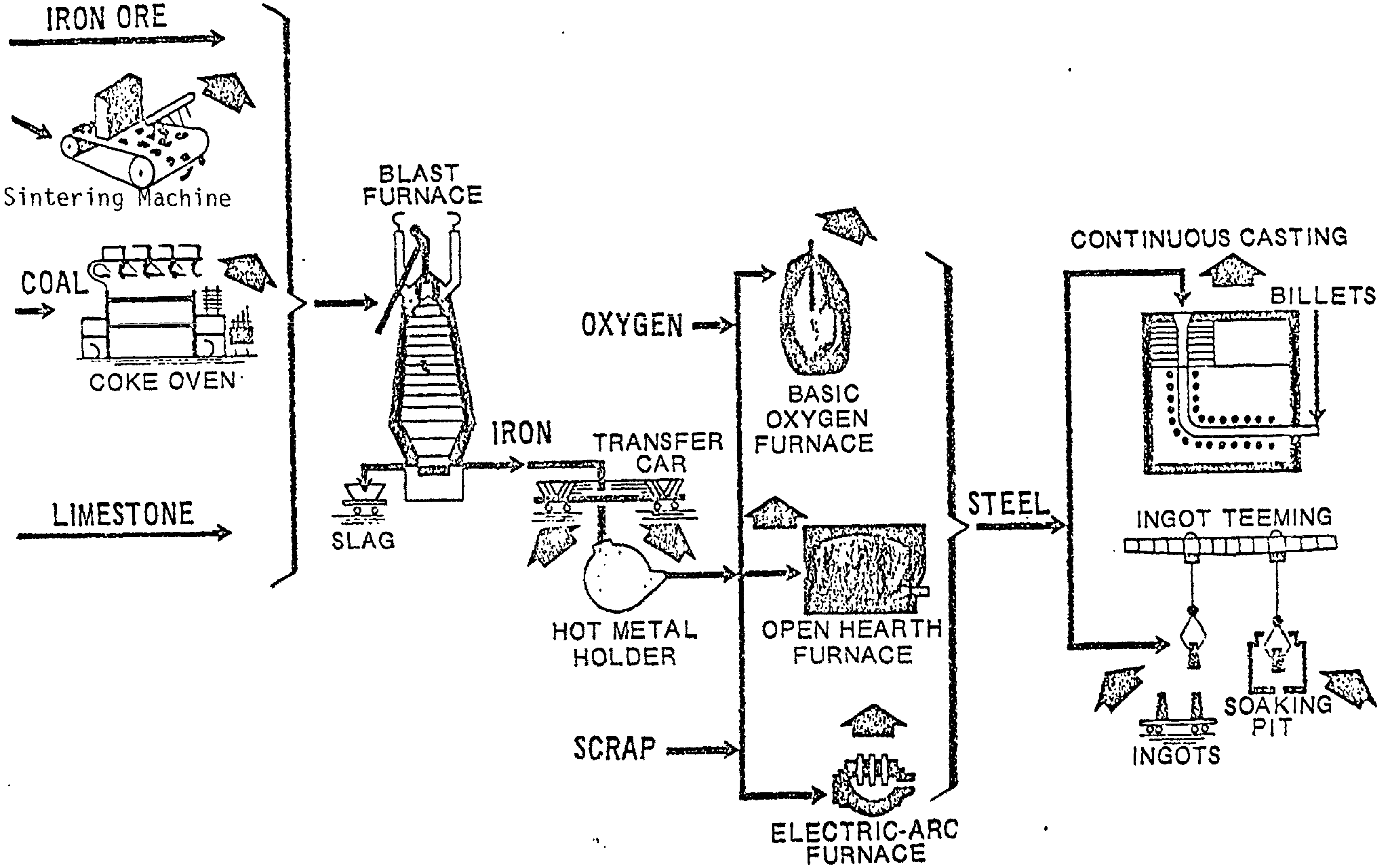


Figure 3-1. Flow-diagram of an iron and steel plant.

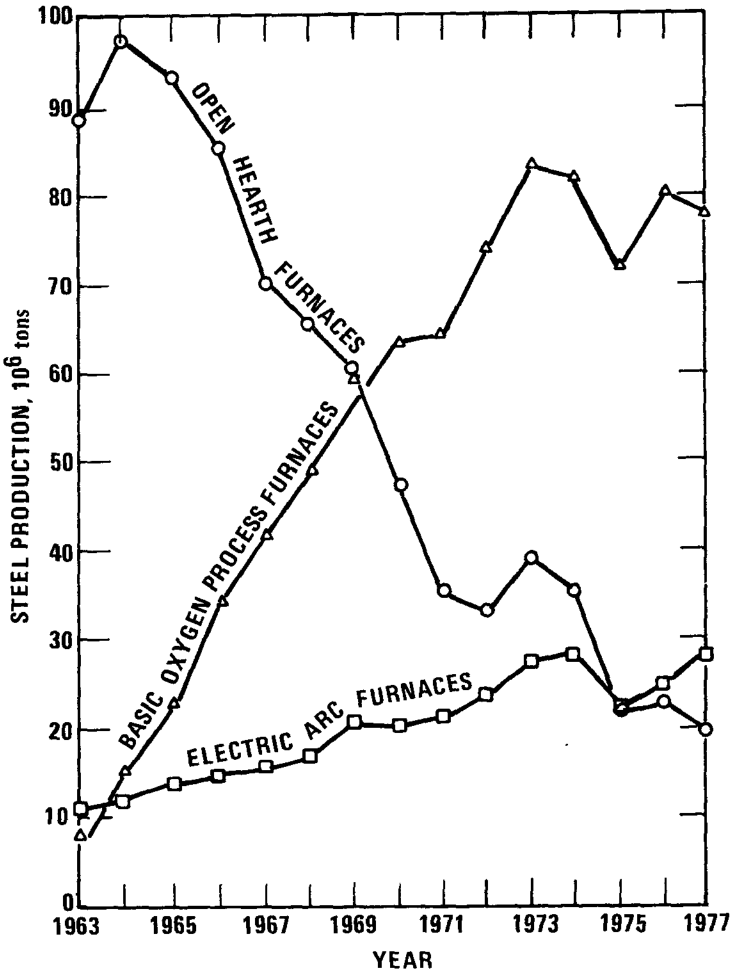


Figure 3-2. Steel production trend by type of furnace.

In fact, about 98 percent of the steel produced by EAF's in 1977 was recycled steel scrap.[2] EAF's are also particularly suited to production of alloy steels where only small batches are needed.

The steel industry categorizes the majority of electric furnaces into electric arc (EAF), argon-oxygen decarbonization (AOD), vacuum arc remelting (VAR), vacuum induction melting (VIM), consumable electrode melting (CEM), and electroslag remelting (ESR) furnaces. Each has a specific function for producing different types of steel. The existing NSPS exempts AOD, VAR, VIM, and ESR electric furnaces because the tonnages produced were found to be significantly less than the production from conventional electric arc furnaces. Some differences are involved in the operation of these furnaces, and the emission rates may vary considerably. For these reasons, the furnaces were made exempt from the NSPS.

In 1977, electric arc furnaces produced 27,882,000 tons of steel. Of this amount, 70 percent was carbon steel, 23 percent was alloy steel, and 7 percent was stainless steel. This production accounts for 18 percent of the carbon steel, 42 percent of the alloy steel, and all of the stainless steel produced in all furnace types.[2]

In 1977, the 303 EAF's in the United States were operated by 85 companies at 114 locations. Furnace capacity ranges from an almost toy-scale 3 tons to 400 tons, with about 50 percent of the furnaces under 49 tons, 25 percent at 50 to 99 tons, 9 percent at 100 to 149 tons, 10 percent at 150 to 199 tons, 5 percent at 200 to 300 tons, and 1 percent over 301 tons capacity. Larger furnaces are usually located in integrated steel mills. Many of the smaller furnaces are in small plants that produce a limited variety of products or small quantities of specialty steels.

Among the factors now tending to increase EAF steel production are: increasing blast furnace energy costs, larger supplies of steel scrap, growing use of specialty steels, additional mini-steel plants that normally use EAF's exclusively, and adoption of ultra-rapid steel melting technology from Japan and other foreign countries.

3.2 Description of the Process

Electric arc furnaces are cylindrical refractory-lined vessels with carbon electrodes that are lowered through the furnace roof (Figure 3-3). With the electrodes retracted, the furnace roof can be rotated aside to permit the charge of scrap steel to be dropped into the furnace. Alloying agents and slag materials are usually added through the doors on the side of the furnace. Some smaller or older furnaces are charged through these side doors. Current is applied to the electrodes as they descend into the furnace. The scrap is melted by the heat generated by the arc as it shorts between the electrodes and the scrap. The slag and melt are poured from the furnace by tilting it.

The production of steel in an EAF is a batch process. Cycles or "heats" range from about 1.5 to 5 hours to produce carbon steel and from about 5 to 10 hours or more to produce alloy steel. Scrap steel is charged to begin a cycle, and alloying agents and slag materials are added for refining. Each cycle normally consists of alternate charging and melting operations, refining (which usually includes oxygen blowing), and tapping.

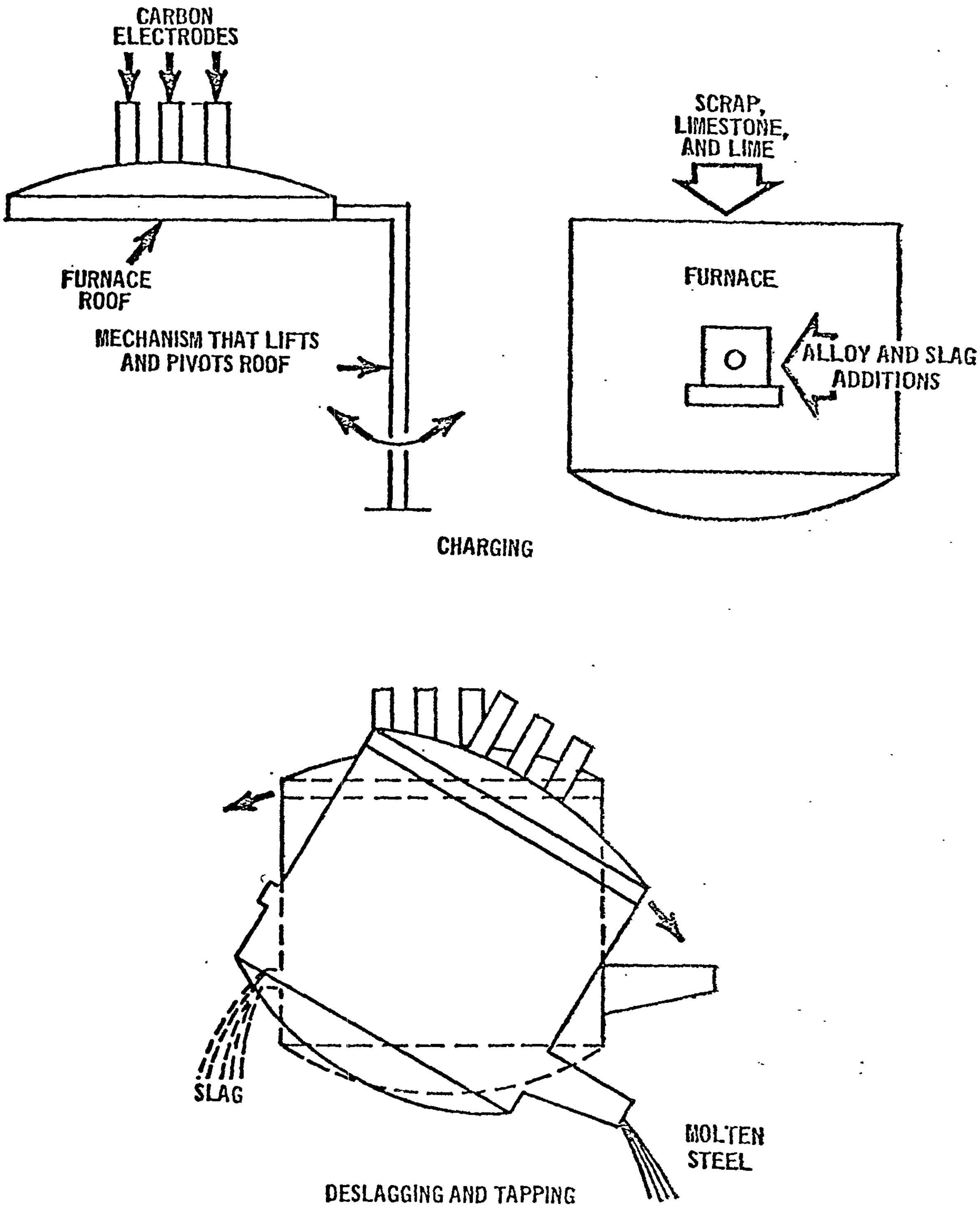


Figure 3-3. Electric-arc steel furnace.

