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UKRAINE
Round 2 Environmental Audit:
Illich Iron & Steel Plant
in Mariupol

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For the New Independent States of the former Soviet Union

A USAID Project Consortium Led by CH2M HILL

Introduction and Executive Summary

This report summarizes the findings of an environmental site assessment (ESAs) conducted at the Illich Iron and Steel Plant in Mariupol, Ukraine The objective of this audit was two-fold. First, to provide instruction and guidance on approaches to conducting ESAs or environmental audits, and secondly to provide the cooperating enterprise a document which identifies pollution prevention opportunities and could possibly be used as a basis to attract financial resources for implementation of modernization improvements.

The audit was conducted by a Ukrainian team trained under the Environmental Policy and Technology Project and managed as part of Task 1 of Delivery Order 13. Since one of the purposes of this report was to enforce the principles of pollution prevention ESAs, the first half of the report highlights US and Western European steelmaking practices and provides some data on typical emissions for steelmaking plants in the US. This information is believed useful to Illich in making relative comparisons of their facility's discharges and in possibly applying example pollution prevention practices used by this industry in other countries.

INDUSTRIAL PROCESS DESCRIPTION

The following is a description of the major industrial processes within the iron and steel industry, including the materials and equipment used, and the processes employed It is designed for those interested in gaining a general understanding of the industry, and for those interested in the inter-relationship between the industrial process and the topics described in subsequent discussions on pollutant outputs and pollution prevention opportunities

Specifically, the discussions provide a description of commonly used production processes, associated raw materials, the byproducts produced or released, and the materials either recycled or transferred off-site. This discussion, coupled with schematic drawings of the identified processes, provide a concise description of where wastes are produced in the manufacturing process. This section also describes the potential fate (via air, water, and soil pathways) of these waste products Relative comparisons to the Illich Steel Plant are made in subsequent sections of the report

Industrial Processes in the Iron and Steel Industry

In view of the high cost of most new equipment and the relatively long lead time necessary to bring new equipment on line in the steel industry, changes in production methods and products in the steel industry are typically made gradually Installation of major pieces of new steelmaking equipment may cost millions of dollars and require additional retrofitting of other equipment Even new process technologies that fundamentally improve productivity, such as the continuous casting process (described below), are adopted only over long periods of time.

Environmental legislation around the world is challenging the industry to develop cleaner and more efficient steelmaking processes at the same time competition from substitute materials are forcing steelmakers to invest in cost-saving and quality enhancing technologies In the long term, the steel industry in well developed countries is moving towards more simplified and continuous manufacturing technologies that reduce the capital costs for new mill construction and allow smaller mills to operate efficiently The companies that excel will be those that have the resources and foresight to invest in such technologies

Steel is an alloy of iron usually containing less than one percent carbon The process of steel production occurs in several sequential steps Refer to Figure 1 The two types of steelmaking technology in use today are the basic oxygen furnace (BOF) and the electric arc furnace (EAF) Although these two technologies use different input materials, the output for both furnace types is molten steel which is subsequently formed into steel mill products The BOF input materials are molten iron, scrap, and oxygen In the EAF, electricity and scrap are the input materials used BOFs are typically used for high tonnage production of carbon steels, while EAFs are used to produce carbon steels and low tonnage alloy and specialty steels The processes leading up to steelmaking in a BOF are very different than the steps proceeding steelmaking in an EAF, the steps after each of these processes producing molten steel are the same.

When making steel using a BOF, cokemaking and ironmaking precede steelmaking; these steps are not needed for steelmaking with an EAF Coke, which is the fuel and carbon source, is produced by heating coal in the absence of oxygen at high temperatures in coke ovens Pig iron is then produced by heating the coke, iron ore, and limestone in a blast furnace In the BOF, molten iron from the blast furnace is combined with flux and scrap steel where high-purity oxygen is injected This process, with cokemaking, ironmaking, steelmaking, and subsequent forming and finishing operations is referred to as fully integrated production Alternatively, with an EAF, the

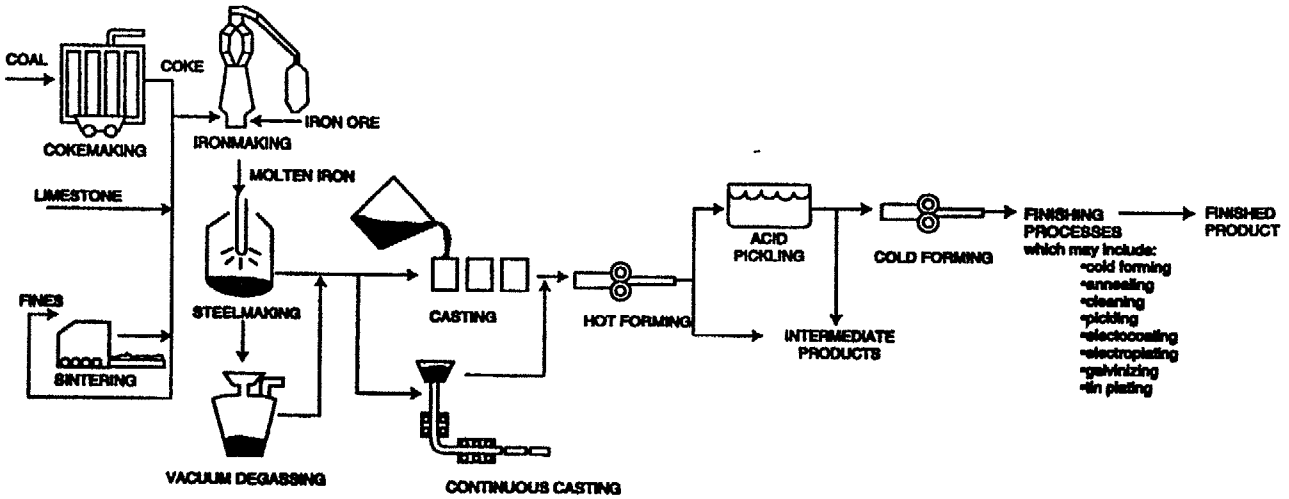


Figure 1. Process Overview of Iron and Steel Manufacturing Process.

input material is primarily scrap steel, which is melted and refined by passing an electric current from the electrodes through the scrap The molten steel from either process is formed into ingots or slabs that are rolled into finished products Rolling operations may require reheating, rolling, cleaning, and coating the steel A description of both steelmaking processes follows

Steelmaking Using the Basic Oxygen Furnace

The process of making steel in a Basic Oxygen Furnace (BOF) is preceded by cokemaking and ironmaking operations In cokemaking, coke is produced from coal In ironmaking, molten iron is produced from iron ore and coke Each of these processes and the subsequent steelmaking process in the BOF are described below It is important to note that this is the fundamental technology in the Ukraine with a distinct difference from western enterprises In older western enterprises, coking operations were typically integrated into a steel mill operation, whereas in Ukraine they are independent, merchant operations.

