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A USAID Project Consortium Led by CH2M HILL

Environmental Audit of the Azovstal Metallurgical Plant in Mariupol, Ukraine

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PREFACE

Under the 1992 Freedom Support Act, the United States Congress initiated a program to provide various forms of assistance to newly independent states (NIS) of the former Soviet Union. Cooperative Agreements were signed between representatives of the U.S. government and each country in which assistance was to be undertaken. The U.S. Agency for International Development (USAID) was given responsibility to coordinate all U.S. government assistance to the NIS under the Act.

Through competitive bidding, USAID awarded a multi-year contract to a team managed by CH2M HILL International Services, Inc. (CH2M HILL) to support implementation of an environmental assistance program to republics of the former Soviet Union. Under this contract, termed the Environmental Policy and Technology (EPT) Project, CH2M HILL is to assist USAID's missions in Moscow, Kyiv, and Almaty undertake a program to promote environmental improvements in the NIS. The USAID mission in Kyiv supports environmental, and other, assistance programs to Ukraine, Belarus, and Moldova. These western republics of the former Soviet Union are termed WESTNIS. CH2M HILL has established an office in Kyiv from which to perform services in the WESTNIS region under the EPT Project.

The CH2M HILL team includes the following organizations:

- Center for International Environmental Law
- Clark Atlanta University/HBCUMI Environmental Consortium
- Consortium for International Development
- Ecojuris
- Environmental Compliance, Inc.
- Harvard Institute for International Development
- Hughes Technical Services Company
- International Programs Consortium
- International Resources Group, Ltd.
- Interfax Newsagency
- K & M Engineering
- Ogden Environmental and Energy Services Company
- Price Waterhouse
- World Wildlife Fund (US)

As part of Contract NO. CCN-003-Q-09-3165-00 - Delivery Order # 09, Subtask 1.2, a series environmental audits at industrial enterprises in the Donetsk Oblast are being implemented. The purpose of these audits is to assist industrial enterprises in identifying approaches to implement pollution reduction and waste minimization programs.

This report documents an initial audit made at Azovstal Metallurgical Plant in Mariupol. The management of this facility has granted permission to conduct a brief, on-site inspection of their operating facility for the purpose of obtaining a critical, independent assessment of the overall operations with emphasis given to identifying pollution prevention

investment opportunities. The purpose of this report is to provide guidance to the facility in defining technologies that could be implemented, resulting in better management of their wastes and pollution. A number of pollution prevention investment opportunities that can be categorized as plant modernization projects are identified herein. It is recommended that this report be shared with financial lending institutions like the World Bank in order to develop detailed investment strategies that will assist this facility. It should be emphasized that the report and its conclusions should be viewed as preliminary, and further, the recommendations, critical assessments, and conclusions are confidential to the Azovstal Metallurgical Plant and USAID.

DISCLAIMER

The audit has been implemented and the report prepared as a task assigned under the Environmental Policy and Technology Project (EPT), a program funded by the United States Agency for International Development. The study and recommendations made in this report are based on observations made by an independent audit team that has been trained by the EPT Project to conduct environmental site assessments. All members associated with this task have used best judgements and experience in formulating the recommendations and conclusions of this study. However, reviewers of this report must note that the information presented herein is based on data collected and observations made at the time of the audit and hence, the report does not necessarily, nor is claimed to accurately characterize the subject facility. Lack of certain information as well as the opportunity to conduct a long term audit over time restricts this report to initial impressions and therefore conclusions and recommendations could be inaccurate or challenged by subsequent audits. Finally, the report should not be viewed as either an endorsement or negative evaluation of the facility, its operation, and/or the management of Azovstal by the EPT Project or USAID, nor does it contain information which can confirm any violation of statutes, regulations, or release limits in any way imposed on this facility.

ACKNOWLEDGMENTS

The report has been prepared by the Environmental Policy and Technology (EPT) Project which is a USAID multi-year contract to a team managed by CH2M HILL International Services, Inc. (CH2M HILL) to support implementation of an environmental assistance program to republics of the former Soviet Union. The author/s of this report is the EPT Project Manager for the Donetsk Industrial Waste Management Program, assisted by a team of U.S. and Ukrainian auditors.

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Section 1
EXECUTIVE SUMMARY

This report documents an on site investigation of the Azov Steel Metallurgical Plant (referred to as Azovstal) located in Mariupol, Ukraine. The purpose of this audit was to identify potential pollution prevention opportunities that could result in significant savings to the manufacturing operation and to develop and apply a generalized approach and methodology to conducting environmental site assessments or audits for the steel industry in Ukraine. Information in the form of data, photographs, interviews with management and operating personnel, and in some cases field measurements were collected by an independent auditing team that was organized and trained by the Environmental Policy & Technology Project (EPT), a program which is funded by the United States Agency for International Development (USAID). The information and recommendations of this report have been treated confidential to Azovstal and are not for general public knowledge. There are however significant modernization projects identified in this study which if implemented could result not only in major reductions in pollution, but drastic improvements to the profitability of the operation and hence help ensure the operation's sustain ability. In this regard it is recommended that the report be shared with financial lending institutions like the World Bank and European Bank of Reconstruction and Development, or private investment sources that are seeking Ukrainian enterprises to invest in. It should be noted that recommendations and estimates based on potential savings for pollution prevention opportunities should be viewed as approximations only, and at best, order of magnitude estimates of the investment requirements. Limited resources and time have restricted a more detailed set of recommendations. Specific projects identified will require more careful and detailed engineering studies and business evaluations. Finally, a small scale pilot demonstration project to illustrate the benefits of pollution prevention audits and management practices has been identified from the audit. This project and a detailed engineering estimate are included in the report , along with recommendations that USAID provide the necessary funding for this pilot demonstration.

Section 2.
OBJECTIVES OF THE AUDIT

2.1 The Environmental Site Assessment

The audit performed at the Azovstal Metallurgical Plant located in Mariupol was an environmental site assessment (ESA) aimed at identifying pollution prevention opportunities that could result in significant savings in operating costs, product quality improvements, manufacturing efficiencies, while at the same time resulting in reductions in harmful emissions to the environment. In more specific terms, the objectives of this audit which the EPT Project is recommending as the standardized set of objectives for all subsequent audits conducted are:

- to help develop a structured approach to environmental management policy
- to address multi-media issues and relate them to environmental management needs
- to introduce the concept of intra-plant pollutant trading on multi-media basis
- to effect a common sense approach prioritization environmental management efforts taking into account economic, human resource and technological barriers to success
- to emphasize the need for environmental management credibility for the Iron and Steel global market as well as the major lending institutions through ISO 14000 certification and development of an environmental management system (EMS)
- to shift management focus from polluted-site cleanup and pollution control to pollution prevention (P2).

2.2 Facility Documentation

A further objective of the audit was to document the manufacturing equipment and systems at the audit site, the historical use and the environmental damage to the site, the ongoing operational management approach that affects the environment, the human, technology and communication factors that impact environmental management effectiveness. To this objective, some insight into the mentality of current management is also noted in the report, for without management commitment it is not possible to implement an effective environmental management system.

2.3 Materials-Use Documentation

A further objective of the audit was to identify all process starting feed materials, quantify them and to characterize them and their ultimate fate in the manufacturing process using process and materials flowsheets. This type of documentation enables accurate identification, characterization and quantification of sources of pollutant releases and toxic wastes.

2.4 Pollution Prevention Design

For each identifiable pollutant release and process waste, design of procedures or systems should be recommended for :

- pollutant minimization - by process material change, inventory control, process conditions changes, product modification or maintenance enhancement;
- recycling of pollutants - within the manufacturing operation;
- reclamation of pollutants - for other uses external to the mill;
- pollutant release mitigation

2.5 Pollution Prevention Demonstration Projects

Finally, through execution of all of the above tasks, the objective is to identify one or more pollution prevention projects for demonstration under the USAID program with a view to future large-scale pollution prevention projects implemented under major lending institution funding.

Section 3.
IRON AND STEEL MILL AUDIT PLAN AND PROTOCOL

The specific objectives for conducting the audit at the Azovstal facility can be summarized as follows :

- To describe the mill's overall operations, identify operating units within the mill on a process flowsheet, and to identify the flow of materials through the mill.

- To identify all significant wastes and air releases and to identify their points of generation on the process flowsheet.

- To characterize these releases and wastes through knowledge of the process, and in some cases by limited sampling and analysis.

- To provide an initial evaluation or assessment of the economic viability for the following three areas :

  for recycling the wastes or releases within the mill, or for reclamation (i.e., use external to the mill), or

  for reduction of the wastes or releases by process, or

  materials modification.

The following is the *Protocol* developed and applied to the audit. It is recommended that this procedure be followed on all subsequent audits:

Step 1. Meet with the Mill Management and the Environmental Manager for whatever length of time is required for the purposes of accomplishing the following:

- To agree on the audit procedure (modifications may be necessary based on constraints, including safety related issues, within the plant)

- To review the specific information needs or requirements of the audit team (such as process flow sheets, reported releases, inventory of materials, flow rates, operating limitations, etc.) An extensive list of data needs typically examined in the audit can be found in the *Workbook on Conducting the Environmental Audit for Pollution Prevention and Waste Management (1996)*. This publication was prepared for environmental auditors under the EPT Project and is available at the Technical Information Center in Donetsk. The meeting should be geared towards reducing the list to a manageable number of issues that will satisfy the requirements and objectives of the audit. At the same time, the meeting will identify areas where management

simply does not have reliable information, and hence can identify plant needs in terms of managing their wastes, and subsequently identifying a specific area of the manufacturing process where the audit team may wish to spend additional attention to.

- Draw a process flowsheet of the mill showing the significant waste and release generation points. *Note - the flowsheet is an essential tool to be used both during the actual audit and in analyzing the information collected. The audit team should use this as their* ***road map*** *while inspecting the mill and in formulating recommendations for particular processes.*

- Identify who will conduct the audit for the mill management and what specific assistance and cooperation will be needed. The manager should assign one or more specialists or operating personnel to accompany the audit team and should agree on full cooperation during the physical inspection.

- Establish a schedule for a pre-site visit and for the actual audit.

Step 2. Conduct a Pre-site visit. The lead auditor, or if appropriate, the audit team should visit the facility for up to a one-day *walk-through.* The purpose of this initial visit is to accomplish the following ·

- To ensure that the process flow sheet develop accurately characterizes the mill operations

- To enable a judgement that sufficient time and manpower has been allocated for the physical inspection to obtain all the data needs identified in *Step 1.*

- To identify specific areas or processes where sampling may be necessary, and if sampling points are identified, to assess how many samples are needed and what analytical support will be needed, as well as the size of samples and methods of preserving samples in the event that post analysis is needed.

- To assess safety precautions that the audit team needs to take, including identifying and becoming familiar with any safety rules and procedures that the mill enforces.

Step 3. Conduct the audit. For the audit conducted at Azovstal, and subsequent audits, because of the specific objectives of the study, the major documentation and data needs are based on visual observations. This audit and subsequent audits should follow a logical progression through the mill based on the flow of materials for manufacturing steel. Hence the team followed the process flowsheet during the inspection. This approach provided a further verification and corrections to the process flowsheet describing the operations, and was heavily

supported by video and still photographic evidence. During the inspection, the team was instructed to focus on the *wastes and release generation points* that were identified in *Step 1*. These *points* were assigned a numeric code on the flowsheet and a data log was created to record specific observations and data. Photographs of the releases were obtained and an additional numeric code applied so that the photographs and video could be matched to the identification number assigned to each release point on the process flow sheet. This procedure helps to facilitate post analysis of the information gathered during the environmental site assessment.

Step 4. Post Analysis. For each waste and release, the team collectively characterized the wastes and releases based on their knowledge of these streams, and in terms of the physical forms, characteristics and chemical composition. The amount of time required to perform this step depends on the quantity of information collected and the complexity of the process, as well as the constraints placed on the audit. In this case study, four days was allotted to post analysis of the information. This enabled the team to prepare preliminary recommendations and to further identify additional data needs that a subsequent, more detailed audit might address. As part of this step, a preliminary meeting with the mill management, and in particular the environmental engineer representing the facility is advisable. The purpose of this meeting is to review some of the preliminary recommendations and to ensure that the audit team has accurately characterized the process and discharge streams. This also provides an opportunity to obtain initial reactions or impressions from the mill management on the overall value of the audit to them. For this audit, a three hour post meeting enabled the team to obtain some cost and engineering estimates on several pollution prevention opportunities identified during the study.

Step 5 The Audit Report The final documentation of the study and its recommendations should be made One of the objectives of this study is to provide Azovstal and facilities like it, a standardized approach and format for conducting *self-audits*. The EPT Project recommends self-audits because it is the best known approach for implementing an effective environmental management system that is aimed at improving the profitability and sustain ability of the mill. The self-audit basically means that the mill management commit to having pollution prevention type audits conducted on a regular basis. We recommend two types of self audits. The first type, is in essence what has been conducted in this study. That is, inviting an independent team to conduct the audit, with the close cooperation of management. An independent audit team will indeed provide the most objective and critical assessment of the operations. It should however be agreed that such a study be treated as confidential information to the facility, especially if the services are paid for. Such documentation is clearly the property of the enterprise if it has contracted the services of an external audit team to provide a critical evaluation of its operations and environmental problems. This further means that the enterprise management will have the latitude to decide on the circulation of such a document (meaning, for internal use to improve operations, or if evaluations are highly favorable, to use as a basis for attracting financial resources for

modernization and investments). The second type of self audit is simply to establish an internal team, comprised of process and environmental engineering department personnel. This audit team can apply the same principles presented in this report to identify incentives for pollution prevention. Small audits conducted internally within an organization can provide a basis for incremental improvements or incentives, and if conducted on a regular basis, with application of small scale modernization projects supported by management, can result in significant improvements with time. It is recommended that the general format for the report presented herein be applied in the final documentation. The approach taken in the study and in the report is to make comparisons to *cleaner technologies*. Hence comparisons are made between the technologies used at Azovstal and those used in the United States where strict environmental enforcement has driven the application of *green products and clean technologies*. This comparison also enables a basis for an economic evaluation since the cost for existing clean technology is well known in the United States.

Section 4.
IRON AND STEEL PRODUCTION· STATE-OF-THE-ART U.S. TECHNOLOGY

The production of steel at a typical integrated iron and steel plant is accomplished using several interrelated processes. The major operations are: (1) coke production, *which is carried out external to steel mills in the Ukraine with merchant coking enterprises*, (2) sinter production, (3) iron production, (4) iron preparation, (5) steel production, (6) semifinished product preparation, (7) finished product preparation, (8) heat and electricity supply, and (9) handling and transport of raw, intermediate, and waste materials.

4.1 Sinter Production

The sintering process converts fine-sized raw materials, including iron ore, coke breeze, limestone, mill scale, and flue dust, into an agglomerated product, sinter, of suitable size for charging into the blast furnace. The raw materials are sometimes mixed with water to provide a cohesive matrix, and then placed on a continuous, traveling grate called the sinter strand. A burner hood, at the beginning of the sinter strand ignites the coke in the mixture, after which the combustion is self supporting and it provides sufficient heat, 1300 to 1480°C (2400 to 2700°F), to cause surface melting and agglomeration of the mix. On the underside of the sinter strand is a series of windboxes that draw combusted air down through the material bed into a common duct, leading to a gas cleaning device. The fused sinter is discharged at the end of the sinter strand, where it is crushed and screened. Undersize sinter is recycled to the mixing mill and back to the strand. The remaining sinter product is cooled in open air or in a circular cooler with water sprays or mechanical fans. The cooled sinter is crushed and screened for a final time, then the fines are recycled, and the product is sent to be charged to the blast furnaces.

4.2 Iron Production

Iron is produced in blast furnaces by the reduction of iron bearing materials with a hot gas. The large, refractory lined furnace is charged through its top with iron as ore, pellets, and/or sinter, flux as limestone, dolomite, and sinter, and coke for fuel. Iron oxides, coke and fluxes react with the blast air to form molten reduced iron, carbon monoxide (CO), and slag. The molten iron and slag collect in the hearth at the base of the furnace. The byproduct gas is collected through offtakes located at the top of the furnace and is recovered for use as fuel.

The molten iron and slag are removed, or cast from the furnace periodically. The casting process begins with drilling a hole, called the *taphole*, into the clay-filled iron notch at the base of the hearth. During casting, molten iron flows into runners

that lead to transport ladles. Slag also flows into the clay-filled iron notch at the base of the hearth. During casting, molten iron flows into runners that lead to transport ladles. Slag also flows from the furnace, and is directed through separate runners to a slag pit adjacent to the casthouse, or into slag pots for transport to a remote slag pit. At the conclusion of the cast, the taphole is replugged with clay. The area around the base of the furnace, including all iron and slag runners, is enclosed by a casthouse. The blast furnace byproduct gas, which is collected from the furnace top, contains CO and particulate. Because of its high CO content, this blast furnace gas has a low heating value, about 2790 to 3350 joules per liter (J/L) (75 to 90 British thermal units per cubic foot ,Btu/ft^3) and is used as a fad within the steel plant. Before it can be efficiently oxidized, however, the gas must be cleaned of particulate. Initially, the gases pass through a settling chamber or dry cyclone to remove about 60 percent of the particulate. Next, the gases undergo a 1- or 2-stage cleaning operation. The primary cleaner is normally a wet scrubber, which removes about 90 percent of the remaining particulate. The secondary cleaner is a high-energy wet scrubber (usually a venturi scrubber) or an electrostatic precipitator, either of which can remove up to 90 percent of the particulate that eludes the primary cleaner. 'Together these control devices provide a clean fuel of less than 0.05 grams per cubic meter (g/m^3) (0.02 grains per cubic foot [gr/ft^3]). A portion of this gas is fired in the blast furnace stoves to preheat the blast air, and the rest is used in other plant operations.

4.3 Hot Metal Desulfurization

Sulfur in the molten iron is sometimes reduced before charging into the steelmaking furnace by adding reagents. The reaction forms a floating slag which can be slammed off. Desulfurization may be performed in the hot metal transfer (torpedo) car at a location between the blast furnace and basic oxygen furnace (BOF), or it may be done in the hot metal transfer (torpedo) ladle at a station inside the BOF shop, or using an independent separate desulfurization unit, *as is the case at Azovstal.*

The most common reagents are powdered calcium carbide (CaC_2) and calcium carbonate ($CaCO_3$) or salt-coated magnesium granules. Powdered reagents are injected into the metal through a lance with high-pressure nitrogen. The process duration varies with the injection rate, hot metal chemistry, and desired final sulfur content, and is in the range of 5 to 30 minutes.

4.4 Steelmaking Process: The Basic Oxygen Furnaces

In the basic oxygen process (BOP), molten iron from a blast furnace and iron scrap are refined in a furnace by lancing (or injecting) high-purity oxygen. The input material is typically 70 percent molten metal and 30 percent scrap metal. The oxygen reacts with carbon and other impurities to remove them from the metal. The reactions are exothermic, i.e., no external heat source is necessary to melt the scrap and to raise the temperature of the metal to the desired range for tapping.

The large quantities of CO produced by the reactions in the BOF can be controlled by combustion at the mouth of the furnace and then vented to gas cleaning devices, as with open hoods, or combustion can be suppressed at the furnace mouth, as with closed hoods. BOP steelmaking is conducted in large refractory lined pear shaped furnaces. Conventional BOFs have oxygen blown into the top of the furnace through a water-cooled lance. A typical BOF cycle consists of the scrap charge, hot metal charge, oxygen blow (refining) period, testing for temperature and chemical composition of the steel, alloy additions and reblows (if necessary), tapping, and slogging. The full furnace cycle typically ranges from 25 to 45 minutes.

4.5 Steelmaking Process: The Electric Arc Furnace

Electric arc furnaces (EAF) are used to produce carbon and alloy steels. The input material to an EAF is typically 100 percent scrap. Cylindrical, refractory lined EAFs are equipped with carbon electrodes to be raised or lowered through the furnace roof. With electrodes retracted, the furnace roof can be rotated aside to permit the charge of scrap steel by an overhead crane. Alloying agents and fluxing materials usually are added through the doors on one side of the furnace. Electric current of the opposite polarity electrodes generates heat between the electrodes and through the scrap. After melting and refining periods, the slag and steel are poured from the furnace by tilting.

The production of steel in an EAF is a batch process. Cycles, or "heats", range from about 1-1/2 to 5 hours to produce carbon steel and from 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 Stages of each cycle normally are charging and melting operations, refining (which usually includes oxygen blowing), and tapping.