AOD furnaces are refractory-lined vessels generally U-shaped like basic oxygen furnaces. They are used to refine hot metal from EAF furnaces. Molten steel from the EAF is transferred by ladle to the AOD furnace. Although procedures vary somewhat, major alloy additives are made in the AOD. A mixture of argon-oxygen is blown into the molten steel through tuyre pipes in the bottom or side of the furnace to oxidize the carbon. Nitrogen can also be added through these pipes if a nitrogen-bearing grade of steel is desired. After carbon oxidation is complete, additional fluxes are added to remove sulfur and other undesirable impurities from the molten metal. Upon completion of the refining process, excess slag is removed and the remaining molten steel is cast into ingots or electrodes for further processing. The complete AOD process usually takes about 90 minutes.

During the carbon oxidizing process, emissions from an AOD furnace are given off as copious dense black fumes. When decarbonization is complete, the emissions are much less, but are still quite significant. The opacities of emissions from AOD's are similar to those from EAF's, but mass emission data are not available.

VIM and VAR furnaces are sealed refining furnaces that remelt materials made by the other furnaces for very special types of steel products. Current applied across the furnaces generates heat to the material to be remelted, and a vacuum to about 5 micrometers is drawn at the same time to degas the molten steel. The steel is reformed into a new ingot or electrode, which may be further processed. As shown in Figure 3-4, the electrode is a long (10-15 feet) cylindrical (6-12 inches in diameter) piece of steel. The electrode is used in all the remelting furnaces, except the VIM furnace, which requires smaller than fist-size pieces for easier remelting. Imperfections in castings made from this steel are eliminated by degasing. Because these furnaces operate under a vacuum, no emissions are generated.

ESR melting is a hyper-refining process in which ingots (electrodes) made from the EAF, VIM, and VAR furnaces are remelted under a specially compounded molten slag. Figure 3-4 is a schematic of the ESR furnace system. Steels produced in an ESR furnace have more uniform grain structures, fewer defects, and better mechanical properties than conventionally produced steels. Figure 3-5 shows one of the features of steel made from an ESR furnace. Current applied across the furnace generates heat to remelt the electrode. New and usually larger ingots are made. There are no emissions generated during this process.

3.3 Emission Sources

Most emissions occur during the early "melting" portion of a furnace cycle, although significant quantities are also emitted during charging, tapping, and oxygen-blowing operations. Emissions of up to 30 pounds of particulate matter per ton of steel produced [4,5] are generally acknowledged. Information supplied by steel manufacturers on the quantity of particulate matter collected by control devices suggests, however, that 30 pounds per ton may actually be conservative [6] for production of carbon steel and that 15 pounds per ton is a reasonable value for alloy steels.

Particulate matter emissions may also vary from cycle to cycle and from batch to batch. Contamination of the scrap steel with dust, oil, or volatile metals, for example, increases emissions during charging. An increase in electrical power to a furnace increases emissions during the scrap melting. Variations in the quantity of oxygen blown varies emissions during the blow.

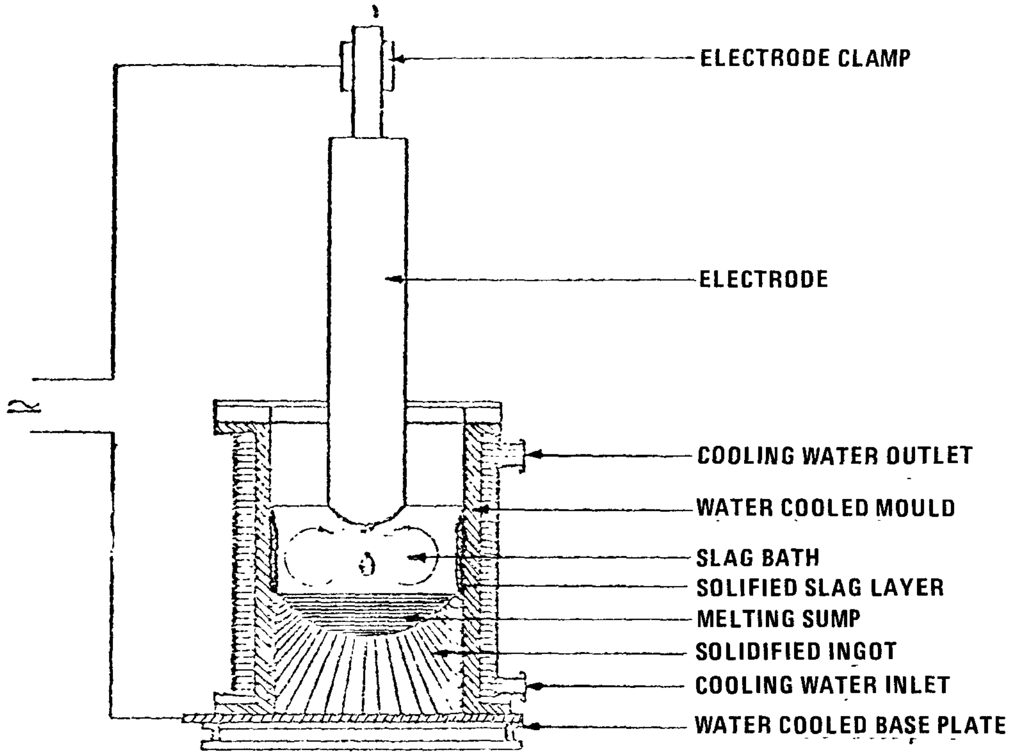


Figure 3-4. Electroslag remelting process in which a solidified ingot is remelted and reformed into a superior product.

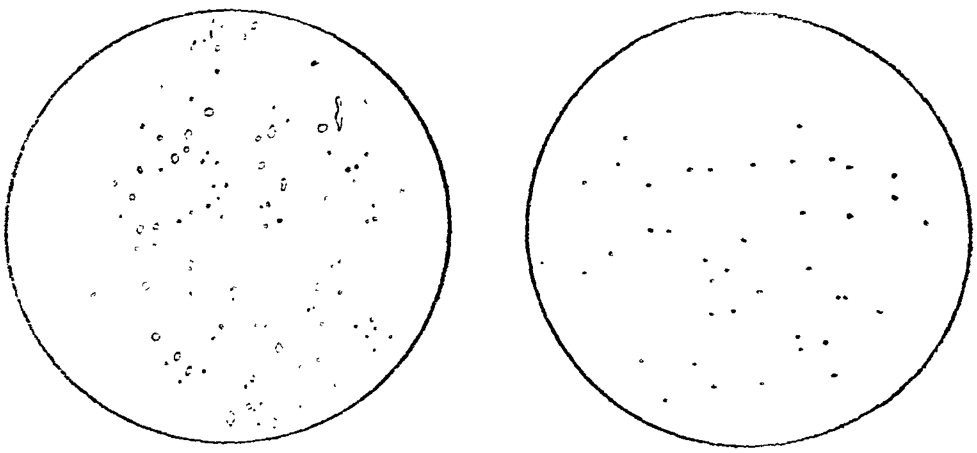


Figure 3-5. Slag in H13 bar before (left) and after (right) refining.

3.4 References for Section 3.0

1. Annual Statistical Report - American Iron and Steel Institute - 1977, published by the American Iron and Steel Institute, p. 53.

2. Ibid, p. 72.

3. World Steel Industry Data Handbook, Volume 1:33, Metal Processing - 1978.

4. Iron and Steel Industry, prepared by Environmental Engineering, Incorporated for EPA, Contract No. CPA 70-142, March 15, 1971, p. 8-6.

5. Letter from George N. Stoumpas, American Iron and Steel Institute, to Randy D. Seiffert, EPA, January 23, 1973.

6. Background Information for Standards of Performance: Electric Arc Furnaces in the Steel Industry, Volume 1, page 10, EPA 450/2-74-017a, October 1974.

4.0 STATUS OF EMISSION CONTROL TECHNOLOGY FOR ELECTRIC ARC FURNACES

Emission control technology studied during the development of the NSPS has not changed significantly since NSPS promulgation. However, insistence by some local control agencies today that no visible emissions escape the EAF shop has encouraged the use of efficient systems and caused some new concepts to be developed. The more efficient systems and new concepts are discussed in Section 4.1.1 through 4.1.6. Other EAF control systems are discussed in Sections 4.1.7 through 4.1.10. The major difference among all the systems is the method used to capture the emissions from the furnaces.

4.1 CAPTURE SYSTEMS AND CONTROL DEVICES

4.1.1 Canopy Hoods in a Shop With a Sealed Roof

The canopy hood (CH) system (Figure 4-1) consists of a canopy hood suspended directly above each furnace connected to fans and ducts that evacuate the air. Since these hoods must not restrict movement of the crane that transports charges by raw materials to the furnaces, 30 to 40 feet of clear area is provided immediately above the furnaces. Furnaces charged through doors in the side or fed through a chute do not require much freeboard and hoods can be built nearer the furnace.

During charging, the fumes rising rapidly from the furnace are often deflected from the hood by the crane and its charging bucket. Cross drafts within the building and large fluctuations in emissions that sometimes exceed the capacity of the hood also cause a great deal of emissions to bypass the hood. Because the building is sealed, fugitive emissions not captured in the hood accumulate in the upper part of the building and are gradually drawn into designed openings provided in the CH ductwork.

Canopy hoods are sometimes divided into sections and are dampered to maximize draft directly above the point of greatest emissions during charging, tapping, or slagging operations.

After capture, the effluent is cleaned in the fabric filter. The hot furnace gas must be cooled by water sprays, radiant coolers, dilution air, or some combination of these devices to prevent rapid degradation of the fabric. Electrostatic precipitators and Venturi scrubbers are sometimes used. If a precipitator is used, the gas is humidified to maximize the efficiency of the precipitator. Only the Venturi scrubber does not require any special treatment of the exhaust gas.

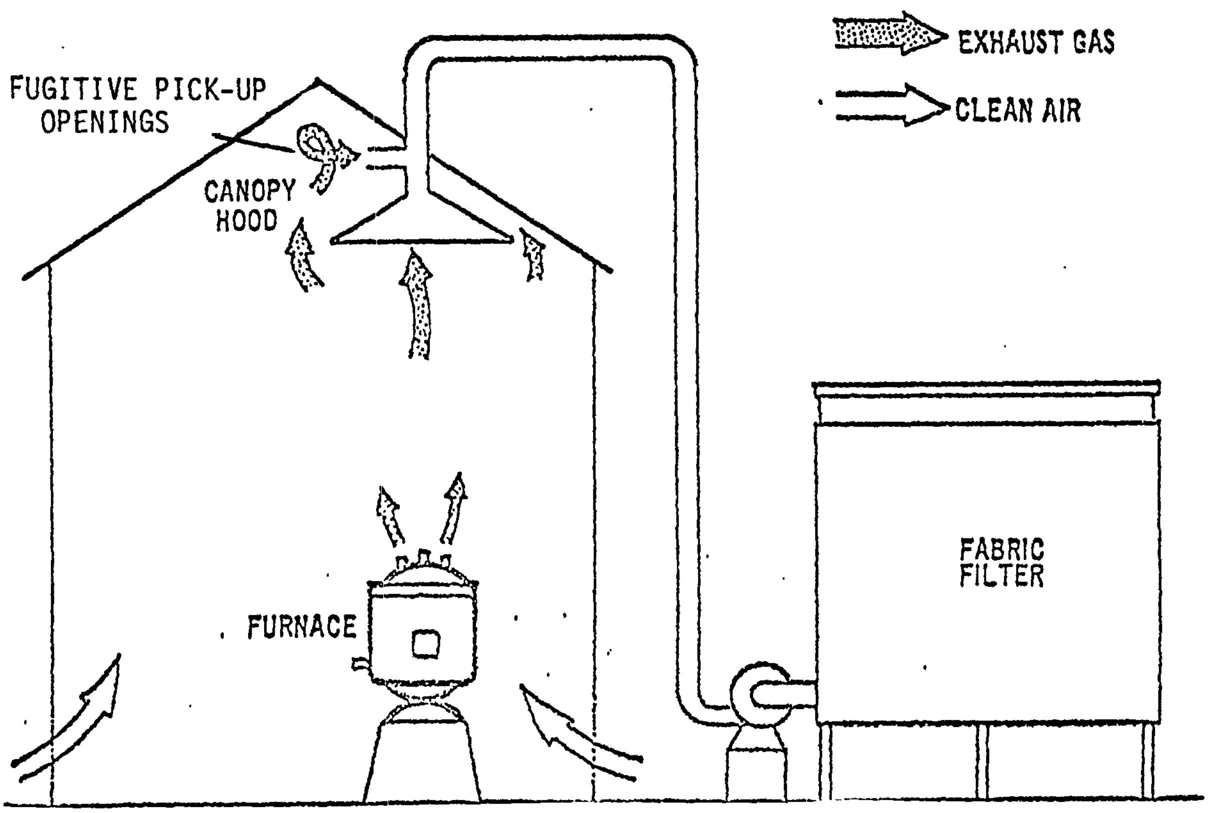


Figure 4-1. Canopy hood (CH) closed roof.

4.1.2 Direct Shell Evacuation in a Shop with Either Building Evacuation or Canopy Hoods and a Sealed Roof

The direct shell evacuation system (DSE) unquestionably provides the best control during meltdown and refining, and either building evacuation (Figure 4-2) or canopy hoods (Figure 4-3) captures emissions during charging and tapping. The air flow to the canopy hoods or various strategically located inlets to building evacuation ducts can be shifted as ventilation requirements and emission of particulate from different furnaces dictate. Separate control devices can be used, or a single one can serve both systems.