Cokemaking

Coal processing in the iron and steel industry typically involves producing coke, coke gas and by-product chemicals from compounds released from the coal during the cokemaking process Refer to Figure 2 Coke is carbon-rich and is used as a carbon source and fuel to heat and melt iron ore in ironmaking The cokemaking process starts with bituminous pulverized coal charge which is fed into the coke oven through ports in the top of the oven After charging, the oven ports are sealed and the coal is heated at high temperatures (1600 to 2300°F) in the absence of oxygen Coke manufacturing is done in a batch mode where each cycle lasts for 14 to 36 hours A coke oven battery comprises a series of 10 to 100 individual ovens, side-by-side, with a heating flue between each oven pair Volatile compounds are driven from the coal, collected from each oven, and processed for recovery of combustible gases and other coal byproducts The solid carbon remaining in the oven is the coke The necessary heat for distillation is supplied by external combustion of fuels (e g , recovered coke oven gas, blast furnace gas) through flues located between ovens At the end of the heating cycle, the coke is pushed from the oven into a rail quench car The quench car takes it to the quench tower, where the hot coke is cooled with a water spray The coke is then screened and sent to the blast furnace or to storage

In the by-products recovery process, volatile components of the coke oven gas stream are recovered including the coke oven gas itself (which is used as a feed to the coke oven), naphthalene, ammonium compounds, crude light oils, sulfur compounds, and coke breeze (coke fines) During the coke quenching, handling, and screening operation, coke breeze is produced Typically, the coke breeze is reused in other manufacturing processes on-site (e g , sintering) or sold off-site as a by-product.

The cokemaking process is one of the steel industry's areas of greatest environmental concern, with air emissions and quench water as major problems In efforts to reduce the emissions associated with cokemaking, U S steelmakers are turning to technologies such as pulverized coal injection, which substitutes coal for coke in the blast furnace Use of pulverized coal injection can replace about 25 to 40 percent of coke in the blast furnace, reducing the amount of coke required and the associated emissions Steel producers also inject other fuels, such as natural gas, oil, and tar/pitch to replace a portion of the coke The Illich Plant, like other facilities in the Ukraine, do not implement this practice

Quench water from cokemaking is also an area of significant environmental concern In Europe, some plants have implemented technology to shift from water quenching to dry quenching which

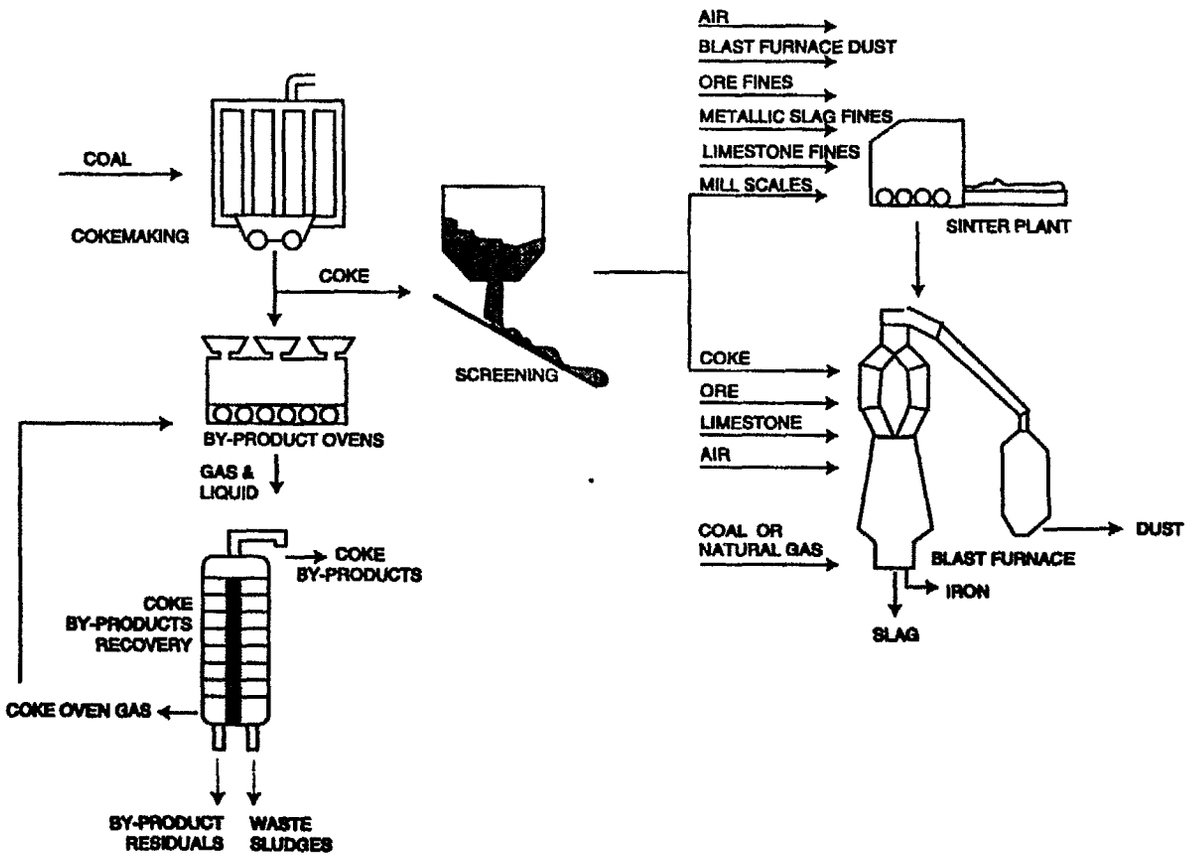


Figure 2. Iron and Steel Manufacturing - Cokemaking and Ironmaking.

eliminates suspected carcinogenic particulates and VOCs However, major construction changes are required for such a solution and considering the high capital costs of coke batteries, combined with the depressed state of the steel industry and increased regulations for cokemaking, it is unlikely that new facilities will be constructed Instead, industry experts expect to see an increase in the amount of coke imported For this reason, merchant coking operations in the Ukraine should be aggressively seeking export markets in Western Europe

Ironmaking.

In the blast furnace, molten iron is produced as shown in Figure 2 Iron ore, coke, and limestone are fed into the top of the blast furnace Heated air is forced into the bottom of the furnace through a bustle pipe and tuyeres (orifices) located around the circumference of the furnace The carbon monoxide from the burning of the coke reduces iron ore to iron The acid part of the ores reacts with the limestone to create a slag which is drawn periodically from the furnace. This slag contains unwanted impurities in the ore, such as sulfur from the fuels. When the furnace is tapped, iron is removed through one set of runners and molten slag via another. The molten iron is tapped into refractory-lined cars for transport to the steelmaking furnaces Residuals from the process are mainly sulfur dioxide or hydrogen sulfide, which are driven off from the hot slag The slag is the largest by-product generated from the ironmaking process and is reused extensively in the construction industry Blast furnace flue gas is cleaned and used to generate steam to preheat the air coming into the furnace, or it may be used to supply heat to other plant processes The cleaning of the gas may generate air pollution control dust in removing coarse particulates (which may be reused in the sintering plant), and water treatment plant sludge in removing fine particulates by venturi scrubbers

Sintering is the process that agglomerates fines (including iron ore fines, pollution control dusts, coke breeze, water treatment plant sludge, coke breeze, and flux) into a porous mass for charging to the blast furnace Through sintering operations, a mill can recycle iron-rich material, such as mill scale and processed slag Not all mills have sintering capabilities The input materials are mixed together, placed on a slow-moving grate and ignited Windboxes under the grate draw air through the materials to deepen the combustion throughout the traveling length of the grate. The coke breeze provides the carbon source for sustaining the controlled combustion In the process, the fine materials are fused into the sinter agglomerates, which can be reintroduced into the blast furnace along with ore Air pollution control equipment removes the particulate matter generated during the thermal fusing process For wet scrubbers, water treatment plant sludge are generally land disposed waste, which is a serious problem at Illich and other steel mills in the Ukraine If electrostatic precipitators or baghouses are used as the air pollution control equipment, the dry particulates captured are typically recycled as sinter feedstock