4.6 Open Hearth Furnaces

The open hearth furnace (OHF) is a shallow, refractory-lined basin in which scrap and molten iron are melted and refined into steel. Scrap is charged to the furnace through doors in the furnace front. Hot metal from the blast furnace is added by pouring from a ladle through a trough positioned in the door. The mixture of scrap and hot metal can vary from all scrap to all hot metal, but a half-and-half mixture is most common. Melting heat is provided by gas burners above and at the side of the furnace. Refining is accomplished by the oxidation of carbon in the metal and the formation of a limestone slag to remove impurities. Most furnaces are equipped with oxygen lances to speed up melting and refining. The steel product is tapped by opening a hole in the base of the furnace with an explosive charge. The open hearth steelmaking process with oxygen lancing normally requires from 4 to 10 hours for each heat.

4.7 Semifinished Product Preparation

After the steel has been tapped, the molten metal is teemed (poured) into ingots which are later heated and formed into other shapes, such as blooms, billets, or slabs. The molten steel may bypass this entire process and go directly to a continuous casting operation. Whatever the production technique, the blooms, billets, or slabs undergo a surface preparation step, *scarfing*, which removes surface defects before shaping or rolling. Scarfing can be performed by a machine applying jets of oxygen to the surface of hot semifinished steel, or by hand (with torches) on cold or slightly heated semifinished steel.

Section 5
AZOVSTAL PLANT DESCRIPTIONS

5.1 Overview

The Azovstal Plant consists of the following process units:

- Agglomeration (sintering), including slaking of lime for sintering feed preparation,
- Blast Furnace (BF) for iron making from agglomerate feed,
- Desulfurization of pig iron,
- Mixing of steel-making feed,
- Basic Oxygen Furnace (BOF) operation to produce steel ingots,
- Alternative Electric Arc Furnace (EAF) or Open Hearth Furnace operations to produce steel.

While there are the same process steps carried in U.S. production of steel from iron ore, the Azovstal practice differ significantly from the U.S. baseline mode of operation that incorporates pollution prevention today.

The Azovstal steel and ferromanganese alloy products do satisfy the ISO 9,000 standard to enable export to Western world markets. The plant sells approximately 60 % of their steel to the export market, including the United States, Canada, parts of Western Europe and Eastern Europe, with no one dominating market sector. Plant management claimed that their steel has a significant price advantage in the United States, and sells for $ 40 to $ 50 per ton below domestic U.S. sources, however the management declined to comment on what the profit margin is.

The plant produced 7 million tons of steel in 1992, but due to a significant decline in the exports, production demand dropped to 4-million tons of steel in 1995, but is expected to grow to 5-million tons of steel in 1996. The plant is not operating at full capacity, and best estimates from interviews indicate that current production is only at 55 to 60 % of nameplate capacity. Figure 1 provides two photographs which provide an overview of the facility and magnitude of the size of the operation.

U.S. experience in steel making indicates that the process utilizes 2 to 3 tons of feed material to produce each ton of steel. Accordingly, nearly 1 to 3 tons of waste generation occurs for each ton of steel produced, and for 5-million tons of steel produced in 1996 some 8-million tons of waste releases are generated at the plant,

notwithstanding recycling and reclamation implemented to prevent pollution. The flowsheet for the process is shown in Figure 2.
Discussions concerning key features associated with each of the process operations within the plant are given below.

5.2 Agglomeration (Sintering)

In the first process step at Azovstal there are 7 million tons per year of iron ore agglomerated using a pair of 65-year old sintering grates; each one is 65 meters long to effect an abbreviated agglomeration cycle. The agglomerate mix is slightly less alkaline (2:25, acid:alkaline ratio) than is normal for blast furnace operations to reduce waste emissions.

The coke, iron ore and lime feedstocks are mixed with water to increase agglomerate cohesiveness. The burning of coke feed sustains combustion and maintains the needed 1,500°C sintering temperature. This is illustrated in the top photograph of Figure 1 and in the photographs shown in Figure 3. Figure 3A shows the operation of lime transport to agglomeration, and Figure 3B shows rail cars bringing coke to agglomeration

Under the moving strand or grate, windboxes draw down air through the agglomerate bearing undersized agglomerate. The underflow air and the dust from the hot, exit end of the strand of each unit go to separate banks of venturi wet scrubbers. The strand underflows bearing fines separately go through wet scrubbing and then back to the feed end of the strand. The wet scrubbing systems are described in *Section 6.2* of this report.

5.3 Blast Furnaces: The Iron Making Process

The agglomerate is charged to the tops of the blast furnaces, and molten iron and slag are drawn from the furnace bottom. There are six blast furnaces, each with a capacity of more than 1-million tons per year of iron production. At the base of each blast furnace are tap holes from which iron and slag are periodically tapped. Pig iron goes to the cast house or to ladles under each furnace. Slag is drained in an open uncovered trench to ladles for transport to slag by-product operations. Azovstal sells the slag for building materials and as a highway paving material. No estimates could be obtained on pricing structure or tonnages typically sold. In general, however this is believed to be a soft market with low prices.

Blast furnaces #'s 1,2,3,4 and 6 were operational at the time of the audit. Unit # 5 was shut down for a scheduled maintenance turnaround. Unit # 3 is being used to test and demonstrate the viability of using a nitrogen blanket to suppress the release of dust at the blast furnace tap, which is a significant source of hazardous emissions. The success to date with this manually operated nitrogen suppression blanket is described in *Section 5.5* for the mixer operation. The six furnaces have

the usual wet scrubbers but no nitrogen or water suppression.

Figures 4 through 9 show this operation Figure 4 shows a photograph of Blast Furnace # 1 which is typical of the other units Figure 5 is a photograph of Blast Furnace # 3 which has been equipped with the nitrogen blanket capability. Figure 6 shows a photograph of the lower operating deck to Blast Furnace # 3. Figure 7 shows a photograph of the slag tap at Blast Furnace # 3, and Figure 8 provides a view of the iron tap on the same unit.

Figure 9 shows the slag tap from Blast Furnace # 3 which is simply allowed to flow onto the process floor area with minimal diking precautions. The photographs provided in Figures 4 through 9 typify the operations at all six units. The operation in general is extremely hazardous and far below U.S. operating practices from a safety standpoint. Virtually no operators in this part of the plant were observed to have any safety equipment other than hard hats, for which more than half of the operators simply did not bother wearing. In addition, there were no indications of first aid stations, respirators, eye/face protection, hearing protection or alarms, and a gross lacking of safety railings. General housekeeping practices were totally devoid in this stage of the operation. As a general rule, no safety records are maintained so statistical information on worker health and safety cannot be noted, however one informal interview with a site operator revealed that a fatality had occurred within the month prior to the audit

5.4 Desulfurization

Pig iron produced in the blast furnaces is transported to a dedicated unit designed to carry out desulfurization. There are two parallel units each with a five-ladle capability and a single battery of six cyclones to handle both units.

As described in Section 5.3 of this report, the dust-bearing furnace gases from desulfurization are aspirated to a separate building provided for air cleaning. Figure 10 shows the gas collected from the top of the furnace. Altogether there are six cyclones and one electrostatic precipitator, which from initial observation seems adequate. However, the electrostatic precipitator is not operational and there appear to be no plans for either repairing the unit or replacing it. There is a set of new upgraded cyclones on site, but no "collectors" and no funds have been allocated or are available to obtain them. Azovstal management discussed with the audit team a capital project of $2-million to replace the non-functional electrostatic precipitator with a set of high temperature fabric filters (bag houses). Although the project has been scoped out in terms of the preliminary engineering design and cost estimates, the facility has not authorized the project and does not foresee any immediate sources of funding within its current operating budget. The current operation with cyclones only indicates that only about 60 + % capture efficiency is being accomplished. The use of a portable particulate analyzer during the audit showed that a rough estimate of the emissions may be on the order of 2000 to 3000 micrograms per cubic meter of dust, which far exceeds Ukrainian air

discharge limits. Very preliminary estimates indicate that if a well designed particulate capture system such as baghouses were to be installed, nearly 250 tons per year of solids bearing 20% graphite could be recovered. This is a potential reclamation project whereby part of the investment could be handled by the sale of recoverable materials.

In the desulfurization operations at Azovstal, manganese and/or manganese oxide are mixed with the pig iron and reacted to remove sulfur to skim or slag in the form of magnesium sulfide (MgS). The oxidation of manganese to ironic forms for manganese sulfide formation is highly exothermic and violent. Large quantities of burning metal are released during the 10-30 minute cycle.

Figures 11 through 15 provide photographs of the gas cleaning operation. Figure 11 depicts the flue gas cleaning operation. A close up photograph showing the multi clone arrangement is provided in Figure 12. Figure 13 is a photograph of one of the new cyclone units acquired for the modernization (again, the reader should note that capital funding has been reported by management to be unavailable to install these units). Figure 14 provides still another view of the gas cleaning operation. Finally, Figure 15 provides a photograph of an accidental discharge of hot slag during the desulfurization operation. This incident was captured on video footage which is separate documentation available to reviewers of this report. The incident appears to be typical of the operation and again highlights extremely poor controls for worker safety.

5.5 Mixing Operations

At Azovstal there are two mixers used to prepare Bessemer converted feed. Only one of them is currently functioning. The second mixer unit is under a three month turnaround for repairs and is a potential site for a small scale pollution prevention demonstration (described in Appendix A of this report). Each mixer has a capacity of 2500 tons and are reportedly the largest mixers in the world for this type of operation. The units are both housed in one building and have significant air emissions that represent an endangerment to worker health and safety and certainly contribute to the overall air discharges of the plant. There are two points of air emissions on each mixer. These are at the pig iron charge inlet (top of mixer), and at the molten metal discharge station (near the bottom of each mixer). Refer to the photographs in Figures 16 and 17. Field measurements using a particulate air monitor indicates dust concentrations in the league of 700 to 900 mg per cubic meter of air, as compared to 100 mg dust per cubic meter of air based on Ukrainian permissible discharge limits. Air emissions during certain periods of this operation in fact seemed significantly higher, and in fact visibility was significantly impaired during loading and unloading operations, as illustrated in Figure 18. It may be noted in Figure 18 that workers simply have no personal protection such as respirators, and only a limited number of operating personnel where observed to wear hard hats.

There is an existing particulate capturing system in place comprised of capturing hoods at the two discharge locations, and a battery of cyclones which appear undersized and in need of repairs for the operation. Each of the mixer air capturing systems is operated by its own 12 Killowat centrifugal blower. On the second mixer which is undergoing repairs, the blower requires major overhauling and replacement of the motor Nitrogen suppression, which is a means of reducing dust and fume emissions, has been demonstrated on one mixer experimentally, but the connectors/ducts have been removed. The experiment was not totally successful due to inadequate connections.

At the one mixer's hot unloading end, a hood collects fumes and dust unsuccessfully as repeated accidents show. A typical incident is shown by the photograph in Figure 19. However, tests indicate that the use of connected hoods at the mixer and hot discharge release points could enable 20-30% of the dust reclamation and control to reduce releases to below 100 mg dust per cubic meter when nitrogen suppression is applied at both ends and is combined with effective use of 32 cyclones currently installed.

Moreover control of oxidation of pig iron at the mixing location by nitrogen suppression will effectively minimize the formation of ferrous oxides on top of the ladles used to transport mixed pig iron to the Bessemer converter, thereby reducing the need for dangerous fracturing following mixing, before charging of the Bessemer converter. A photograph of the manual fracturing procedure used at Azovstal is shown in Figure 20. Once the mixer discharges the molten pig iron, it is transported to the converter in ladles. This is shown by the photograph in Figure 21.

The audit team collectively recognize that the use of nitrogen suppression could improve the operation in several ways, the most significant of which is a reduction in harmful air emissions. There are however economic advantages to this practice which are descried in *Appendix A*. The main problems preventing nitrogen blanketing at the mixer reactor and hot-end unloading are the lack of connector ducts and piping for nitrogen. In addition, an inadequate supply of nitrogen is a serious long-term problem for the plant. Current nitrogen availability is restricting the use of pure nitrogen, causing diluted wet nitrogen use even at Blast Furnace #3 which is purely experimental and manual. Automatic nitrogen feed in the six Blast Furnaces and Bessemer converter would call for nitrogen demand that could only be delivered by a world-size nitrogen plant costing nearly $1-billion, or several smaller dedicated nitrogen supply (BOF, Blast Furnace, sintering, etc.) units costing even more in total if so elected. No such plan has even been conceptualized. For the mixing alone, a $15-million nitrogen generator would be optimal.

5.6 Basic Oxygen Furnace Bessemer Converter

The single operating Bessemer Converter (Basic-Oxygen Furnace) operates virtually without any air emissions controls. Ladles of mixed pig iron are transported to the furnace, charged, reacted and steel product is unloaded without nitrogen blankets.

Charging is carried out with the furnace tilted forward. Then the furnace is tilted backward to collectors that point the air releases (with no suppression) to the chimney and to the ambient atmosphere. The oxygenated reaction generates voluminous dust containing metal oxides because of the lack of suppression. The furnace is once again tilted forward to facilitate off-loading into ladles for transport to ingot formation and product pre-finishing. The emissions from this operation are simply enormous and exceeded the upper limits of sensitivity on chemical specific air monitors that the audit team had during the course of the audit. Figure 22 shows some photographs of the unloading operation at the converter.

Section 6.
AZOVSTAL PLANT WASTES AND RELEASES

6.1 Overview

This section characterizes the individual releases and discharge to the environment caused by plant operations observed at the time of the audit. It must be emphasized that none of the conclusions or observations made from this audit are sufficiently detailed for design or legal purposes. This audit of ongoing average or monetary experience in the plant could not confirm any violation of statutes, regulations or release limits in any way imposed on this facility. This report is based on observations made only during the physical site inspection and a limited number of air quality samples obtained with field sampling instruments. Commitments for major investments for correction of observed problems should be based on detailed engineering studies over representative operational time periods.

In this section of the report, the practice of Azovstal is compared with equivalent practice in the U.S., where most of the iron and steel industrial environmental controls have been effected over the last twenty years.

In the U.S., most sintering or agglomeration units have been shut down, as have coking operations. Sintering and coking operations always release voluminous and highly toxic chemicals such as Benzo-A-pyrene (*a highly potent carcinogen*). Total toxic and carcinogen releases from such operations in the U S. once exceeded 10-tons per year per plant. In the U.S. these operations have been replaced by direct coal dust injection to the Blast Furnace interior

6.2 Sintering

At the few U.S. facilities, where coking and sintering has been continued, the waste streams that are recycled from other parts of the plant are pretreated to avert introduction of pollutants to the process. Most U.S. sintering operations have been discontinued.

At the Azovstal plant the sintering releases at the hot end of the strand and the strand underflow contains iron oxides, sulfur oxides, fluorides, sulfides, phenol cyanides, zinc, lead and copper compounds. Most of the air releases are captured by the wet scrubbers and converted to water and solid wastes. U.S. experience shows generation of a broad range of water waste quantities from 100 to 6,000 gallons/ton of sinter. Figures 23 through 29 document the wet scrubber operation at Azovstal which is a significant source of solid and aqueous wastes. Figures 23 and 24 provide photographs of the scrubbers on sintering and agglomeration. Figure 25 shows a grade level view of the wet scrubbers for agglomeration. Figures 26 through 28 are photographs of the agglomeration wet scrubber discharges. Figure

29 provides a photograph of the scrubber wet sludge from agglomeration.

One option at Azovstal would involve eventual replacement of wet scrubbers with dry capture of dust to significantly reduce the total volume of waste generated. A detailed engineering and cost estimate study is recommended for this option.

6.3 Blast Furnace

The main source of released emissions are from blast furnaces at Azovstal iron taps at the bottom of the furnaces. Nearly 40 kg of releases are generated per ton of pig iron produced in U.S. operations. Azovstal experience probably exceeds this rate of release because of the additional releases due to wet scrubber inefficiencies at the top of the furnaces (refer to Figure 30) and the lack of nitrogen or water suppression at the top of the furnace.

Clearly nitrogen suppression would be an important option for pollution control at the pig iron and slag taps. Recovery of graphite and iron oxide at these point sources, followed by reclamation of graphite and recycle of iron oxide to sintering would be a favorable option.

6.4 Desulfurization

The desulfurization slag and overhead dust collected by the six cyclones are the principal sources of waste release for this process step at Azovstal. The slag is composed of copper and zinc sulfides, iron oxide, and manganese sulfide.

The aspirated overhead fumes contain these compounds in lower concentrations plus 10-30% graphite.

The graphite quality for reclamation and rate of recovery could be greatly enhanced by installation of the new cyclones and proposed bag houses. This proposed gas cleaning system would yield 250 tons per year of 70-80% graphite by product.

6.5 Mixing

The fumes generated at the top of the mixing reactor and at the tap used to fill the ladles for pig iron transport to the Bessemer basic oxygen furnace are the principal waste release points. The proposed demonstration project would involve nitrogen blankets and hoods for fume collection at both points to enable reclamation of 150 to 200 tons per year of graphite by-product and significant reductions in fume releases.

6.6 Basic Oxygen Furnace (BOF)

At Azovstal, some 10-20 kg of air emissions are released per ton of steel produced.

For a typical change of 400 tons of steel, nearly 3 tons of fumes are released. These fumes contain the following principal constituents: fluoride, chloroform, arsenic, cadmium, chromium, copper, lead, iron and zinc.

The most significant emissions from the BOF process occur during the oxygen blow period. The predominant compounds emitted are iron oxides, although heavy metals and fluorides are usually present. Charging emissions will vary with the quality and quantity of scrap metal charged to the furnace and with the pour rate. Tapping emissions include iron oxides, sulfur oxides, and other metallic oxides, depending on the grade of scrap used. Hot metal transfer emissions are mostly iron oxides.

BOFs in modern U.S. mills are equipped with a primary hood capture system located directly over the open mouth of the furnaces to control emissions during oxygen blow periods. Two types of capture systems are used to collect exhaust gas as it leaves the furnace mouth: closed hood (also known as an off gas, or the O-C system) or open, combustion-type hood. A closed hood fits snugly against the furnace mouth, ducting all particulate and CO to a wet scrubber gas cleaner. CO is flared at the scrubber outlet stack. The open hood design allows dilution air to be drawn into the hood, thus combusting the CO in the hood system. Charging and tapping emissions are controlled by a variety of evacuation systems and operating practices. Charging hoods, tapside enclosures, and full furnace enclosures are used in the industry to capture these emissions and send them to either the primary hood gas cleaner or a second gas cleaner.

One obvious improvement that could be implemented at Azovstal would be nitrogen blanketing of the BOF, for both the oxygen blow period and the pouring of steel into ladles. A nitrogen plant costing $15-million would be required. This project has not been conceptualized and funding would be required.

Another potential improvement would be recovery of fume dust and recycle of it to the sintering unit for recovery of lost iron values.

Both of these projects would involve millions of dollars in investment but would prevent significant pollution and would recover significant material lost to waste at present.

Section 7.
RECOMMENDATIONS

7.1 Overview and General Recommendations

This section of the report summarizes the recommended pollution prevention measures to be implemented under an environmental management program at Azovstal. Funding for these several actions would far exceed the available internal resources of Azovstal, but continued operation of the steel mill virtually mandates modernization. Cost effective sound management of Azovstal as a privatized business must sustain retirement of obsolete capital facilities to maintain a competitive posture in a global business setting. Furthermore, the mentality of Azovstal management must redirect itself towards a more aggressive philosophy and management structure that is supportive of pollution prevention, incorporating worker productivity and safety issues.

Without modernization, adequate maintenance of the capital plant, and initiatives to effect environmental, health and safety programs, Azovstal will ultimately lose opportunities for product export to the western world, and without such exports, the business will ultimately fail. Recovery of product lost to waste is urgently needed.

Significant loss of worker time due to health and safety mismanagement is a reality in Azovstal's working environment which only adds to losses of valuable feedstock to the environment due to material mismanagement. All of these factors are a reality in Azovstal and this very important mill in the Ukraine steel industry must be corrected.

7.2 Sintering (Agglomeration)

The sintering plant and its air release cleaning units (scrubbers) are very old and obsolete. No such sintering operation would be practiced in the western world.

In the U.S. most sintering operations have been shut down and replaced to use pulverized coal feed direct to the blast furnaces instead of using coked coal and agglomeration. It would be very ambitious to contemplate such a program at Azovstal because it would involve replacement of all six blast furnaces with the new direct reduction, gas-fired systems that are the state-of-the-art technology in the Western world.