This combination of equipment requires lower average air flow rates than a canopy hood or building evacuation system alone, because fewer emissions are released into the shop building and part of the heat load is removed by the direct shell system. However, the air flow must be adequate to assure proper ventilation for an acceptable working environment. Peak air flow rates are used for the building evacuation or canopy hood system during charging and tapping when the DSE system is ineffectual. At other times these peak flows can be reduced.

The direct shell evacuation system cannot be used for all steels, as explained in Section 4.1.8.

4.1.3 Semi-enclosed Furnaces with Direct Shell Evacuation, Canopy Hoods and Tapping Hoods

A new concept for containing air pollution from electric arc furnaces was developed in 1976 for a shop producing carbon steels in two furnaces with 225 tons of capacity each. The furnaces are equipped with conventional

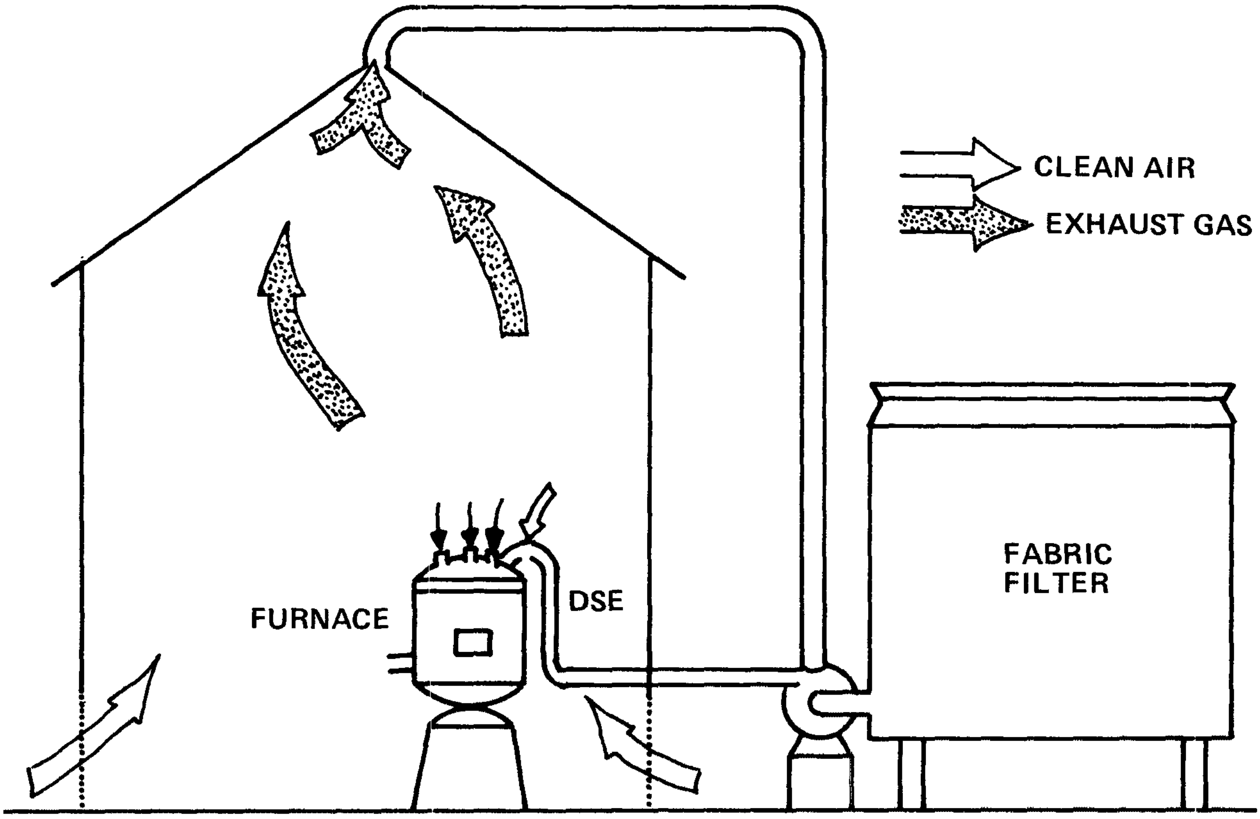


Figure 4-2. Direct shell evacuation - building evacuation (BE) system with closed roof.

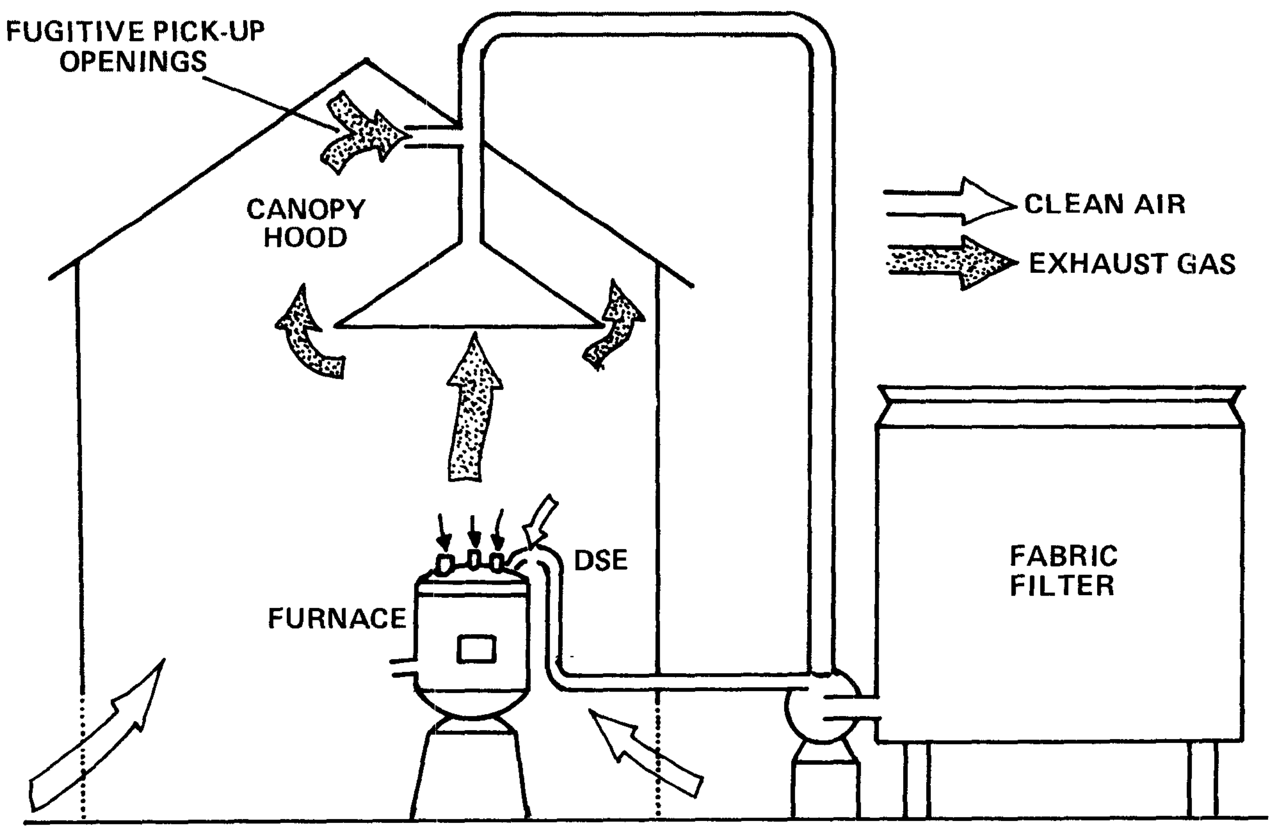


Figure 4-3. Direct shell evacuation - canopy hood (CH) with closed roof.

DSE and CH systems. The major innovations are: (1) enclosures around each furnace that act as chimneys to direct charging fumes up into the canopy hoods (CH) and (2) hoods that capture emissions from the tapping ladle and slag pot. The shop roof is closed above the two furnaces. Figure 4-4 shows these new concepts.

The enclosure walls are designed to allow the crane to travel between the hood and the furnace to position the charging bucket over the furnace. The charging enclosure is ample sized to allow the furnace roof to swing over the tapping area, where it can capture emissions from the pouring spout or any fumes that bypass the tapping hood.

The most significant advance in technology embodied in this new system is the use of a stationary hood that fits close over the tapping ladle, as shown in Figure 4-4. The empty ladle is moved by crane to a railcar, which is rolled under the hood. Molten steel is then poured into the ladle through an opening in one side of the hood. This type of hood cannot presently be used on electric arc furnaces because the crane cables interfere with placement of a hood.

This system also has a stationary hood over the slag pot through which the slag drops to capture the slag emissions, even though they are a minor source of emission from EAF's.

The total air flow design for this system is 630,000 dry standard cubic feet per minute (dscfm) or 1600 dscfm per ton of furnace capacity. This volume is about the same as that used for conventional DSE-CH systems in shops with open roofs. This system combines the lower cost

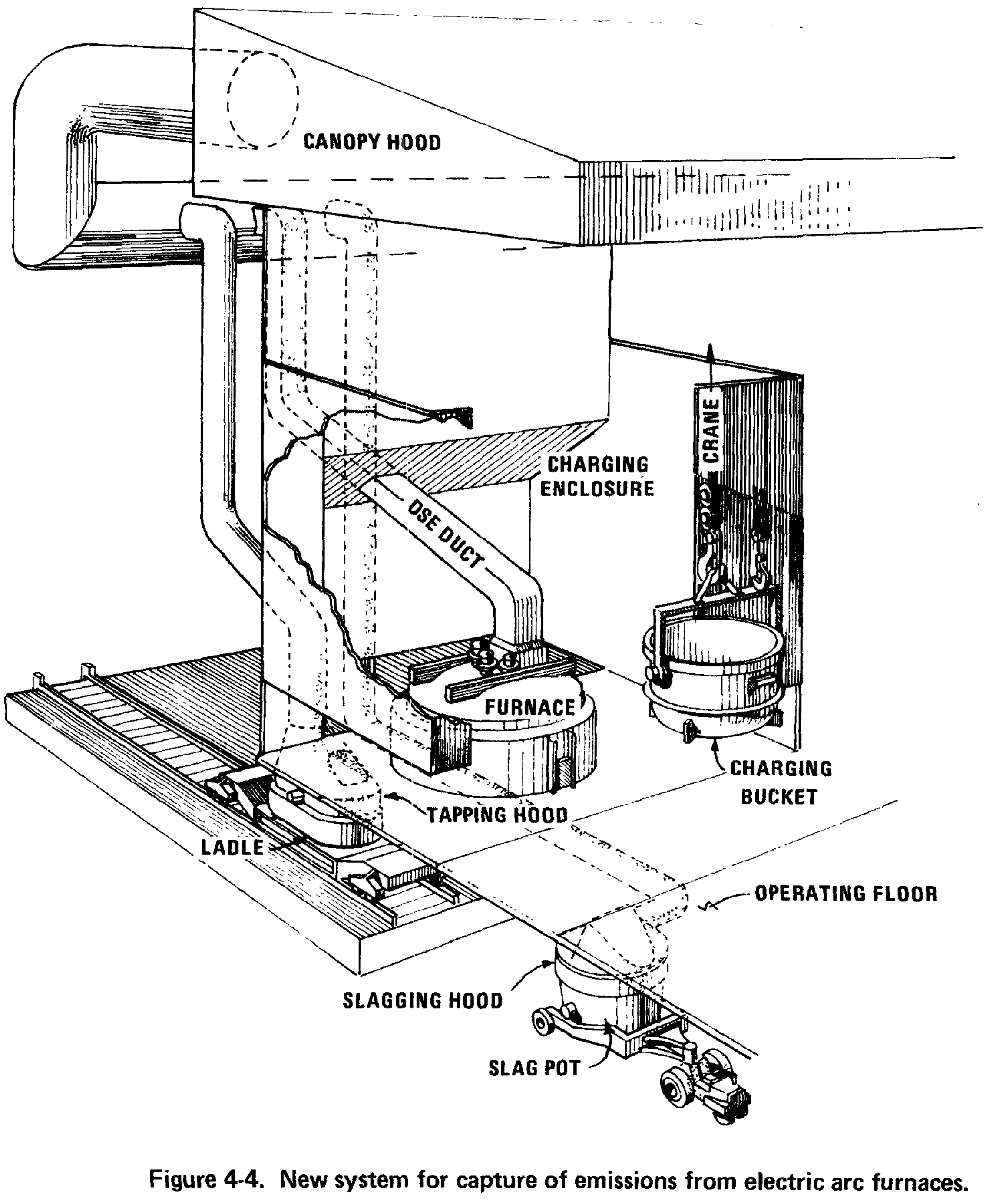


Figure 4-4. New system for capture of emissions from electric arc furnaces.

and energy requirements of a DSE-CH system with the higher capture efficiency of systems with high air flow rates. According to the local agency, this new system achieves better control than previous CH systems, and no visible emissions are noted except during upsets.

4.1.4 Side Draft Hoods

The side draft hood is another fume evacuation system available to EAF's. It is mounted on or near the furnace roof, as illustrated in Figure 4-5. The hood is designed with one side open so that the travel of the electrodes 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 during melting. Large exhaust volumes must be maintained for the side draft to draw fumes laterally 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.