Steelmaking Using the Basic Oxygen Furnace

Molten iron from the blast furnace, flux, alloy materials, and scrap are placed in the basic oxygen furnace, melted and refined by injecting high-purity oxygen. A chemical reaction occurs, where the oxygen reacts with carbon and silicon generating the heat necessary to melt the scrap and oxidize impurities This is a batch process with a cycle time of about 45 minutes Slag is produced from impurities removed by the combination of the fluxes with the injected oxygen Various alloys are added to produce different grades of steel The molten steel is typically cast into slabs, beams or billets The steelmaking process is illustrated in Figure 3

The waste products from the basic oxygen steelmaking process include slag, carbon monoxide, and oxides of iron emitted as dust Also, when the hot iron is poured into ladles or the furnace,

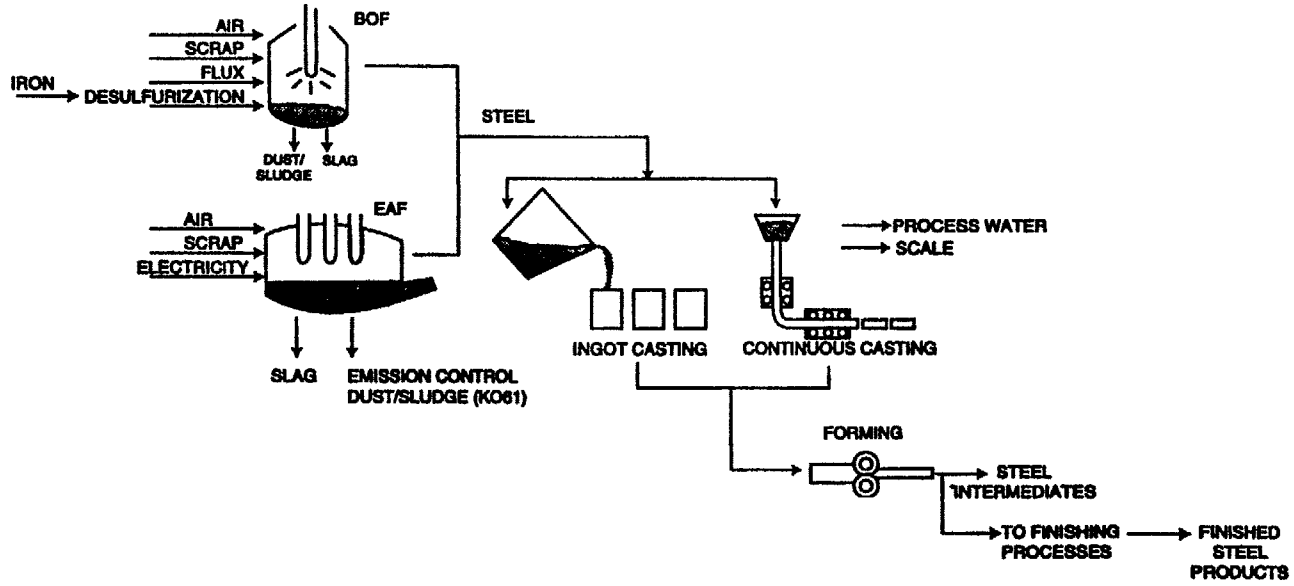


Figure 3. Iron and Steel Maufacturing - Steelmaking

iron oxide fumes are released and some of the carbon in the iron is precipitated as graphite (kish) The BOF slag can be processed to recover the high metallic portions for use in sintering or blast furnaces, but its applications as a saleable construction materials are more limited than the blast furnace slag

Basic oxygen furnaces are equipped with air pollution control systems for containing, cooling, and cleaning the volumes of hot gases and sub-micron fumes that are released during the process Water is used to quench or cool the gases and fumes to temperatures at which they can be effectively treated by the gas cleaning equipment The resulting waste streams from the pollution control processes include air pollution control dust and water treatment plant sludge About 1,000 gallons of water per ton of steel (gpt) are used for a wet scrubber. The principal pollutants removed from the off-gas are total suspended solids and metals (primarily zinc, and some lead)

Steelmaking Using the Electric Arc Furnace (EAF)

In the steelmaking process that uses an electric arc furnace (EAF), the primary raw material is scrap metal, which is melted and refined using electric energy During melting, oxidation of phosphorus, silicon, manganese, carbon and other materials occurs and a slag containing some of these oxidation products forms on top of the molten metal Oxygen is used to decarburize the molten steel and to provide thermal energy This is a batch process with a cycle time of about two to three hours Since scrap metal is used instead of molten iron, there are no cokemaking or ironmaking operations associated with steel production that uses an EAF

The process produces metal dusts, slag, and gaseous products Particulate matter and gases evolve together during the steelmaking process and are conveyed into a gas cleaning system These emissions are cleaned using a wet or dry system The particulate matter that is removed as emissions in the dry system is referred to as EAF dust, or EAF sludge if it is from a wet system and it is considered a hazardous waste The composition of EAF dust can vary greatly depending on the scrap composition and furnace additives The primary component is iron or iron oxides, and it may also contain flux (lime and/or fluorspar), zinc, chromium and nickel oxides (when stainless steel is being produced) and other metals associated with the scrap. The two primary hazardous constituents of EAF emission control dust are lead and cadmium Generally, 20 pounds of dust per ton of steel is expected, but as much as 40 pounds of dust per ton of steel may be generated, depending on production practices Oils are burned off "charges" of oil-bearing scrap in the furnace Minor amounts of nitrogen oxides and ozone are generated during the melting process. The furnace is extensively cooled by water, however, this water is recycled through cooling towers.

Forming and Finishing Operations

Whether the molten steel is produced using a BOF or an EAF, to convert it into a product, it must be solidified into a shape suitable and finished

Forming

The traditional forming method, called ingot teeming, has been to pour the metal into ingot molds, allowing, the steel to cool and solidify The alternative method of forming steel is called continuous casting The continuous casting process bypasses several steps of the conventional ingot teeming process by casting steel directly into semifinished shapes Molten steel is poured into a reservoir from which it is released into the molds of the casting machine The metal is cooled as it descends through the molds, and before emerging, a hardened outer shell is formed

As the semifinished shapes proceed on the runout table, the center also solidifies, allowing the cast shape to be cut into lengths

Process contact water cools the continuously cast steel and, is collected in settling basins along with oil, grease, and mill scale generated in the casting process The scale settles out and is removed and recycled for sintering operations Waste treatment plant sludge is also generated

The steel is further processed to produce slabs, strips, bars, or plates through various forming operations The most common hot forming operation is hot rolling, where heated steel is passed between two rolls revolving in opposite directions Modern hot rolling units may have as many as 13 stands, each producing an incremental reduction in thickness. The final shape and characteristics of a hot formed piece depend on the rolling temperature, the roll profile, and the cooling process after rolling. Wastes generated from hot rolling include waste treatment plant sludge and scale.