However, it would be possible for a cost of $ 3 to 5 million to replace the wet scrubbing systems with a dry system using cyclones and baghouses followed by zinc recovery from the captured dust. Such a dry system would also facilitate recycle of dust from the basic oxygen and electric arc furnaces and would readily facilitate

a return on the investment with 5 to 10 years

7.3 Blast Furnaces

Assuming that the cost of blast furnaces replacement would be prohibitive, at the very least automatic nitrogen blankets should be installed at the pig iron tap for each furnace and nitrogen or water suppression should be installed at the top of each furnace.

The current method of tapping molten slag to create rivers of flowing red-hot metal and scrap is totally unacceptable and very dangerous, especially given the total lack of any railings to prevent worker exposure. Direct molten slag taps with nitrogen blanket discharging into slag ladles is an absolute necessity. Cost of such accommodation for all six blast furnaces would be less than $1-million. Nitrogen blanketing would also be desirable, but the largest problem for all these blast furnace proposals would be the prohibitive cost for a nitrogen plant. There are two options:

- a single new, very large nitrogen plant for all the Azovstal needs at a cost of $60-million, or
- a smaller nitrogen plant just for the blast furnaces at a cost of approximately $15-million.

7.4 Desulfurization

To reduce the air emissions and increase the recovery of quality graphite from the air emissions, it is absolutely necessary to purchase the connectors for the new cyclones and install them at a cost below $250,000. Moreover, it would be useful to further reduce the dust content of the air releases with a new bag-house system that would cost $2-million. Such a system would enable recovery of 250 tons per year of 90% graphite by-product with a value of nearly $100 per ton. Local markets have already been identified for the graphite by-product offtake.

7.5 Mixing

It is recommended that USAID fund the recovery of graphite and cleanup of mixer air releases using a nitrogen blanket in a small scale pollution prevention demonstration. The cost of this project is $ 70,000 with some cost sharing on the part of Azovstal. Appendix A provides a more detailed project description and cost justification.

7.6 Basic Oxygen Furnace (BOF)

The BOF should be automatically nitrogen blanketed during the oxygenated

reaction period of the operating cycle.

Three tons of steel per BOF change would be saved as the suppression would inhibit its release to the environment. But a nitrogen plant at the BOF location would cost $15-million. Alternatively, the BOF unit could use nitrogen from a new central nitrogen unit as proposed for the blast furnaces at a cost of $60 million.

One additional proposal would involve cyclone capture of BOF dust and recycle to sintering at a capital cost of $2 to 3 million. This project will have a full return of investment within 3 to 5 years. No engineering design has even been started for this proposal.

To supplement these recommendations and to assist in further development studies, Appendix B has been compiled, which provides detailed process flow sheets for the various recommendations. These flow sheets represent modern, integrated steel mill operations which can be used as initial models to assess the specific modernization recommendations made in this report.

7.7 Worker Productivity and Safety Issues

The Azovstal Plant like many other facilities in Ukraine, shows enormous mismanagement of worker safety issues, which is well known in Western countries to have a direct bearing on manpower productivity. Management needs to redirect its focus and view the personnel as an essential asset of the plant. During the site investigation, at least three serious accidents were observed and recorded on video. These accidents which may be classified as *near-misses*, did not result in personal injuries, but posed significant threats to worker safety and health. It is recognized that Azovstal has limited financial resources to revamp and modernize the facility to minimize hazardous conditions for the working force, however, there are numerous low cost managerial practices and procedures that could be implemented immediately to minimize personal risks. Among these are properly posted warning and hazard signs, enforcement of the use of safety gear such as hard hats, providing limited personal respiratory protection for the most hazardous areas, worker safety training and meetings, local first aid stations, documented procedures for confined space entry operations, and many others. The fact that management has not implemented such procedures, or if they have little sign of enforcement was observed during the audit, is an indication of misdirected management philosophy. It is recommended that management assign this as one of their priority issues and consider this as part of the investments that must be made in order to ensure the success and sustainability of the facility. Specifically, Azovstal should form, assuming it does not exist, a formal safety department to assess the hazards of their operations and to begin implementing low cost safety measures. Further, this department should establish proper protocols for emergency response procedures, and maintain accurate records of injuries, accident categories (including near misses), and post this information for general knowledge of the workers. By maintaining and publicizing safety records, even bad ones, worker sensitivity and

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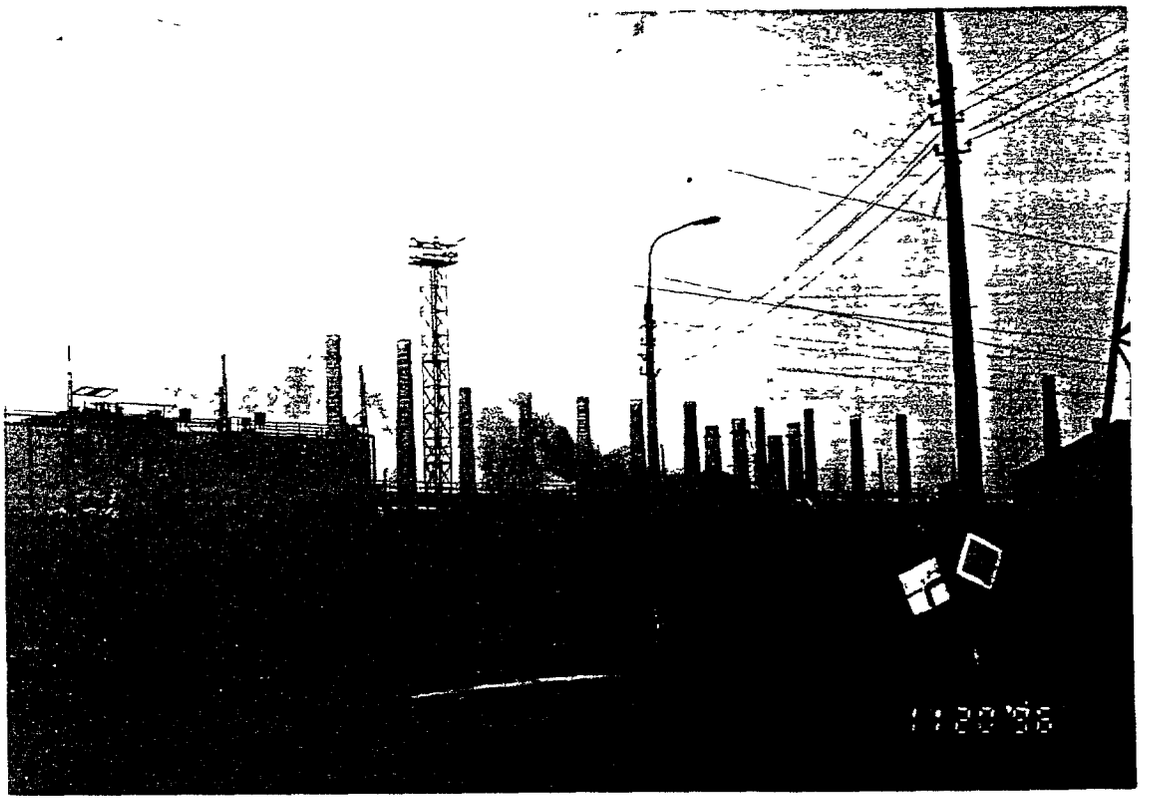


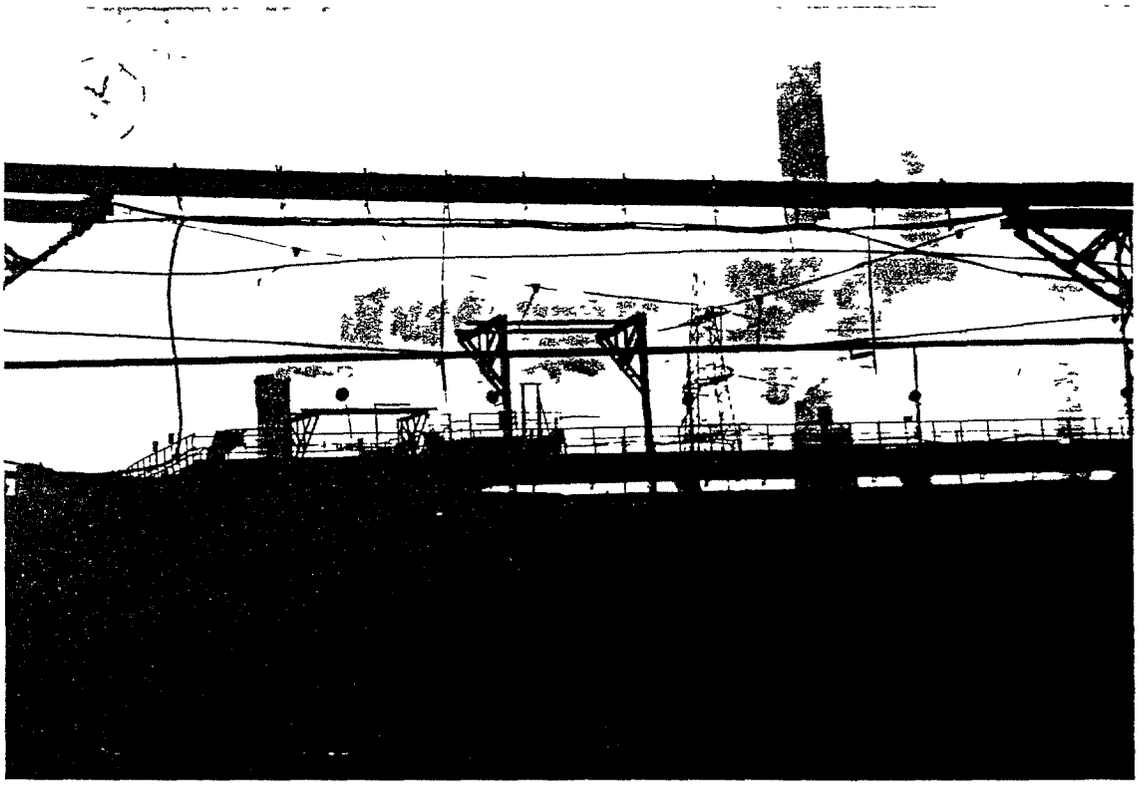


Figure 1. Overview photographs of the Azovstal Plant in Mariupol ,Ukraine.

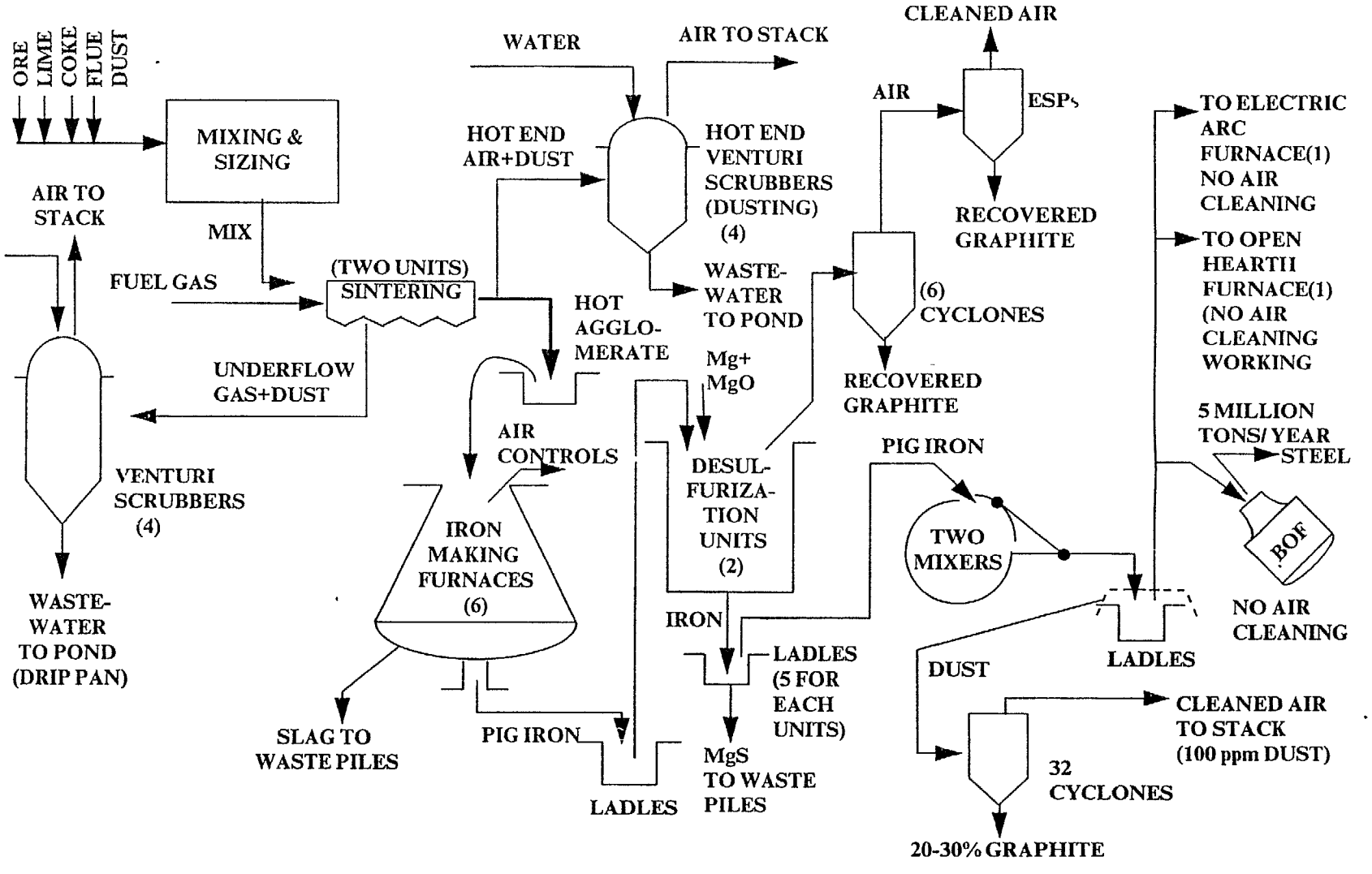
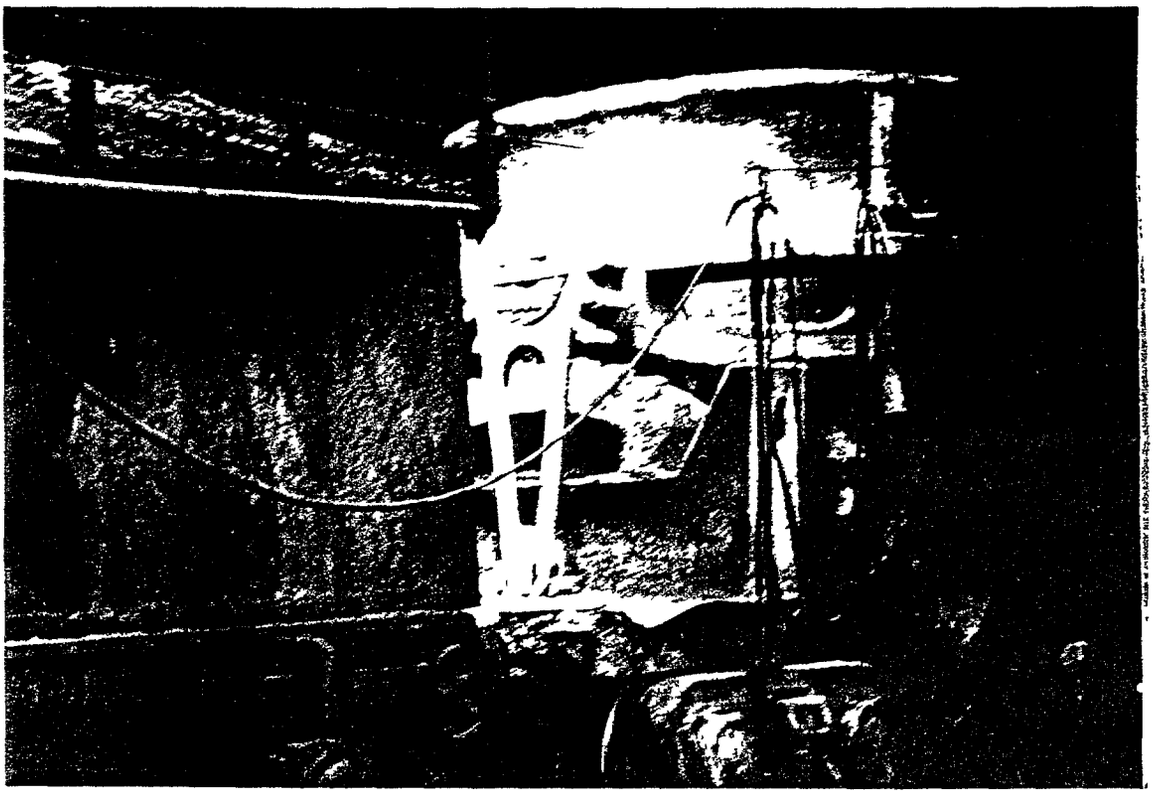


Figure 2. Process flowsheet developed for the AZOVSTAL Plant Audit.



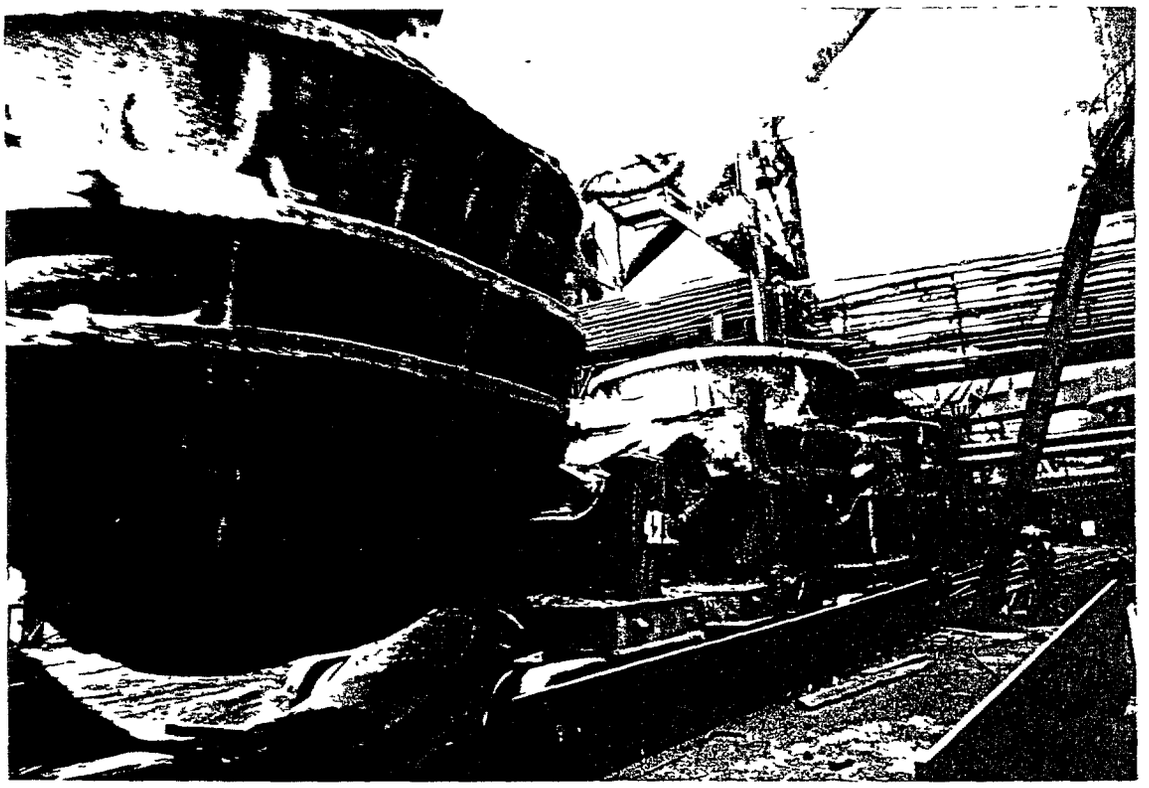


Figure 3A. Lime transport to agglomeration stage.