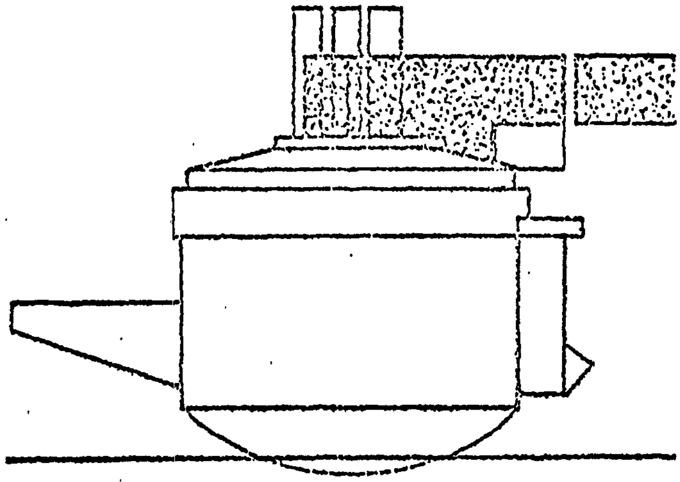


Figure 4-5. Side draft hood.

4.1.5 Furnace Enclosure

Another new concept for containing air pollution from EAF's was applied at a shop containing two 60-ton electric arc furnaces. This concept is a total furnace enclosure, which captures both primary and fugitive emissions. Openings were to be provided in the enclosure for the charging, tapping, and slagging operations. The system is a metal shell shaped somewhat like a barn (Figure 4-6); it completely encloses the furnace and tapping area and can effectively capture emissions from melting, charging, and tapping. A large exhaust duct or hood near the enclosure top removes charging and melting emissions (Figure 4-7) while a separate, local hood contains tapping fumes (Figure 4-8). Tapping fumes are collected by diverting exhaust flow from the enclosure to a local hood adjacent to the ladle. Sliding doors on the front, back, and top of the furnace allow entry of the charge bucket by conventional crane and also provide for slagging, chemical addition, and oxygen lancing (Figures 4-6 and 4-7).

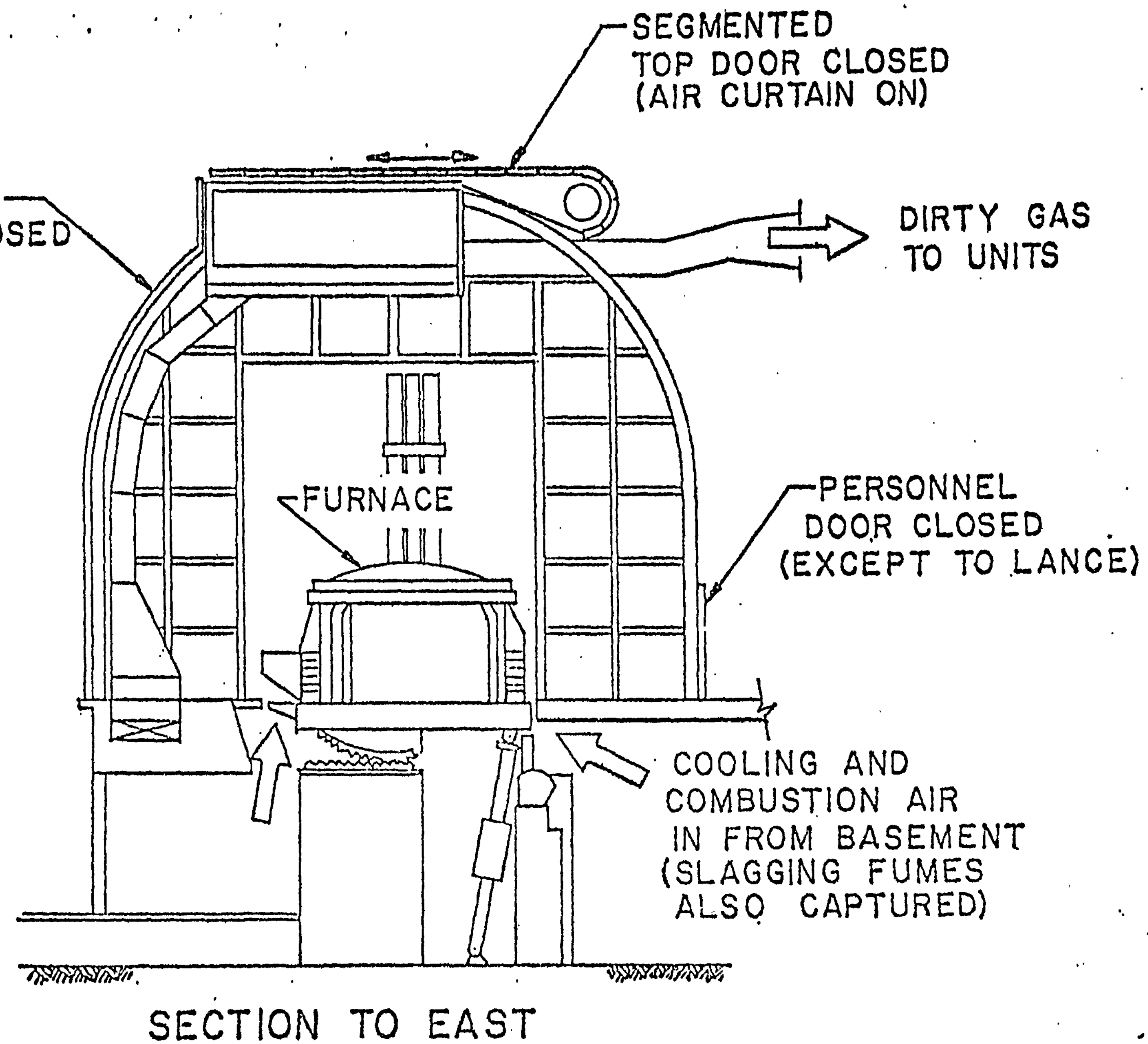
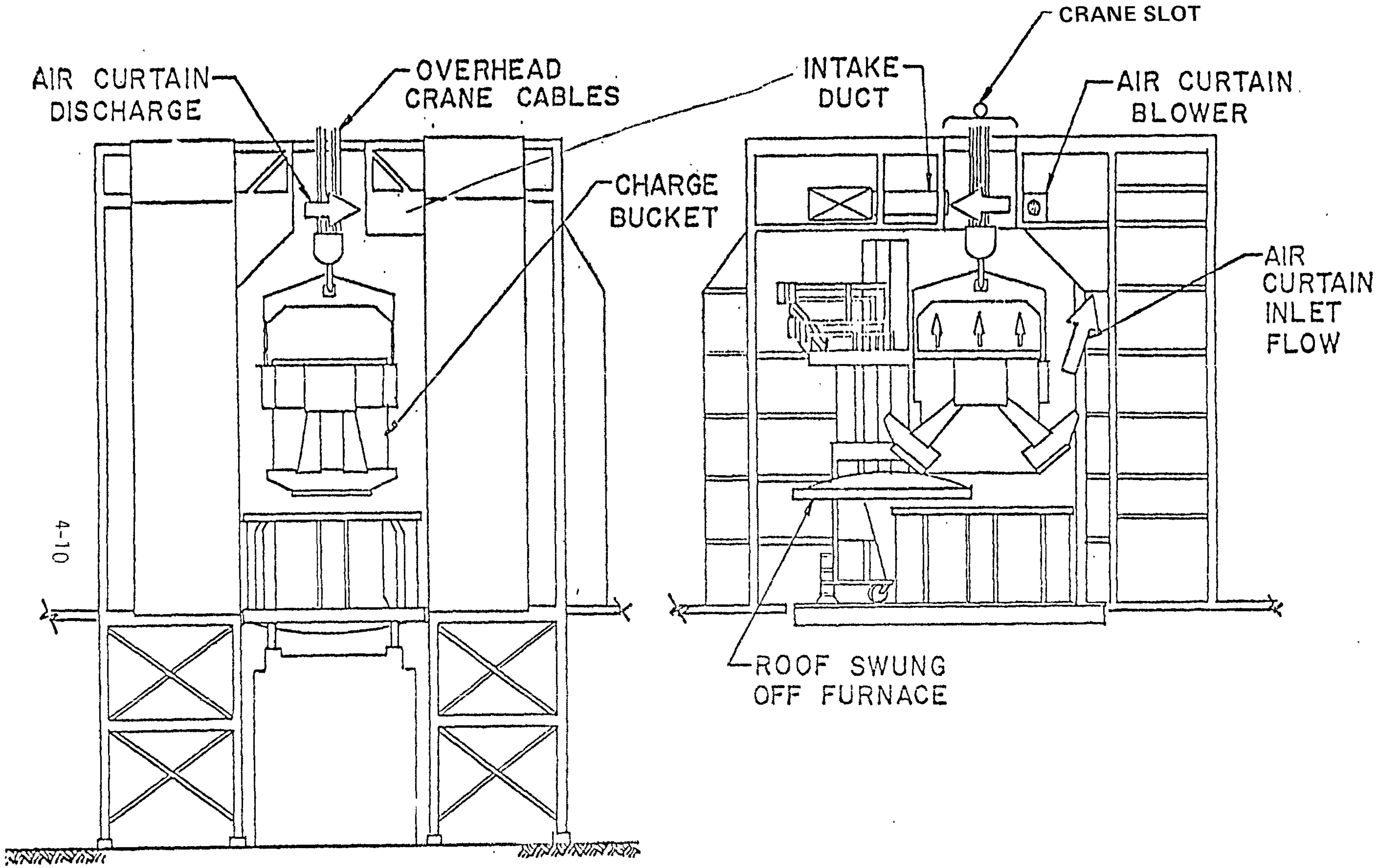


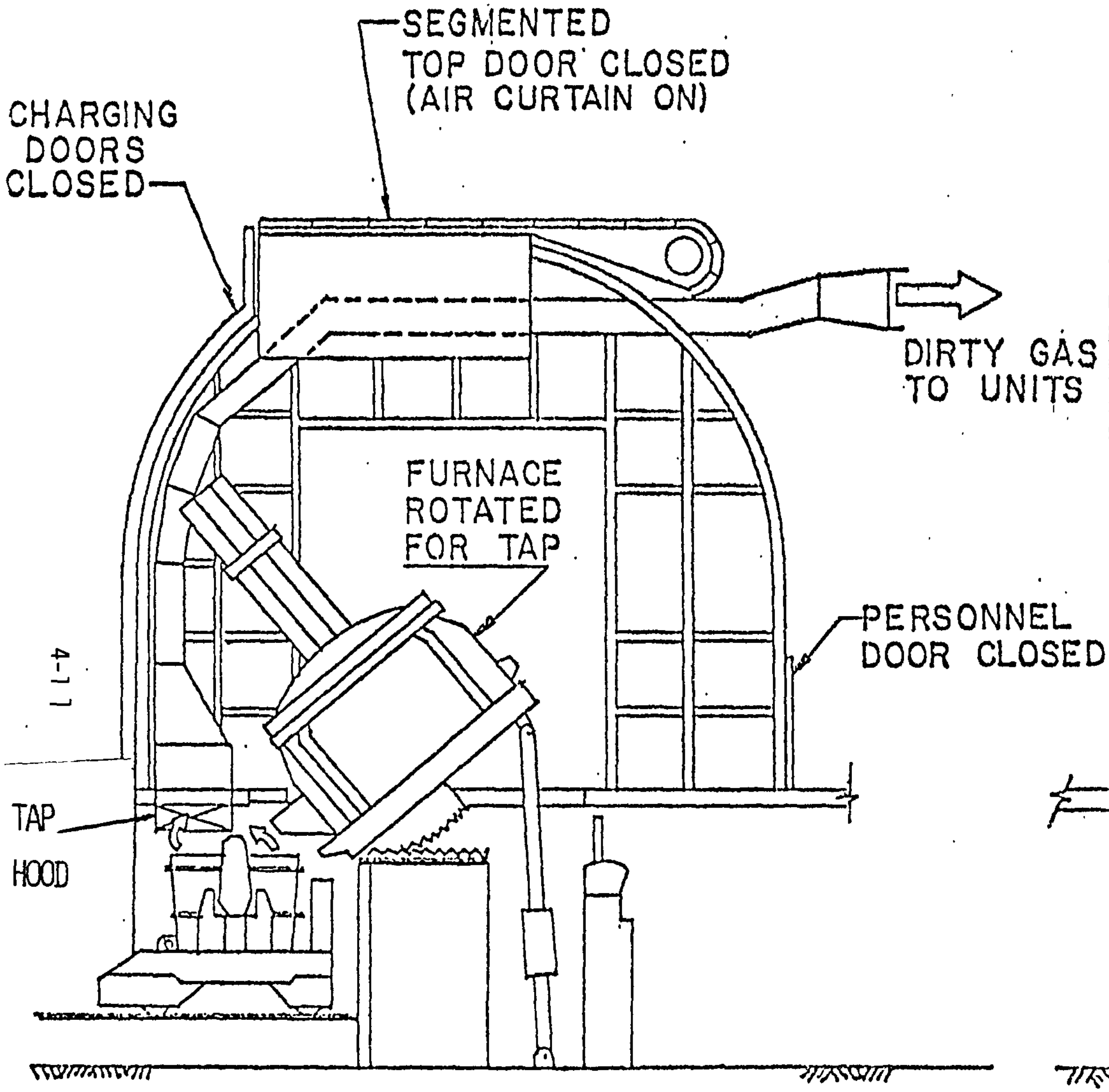
Figure 4-6. Furnace during melt and refine.