In subsequent cold forming, the cross-sectional area of unheated steel is progressively reduced in thickness as the steel passes through a series of rolling stands Generally, wires, tubes, sheet and strip steel products are produced by cold rolling operations Cold forming is used to obtain improved mechanical properties, better machinability, special size accuracy, and the production of thinner gages than hot rolling can accomplish economically During cold rolling, the steel becomes hard and brittle To make the steel more ductile, it is heated in an annealing furnace

Process contact water is used as a coolant for rolling mills to keep the surface of the steel clean between roller passes Cold rolling operations also produce a waste treatment plant sludge, primarily due to the lubricants applied during rolling Grindings from resurfacing of the worn rolls and disposal of used rolls can be a significant contributor to the plant's wastestream

Finishing

One of the most important aspects of a finished product is the surface quality To prevent corrosion, a protective coating may be applied to the steel product Prior to coating, the surface of the steel must be cleaned so the coating will adhere to the steel Mill scale, rust, oxides, oil, grease, and soil are chemically removed from the surface of steel using solvent cleaners, pressurized water or air blasting, cleaning with abrasives, alkaline agents or acid pickling. In the pickling process, the steel surface is chemically cleaned of scale, rust, and other materials Inorganic acids such as hydrochloric or sulfuric acid are most commonly used for pickling Stainless steels are pickled with hydrochloric, nitric, and hydrofluoric acids. Spent pickle liquor is generally considered a hazardous waste, if it contains considerable residual acidity and high concentrations of dissolved iron salts Pickling prior to coating may use a mildly acidic bath which is not considered hazardous

Steel generally passes from the pickling bath through a series of rinses Alkaline cleaners may also be used to remove mineral oils and animal fats and oils from the steel surface prior to cold rolling Common alkaline cleaning agents include caustic soda, soda ash, alkaline silicates, phosphates

Steel products are often given a coating to inhibit oxidation and extend the life of the product Coated products can also be painted to further inhibit corrosion Common coating processes include galvanizing (zinc coating), tin coating, chromium coating, aluminizing, and tome coating (lead and tin) Metallic coating application processes include hot dipping, metal spraying,

metal cladding (to produce bi-metal products), and electroplating Galvanizing is a common coating process where a thin layer of zinc is deposited on the steel surface

Raw Materials and Pollution Outputs

Numerous outputs are produced as a result of the manufacturing of coke, iron, and steel, the forming of metals into basic shapes, and the cleaning and scaling of metal surfaces These outputs include

Cokemaking

Inputs
· Coal, heat, quench water

Outputs
· Process residues from coke by-product recovery
· Coke oven gas by-products such as coal tar, light oil, ammonia liquor, and the remainder of the gas stream is used, as fuel Coal tar is typically refined to produce commercial and industrial products including pitch, creosote oil, refined tar, naphthalene, and bitumen
Charging emissions (fine particles of coke generated during oven pushing, conveyor transport, loading and unloading of coke that are captured by pollution control equipment Approximately one pound per ton of coke produced are captured and generally must be disposed of)
Ammonia, phenol, cyanide and hydrogen sulfide
· Oil
Lime sludge, generated from the ammonia still
Decanter tank tar sludge
Benzene releases in coke by-product recovery operations
Naphthalene residues, generated in the final cooling tower
· Tar residues
· Sulfur compounds, emitted from the stacks of the coke ovens
· Wastewater from cleaning and cooling (contains zinc, ammonia still lime, or decanter tank tar, tar distillation residues
· Coke oven gas condensate from piping and distribution system

Ironmaking

Inputs
· Iron ore, coke, sinter, coal, limestone, heated air

Outputs·
· Slag, which is either sold as a by-product, primarily for use in the construction industry, or landfilled
· Residual sulfur dioxide or hydrogen sulfide
· Particulates captured in the gas, including the air pollution control (APC) dust or waste treatment plant (WTP) sludge
· Iron is the predominant metal found in the process wastewater
Blast furnace gas (CO)

Steelmaking

Inputs

In the steelmaking process that uses a basic oxygen furnace (BOF), inputs include molten iron, metal scrap, and high-purity oxygen

In the steelmaking process that uses an electric arc furnace (EAF), the primary inputs are scrap metal, electric energy and graphite electrodes

For both processes, fluxes and alloys are added, and may include fluorspar, dolomite, and alloying agents such as aluminum, manganese, and others

Outputs

Basic Oxygen Furnace emission control dust and sludge, a metals-bearing waste.

Electric Arc Furnace emission control dust and sludge, generally, 20 pounds of dust per ton of steel is expected, but as much as 40 pounds of dust per ton of steel may be generated depending on the scrap that is used.

· Metal dusts (consisting of iron particulate, zinc, and other metals associated with the scrap and flux (lime and/or fluorspar)) not associated with the EAF.

· Slag

Carbon monoxide

· Nitrogen oxides and ozone, which are generated during the melting process

Forming, Cleaning, and Descaling

Inputs

Carbon steel is pickled with hydrochloric or sulfuric acid, stainless steels are pickled with hydrochloric, nitric, and hydrofluoric acids

Various organic chemicals are used in the pickling process

Alkaline cleaners may also be used to remove mineral oils and animal fats and oils from the steel surface Common alkaline cleaning agents include caustic soda, soda ash, alkaline silicates, · phosphates

Outputs

Wastewater sludge from rolling, cooling, descaling, and rinsing operations which may contain cadmium, chromium, lead

· Oils and greases from hot and cold rolling

· Spent pickle liquor

· Spent pickle liquor rinse water sludge from cleaning operations

·Waste water from the rinse baths Rinse water from coating processes may contain zinc, lead, cadmium, or chromium

Grindings from roll refinishing may be hazardous wastes especially if they contain chromium

Zinc dross

Management of Chemicals in the Production Process

In the United States, the Pollution Prevention Act of 1990 (PPA) requires facilities to report information about the management of chemicals in waste and efforts made to eliminate or reduce those quantities These data have been collected annually beginning with the 1991 reporting year The data summarized below cover the years 1992-1995 and is meant to provide a basic understanding of the quantities of waste handled by the industry and the methods typically used to manage this waste This type of waste management data can be used to assess trends in source reduction within individual industries and facilities, and for specific chemicals This information could then be used as a tool in identifying opportunities for pollution prevention compliance assistance activities

From the yearly data presented in Table 1 it is apparent that the portion of wastes reported as recycled on-site has increased and the portions treated or managed through energy recovery on-site have decreased between 1992 and 1995 The PPA requires these projections to encourage facilities to consider future waste generation and source reduction of those quantities as well as movement up the waste management hierarchy Future-year estimates are not commitments that facilities reporting are required to meet It is recommended that Ukraine consider implementing a similar reporting system

Table 1 shows that the iron and steel industry in the United States managed about 1 3 billion pounds of production-related waste (total quantity of TRI chemicals in the waste from routine production operations) in 1993 (column B) Column C reveals that of this production-related waste, over half (52%) was either transferred off-site or released to the environment, and most of this quantity was recycled off-site (typically in a metals recovery process). Column C is calculated by dividing the total TRI transfers and releases by the total quantity of production-related waste In other words, about 48% of the industry's TRI wastes were managed on-site through recycling, energy recovery, or treatment as shown in columns E, F and G, respectively The majority of waste that is released or transferred off-site can be divided into portions that are recycled off-site, recovered for energy off-site, or treated off-site as shown in columns H, I and J, respectively The remaining portion of the production related wastes (15% for 1993), shown in column D, is either released to the environment through direct discharges to air, land, water, and underground injection, or it is disposed off-site Direct comparisons to Illich or the Ukrainian Steelmaking industry are not possible because of the lack of accurate reporting data on wastes

Table 1. Source Reduction and Recycling Activity for Iron and Steel Industry Reported