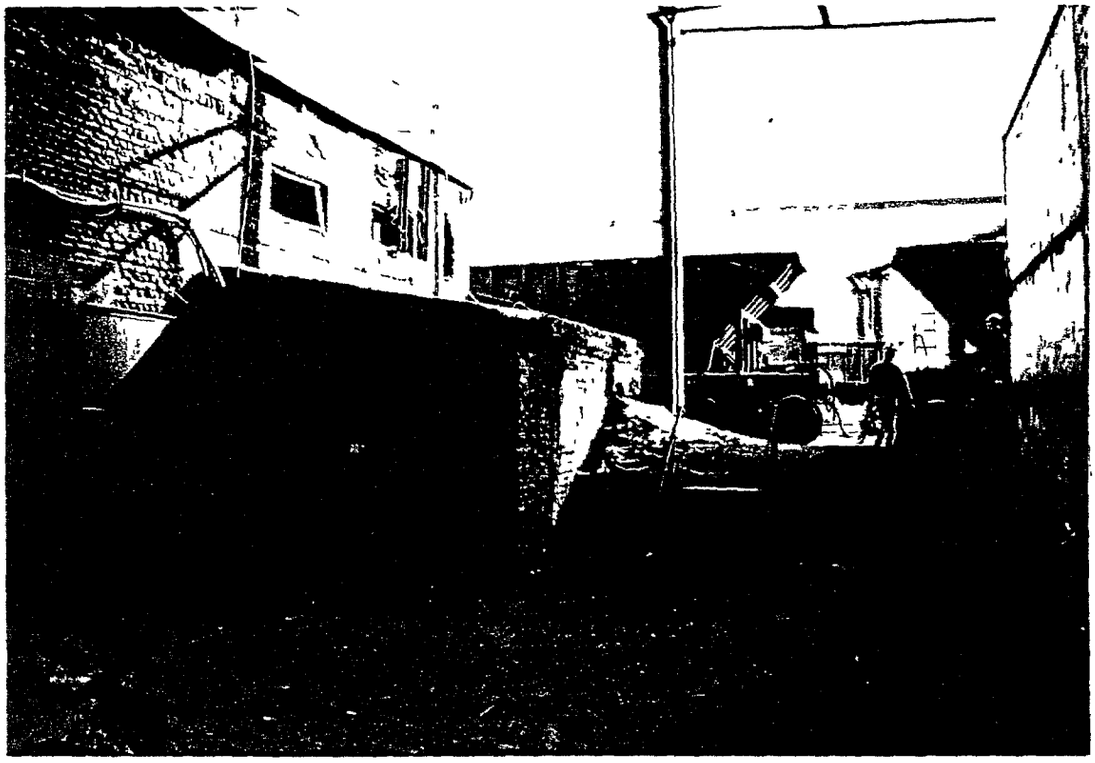


Figure 3B. Rail cars transporting coke to agglomeration stage.

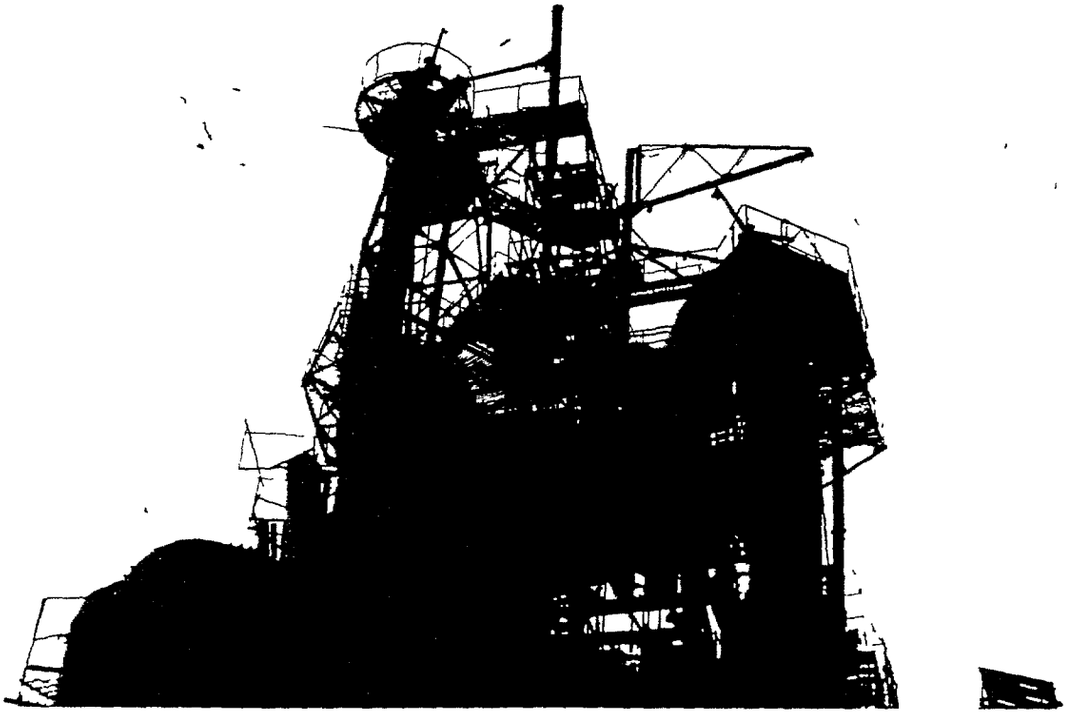


Figure 4. Blast furnace #1

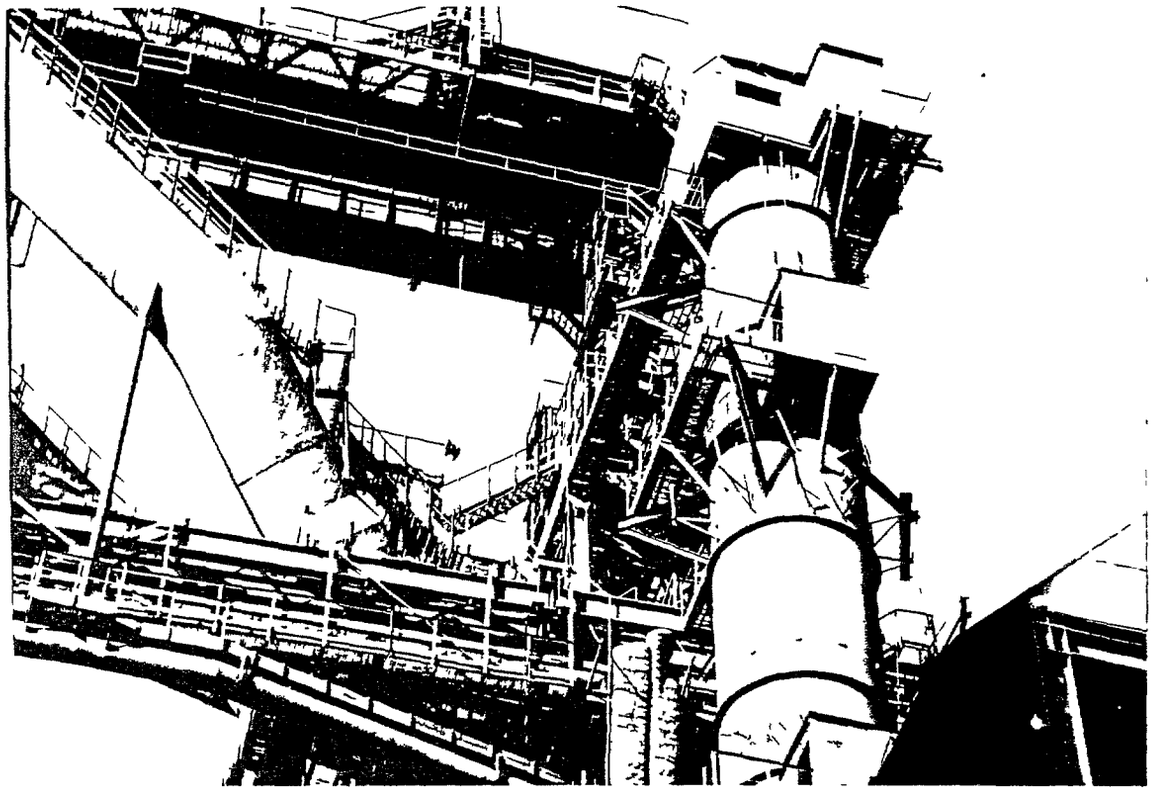


Figure 5. Blast Furnace #3 with nitrogen blast.

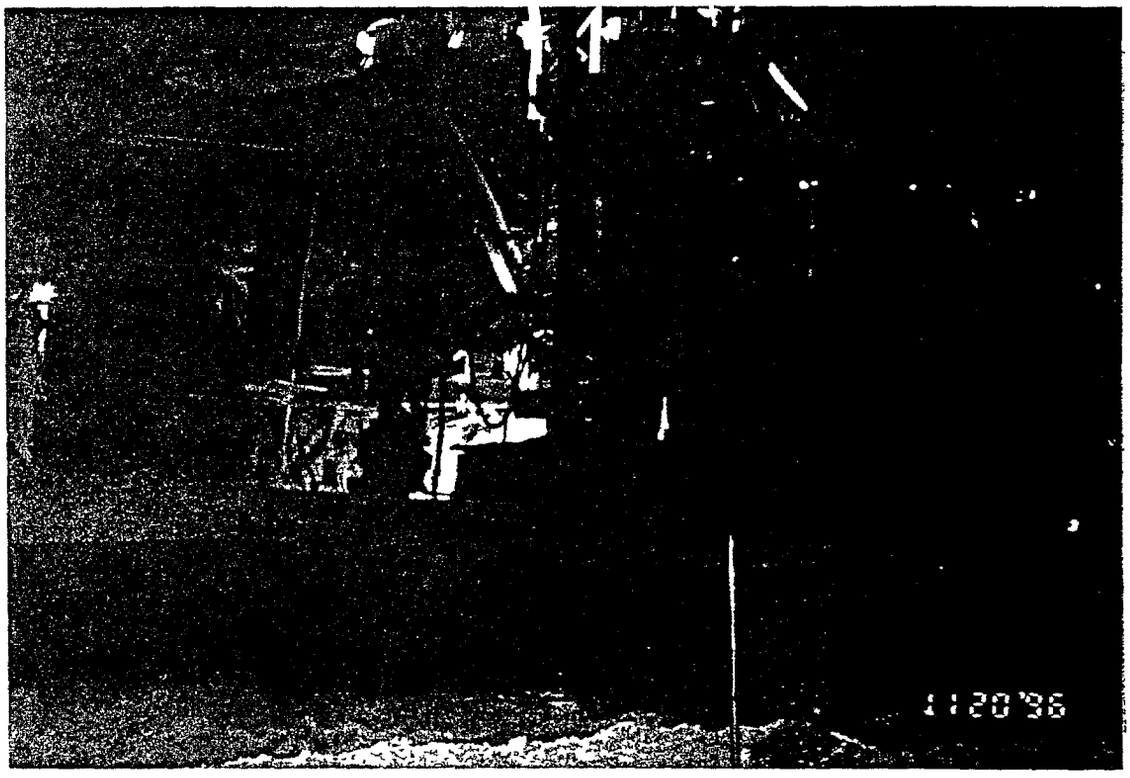


Figure 6 Photograph slowing lower operating deck of Blast Furnace #3.

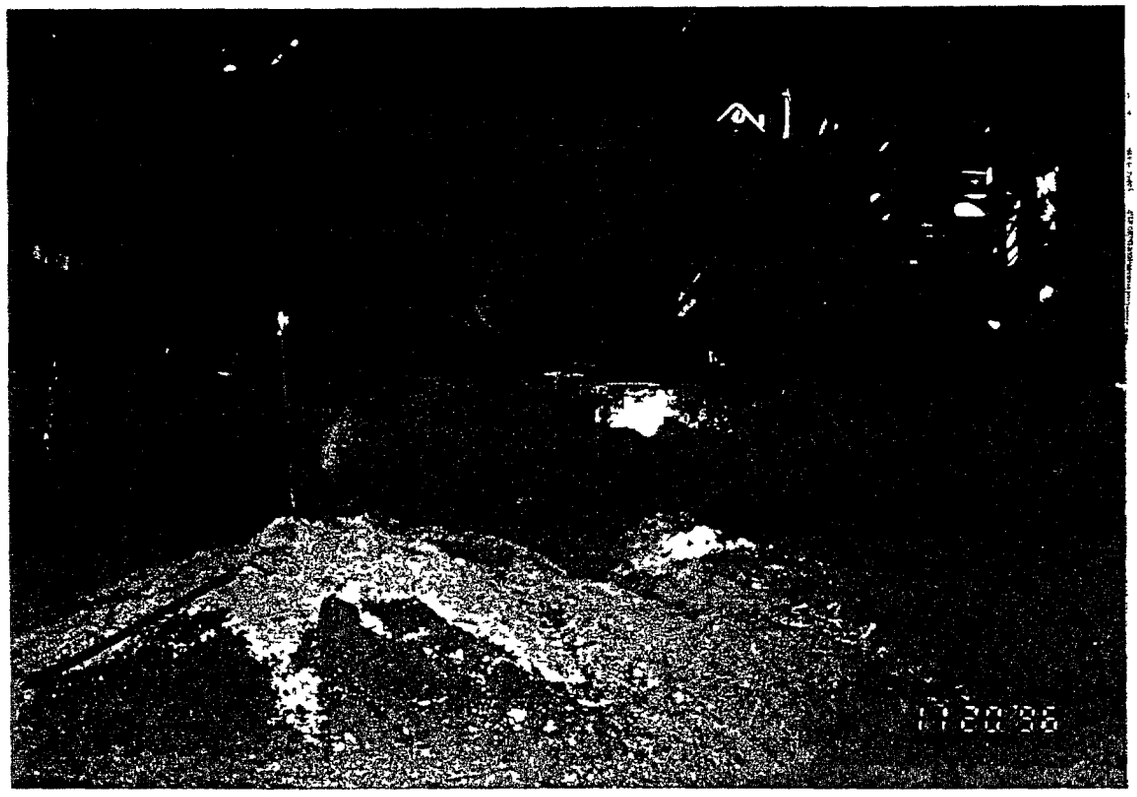
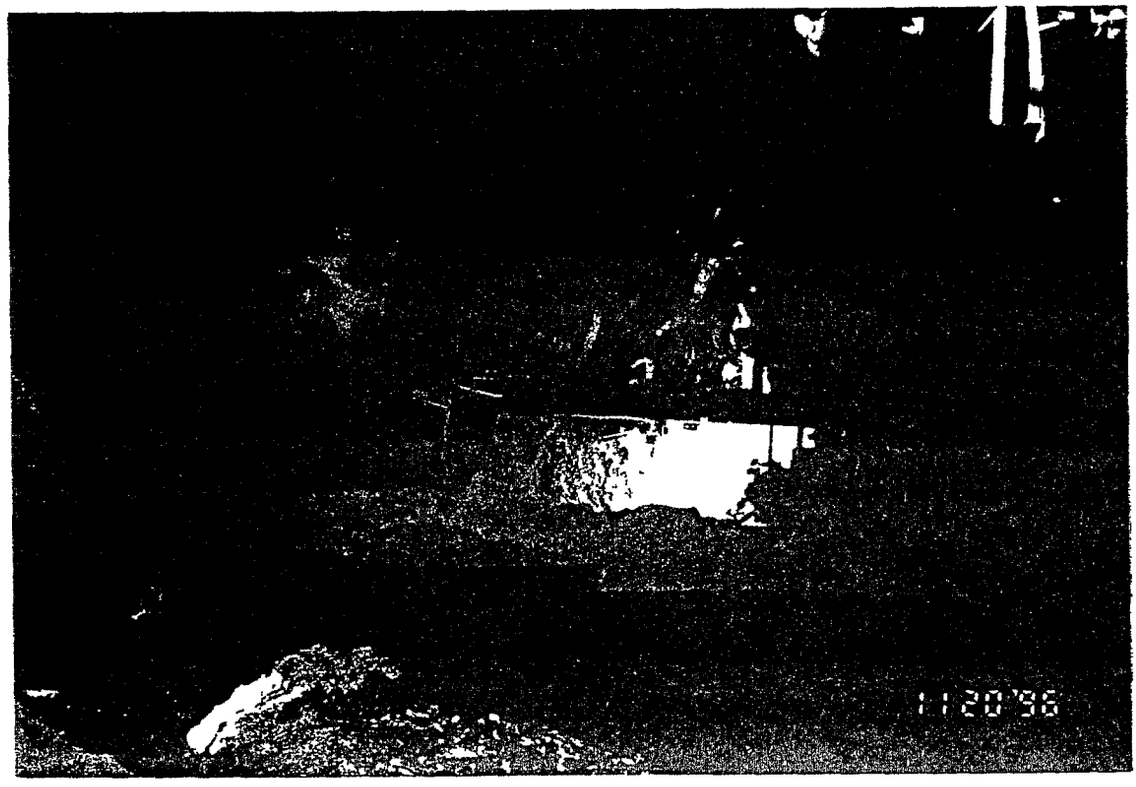


Figure 7. Photograph of slag tap at Blast Furnace #3.



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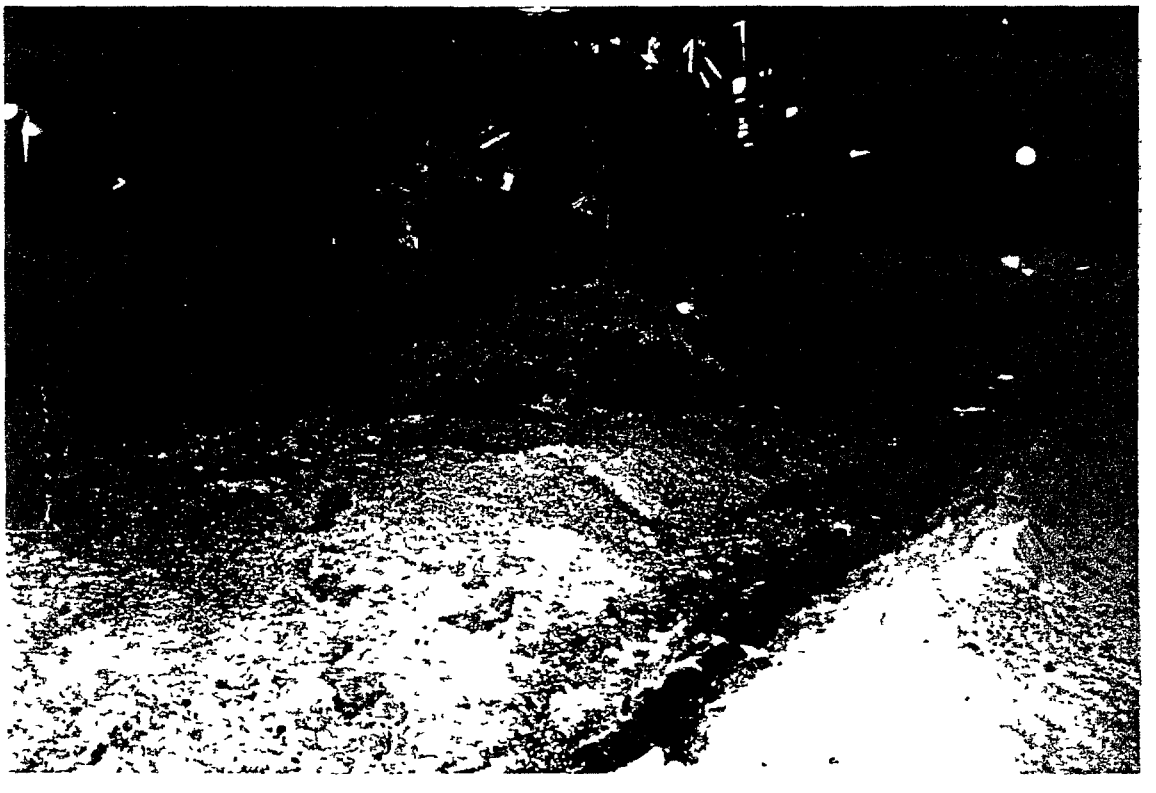

Figure 9. Shows Slag tap from Blast Furnace #3 in normal operation.