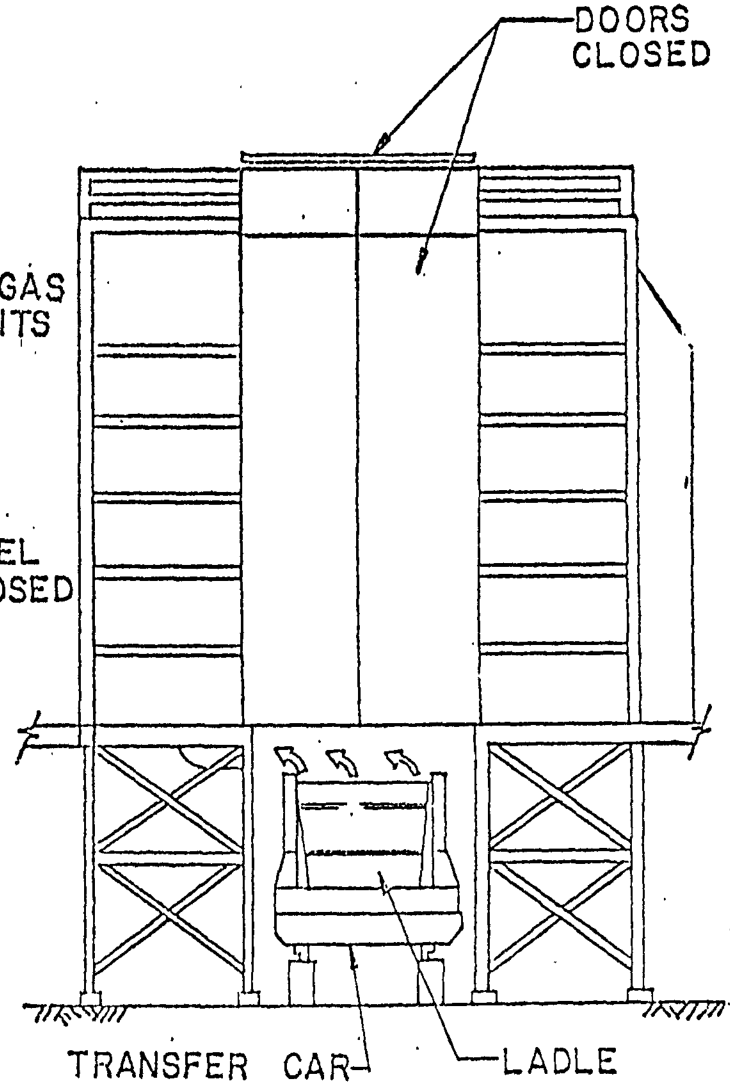
VIEW TO SOUTH
(DOORS SHOWN OPEN FOR CLARITY)
(FRONT OF FURNACE)

SECTION TO NORTH
(BACK OF FURNACE)

Figure 4-7. Furnace being charged.



SECTION TO EAST



VIEW TO SOUTH

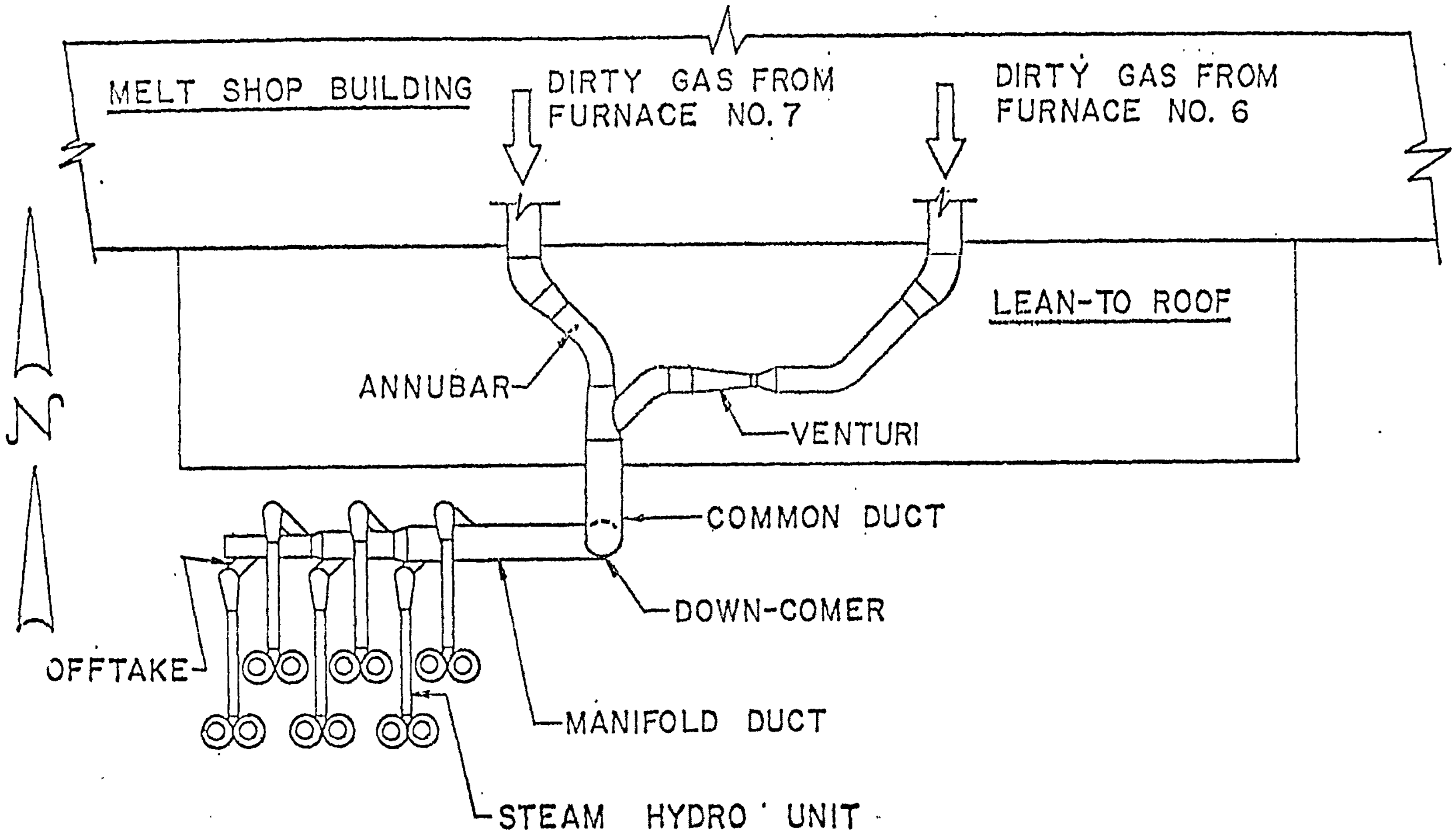


Figure 4-9. Gas cleaning system layout.

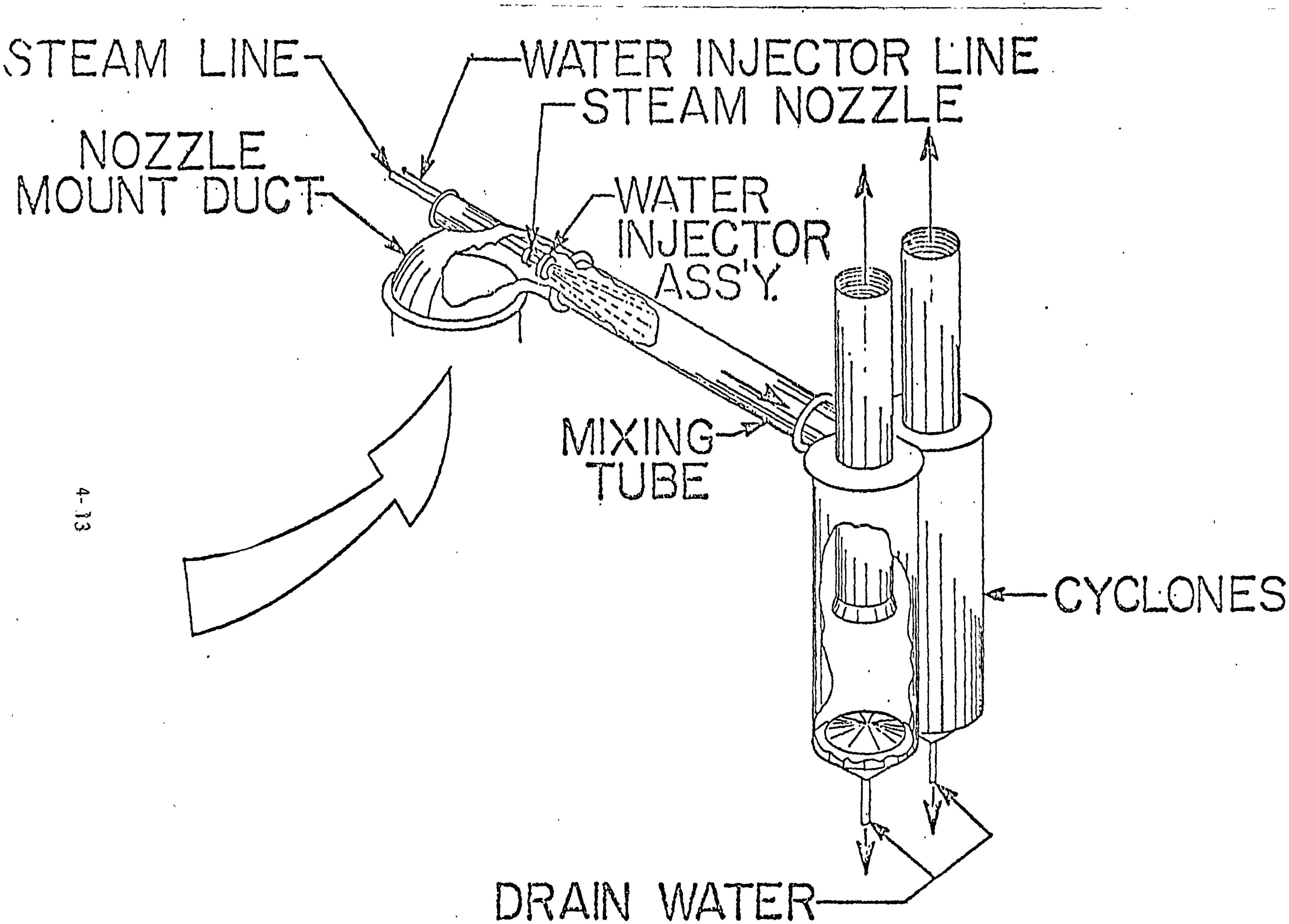


Figure 4-10. Typical steam hydro unit.

During melting, doors are closed and fumes are exhausted from the enclosure by a large rectangular exhaust duct located below the enclosure top, above the furnace. Between 75,000 and 90,000 afcm is withdrawn from each enclosure by suction developed by the company's proprietary Steam-Hydro scrubber, which cleans furnace exhaust (Figures 4-9 and 4-10). Slagging, chemical additions and oxygen lancing are conducted through a third set of doors at the rear of the furnace. The furnace is tapped in a ladle, which is placed on a rail car by the overhead crane and then rolled into position under the enclosure. Tapping fumes are collected by diverting the air flow from the main exhaust duct at the top of the enclose to a hood adjacent to the ladle. Both furnaces and enclosures rest on a platform about 6.3 m (20 ft) above the melt shop floor. This arrangement provides room for the tapping ladle car and also provides air flow from underneath the furnaces to carry fumes to the main exhaust duct.

During charging, the segmented top door (Figure 4-6) is opened to allow the crane to enter with the charge bucket (Figure 4-7) and the feed material is discharged to the FAF. The unique feature about the charging system is that a curtain of air is blown across the open top of the enclosure (Figure 4-7) to push the charging emissions into the intake duct leading to the scrubber. This was designed to prevent most of the charging emissions from escaping the enclosure and building. The company reports it has not encountered any major problems in using the enclosure. According to the company, about 90 percent or better of the charging emissions are contained by the enclosure; however, recent EPA observations of this facility report capture efficiency of 50 to 90 percent, depending upon the operation. There appear to be some engineering deficiencies in the design of the enclosure which could be corrected on newer systems and improve the collection efficiency. Another criticism of the furnace enclosure is that only clean scrap can be melted because flames from contaminating oil and organic matter from the hot furnace reach the top of the enclosure. The company indicated that trial runs using dirty scrap showed additional enclosure height would be necessary if dirty scrap were to be used routinely. The fact that furnace enclosures are being used in large BOPF shops suggests that this system offers a comprehensive solution to the many problems of controlling process and fugitive emissions from EAF's.

4.4.6 Brusa Closed Charging System

The Brusa closed charging system, illustrated in Figure 4-11, has been operating on a steel-making furnace in Italy for several years. Exhaust gases from the hot furnace are vented through a rotary kiln or drum. Charge material is fed continuously down through the kiln and into the furnace, where it is preheated by furnace gases to about 1000^{o}C. Volatile matter entrained in the charge is thus oxidized and withdrawn at the top of the kiln along with furnace exhaust gases.