A	B	C	D	On-Site			Off-Site		
Year	Quantity Of Production-Related Waste (10^6lbs)[a]	%Released and Transferred[b]	%Released and Disposed[c] Off-site	E	F	G	H	I	J
				% Recycled	%Energy Recovery	% Treated	% Recycled	%Energy Recovery	% Treated
1992	1,301	40%	10%	32%	2%	16%	34%	1%	5%
1993	1,340	52%	15%	24%	1%	17%	35%	1%	6%
1994	1,341	---	15%	23%	1%	18%	37%	1%	6%
1995	1,357	---	15%	22%	1%	18%	38%	1%	6%

[a] Does not include any accidental, non-production related wastes
[b] Total TRI transfers and releases as reported in Section 5 and 6 of Form R as a percentage of production related wastes, this value may not equal the sum of the percentages released and transferred due to reporting errors in Section 8
[c] Percentage of production related waste released to the environment and transferred off-site for disposal

CHEMICAL RELEASE AND TRANSFER PROFILE

The following provides background information on typical pollutant releases by this industry The best source of comparative pollutant release information in the United states is the Toxic Release Inventory System (TRI) TRI data provide the type, amount and media receptor of each chemical released or transferred.

The following definitions are based upon standard definitions developed by the US EPA's Toxic Release Inventory Program The categories below represent the possible pollutant destinations that can be reported It is useful for a facility to examine these data in comparison to their own outputs

RELEASES - are an on-site discharge of a toxic chemical to the environment This includes emissions to the air, discharges to bodies of water, releases at the facility to land, as well as contained disposal into underground injection wells.

Releases to Air (Point and Fugitive Air Emissions) - Include all air emissions from industry activity Point emission occur through confined air streams as found in stacks, ducts, or pipes Fugitive emissions include losses from equipment leaks, or evaporative losses from impoundments, spills, or leaks

Releases to Water (Surface Water Discharges) - encompass any releases going directly to streams, rivers, lakes, oceans, or other bodies of water Any estimates for storm water runoff and non-point losses must also be included

Releases to Land - includes disposal of toxic chemicals in waste to oil-site landfills, land treated or incorporation into soil, surface impoundments, spills, leaks, or waste piles These activities must occur within the facility's boundaries for inclusion in this category

Underground Injection - is a contained release of a fluid into a subsurface well for the purpose of waste disposal

TRANSFERS - is a transfer of toxic chemicals in wastes to a facility that is geographically or physically separate from the facility reporting under TRI. The quantities reported represent a movement of the chemical away from the reporting facility Except for off-site transfers for disposal, these quantities do not necessarily represent entry of the chemical into the environment

Transfers to POTWs - are wastewaters transferred through pipes or sewers to a publicly owned treatments works (POTW) Treatment and chemical removal depend on the chemical's nature and treatment methods used. Chemicals not treated or destroyed by the POTW are generally released to surface waters or landfilled within the sludge

Transfers to Recycling - are sent off-site for the purposes of regenerating or recovering still valuable materials. Once these chemicals have been recycled, they may be returned to the originating facility or sold commercially

Transfers to Energy Recovery - are wastes combusted off-site in industrial furnaces for energy recovery Treatment of a chemical by incineration is not considered to be energy recovery

Transfers to Treatment - are wastes moved off-site for either neutralization, incineration, biological destruction, or physical separation In some cases, the chemicals are not destroyed but prepared for further waste management.

Transfers to Disposal - are wastes taken to another facility for disposal generally as a release to land or as an injection underground.

EPA Toxic Release Inventory for the Iron and Steel Industry

This section summarizes TRI data of facilities involved in the production of iron and steel products who report their operations in the United States These include blast furnaces and steel mills, steel wire manufacture, and cold rolled steel products but also include a small number of nonferrous operations. The *Census of Manufactures* reports 1,118 iron and steel establishments in the U.S. Although 381 iron and steel facilities filed TRI reports in 1993, only 155 facilities (41 percent) classified (blast furnaces and steel mills) are responsible for over 75 percent of reported releases and transfers.

According to TRI data, the iron and steel industry released and transferred a total of approximately 695 million pounds of pollutants during calendar year 1993. These releases and transfers are dominated by large volumes of metal-bearing wastes. The majority of these wastes (70 percent or 488 million pounds) are transferred off-site for recycling, typically for recovery of the metal content *Transfers* of TRI chemicals account for 86 percent of the iron and steel industry's total TRI-reportable chemicals (609 million pounds) while *releases* make up 14 percent (85 million pounds) Metal-bearing wastes account for approximately 80 percent of the industry's transfers and over fifty percent of the releases

- Releases from the industry continue to decrease, while transfers increased from 1992 to 1993 The increase in transfers is likely due to increased off-site shipments for recovery of metals from wastes This shift may also have contributed to the decrease in releases Another factor influencing an overall downward trend since 1988 in releases and transfers is the steel mill. production decrease during the 1988 to 1993 period in the USA In addition, pollution control equipment and a shift to new technologies, such as continuous casting, are responsible for significant changes in the amount and type of pollutants released during steelmaking. Finally, the US industry's efforts in pollution preventing also play a role in driving pollutant release reductions.

Evidence of the diversity of processes at facilities reporting to TRI is found in the fact that the most frequently reported chemical (sulfuric acid) is reported by only 41 percent of the facilities; the sixth most frequently reported chemical was used by just one-fourth of TRI facilities. The variability in facilities' pollutant profile may be attributable to a number of factors. Fewer than 30 of the facilities in the TRI database are fully integrated plants making coke, iron, and steel products The non-integrated facilities do not perform one or more of the production steps and, therefore, may have considerably different emissions profiles. Furthermore, steel making operations with electric arc furnaces have significantly different pollutant profiles than those making steel with basic oxygen furnaces.

Releases

The iron and steel industry releases just 14 percent of its TRI total poundage Of these releases, over half go to on-site land disposal, and one quarter of releases are fugitive or point source air emissions Manganese, zinc, chromium, and lead account for over 90 percent of the on-site land

disposal The industry's air releases are associated with volatilization, fume or aerosol formation in the high temperature furnaces and byproduct processing. Ammonia, lighter weight organics, such as methanol, acids and metal contaminants found in the iron ore are the principal types of chemicals released to the air. In addition to air releases of chemicals reported in TRI, the iron and steel industry is a significant source of particulates, carbon monoxide, nitrogen oxides and sulfur compounds due to combustion. Ammonia releases account for the largest part of the fugitive releases (approximately 42 percent) and 1, 1, 1-trichloroethane, hydrochloric acid, zinc compounds, and trichloroethylene each contribute another 4 - 5 percent. Underground injection (principally of hydrochloric acid) makes up about 14 percent of the releases reported by the industry

Transfers

Eighty percent of transfers reported by U.S. industries are sent off-site for recycling. Zinc, manganese, chromium, copper, nickel, and lead are the six metals transferred by the greatest number of facilities ~~(refer to Ta~~ble 3).

Acids used during steel finishing, such as hydrochloric, sulfuric, nitric, and phosphoric acids, account for another 17 percent of transfers. These acids are most often sent off-site for recycling or for treatment. Hydrochloric acids are also managed by on-site underground injection The next class of chemicals of significant volume in TRI are solvents and lightweight carbon byproducts, including: 1,1,1-trichloroethane, trichloroethylene, phenol, xylene, methanol, and toluene. These solvents are primarily released as fugitive air emissions, but also from point sources. A small percentage of these solvents are transferred off-site for recycling.