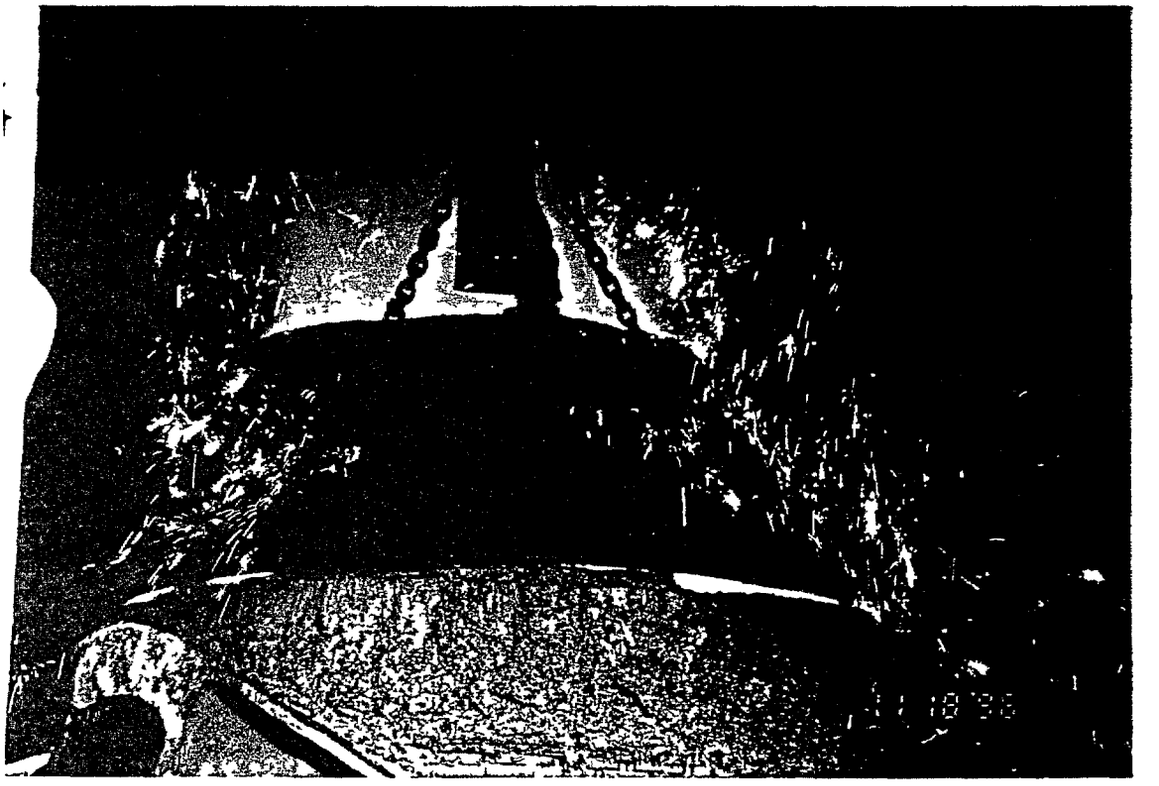

Figure 10. Photograph of Contaminated furnace gas being aspirated to the desulfurization stage.

Figure 11. Flue gas cleaning operation in desulfurization.

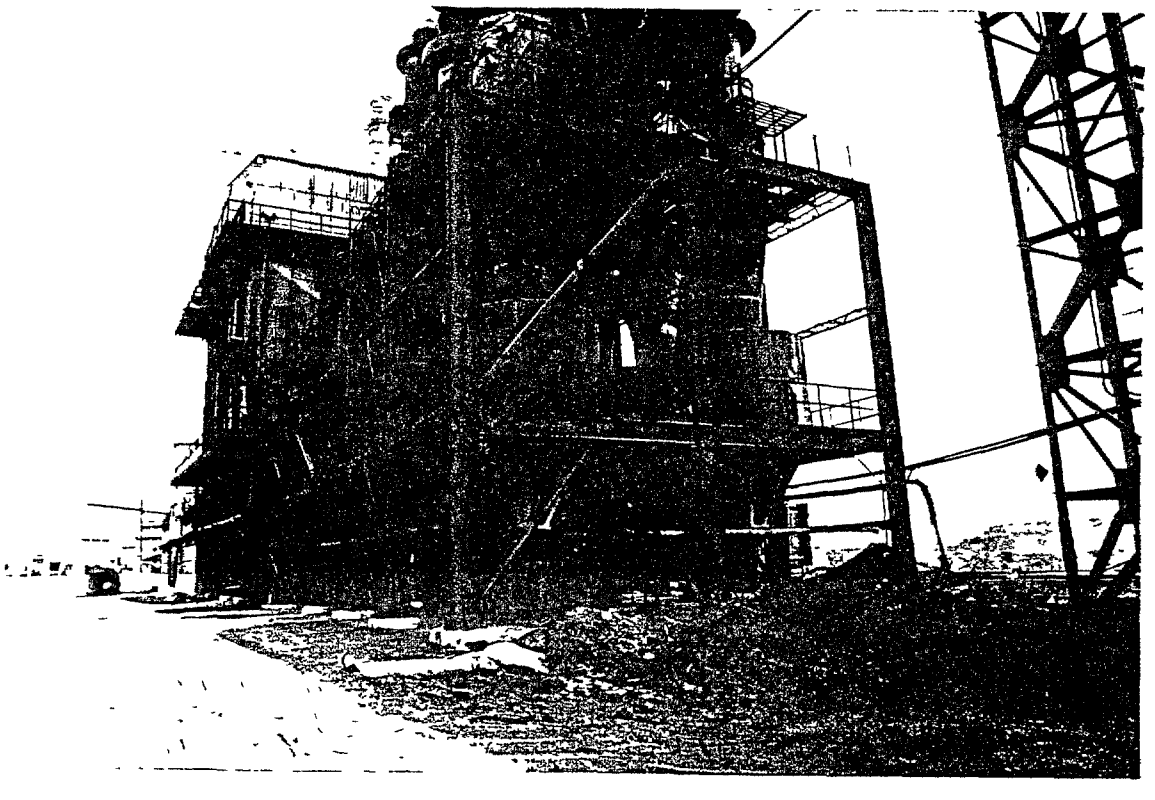

Figure 12. Shows current multi clone system used in the desulfurization stage.

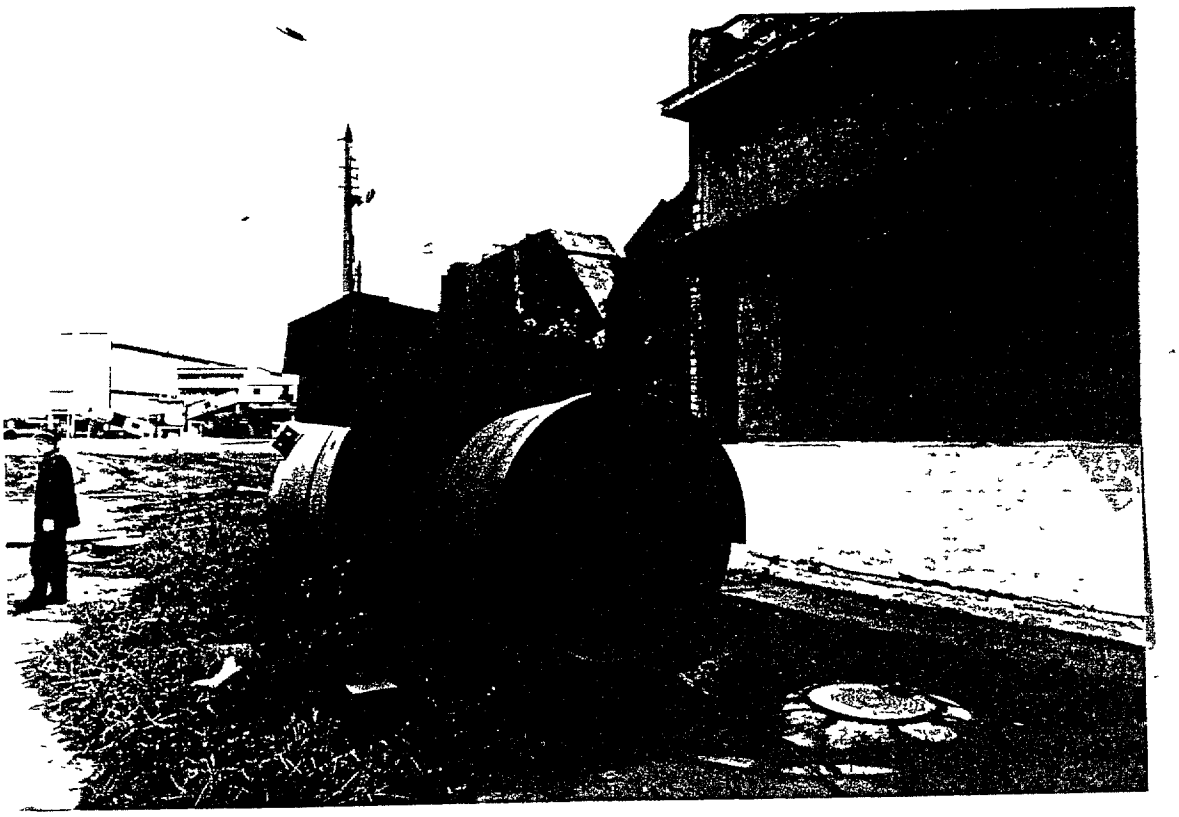

Figure 13 New cyclone units sitting idle.

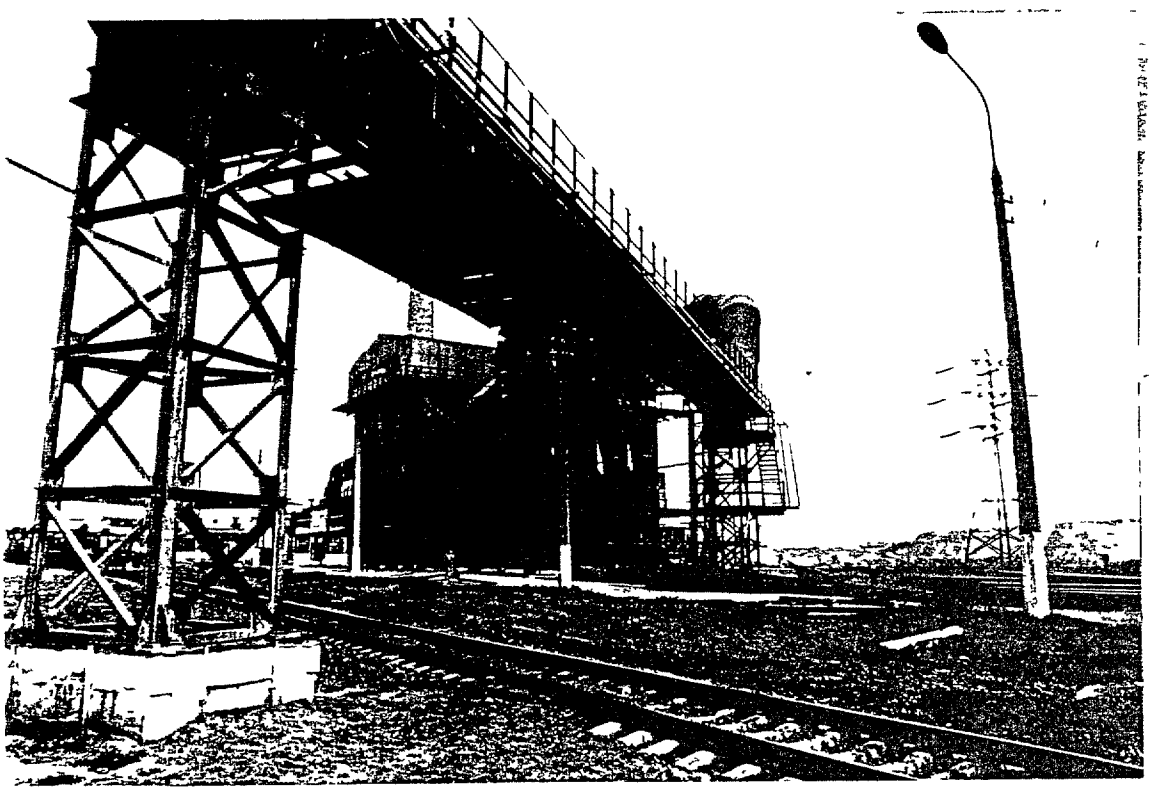

Figure 14. Another view of air cleaning operations during desulfurization .

Figure 15 Desulfurization accident observed during the audit.

Figure 16. Shows top of mixer where pig iron is charged and significant fumes and dust emissions occur.

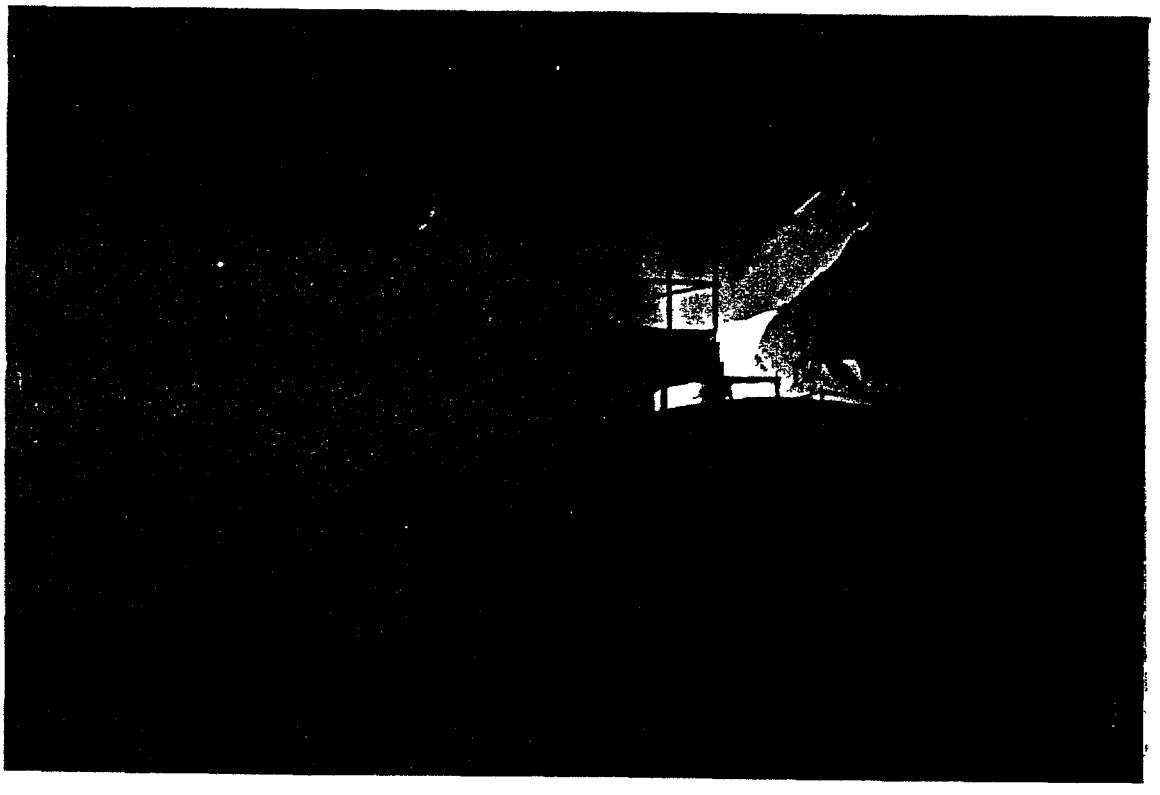

Figure 17. Photograph of mixer unloading operation.

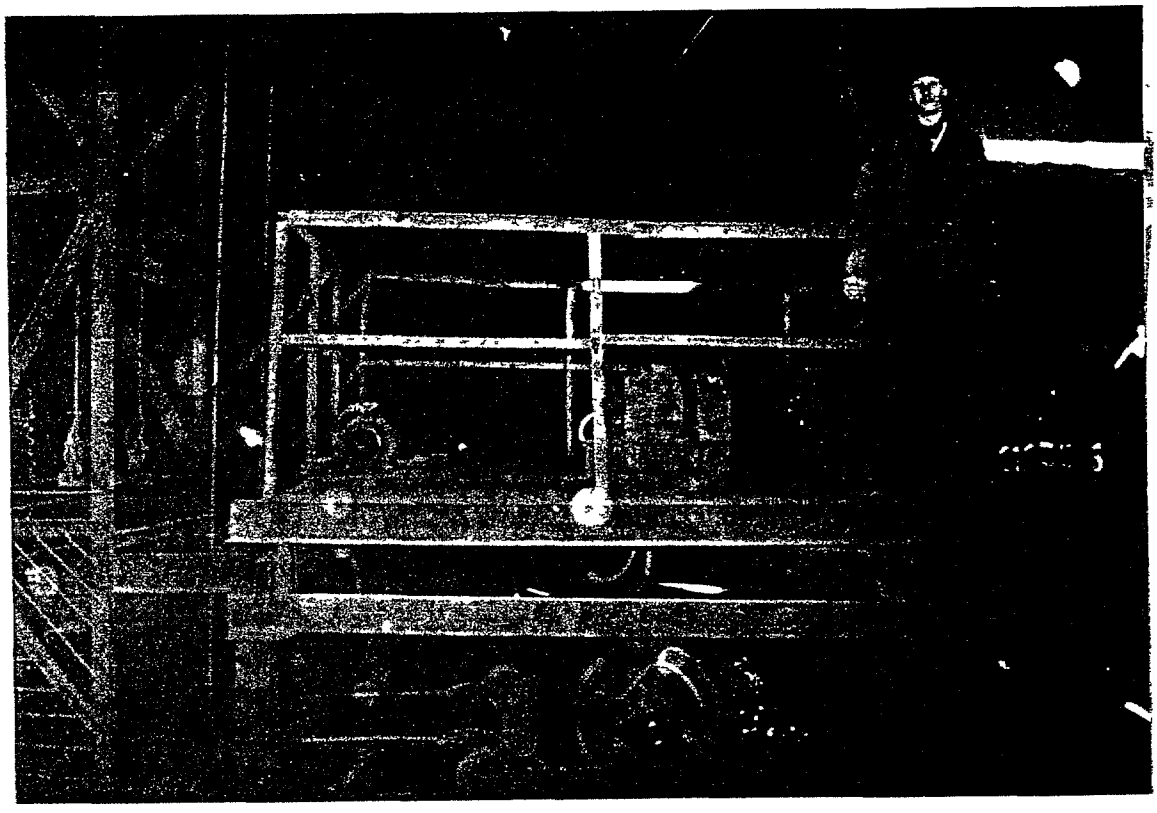

Figure 18. Shows worker standing on platform near one of the mixers during an unloading operation.

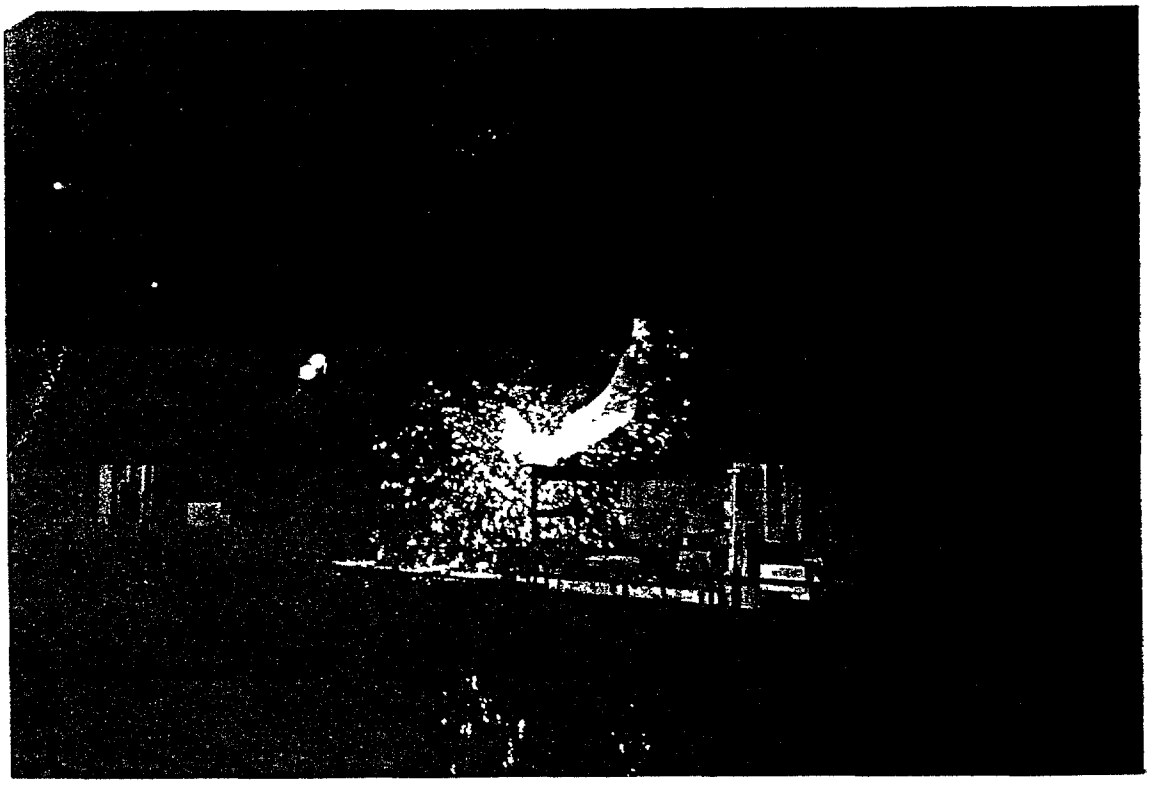

Figure 19. Shows a mixer accident observed during the audit.