This system has the advantages of heat recovery and containment of charging emissions in a fashion allowing for simple collection and ducting to a control device. This type of steel making is a continuous process in that charge material is continuously added and the furnace is tapped frequently. There is a trend toward this type of operation in steel-making furnaces, only one domestic foundry EAF is known to use continuous charging. The Brusa and other conceptual designs for closed charging systems require small-sized scrap that will pass through the enclosed conveyor system.

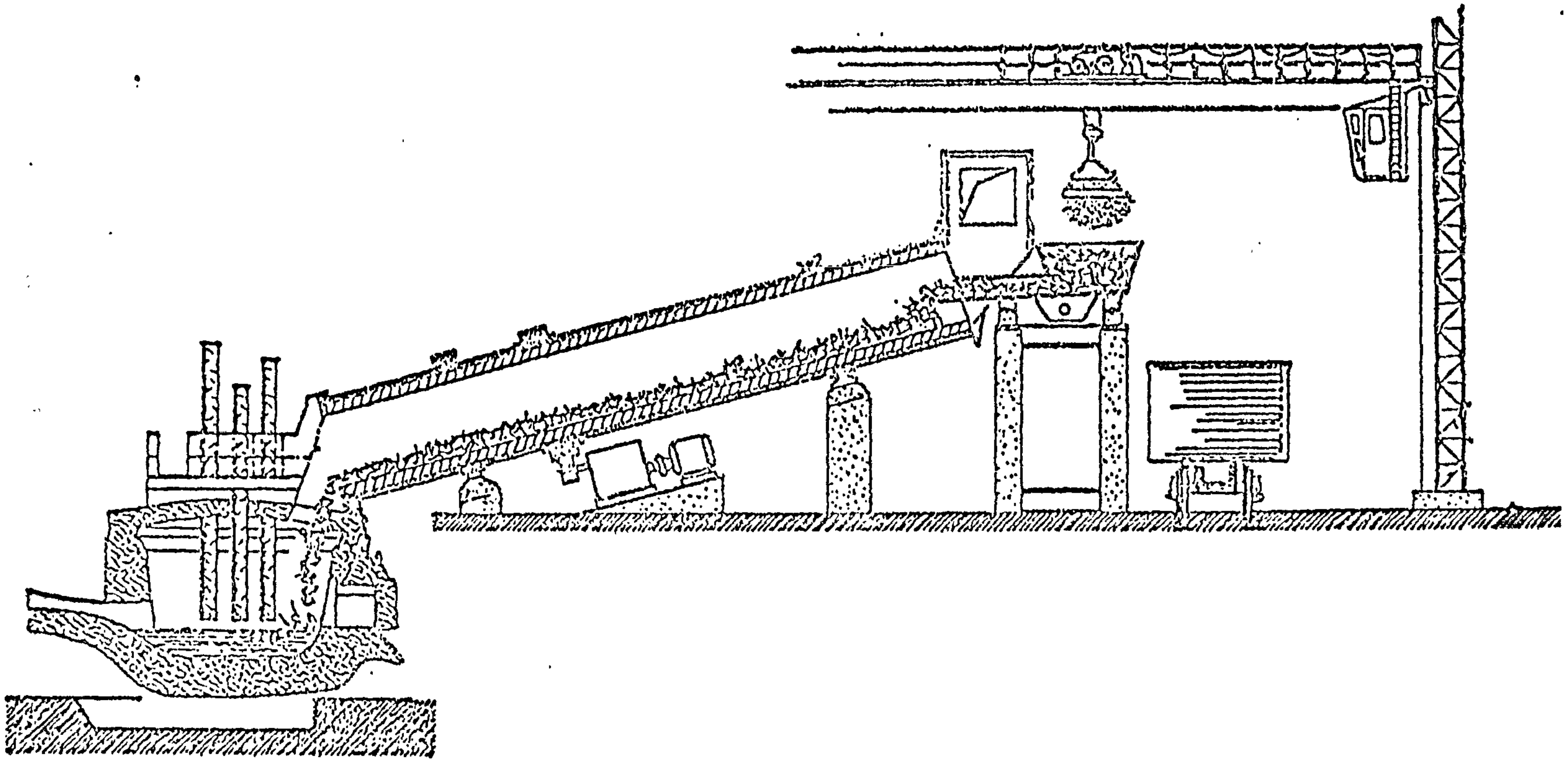


Figure 4-11. Brusa charging and preheating system.

4.1.7 Canopy Hoods In Combination With Natural Ventilation Through Open Roof

The canopy hoods (CH) are identical to those described previously; but, as shown in Figure 4-12, in some shops the roof monitors allow natural ventilation to augment ventilation resulting from the hood suction. Unfortunately, they also allow any fume that bypasses the hoods to escape the building as visible emissions. Air flows through canopy hoods in this type of system are quite high but less than required with a sealed roof. Only fabric filters are known to be used with this system.

4.1.8 Direct Shell Evacuation System in Combination With Natural Ventilation Through Open Roof)

The direct shell evacuation system, shown in Figure 4-13, withdraws all potential emissions directly from within the furnace before they can escape and be diluted by the ventilation air. A water-cooled air exhaust duct, which extends through the furnace roof, is jointed near the furnace with a gap of one to several inches separating the ends of the two duct sections. This separation permits the furnace roof to be elevated and rotated aside to permit top charging and tilting of the furnace for tapping and slagging. (During such times, DSE systems are ineffectual and emissions rise directly through the roof of the shop.) A few DSE systems remain in operation while the furnace is tilted. The incremental improvement in the capture of emissions is very small, however, because the bulk of tapping and slagging emissions are from the ladle or slag pot. During operation, the DSE system maintains a negative pressure within the furnace. As a result, air is drawn into the furnace around

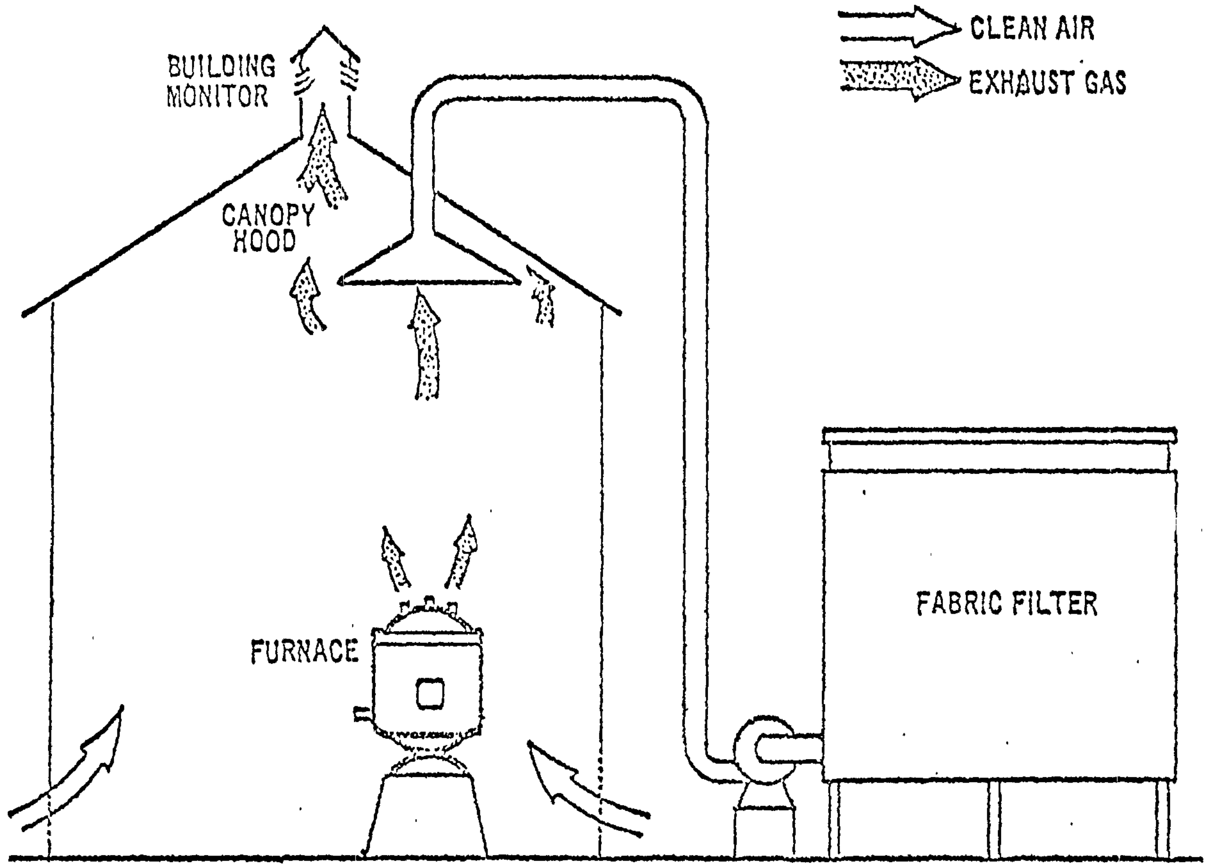


Figure 4-12. Canopy hood (CH) with open roof.

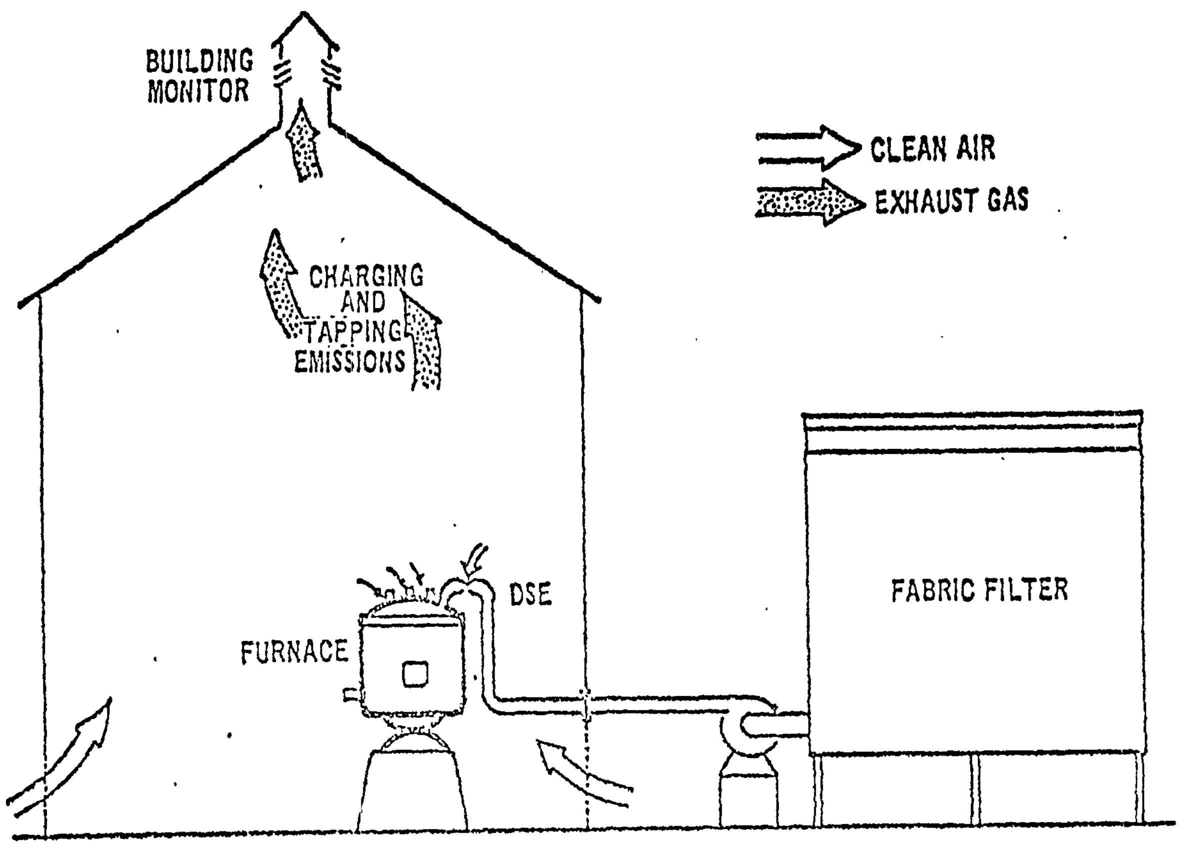


Figure 4-13. Direct shell evacuation (DSE) system with open roof.

the electrodes and through the gap into the exhaust duct. This air not only cools the exhaust gas, but it permits combustion of the large amounts of carbon monoxide present.

A well designed and operated DSE system is desirable not only because it can capture essentially all the dust generated during meltdown and refining (including emissions during the oxygen blow), but also because it inherently restricts the gas to be cleaned. The DSE system provides maximum removal efficiency with minimal energy requirements. Unfortunately, as mentioned earlier, when the furnace is being charged or tapped, emissions billow to the roof. If the roof is open, the emissions exhaust directly to the atmosphere in a very visible plume.