Chemicals sent off-site for disposal (primarily zinc, sulfuric acid, manganese, and ammonium sulfate) account for another 10 percent of transfers Only approximately 7 percent of chemicals transferred off-site go to treatment These chemicals are primarily hydrochloric acid, sulfuric acid, and nitric acid. Only about one percent of transfers by weight are POTW discharges (mainly sulfuric acid). Another one percent of transfers are sent for energy recovery (with hydrochloric acid as the most significant contributor).

The TRI database contains a detailed compilation of self-reported, facility-specific chemical releases The top reporting facilities for this sector based on pounds released are listed in Table 4. The second list includes facilities that conduct multiple operations Currently, the facility-level data do not allow pollutant releases to be broken apart by industrial process The data presented in these tables is useful to the Illich Metallurgical Plant for comparative purposes The audit conducted by our team was not quantitative enough to enable comparisons , however clearly the subject facility should be concerned with its utilization of Oblast territory for waste disposal practicies as this would constitute an off-site transfer

Exhibit 2. Releases for Iron and Steel Facilities (SIC 331) in TRI, by Number of Facilities Reporting (1993 Releases reported in pounds/year).

CHEMICAL NAME	#REPORTING CHEMICAL	FUGITIVE AIR	POINT AIR	WATER DISCHARGES	UNDERGROUND INJECTION	LAND DISPOSAL	TOTAL RELEASES	AVG RELEASE PER FACILITY
SULFURIC ACID	157	385,882	321,639	27,700	0	4,705	739,926	4,713
MANGANESE COMPOUNDS	110	472,855	808,182	145,595	4,800	21,252,405	22,683,837	206 217
CHROMIUM COMPOUNDS	108	19 821	87,971	53,107	4,800	1,953,629	2,119,328	19 623
ZINC COMPOUNDS	108	596,037	874,585	121,804	250	13,497,412	15,090,088	139,723
HYDROCHLORIC ACID	102	612,814	1,469,639	25	11,726,300	744	13,809,519	135,387
CHROMIUM	95	10,858	24,926	4,432	0	415,839	456,055	4,801
MANGANESE	94	38,655	42,782	79,069	0	791,189	951,695	10,124
NICKEL COMPOUNDS	86	9,030	12,107	11,007	1,100	654,514	687,758	7,997
NICKEL	83	10,505	19,817	9,490	3,200	126,359	169,371	2,041
NITRIC ACID	66	96,647	487,887	39	0	44,730	629,303	9,535
LEAD	61	34,634	107,468	17,088	0	126,479	285,669	4,683
LEAD COMPOUNDS	61	55,593	76,024	11,559	0	1,087,501	1,230,677	20,175
AMMONIA	59	5,162,886	1,012,664	4,836,185	860,000	6,479	11,878,214	201,326
PHOSPHORIC ACID	56	78,666	7,672	260	0	142,814	229,412	4,097
COPPER COMPOUNDS	51	10,474	81,731	8,918	1,100	1,518,033	1,620,256	31,770
COPPER	36	17,281	4,902	3,237	0	16,320	41,740	1,159
ZINC (FUME OR DUST)	36	328,089	322,975	58,831	0	3,571,000	4,280,895	118,914
XYLENE (MIXED ISOMERS)	32	172,712	76,091	510	0	274	249,587	7,800
HYDROGEN FLUORIDE	30	96,276	133,328	19	0	20,789	250,412	8,347
TOLUENE	30	222,938	408,507	513	0	328	632,286	21,076
NAPTHALENE	26	98,890	35,809	1,830	15,000	300	151,829	5,840
BENZENE	24	482,755	347,643	911	7,000	600	838,909	34,955
CYANIDE COMPOUNDS	24	14,928	91,928	72,033	41,000	909	220,798	9,200
CHLORINE	23	16,510	6,409	48,910	0	0	71,829	3,123
ETHYLENE GLYCOL	21	52,505	255	99,306	0	6,950	159,016	7,572
ETHYLENE	20	196,170	771,732	0	0	0	967,902	48,395
BARIUM COMPOUNDS	19	847	1,260	12,523	0	140,857	155,487	8,184
1,1,1-TRICHLOROETHANE	19	1,184,793	160,942	0	0	0	1,345,735	70,828
ANTHRACENE	17	3,830	11,636	9	0	0	15,475	910
PHENOL	16	101,903	77,677	30,445	76,000	23,817	309,842	19,365
ALUMINIUM (FUME OR DUST)	15	5,536	56,575	22,522	0	210,064	294,697	19,646
PRIPYLENE	15	28,149	81,649	0	0	0	109,798	7,320
METHANOL	14	487,709	18	0	0	35	487,762	34,840
DIBENZOFURAN	13	2,571	29	0	0	0	2,600	200
MOLYBDENIUM TRIOXIDE	13	923	852	1,860	0	6,450	10,085	776
ETHYLBENZENE	12	13,504	3,803	250	0	0	17,557	1,463
TRICHLOROETHYLENE	12	572,277	484,600	5	0	0	1,056,882	88,074
AMMONIUM SULFATE (SOLUTION)	10	5	0	5,693	0	0	5,698	570
CADMIUM COMPOUNDS	10	904	1,391	5,	0	0	2,300	230
STYRENE	10	4,724	636	5	0	7	5,372	537
COBALT	9	419	684	3,709	0	760	5,572	619
GLYCOL ETHERS	8	76,065	268,798	0	0	0	344,863	43,108
DICHLOROMETHANE	7	133,725	264,215	0	0	0	397,940	56,849
COBALT COMPOUNDS	6	18	781	535	0	3,100	4,434	739
CRESOL (MIXED ISOMERS)	6	6,341	1,801	259	0	0	8,401	1,400
QUINOLINE	6	379	1,801	5	0	0	2,185	364

Exhibit 2 (cont.): Releases for Iron and Steel Facilities (SIC 331) in TRI, by Number of Facilities Reporting (1993 Releases reported in pounds/year).

CHEMICAL NAME	#REPORTING CHEMICAL	FUGITIVE AIR	POINT AIR	WATER DISCHARGES	UNDERGROUND INJECTION	LAND DISPOSAL	TOTAL RELEASES	AVG RELEASE PER FACILITY
QUINOLINE	6	2,185	379	1,801	5	0	2,185	364
1,2,4- TRIMETHYLBENZENE	6	9,730	434	0	0	0	10,164	1,694
ANTIMONY COMPOUNDS	5	1,715	110	635	0	1,052	3,512	702
BIPHENYL	5	202	1	0	0	0	203	41
ANTIMONY	4	803	650	5,515	0	1,300	8,260	2,067
TETRACHLOROETHYLENE	4	34,498	10,800	0	0	0	45,290	11,325
ACETONE	3	340,285	0	0	0	0	340,285	113,428
BARIUM	3	373	996	4,416	0	117,264	123,049	41,016
CADMIUM	3	24	388	0	0	0	412	137
SEC-BUTYL ALCOHOL	3	56,794	10,650	250	0	0	67,694	22,565
VANADIUM (FUME OR DUST)	3	4,180	700	3,200	0	22,000	30,080	10,027
CALCIUM CYANAMIDE	2	0	0	0	0	0	0	0
CARBON DISULFIDE	2	1,638	250	0	0	0	1,888	944
DIETHANOLAMINE	2	1,900	0	25,000	0	0	26,900	13,450
HYDROGEN CYANIDE	2	5	10	0	0	0	15	8
METHYL ETHYLKETONE	2	3,700	51,400	0	0	0	55,100	27,550
N-BUTYL ALCOHOL	2	250	27,807	0	0	0	28,057	14,029
SILVER	2	5	0	0	0	0	5	3
THIOUREA	2	250	0	767	0	0	1,017	509
ALUMINIUM OXIDE (FIBROUS)	1	250	0	0	0	0	250	250
ARSENIC	1	15	15	0	0	0	30	30
BROMOTRIFLUOROMETHANE	1	250	0	0	0	0	250	250
BUTYL BENZYL PHITALATE	1	0	0	0	0	0	0	0
CARBON SULFIDE	1	250	0	0	0	0	250	250
METHYL ISOBUTYL KETONE	1	170	0	0	0	0	170	170
POLYCHLORINATED BIPHENYLS	1	0	0	0	0	0	0	0
PYRIDINE	1	750	16,000	0	8,200	0	24,950	24,950
SELENIUM COMPOUNDS	1	0	0	0	0	0	0	0
1,3- BUTADIENE	1	250	0	0	0	0	250	250
2,4- DIMETHYLPHENOL	1	250	0	0	0	0	250	250
TOTAL	381	12,377,570	9,174,029	5,729,986	12,748,750	45,767,008	85,797,343	85,797,343