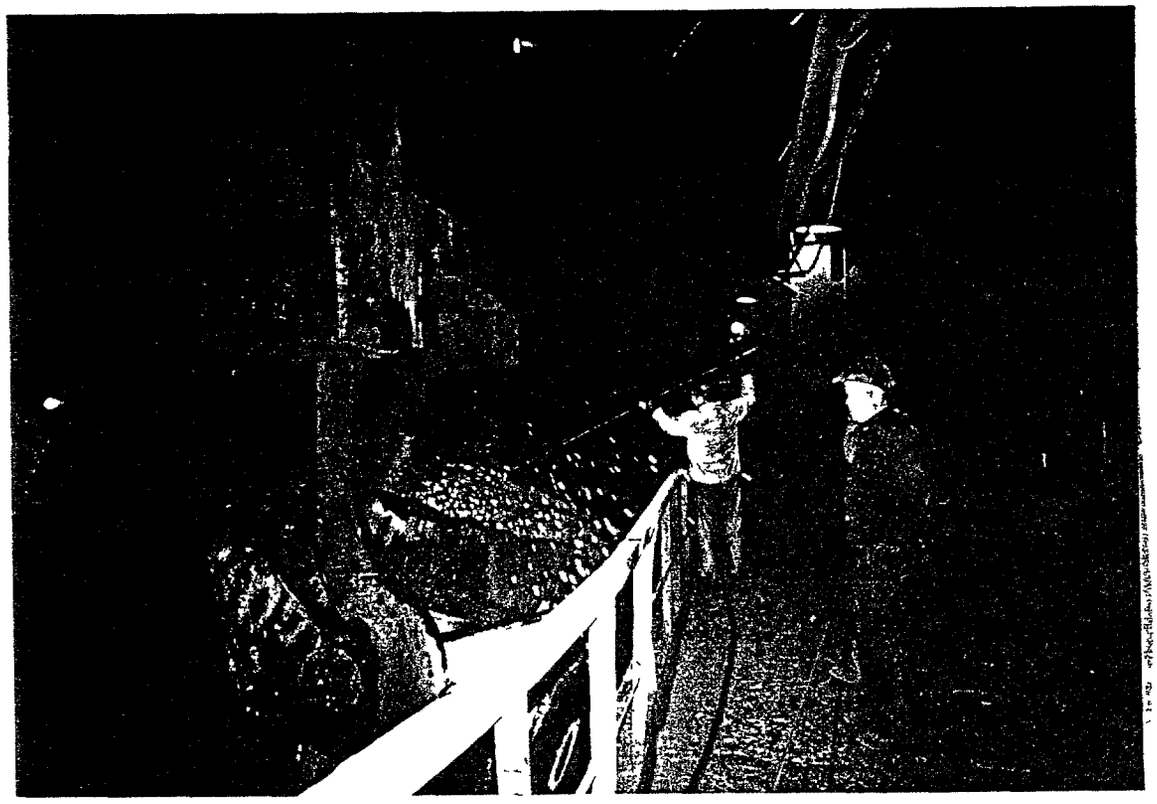

Figure 20. Photograph of fracturing procedure - worker breaking iron crust aft er mixer discharge.

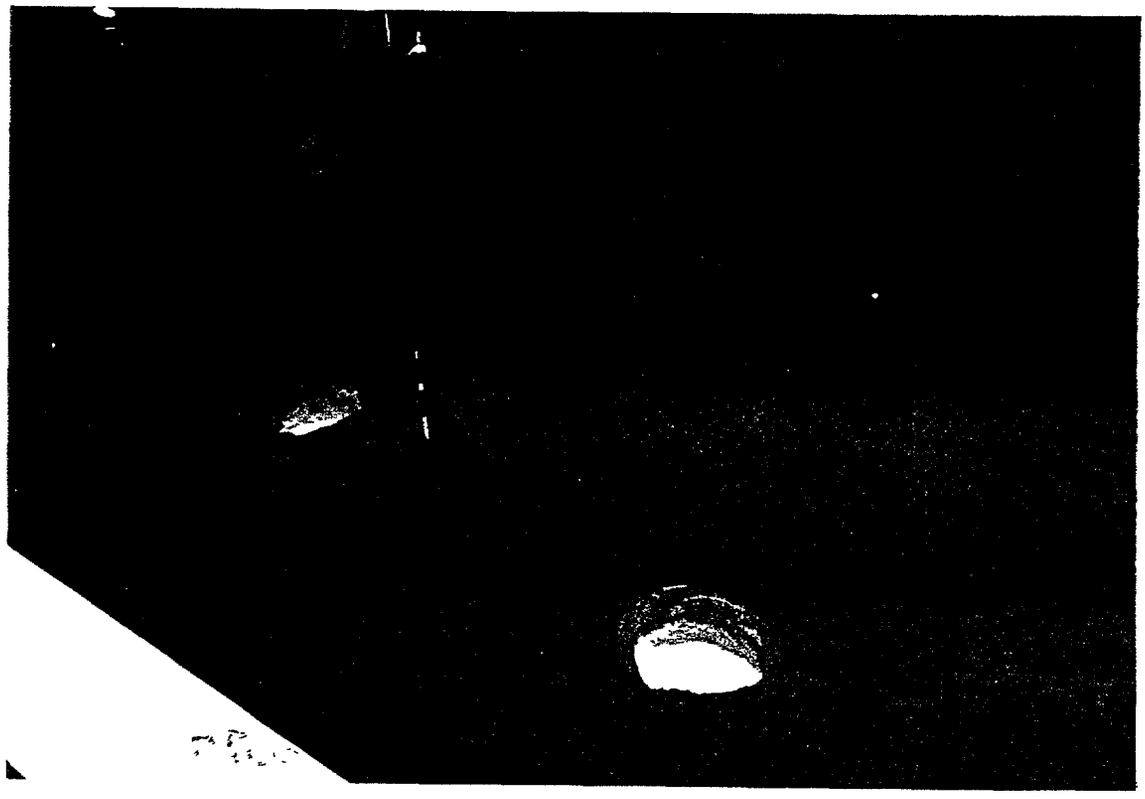

Figure 21. Photograph showing the molten mixed iron being moved to the converter.

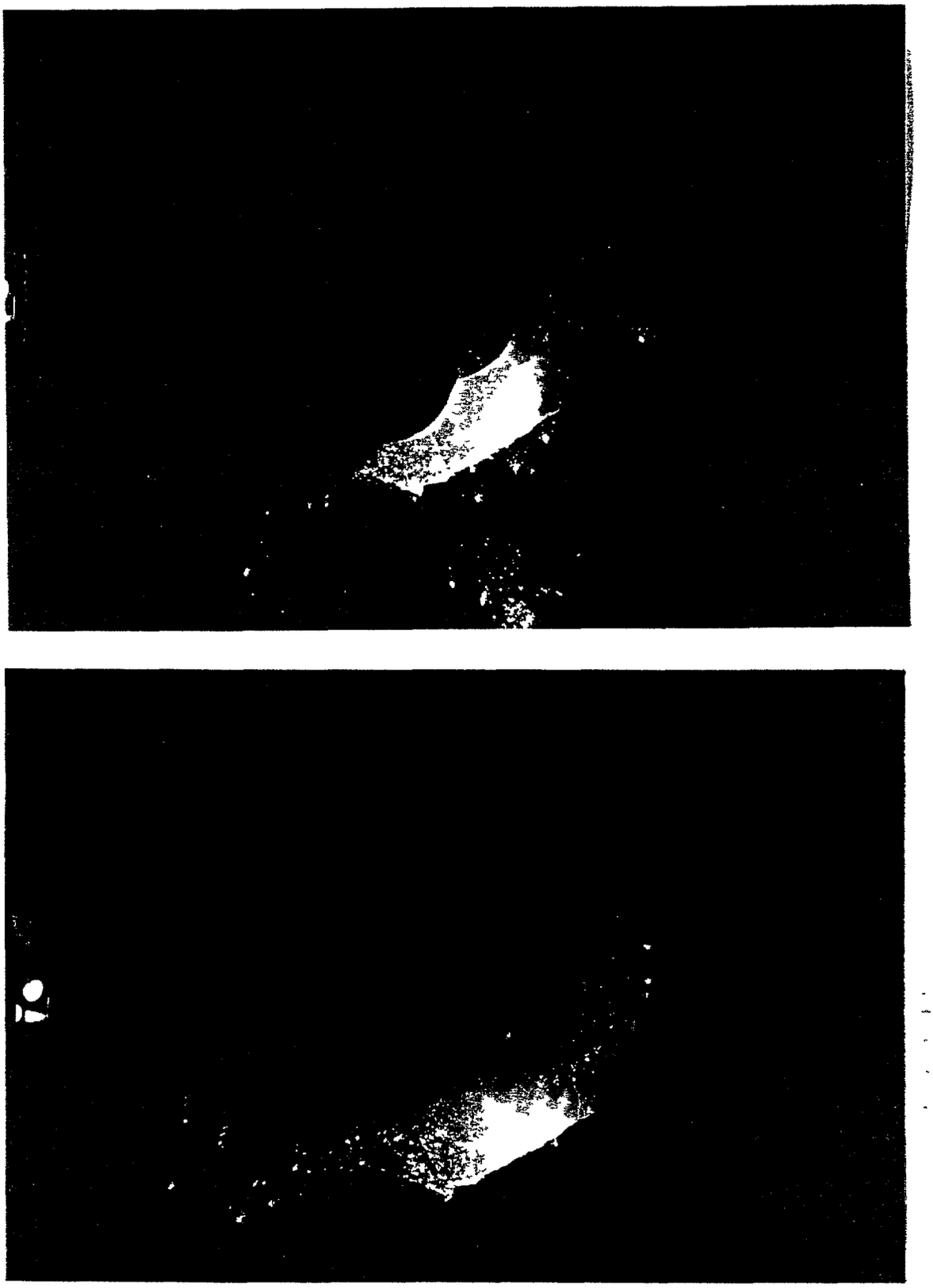

Figure 22. Photographs showing steel being unloaded from the converter.

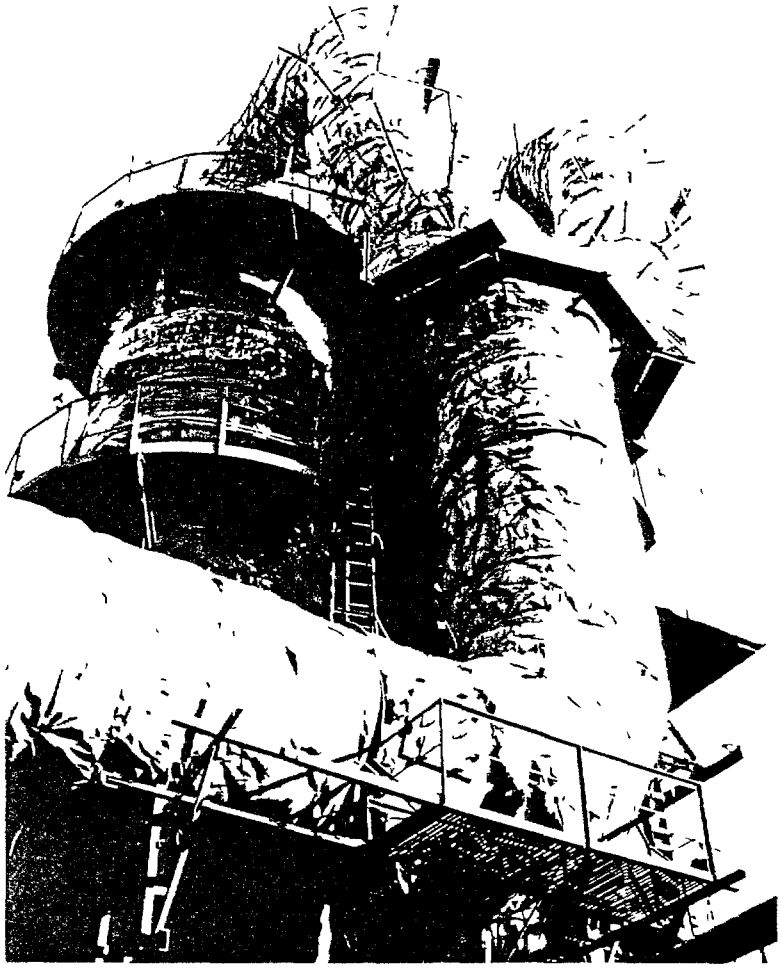

Figure 23. Photograph of wet scrubbers on sintering operation.

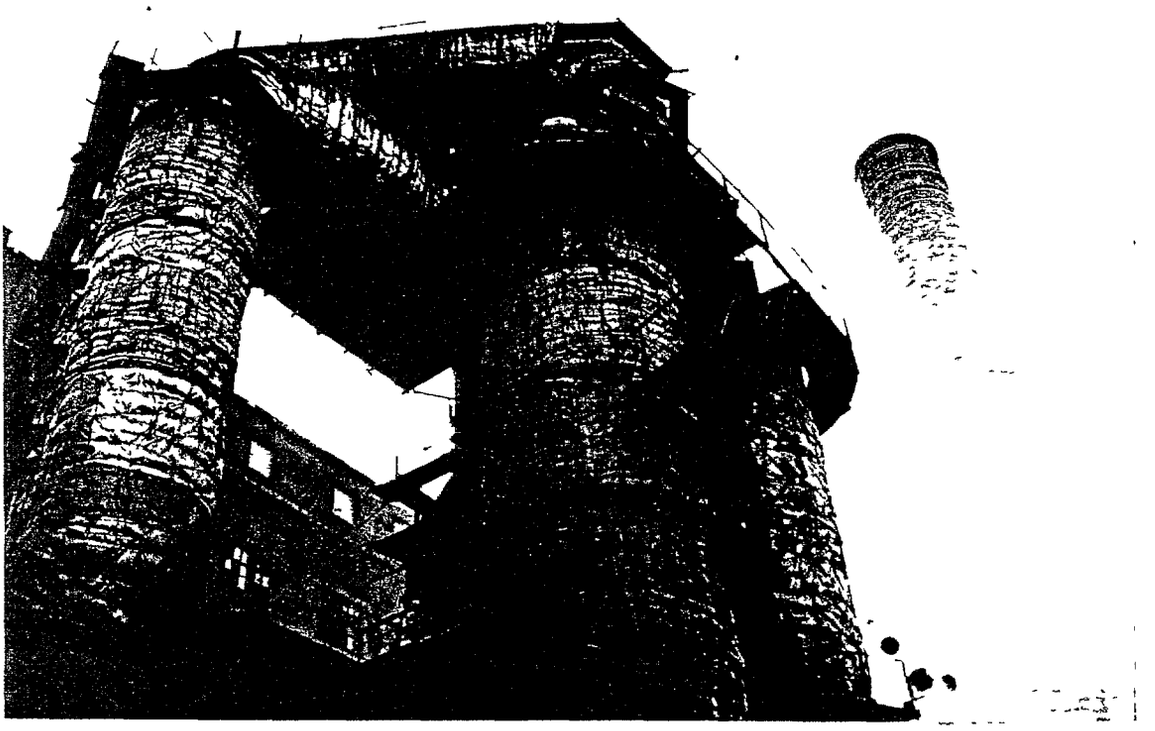

Figure 24. Shows agglomerate wet scrubbers.

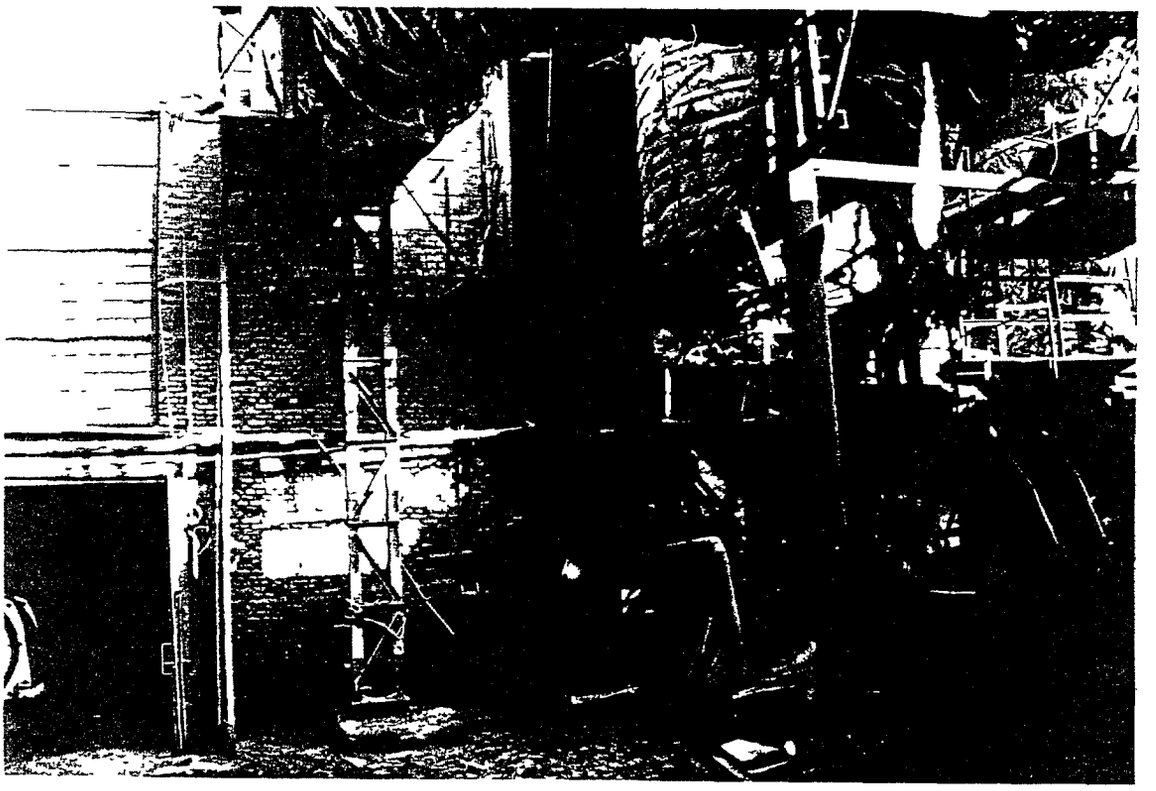

Figure 25 Photograph of wet scrubbers - grade level, for agglomeration.

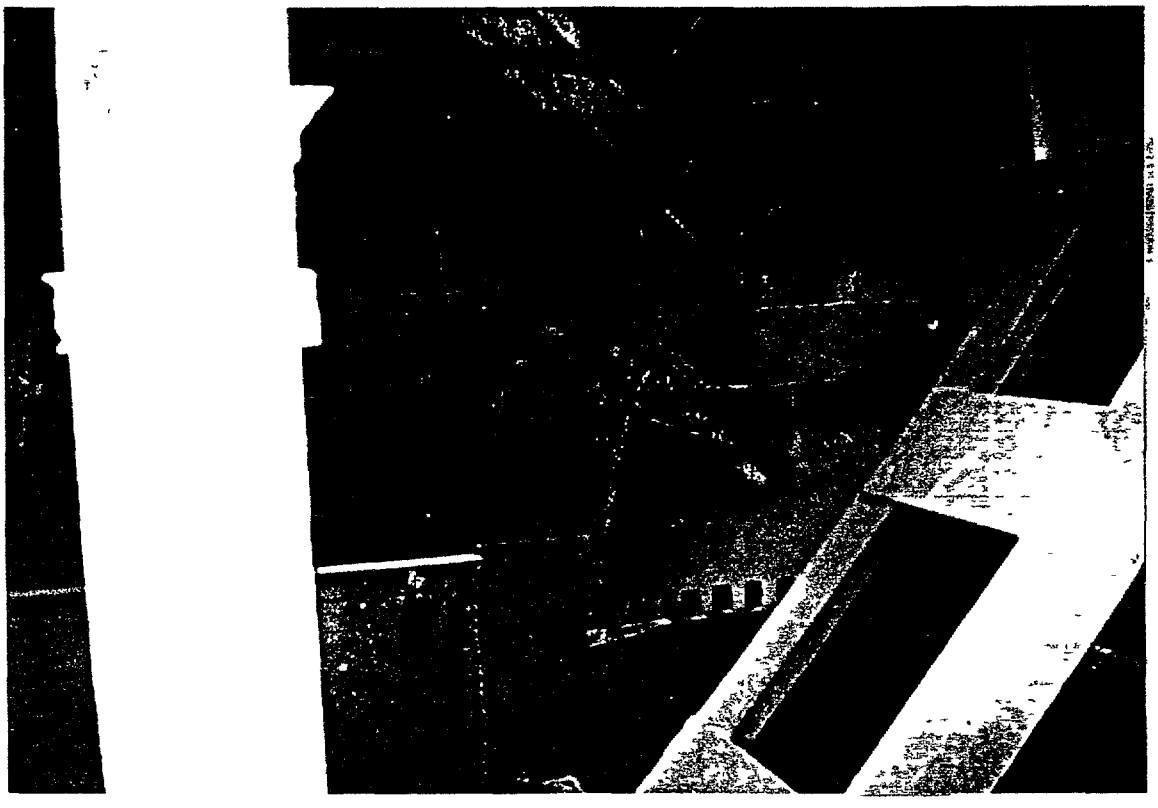

Figure 26. Shows agglomeration wet scrubber discharge .