DSE cannot be used in the manufacture of all steels. During the production of some alloys, a second slagging operation is necessary. A "reducing" slag is used to remove certain impurities from the melt. Air will oxidize these slags and render them ineffectual. At such times, induction of air into the furnace is intolerable. Although it would appear that the fan on the DSE system could be turned off when the "reducing slag" is in the furnace, the industry advances a theory that the configuration of the furnace roof that accommodates the DSE system interferes with the required temperature homogeneity of the melt. The absence of refractory where the discharge duct enters the roof is alleged to constitute a surface which absorbs more radiant heat from the melt than it returns, and results in a cold spot in the molten steel. Recently, air curtains have been used to prevent oxidizing air from entering a furnace. Air curtains also therefore promote better temperature control within the furnace.[1] Some furnaces may not be able to use air curtains because of their specific operation and design.

4.1.9 Building Evacuation in Shop with Closed Roof

With the building evacuation system (BE), the entire building is used to capture dust from the furnaces. As shown in Figure 4-14, hot exhaust gases containing dust billow to the roof of the shop, where they are drawn into ducts leading to a fabric filter. Because the removal capacity of the duct may be less than the furnace release rate, dust-laden gas sometimes accumulates beneath the closed roof during periods of high dust generation. Since air cannot escape except through the control device, the dust does not create an outside pollution problem.

Since all ventilation air must exhaust through the control device, operating costs have limited these systems to fabric filter collectors. Gas cooling systems have not been necessary because the ambient air drawn into the building mixes with and cools the dust-laden gases.

In two aspects, BE systems appear to be superior to DSE systems. They capture fumes from the charging and tapping operation, and operate without any visible emissions from the building. They also have no effect on "reducing slags" and are often the choice of shops that produce alloy steels.

4.1.10 Direct Shell Evacuation in Shop with Canopy Hoods with Open Roof

This combination is identical to the system described in Section 4.1.2, with one notable exception: the open roof monitors permit natural ventilation. Because the open roof will satisfy ventilation requirements, continuous air flow through the canopy hood is not required. As a result, the hoods can be operated on demand to capture charging and tapping emissions.

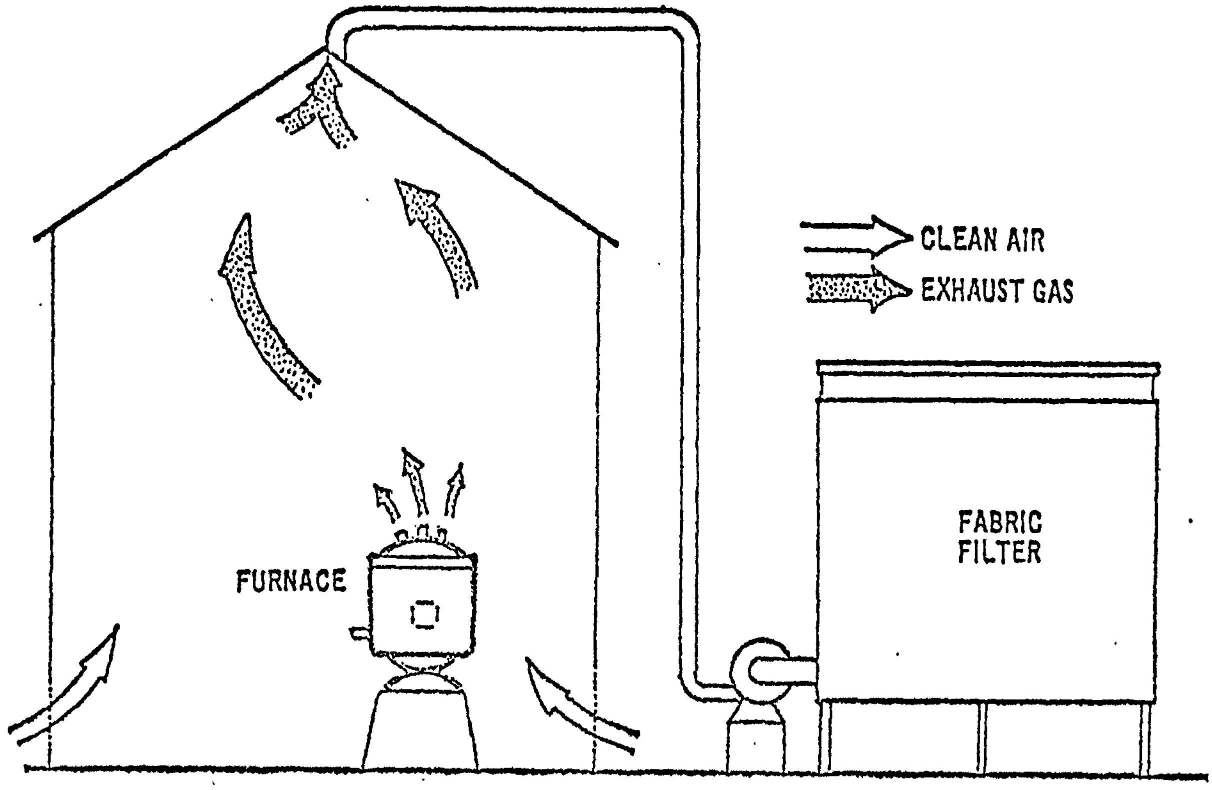


Figure 4-14. Building evacuation (BE) system with closed roof.

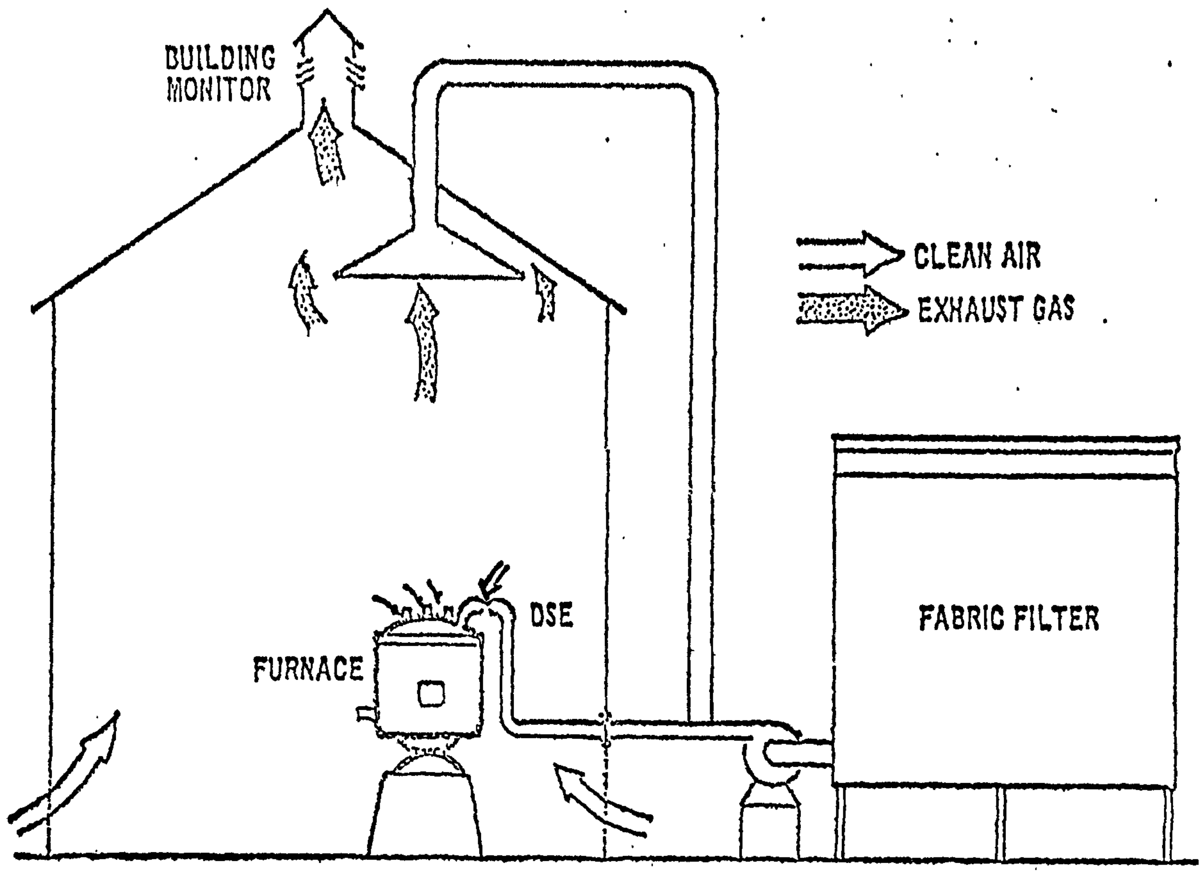


Figure 4-15. Direct shell evacuation (DSE)-canopy hood system with open roof.

Fumes not captured by the hoods escape as a visible emission through the open roof monitors. Shops with many furnaces that have staggered charging and tapping cycles will probably have visible emissions through some portion of the roof monitors much of the time.

Such losses can be minimized. Louvers on the openings in the roof can be automated to close during periods when the DSE is out of service, to preclude emissions of fumes that bypass the canopy. Fugitive dust openings in the exhaust ductwork of the canopy hood could extract the fugitive emissions that are trapped near the roof. Such a system will probably not eliminate all visible emissions, as some fume will still be trapped in the roof when it is reopened for ventilation. Also, in a shop with many furnaces where many charges and taps occur, the louvers may have to be closed most of the time. The system would then approach a BE system.

Because the forced ventilation is supplemented by natural ventilation, this combination system requires less forced air flow and less energy than systems with a closed roof on the shop.

4.2 Effectiveness of Various Control Techniques

Because direct assessment of these capture systems is difficult, few attempts are made to measure their efficiencies. Efficiency "measurements' are usually visual estimates, which can vary considerably among observers. Estimates of emission rates for the various control systems are, then, extremely dependent on the values and estimates assumed.

For NSPS development, theoretical emission rate calculations were based on a canopy hood capture efficiency of 80 percent from an estimated range of 70 to 90 percent, depending upon several variables.[2] These variables include the age of plant, design of hood, distance of hood to EAF, shop configuration, air currents in building, building design, and rate of air flow to control system.

Because of the many variables involved, the newer technology requires closed roofs and scavenger ducts to capture those emissions escaping the hoods. At some shops full or partial enclosure of the electric arc furnace is reported to capture 90 percent of all furnace emissions.[3] Again, this is a visual observation rather than a measurement, but the furnace enclosure configuration appears to improve the reliability of the visual observation compared to canopy hoods, which may be 40 feet or more above the source of emissions. The semi-enclosed furnace system also appears to provide better canopy hood capture efficiency because of the ability to direct the emissions more effectively into the canopy hoods. Visual observations of this system estimate a hood capture efficiency of 90 percent; but because the roof is sealed, all of the emissions should be captured and directed to a control device.

In conclusion, current control technology such as total furnace enclosure, partial furnace enclosure with canopy hoods, canopy hoods with fugitive dust pickup system, and sealed roof provides for improved capture and control of all furnace emissions compared to the systems in use at the time of promulgation of the NSPS. Also, controls for tapping and other fugitive emissions can be installed to further improve the control of significant sources of EAF emissions.

4.3 CONTROL TECHNOLOGY APPLICABLE TO NSPS FOR EAF FURNACES

Emission control technology to meet current NSPS is directed to controlling only primary emissions. All the systems for the NSPS study used a baghouse for the control device. The present NSPS provides only limited control of fugitive emissions, meaning some of the emissions from tapping and charging are not captured by the canopy hoods. The visible emission portion of the NSPS is intended primarily to regulate or to allow for some of these emissions. The NSPS is generally based on direct shell evacuation with canopy hoods and an open monitor or canopy hoods with adjustable louvers in the monitor that can be closed to contain heavy emissions and opened when there are no significant emissions. In the NSPS development, this system was considered the most effective, considering costs.

4.4 CONTROL TECHNOLOGY IN CURRENT USE ON NEW EAF SHOPS

The control technology reviewed for this study revealed that well-controlled EAF shops can use (1) direct shell evacuation and canopy hoods with a closed roof, (2) canopy hoods with a fugitive dust pickup system and a closed roof, (3) total furnace enclosure with an open roof (however, the roof could be closed in future designs), and (4) semi-enclosed furnace and canopy hoods with a fugitive dust pickup system and a closed roof. The reasons for the change from an open roof to a closed roof are: (1) the insistence of some local air pollution control agencies on a more stringent visible emission limitation on the EAF shop than required by the NSPS, (2) to meet EPA's off-set policies, or (3) to prevent significant deterioration of the air quality in an area. These control systems also control essentially all emissions from the EAF shop, including those from charging, tapping, slagging, and teeming operations and AOD furnaces and ladle fumes.

The concern for the high cost attributed to handling large volumes of gases from the evacuation of gases from a closed roof building apparently has been overcome by using canopy hoods and adding a fugitive duct system in the closed roof monitor to collect fugitive emissions. This type of system allows for collecting and restraining the fugitive dust emissions within the building and slowly drawing these emissions into the control device as the process goes through its cycles. Also, the gas volume is reduced in comparison to that involved in building evacuation, because direct shell evacuation or canopy hoods still collect the greatest portion of the emissions, while the fugitive dust system is designed only to pick up the small balance of the emissions.