Exhibit 3. Releases for Iron and Steel Facilities (SIC 331) in TRI, by Number of Facilities Reporting (1993 Releases reported in pounds/year).

CHEMICAL NAME	#REPORTING CHEMICAL	POTW DISCHARGES	DISPOSAL	RECYCLING	TREATMENT	ENERGY RECOVERY	TOTAL TRANSFERS	AVG TRANSFER PER FACILITY
SULFURIC ACID	157	7,192,127	11,060,393	15,416,092	6,533,083	0	40,295,552	256,660
MANGANESE COMPOUNDS	110	1,498	2,500 170	25,091,810	514,579	0	28,108,057	255 528
CHROMIUM COMPOUNDS	108	1,353	1,394,134	25,225,915	312,628	1,059	26,935,089	249 399
ZINC COMPOUNDS	108	8,611	34,813,453	157,386,808	5,021,396	3,100	197,233,368	1,826,235
HYDROCHLORIC ACID	102	217,138	395,161	32,888,151	23,981,197	8,497,000	65,978,647	646,849
CHROMIUM	95	2,289	1,010,326	32,865,366	36,816	750	33,915,547	357,006
MANGANESE	94	2,461	4,442,385	39,076,967	40,744	0	43,562,557	463 431
NICKEL COMPOUNDS	86	4,678	381,519	8,831,918	121,984	0	9,340,099	108,606
NICKEL	83	2,091	455,271	13,271,504	57,207	0	13,786,073	166,097
NITRIC ACID	66	51,087	1,616,149	54,046	3,073,168	0	4,794,450	72,643
LEAD	61	2,242	515,410	7,382,111	151,145	27	8,050,935	131,983
LEAD COMPOUNDS	61	957	682,835	13,703,747	152,866	0	14,540,405	238,367
AMMONIA	59	488,144	53,077	0	5,650	2,700	549,821	9,319
PHOSPHORIC ACID	56	9	90,626	18,000	19,549	0	128,184	2,289
COPPER COMPOUNDS	51	1,930	99,140	998,167	35,473	0	1,134,710	22,249
COPPER	36	746	63,934	5,598,545	7,123	0	5,670,348	157,510
ZINC (FUME OR DUST)	36	958	669,220	60,234,732	199,821	0	61,104,731	1,697,354
XYLENE (MIXED ISOMERS)	32	308	600	7,360	828	23,816	32,912	1,029
HYDROGEN FLUORIDE	30	28,300	387,574	15,046	827,889	0	1,258,809	41,960
TOLUENE	30	360	650	1,760	7,747	7,897	18,414	614
NAPTHALENE	26	1,578	24,300	0	3,561	900	30,339	1,167
BENZENE	24	1,574	1,800	469	4,477	1,800	10,120	422
CYANIDE COMPOUNDS	24	29,753	3,184	0	13,238	0	46,175	1,924
CHLORINE	23	1,310	250	92,563	0	0	94,123	4,092
ETHYLENE GLYCOL	21	250	16,984	279,247	25,000	57,550	379,031	18,049
ETHYLENE	20	0	0	0	0	0	0	0
BARIUM COMPOUNDS	19	0	132,219	68,028	0	0	200,247	10,539
1,1,1 TRICHLOROETHANE	19	0	2,000	165,861	33,988	79,528	281,377	14,809
ANTHRACENE	17	0	4,200	0	2	0	4,202	247
PHENOL	16	359,945	1,176	0	108,247	6,464	475,832	29,740
ALUMINIUM (FUME OR DUST)	15	5	125,775	47,675,040	0	0	47,800,820	3,186,721
PRIPYLENE	15	0	0	0	0	0	0	0
METHANOL	14	720	0	0	0	0	720	51
DIBENZOFURAN	13	0	2,690	0	0	0	2,690	207
MOLYBDENIUM TRIOXIDE	13	0	750	139,341	0	0	140,091	10,776
ETHYLBENZENE	12	0	325	760	250	1,502	2,837	236
TRICHLOROETHYLENE	12	0	38,556	76,036	53,726	24,191	192,509	16,042
AMMONIUM SULFATE (SOLUTION)	10	0	2,000,000	0	0	0	2,000,000	200,000
CADMIUM COMPOUNDS	10	0	0	194,477	1,369	0	195,843	19,584
STYRENE	10	5	322	0	0	0	327	33
COBALT	9	0	40,026	830,040	7	0	870,073	96,675
GLYCOL ETHERS8	8	0	0	0	1,273	26,000	27,273	3,409
DICHLOROMETHANE	7	0	0	8,229	8,200	750	17,179	2,454
COBALT COMPOUNDS	6	255	444	75,378	1,355	0	77,432	12,905
CRESOL (MIXED ISOMERS)	6	5	5	0	501	2,107	2,618	436
QUINOLINE	6	5	510	0	0	0	515	86

Exhibit 3 (cont.): Releases for Iron and Steel Facilities (SIC 331) in TRI, by Number of Facilities Reporting (1993 Releases reported in pounds/year).