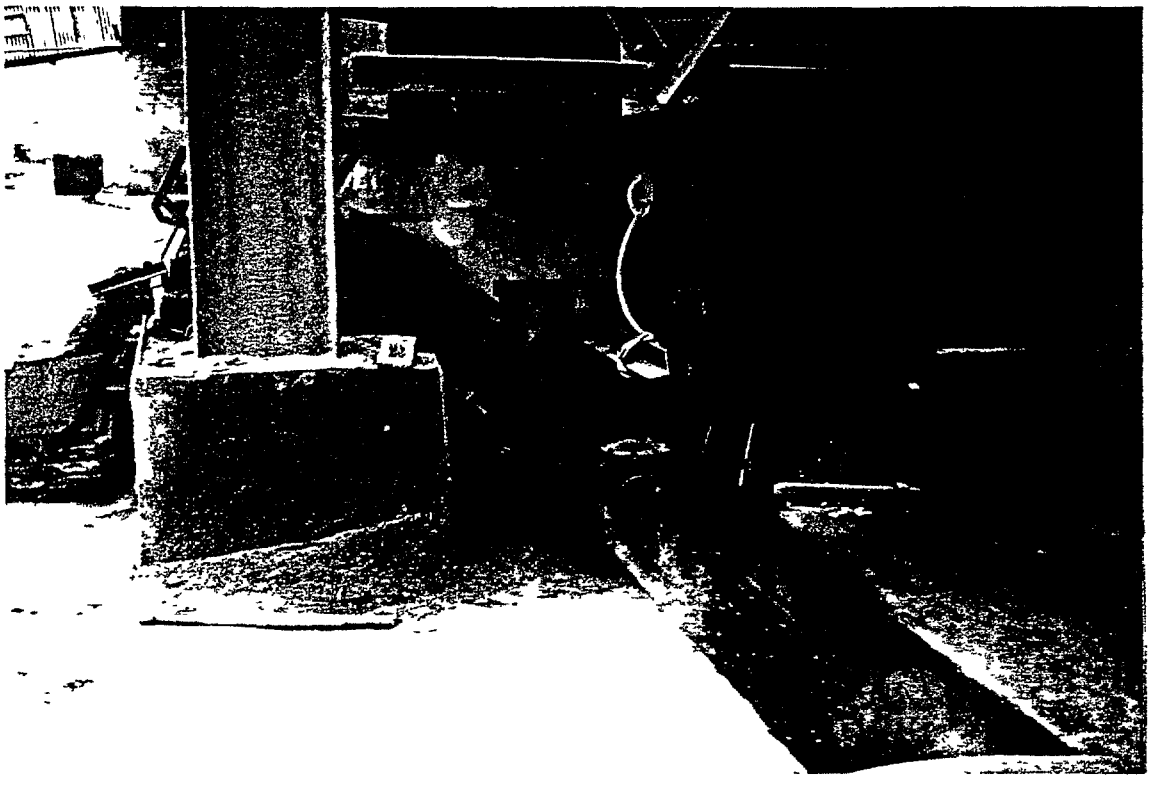

Figure 27. Collection of wet scrubber discharges.

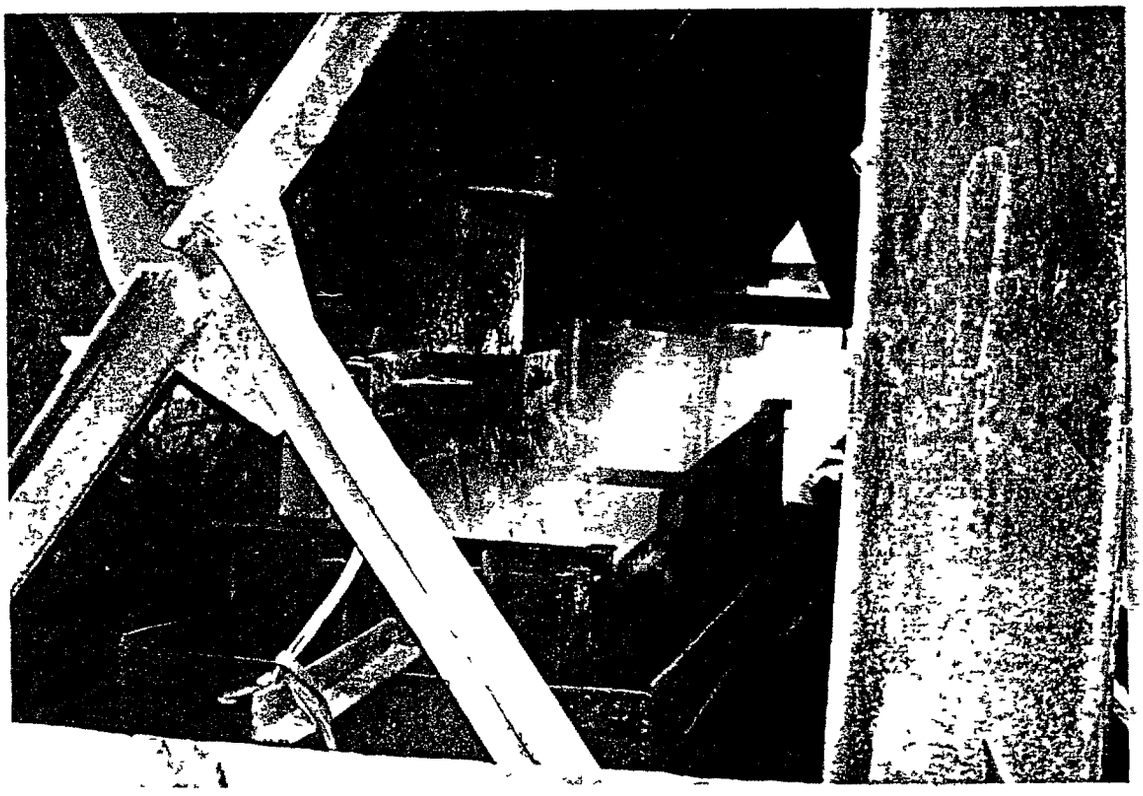

Figure 28. Discharges from agglomeration unit wet scrubbers.

Figure 29. Scrubber wet sludge from agglomeration.

Figure 30. Photograph of wet scrubbers at Blast Furnace # 1 (no nitrogen).

APPENDIX A
RECOMMENDED POLLUTION PREVENTION PILOT DEMONSTRATION PROJECT

Background Description for Project

Azov Steel has a mixer department where they sinter pig iron. There is an opportunity to produce a high purity product, with an additional benefit to increased iron making yields. A single mixer at Azov Steel is 2500 tons in capacity (there are two such units of equal capacity). It is estimated that for every ton of pig iron charged to the mixer, approximately 500 grams of airborne dust is generated. This is a semi-continuous operation in which a total of 5000 tons of pig iron is charged and withdrawn in a 24-hour operation to each mixer operation. This means that approximately 2.75 tons of particulate matter is released to the atmosphere. This translates to an airborne concentration of approximately 700 milligrams per cubic meter (mg/m^3), whereas current allowable discharge levels are 100 mg/m^3.

The composition of the dust has been analyzed by the *Institute of Technical Ecology* (Donetsk), showing that the carbon or graphite purity is on the average 15 weight percent (or in other words, about 1 ton of value added product exists in the airborne dust). The remainder of the dust composition is a mixture of iron oxider (Fe_2O_3, FeO) and iron particles It has been demonstrated that when the sintering process is conducted under inert conditions (in the presence of nitrogen), oxidation of the iron is eliminated. From a particular standpoint, 100% reduction in oxidation cannot be accomplished, however, in a twin operation at Azov Steel, it has been partially demonstrated that a nitrogen atmosphere will sufficiently reduce the iron oxide content to the point where the dust concentration for graphite will increase to about 45 weight percent. This has been shown by semi-commercial pilot demonstration in a joint program between the Institute of Technical Ecology and Azov Steel.

A local facility, the Mariupol Graphite Enterprise, has provided a letter of intent agreeing to purchase the graphite containing dust that is recovered. The letter of intent states that they are willing to pay 10 U S. dollars ($) per ton of dust with a composition of 15% graphite.

At 45% graphite content, Mariupol has agreed to pay $60 per ton and will take 100% of the recovered material. From both mixer operations at Azov Steel, this will amount to 118,260 per year in revenues. It is important to note that this is a delivered cost (i.e., includes transportation, which is not the case at the Donetsk Iron and Steel Works).

The enterprise (Azov Steel) initiated a project approximately 1.5 years ago to capture the dust. Limited resources and changes in priorities diverted their attention away from this problem. The basic dust collecting hardware has already been installed on both mixer units. The particle capture designs at the two mixer stations differ slightly, but in general they are comparable The units however do

not operate properly and do not have a dedicated nitrogen injection system.

A hood has been installed over the discharge of the mixer, which if 100% effective, will capture 300 grams of dust for every ton of sintered product that is dumped. An existing 200 kWt blower transports the dust laden air to a battery of multiclones (32 cyclones housed in a unit). The multiclone housing has a single dipleg which transfers the collected dust to an existing hopper. The clean gas is then discharged to an existing stack.

There are three problems with the existing set-ups. First, neither mixer has a dedicated nitrogen injection system. The nitrogen is viewed important from the standpoint of dust suppression, but as explained later, there is evidence to support that this technique will enhance steel production yields. Secondly, nearly 200 grams of dust per ton of pig iron charge is lost during the charging of the mixer. A hood with connecting ductwork should be tied into the existing capturing system. A third problem is that the current design has improperly installed the blowers on both mixers.

In the current design configuration, the blowers are installed on the leeward side of the multi clones. This is a poor design for one major reason. The blowers vanes (centrifugal machines) are exposed to large, hot particles which subject the machine to excessive mechanical wear, erosion and large vibrations. Also, the current design does not include automatic dampers; thus the unit is subject to uneven air flows and additional vibrational forces. This has resulted in the burning out of one motor on one of the installations, and has created an unacceptable service factor (high maintenance frequency) on the blower for the second unit. We have proposed that the plant repipe the systems so that the blowers are on the discharge side of the multiclone battery to overcome this problem.

Proposed Pollution Demonstration

The EPT project is currently conducting an audit at this facility and is assisting in a short series of tests to confirm that nitrogen injection will increase the graphite levels in recoverable dust. One test already conducted showed an additional advantage for the N_2 injection case. This advantage was an increase in the iron yield (presumably because the iron is not being oxidized). Very preliminary data suggests that the iron yield from a single mixer operation could be increased on the order of 1000 tons per year.

What we are proposing in the following.

- Conduct two (2) weeks of tests to confirm that the N_2 injection technique increases the graphite content in the dust and enhances the steel quality.

- Take a sample of high graphite content dust to Mariupol Graphite Manufacturing Co. and confirm the price of payment and negotiate a three year contract for the off-take of this material.

- After the above pilot demonstration confirms the benefits that we have identified, assist Azov Steel in the following engineering tasks:

1 Design and install an overhead hood to collect dust at the inlet section of one mixer station.

2. Repipe ductwork on both mixer stations so that blowers are protected from excessive vibration and mechanical damage from particles. This will include repiping ductwork so that the blowers intake is on the discharge side of the multiclone batteries. Also, automatic dampers should be installed on the ducts leading from the hood to the multiclone units, and from the suction side of each blower.

3. The motor for the burned out blower should be rewound and made operational

4. Fully automate the N_2 injection system on the one mixer unit that has this capacity, and install a new, fully automated N_2 injection system on the partially constructed mixer unit.

Economic Attractiveness

The entire engineering estimate for this work is $200,000. Azov Steel is agreeing to do a joint demonstration with USAID using their own capital to work on this.

The economic incentives for this project are as follows.

- Recovery of an estimated total dust from both mixers of 1807 tons per year (this assumes a 90% collection efficiency for the multi clone system). Assuming $60 per ton delivered to the Mariupol Graphite Plant, this generates a revenue of $108,432.

- Increase in iron tonnage yield of 2000 tons per year from both mixer operations. Currently, Azov is selling their steel at $350 per ton. Hence the total revenues associated with their value added recovery is $700,000.

Hence the total added value revenues derived from this demonstration are $808,432.

The payback period for this demonstration project as a joint demonstration for both parties on a $200,000 capital investment is 3 months. For USAID, a $70,000 investment results in a payback of 1 month.

In comparison to the Donetsk Iron and Steel Works, this project is nearly 3-4 times more attractive. Furthermore, the management of Azov Steel is much more cooperative in entering into a joint venture and is enabling USAID to participate in a strong cost sharing demonstration. Donetsk Iron Works is expressing concern that the installation costs are higher than originally estimated and are hesitant in signing a joint agreement with USAID. Further negotiations are planned with them.

APPENDIX B
PROCESS FLOW SHEETS FOR INTEGRATED STEEL MILL OPERATIONS

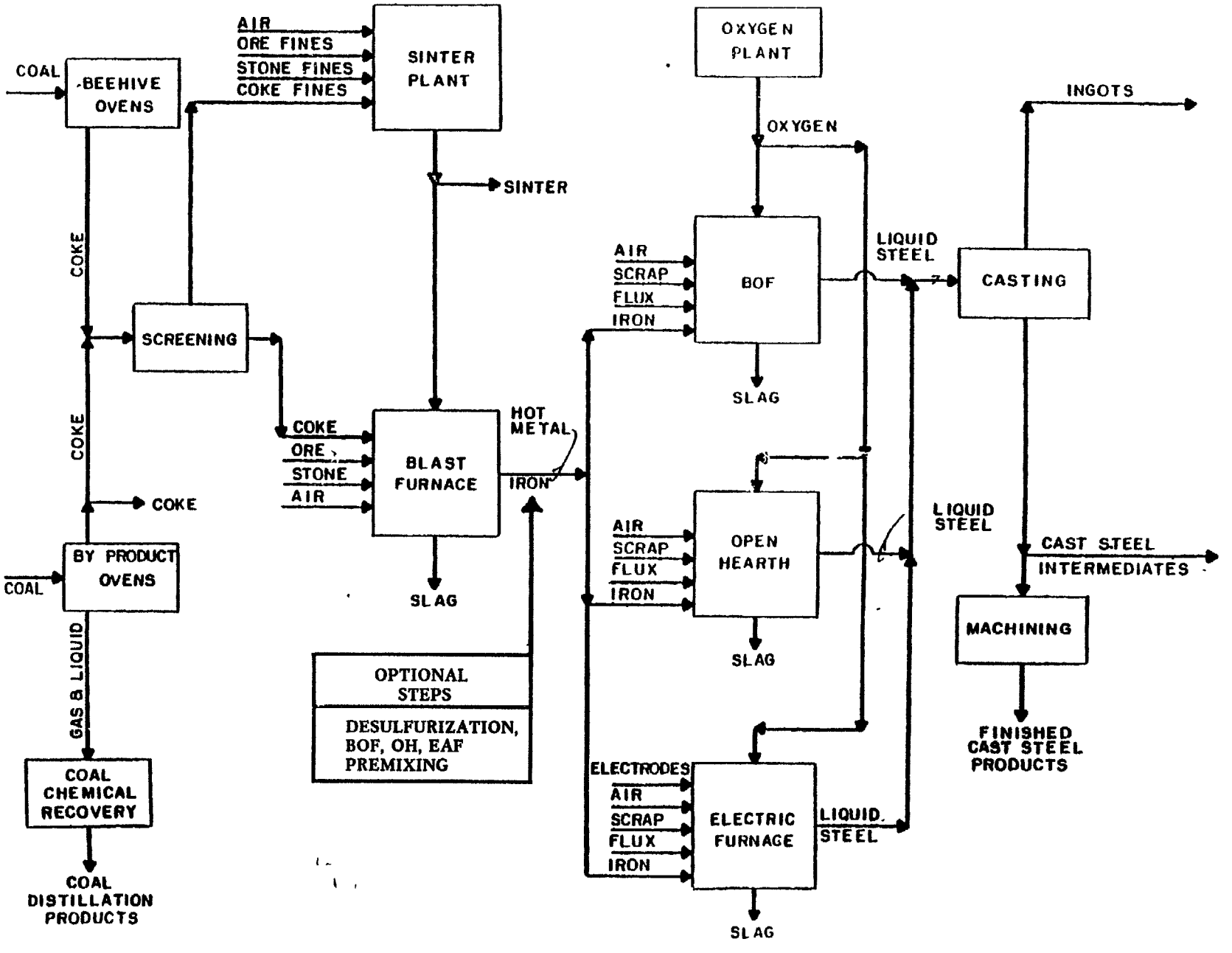

Figure B.1 Steel Product Manufacturing Process Diagram.

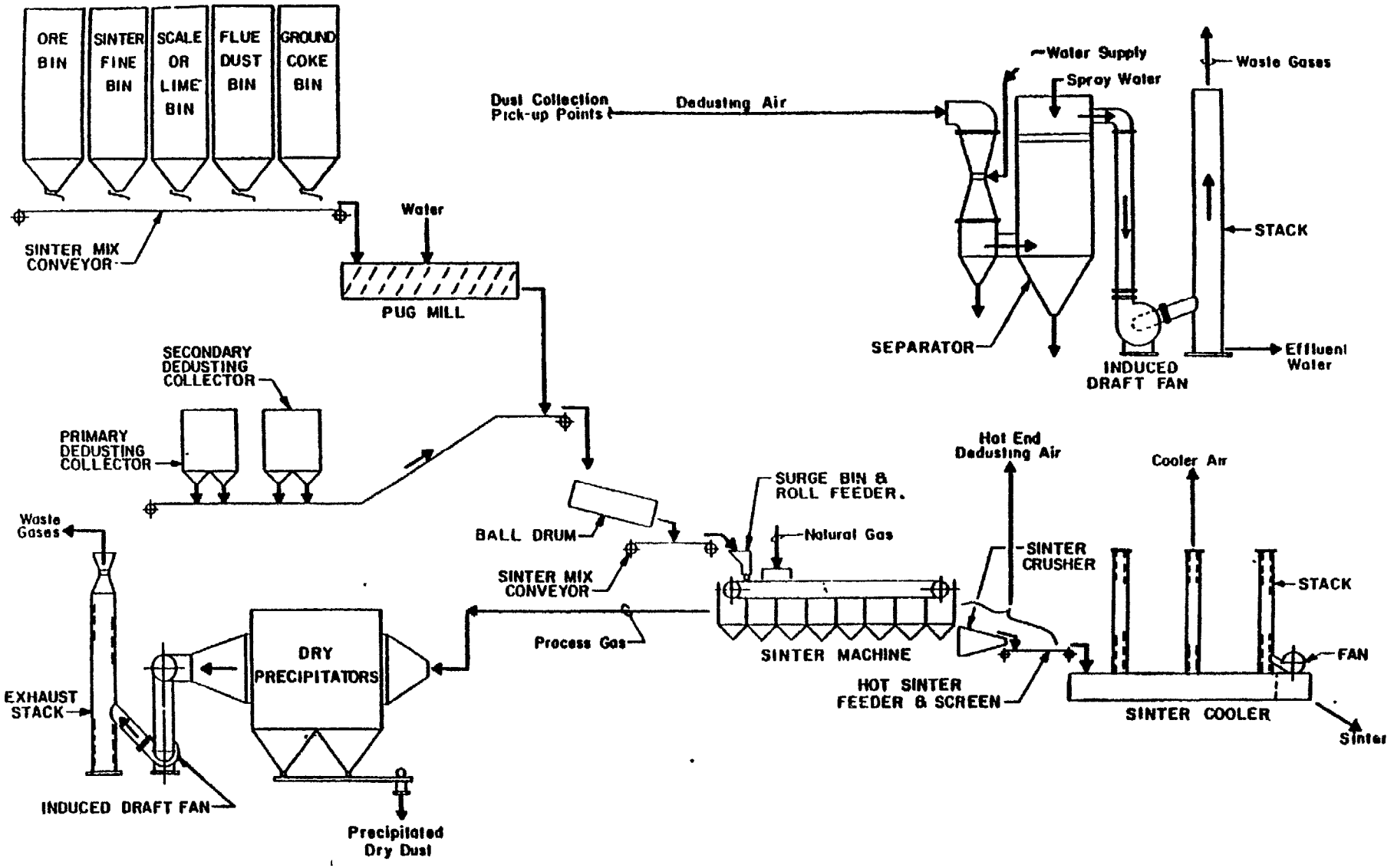

Figure B.2 Sintering Plant - Type I Wet Process Flow Diagram.