There are not enough data available from the testing of these systems to indicate whether one or all of them could be considered "best demonstrated control technology." The only criteria for comparison of these systems during this review was visible emissions. Plant visits and reports from air pollution control agencies indicate that these systems are below the present NSPS for visible emissions.

4.5 POTENTIAL NEW CONTROL TECHNOLOGY

Control technology for future EAF shops can be designed as previously discussed in Section 4.4 or additional control measures can be added to provide better control of the significant sources of fugitive emissions during charging and tapping. Tapping emissions, for instance, can be controlled by using a tight-fitting swing-away hood over the ladle; or a totally enclosed room can be used, with the ladle on a railcar. The industry practice has been to have the crane hold the ladle during tapping; therefore, hoods and enclosures have not been used during the tapping cycle. This concept is slowly disappearing, however.

Another potential technology, used at an EAF shop in Europe and at one foundry in the United States, is to use the gases from the EAF furnace in a kiln to preheat scrap being continuously fed to the furnace. This system permits heat energy recovery and reduces the volumes of gases to be collected and treated. The size of the scrap being fed must be controlled. This system will also need to be reviewed for other negative aspects.

Most of the discussion in this study is devoted to the capture of the emissions. Baghouses are still the most widely used control device; only one proprietary scrubber has been installed since 1974. The design of the baghouse may only vary between having stacks or open tops to discharge the gases. The open-top, pressure-type baghouse is not easy to source test and enforcement based on compliance tests is difficult. Methods for source testing this type of baghouse will have to be developed for enforcement compliance requirements.

4.6 REFERENCES FOR SECTION 4.0

1. Iron and Steel Engineer, July 1978. Air Curtains on Electric Furnaces at Luken Steel Company.

2. Background Information for Standards of Performance: Electric Arc Furnaces in the Steel Industry. U.S. Environmental Protection Agency, Research Triangle Park, N.C. Publication No. EPA-450/2-74-017a. October 1974.

3. Blair and Martin, 1978. EAF Fume Control at Lone Star Steel Company, Lone Star, Texas.

5.0 CURRENT STANDARD FOR EAF'S IN STEEL INDUSTRY

The NSPS regulates EAF's and their associated dust-handling equipment that were planned, under construction, or being modified after October 31, 1974. An existing EAF is subject to the promulgated NSPS if: (1) a physical or operational change in the existing facility causes an increase in the emission rate to the atmosphere of any pollutant to which the standards applies, or (2) if in the course of reconstruction of the facility the fixed capital cost of the new components exceeds 50 percent of the fixed capital cost that would be required to construct a comparable new facility that meets the NSPS.

5.1 EXEMPTIONS FROM NSPS

Electric arc furnaces that process prereduced ore pellets are exempt from the NSPS because the process was in the development stage at the time of the NSPS investigation. Also, emissions from this type of furnace are reportedly generated at different rates and cycle times than those from conventionally charged EAF's; therefore, the cycle for these furnaces would be different.

Electric arc furnaces used in foundries are not covered in this NSPS, but will be covered under another NSPS regulation, specifically for the foundry industry. Specialty furnaces, such as, AOD, VAR, VIM, CEM, and ESR furnaces, are exempt from this standard because they were not entirely investigated during the development of the NSPS for conventional EAF's. These furnaces produce specialty steels, and the number of such furnaces is relatively small compared to conventional EAF's. Emission rates and process information for these types of furnaces were not completely documented during NSPS development.

5.2 NSPS FOR PARTICULATE EMISSIONS

Particulate matter is the EAF pollutant to be controlled by the NSPS, as defined by 40 CFR 60, Subpart AA, dated October 21, 1974:

"On and after the date on which the performance test required to be conducted . . . is completed, no owner or operator subject to the provisions of this subpart shall caused to be discharged into the atmosphere from an electric arc furnace any gases which:

(1) Exit from a control device and contain particulate matter in excess of 12 mg/dscm (0.0052 gr/dscf)."

This standard was derived from test results from six well-controlled plants of various capacities and control systems. Vendor guarantees of the control devices were also used in developing the NSPS. Opacity standards were developed to limit visible emissions from the EAF shops during the various process steps. Recent emission test data are discussed in Section 6.0.

Performance tests to verify compliance with particulate standards for EAF's must be conducted within 60 days after the plant has reached its full capacity production rate, but not later than 180 days after the initial startup of the facility (40 CFR 60.8). The EPA reference methods to be used in connection with EAF testing include:

1. Method 5 for concentration of particulate matter and associated moisture content.
2. Method 1 for sample and velocity traverses.
3. Method ? for volumetric flow rate.
4. Method 3 for gas analysis.

Each performance test consists of three separate 4-hour runs, with a minimum sample volume of at least 4.5 dscm (160 dscf). The arithmetic mean of the three runs is the test result to which performance of record used to determine compliance with the standard (40 CFR 60.8). Performance test requirements, including provision for exceptions and provision for approval of alternative methods, are detailed in 40 CFR 60.8.

Continuous monitoring for the measurement of opacity of emissions from the control device(s) is required.

5.3 PROBLEMS WITH NSPS FOR VISIBLE EMISSIONS

No air pollution control agency has reported any problem with the present NSPS, except that EPA Region IV, (Atlanta, Ga.) expressed concern about the EAF shop opacity requirement or definition.[1] Opacity source tests conducted at one electric arc furnace shop showed that emissions trapped in by a sealed-roof during the charging and tapping cycles escaped when doors were open at each end of the shop, but produced no violation of the NSPS. Also, it was noted that overlapping charging and tapping periods from heat to heat caused some confusion about the NSPS shop opacity requirement. This concern may be valid because the NSPS opacity limits are:

1. Any gases which exit from a central device and exhibit three percent opacity or greater.
2. Any gases which exit from the shop and, due solely to operations of any EAF(s), exhibit greater than zero percent shop opacity except (a) shop opacity greater than zero percent, but less 20 percent, may occur during charging periods and (b) shop

opacity greater than zero percent, but less than 40 percent, may occur during tapping periods.

Some review is needed to determine whether the opacity part of the NSPS needs to be revised to cover problems such as those cited. The review should determine whether:

1. The definitions of charging and tapping periods need to be revised.
2. A NSPS for no visible emissions from an EAF may be viable because technology to control tapping and charging emissions is now available.
3. An EAF shop might be engineered to prevent emissions from drifting out the openings below the closed roof area.
4. This specific situation is a problem for enforcing NSPS for visible emissions

Problems such as these are likely to emerge as agencies start more compliance tests.

5.4 REFERENCE FOR SECTION 5.0

1. Memorandum from Bruce Miller, EPA Region IV, to Drew Trenholm, EPA, OAQPS, ESED. February 28, 1979. Electric Arc Furnace Shop NSPS.

6.0 CURRENT STATUS OF ELECTRIC ARC FURNACES IN STEEL INDUSTRY

6.1 EMISSION DATA SINCE NSPS PROMULGATION

There are five EAF's that are presently subject to NSPS regulations; however, one furnace has not started operation, three are still in the startup mode, and one was tested for visible emissions. This last furnace met the NSPS, but the EAF shop did create the visible emission problem that concerned Region IV discussed in Section 5.3.

Four other recently constructed EAF's were required by local agencies to at least meet NSPS even though the EAF's were not subject to NSPS because their construction started before NSPS promulgation. One shop with two partly enclosed furnaces using canopy hoods and a closed roof was source tested for particulate and visible emissions. The local agency has certified the system as meeting NSPS. However, the control system uses a pressure-type baghouse, and the testing was conducted by company personnel with local agency observers. The testing was conducted by placing a Hi-Vol sampler in the various compartments of the baghouse. The results show the compartment loading ranged from 0.0097 mg/dscm (0.0000042 gr/scf) to 0.08 mg/dscm (0.000035 gr/scf) during 12 tests of 4 to 5 hours duration. This test method has not been approved by EPA. Another EAF shop with a closed roof submitted source test data on a AOD furnace using a canopy hood. The control device, a baghouse with stacks, was source tested using EPA Method 5. The results showed an average of 6.9 mg/m^3 (0.003 gr/ft^3) for the three tests. One shop with a totally enclosed furnace, using a scrubber as the control device, reported a range of 4.4 to 4.8 mg/dscm (0.0019 to 0.0021 gr/dscf) for three tests using EPA Method 5. The tests, conducted by the company, were observed by State and FPA personnel.[1] Two official test reports were submitted to EPA.[1,2]

Although no other source tests have been conducted on any of the EAF's that are required to meet NSPS, Regions III and V have contracts with GCA Corporation and Acurex to study and source test about 20 steel facilities, some of which have EAF's. These contracts should be completed in late 1979.[3]

6.2 COMPARISON OF NEW CONTROL TECHNOLOGY AND CURRENT NSPS EMISSION CONTROL PERFORMANCES

Table 6.1 shows emission reductions expected by the control technology being used today compared to control technology for the current NSPS. The table shows that the total reduction of particulates from EAF shops would be about 50,340 tons per year if the NSPS were revised to include improved emission control technology. Visible emissions would also be significantly reduced.

Data from industry and EPA source tests indicate that uncontrolled particulate emissions from the EAF furnaces average about 25.3 pounds per ton of combined carbon and alloy steel production.[4] Additionally, alloy fugitive emissions from the charging and tapping operation average about 1.5 pound per ton of steel. About 42,000 tons of particulate is generated annually from the charging and tapping operation, plus 353,000 tons per year of uncontrolled particulates generated from the EAF furnaces based. These emission data are based on 27,882,000 tons of steel production by EAF's in 1977.

The control systems considered for the development of the current NSPS were the canopy hood and open roof or direct shell evacuation, canopy hood, and open roof. These systems would reduce uncontrolled

Table 6.1 COMPARISON OF NEW CONTROL TECHNOLOGY AND EXISTING NSPS CONTROL TECHNOLOGY FOR ELECTRIC ARC FURNACES IN STEEL INDUSTRY

Emission category	Control system	Removal efficiency, %		National particulates, tons/yr			
		Current NSPS and open roof	New technology and closed roof	Total emitted (uncontrolled)	Total captured		Reduction
					Old	New	
From furnace	Canopy hood	87	99	353,000	307,110	349,470	42,360
	Direct shell evacuation/ canopy hood	87	99				
	Furnace enclosures or semi-enclosures	Not developed	99				
Charging and tapping	Canopy hood	80	99	42,000	33,600	41,580	7,980
	Direct shell evacuation/ canopy hood	80	99				
	Furnace enclosures or semi-enclosures	Not developed	99				

particulate emissions from EAF furnaces by an average of about 87 percent, collectively. For emissions from the charging and tapping operation, it was assumed that the canopy hoods would be 80 percent efficient.

Presently available control systems are essentially the same as those available for the original NSPS except that closed roofs with fugitive pickup systems are being used. New control technology includes total or semi-enclosed furnaces and in most cases, closed roofs. Even though presently available systems should theoretically capture 100 percent of all emissions and should not allow any visible emissions, 99 percent particulate capture from an EAF shop was assumed because of possible upsets, malfunctions, and other operating problems.

6.3 FUTURE GROWTH

Because of the slow growth in the steel industry at this time and because most new furnaces being planned for the next 4 years are replacements for existing furnaces, the impact of emissions due to growth should be negligible during this period. In fact, emissions could be reduced through the superior control technology being applied to the new furnaces. The exact number of new furnaces that will actually be constructed in the next 4 years cannot be determined because industry representatives are reluctant to state future plans.

6.4 JUSTIFICATION TO REVISE NSPS

There is probably sufficient justification to revise the present NSPS, based on the following considerations:

1. In general, control technology better than that needed to comply with the NSPS is being used by industry today for new and existing EAF shops.

2. Although data on NSPS compliance for new EAF shops are lacking, enough data may be available from existing well-controlled EAF shops to extrapolate to future EAF shops. This is especially true in the visible emission portion of the NSPS.

3. Fugitive emission control technology (especially, for charging and tapping emissions) has been developed.

4. AOD furnaces are significant sources of particulate and visible emissions, and should be considered for inclusion in the NSPS even though they are not really EAF's. However, they are an integral part of an EAF shop operation, and frequently use the same or similar control system as those used by EAF furnaces. This inclusion would probably require an additional definition of an affected facility in the NSPS.

6.5 REFERENCES FOR SECTION 6.0

1. Reinke, J.M., 1976. Letter dated November 1, 1976, to Mr. Michael Maillard. Wayne County Department of Health, Air Pollution Control Division. Detroit, Michigan.

2. Adams, J.I., 1978. Letter dated September 20, 1978 to Mr. John E. McGrogan, P.E. Department of Environmental Resources, Bureau of Air Quality. Wernersville, Pennsylvania.

3. Region III and V Enforcement Divisions, 1979. Personal Communications.

4. Particulate Emission Factors Applicable to the Iron and Steel Industry, Midwest Research Institute Draft Report - Table No. 8, April 5, 1979, EPA Contract No. 68-02-2609.

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15. SUPPLEMENTARY NOTES

16. ABSTRACT

The purpose of this study is to review the current new source performance standards (NSPS) for electric arc furnaces (EAF) in the steel industry and to assess the need for revision on the basis of developments that either have occurred or are expected to occur in the near future: this document contains background information, current status of emission control technology for EAF's, and recommendations for revision of the standard.

17. KEY WORDS AND DOCUMENT ANALYSIS

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