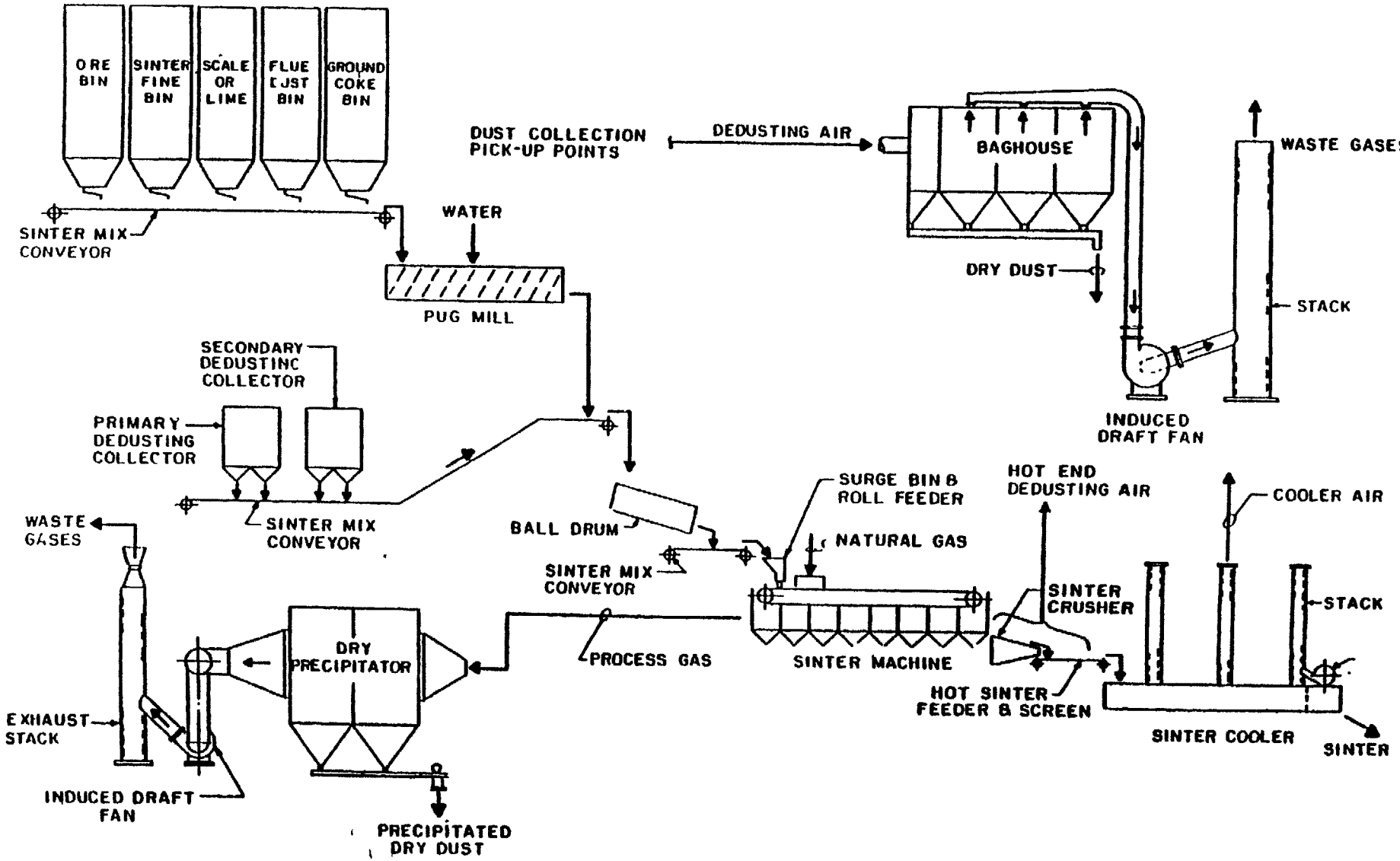

Figure B.3 Sintering Plant - Type II Dry Process Flow Diagram.

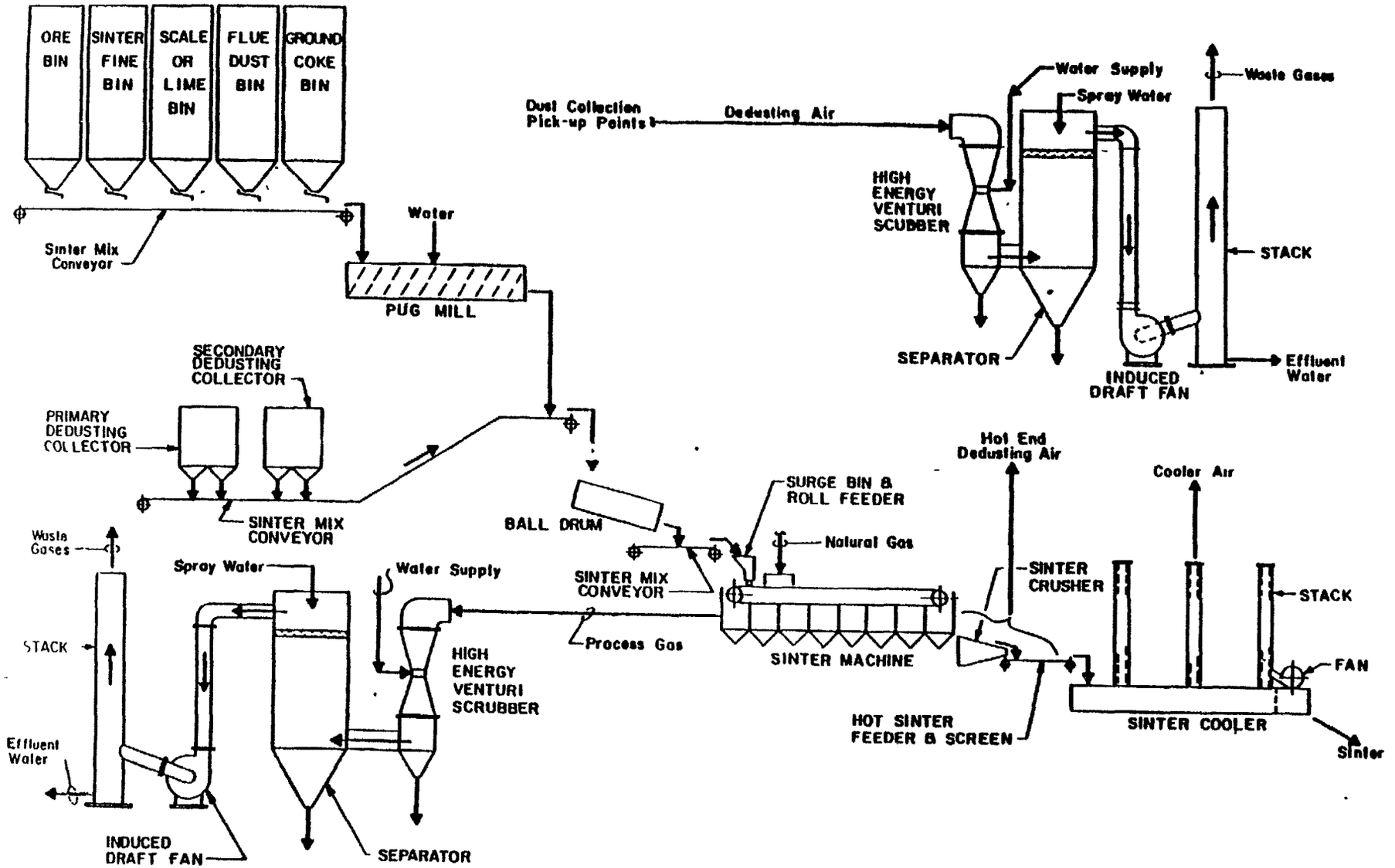

Figure B.4 Sintering Plant - Type III Wet Process Flow Diagram.

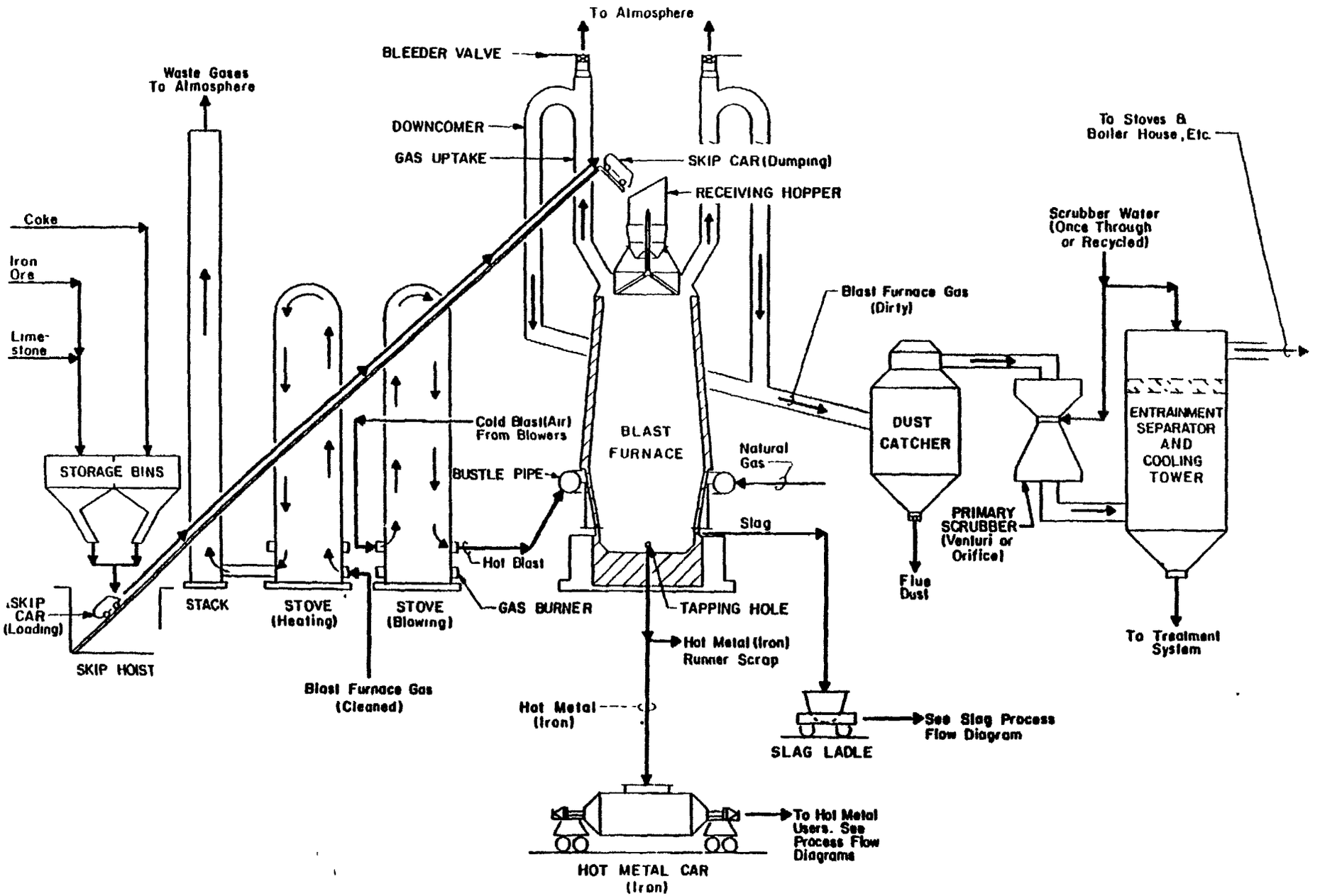

Figure B.5 Blast Furnace - Type I Primary Wet Scrubber Process Flow Diagram.

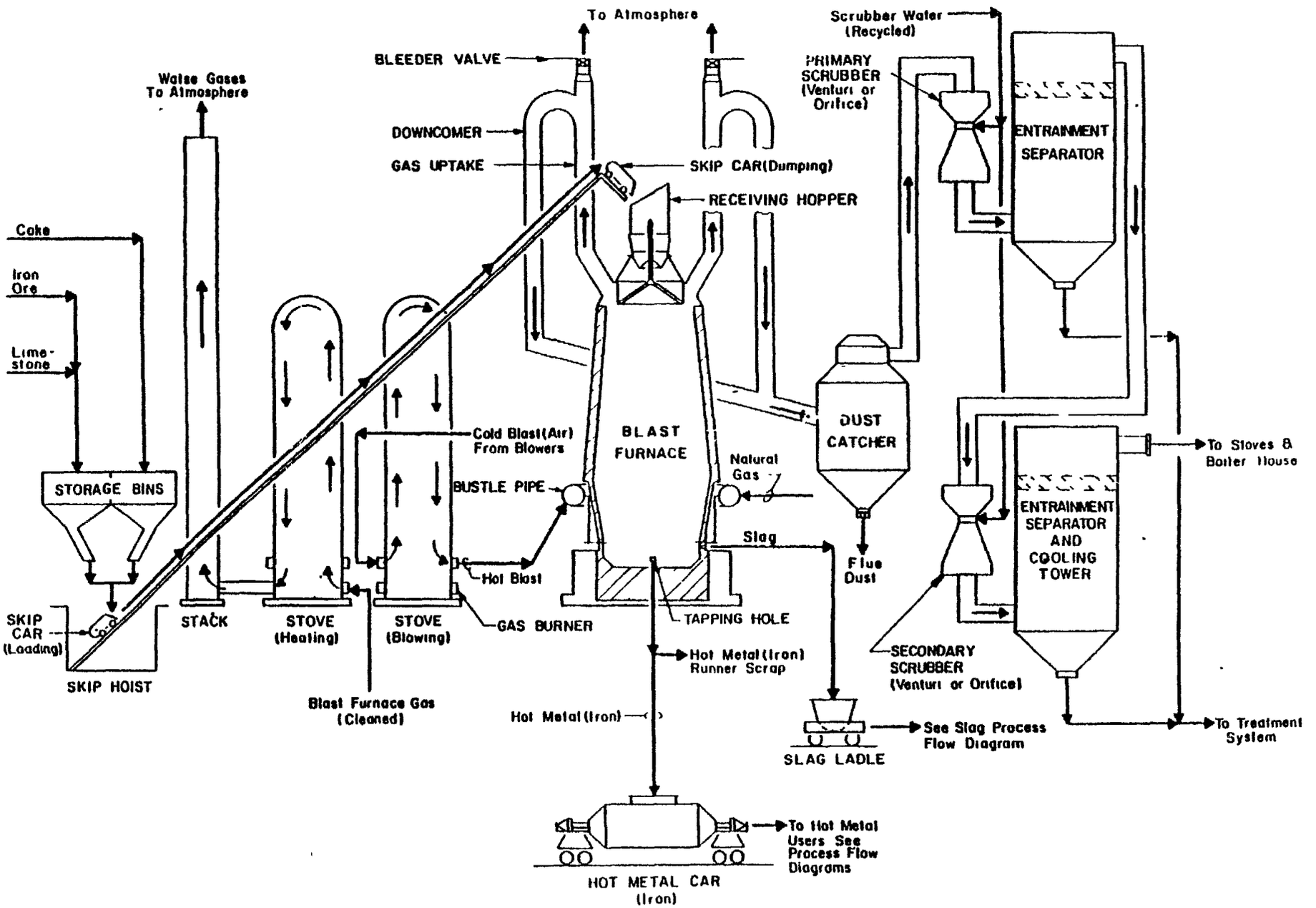

Figure B.6 Blast Furnace - Type II Primary & Secondary Wet Scrubber Process Flow Diagram.

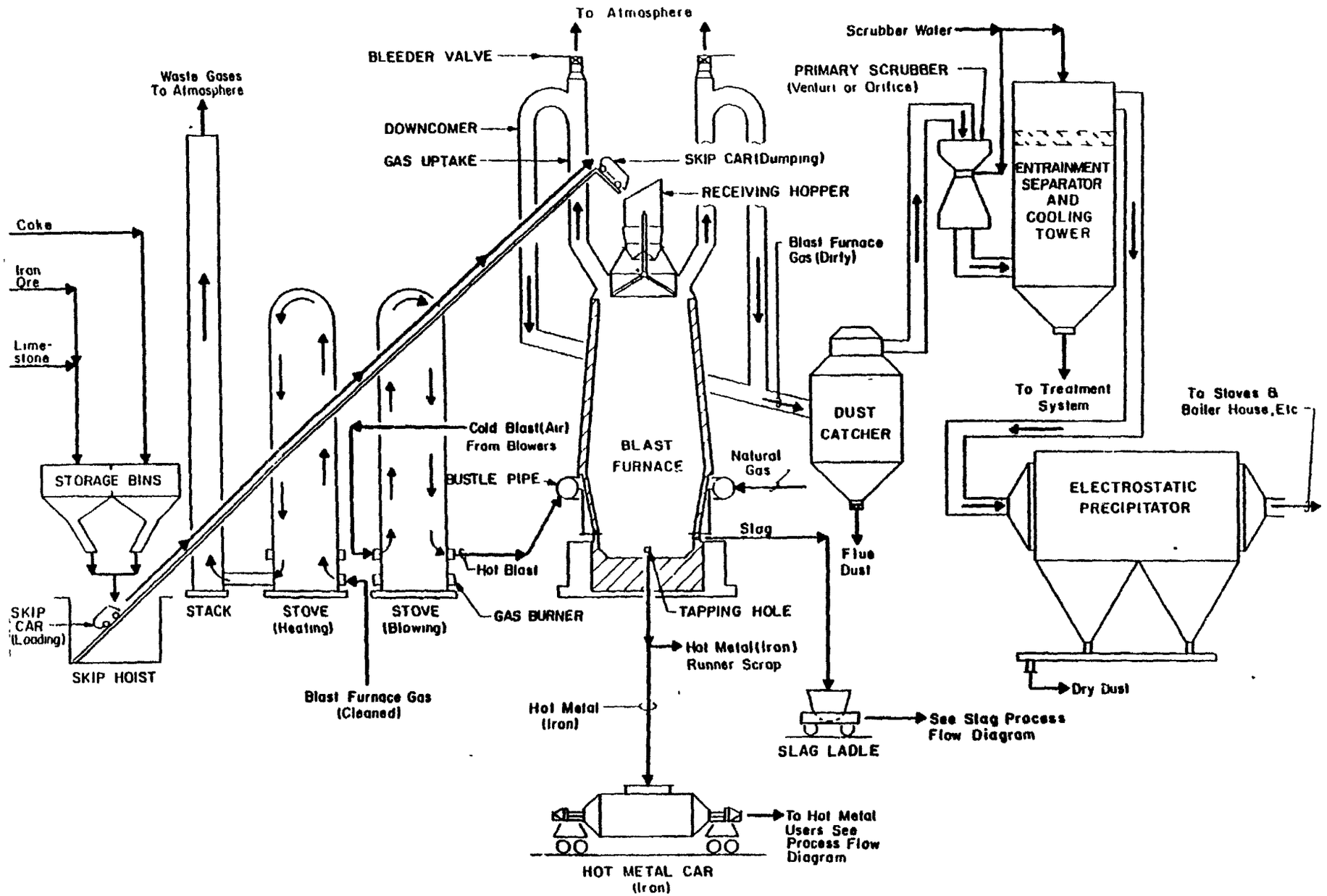

Figure B.7 Blast Furnace -Type III Primary Wet W/Dry Secondary Process Flow Diagram