CHEMICAL NAME	#REPORTING CHEMICAL	POTW DISCHARGES	DISPOSAL	RECYCLING	TREATMENT	ENERGY RECOVERY	TOTAL TRANSFERS	AVG TRANSFER PER FACILITY
QUINOLINE	6	5	510	0	0	0	515	86
1,2,4- TRIMETHYLBENZENE	6	0	380	0	250	750	1,380	230
ANTIMONY COMPOUNDS	5	0	550	0	0	0	410	82
BIPHENYL	5	0	34,855	0	0	0	550	110
ANTIMONY	4	0	4,000	0	0	0	34,855	8,714
TETRACHLOROETHYLENE	4	0	1	13,853	0	3,517	21,370	5,343
ACETONE	3	0	5	0	4,308	0	4,309	1,436
BARIUM	3	0	17,400	3,105	0	0	3,110	1,037
CADMIUM	3	0	0	82,944	0	0	100,344	33,448
SEC-BUTYL ALCOHOL	3	0	0	0	990	0	990	330
VANADIUM (FUME OR DUST)	3	0	0	0	0	0	0	0
CALCIUM CYANAMIDE	0	0	0	0	0	0	0	0
CARBON DISULFIDE	0	0	0	0	0	0	0	0
DIETHANOLAMINE	0	0	0	0	0	0	0	0
HYDROGEN CYANIDE	0	0	0	0	0	0	0	0
METHYL ETHYLKETONE	2	0	0	0	0	339	0	170
N-BUTYL ALCOHOL	2	0	0	0	0	500	2	250
SILVER	2	5	0	2,666	0	0	2	1,336
THIOUREA	0	0	0	0	0	0	2	0
ALUMINIUM OXIDE (FIBROUS)	1	0	0	0	52,717	0	1	52,117
ARSENIC	0	0	0	0	0	0	1	0
BROMOTRIFLUOROMETHANE	0	0	0	0	0	0	1	0
BUTYL BENZYL PHITALATE	0	0	0	0	0	0	1	0
CARBON SULFIDE	0	0	0	0	0	0	1	0
METHYL ISOBUTYL KETONE	0	0	0	0	0	0	1	0
POLYCHLORINATED BIPHENYLS	1	0	18,691	0	6,428	0	1	25,119
PYRIDINE	0	0	0	0	0	0	1	0
SELENIUM COMPOUNDS	1	0	736	0	0	0	1	736
1,3- BUTADIENE	0	0	0	0	0	0	1	0
2,4- DIMETHYLPHENOL	0	0	0	0	0	0	1	0
TOTAL	381	8,402,697	63,104,571	487,776,079	41,420,180	8,742,247	609,539,881	1,599,842

Exhibit 4: Top 10 TRI Releasing Iron and Steel Facilities		
Rank	**Facility**	**Total TRI Releases in Pounds**
1	Elkem Metals Co* - Marietta, OH	18,604,572
2	Northwestern Steel & Wire Co - Sterling, IL	14,274,570
3	Granite City Steel - Granite City, IL	5,156,148
4	Midwest Steel Div Midwest Steel Div - Portage, IN	4,735,000
5	AK Steel Corp Middletown Works - Middletown, OH	4,189,050
6	Bethlehem Steel Corp Burns Harbor Div - Burns Harbor, IN	3 899 470
7	Wheeling-Pittsburgh Steel Corp Mingo Junction Plant - Mingo Junction, OH	3,089,795
8	USS Gary Works - Gary, IN	2,403,348
9	LTV Steel Co Inc Cleveland Works - Cleveland, OH	1,985,131
10	Gulf States Steel Inc - Gadsden, AL	1,959,707

Source· U S EPA *Toxic Release Inventory Database*, 1993.
* This is an Electrometallurgical Products facility, not a steel mill

Summary of Selected Chemicals Released

The following is a synopsis of current scientific toxicity and fate information for the top chemicals (by weight) that facilities within this sector self-reported as released to the environment in the U.S.. Because this section is based upon self-reported release data, it does not attempt to provide information on management practices employed by the sector to reduce the release of these chemicals.

The brief descriptions provided below were taken from the 1993 *Toxics Release Inventory Public Data Release* (EPA, 1994), and the Hazardous Substances Data Bank (HSDB), accessed via TOXNET TOXNET is a computer system run by the National Library of Medicine It includes a number of toxicological databases managed by EPA, the National Cancer Institute, and the National Institute for Occupational Safety and Health. HSDB contains chemical-specific information on manufacturing and use, chemical and physical properties, safety and handling, toxicity and biomedical effects, pharmacology, environmental fate and exposure potential, exposure standards and regulations, monitoring and analysis methods, and additional references. The information contained below is based upon exposure assumptions that have been conducted using standard scientific procedures. The effects listed below must be taken in context of these exposure assumptions that are more fully explained within the full chemical profiles in HSDB. TOXNET can be accessed through the Internet at the Donetsk Technical Information Center.

Ammonia

Sources In cokemaking, ammonia is produced by the decomposition of the nitrogen-containing compounds-which takes place during the secondary thermal reaction (at temperatures greater than 700°C (1296°F)). The ammonia formed during coking exists in both the water and gas that form part of the volatile products. The recovery of this ammonia

can be accomplished by several different processes where the by-product ammonium sulfate is formed by the reaction between the ammonia and sulfuric acid.

Toxicity. Anhydrous ammonia is irritating to the skin, eyes, nose, throat, and upper respiratory system.

Ecologically, ammonia is a source of nitrogen (an essential element for aquatic plant growth), and may therefore contribute to eutrophication of standing or slow-moving surface water, particularly in nitrogen-limited waters. In addition, aqueous ammonia is moderately toxic to aquatic organisms.

Carcinogenicity. There is currently no evidence to suggest that this chemical is carcinogenic.

Environmental Fate. Ammonia combines with sulfate ions in the atmosphere and is washed out by rainfall, resulting in rapid return of ammonia to the soil and surface waters.

Ammonia is a central compound in the environmental cycling of nitrogen. Ammonia in lakes, rivers, and streams is converted to nitrate.

Physical Properties. Ammonia is a corrosive and severely irritating gas with a pungent odor.

Hydrochloric Acid

Sources. During hot rolling, a hard black iron oxide is formed on the surface of the steel This "scale" is removed chemically in the pickling process which commonly uses hydrochloric acid.

Toxicity. Hydrochloric acid is primarily a concern in its aerosol form. Acid aerosols have been implicated in causing and exacerbating a variety of respiratory ailments. Dermal exposure and ingestion of highly concentrated hydrochloric acid can result in corrosivity.

Ecologically, accidental releases of solution forms of hydrochloric acid may adversely affect aquatic life by including a transient lowering of the pH (i.e., increasing the acidity) of surface waters.

Carcinogenicity. There is currently no evidence to suggest that this chemical is carcinogenic.

Environmental Fate. Releases of hydrochloric acid to surface waters and soils will be neutralized to an extent due to the buffering capacities of both systems. The extent of these reactions will depend on the characteristics of the specific environment.

Physical Properties. Concentrated hydrochloric acid is highly corrosive.

Manganese and Manganese Compounds

Sources. Manganese is found in the iron charge and is used as an addition agent added to alloy steel to obtain desired properties in the final product. In carbon steel, manganese is used to combine with sulfur to improve the ductility of the steel. An alloy steel with manganese is used for applications involving relatively small sections which are subject to severe service conditions, or in larger sections where the weight saving derived from the higher strength of the alloy steels is needed.

Toxicity. There is currently no evidence that human exposure to manganese at levels commonly observed in ambient atmosphere results in adverse health effects However, recent EPA review of the fuel additive MMT (methylcyclopentadienyl manganese tricarbonyl)

concluded that use of MMT in gasoline could lead to ambient exposures to manganese at a level sufficient to cause adverse neurological effects in humans.

Chronic manganese poisoning bears some similarity to chronic lead poisoning. Occurring via inhalation of manganese dust or fumes, it primarily involves the central nervous system. Early symptoms include languor, speech disturbances, sleepiness, and cramping and weakness in legs A stolid mask-like appearance of face, emotional disturbances such as absolute detachment broken by uncontrollable laughter, euphoria, and a spastic gait with a tendency to fall while walking are seen in more advanced cases. Chronic manganese poisoning is reversible if treated early and exposure stopped Populations at greatest risk of manganese toxicity are the very young and those with iron deficiencies.

Ecologically, although manganese is an essential nutrient for both plants and animals, in excessive concentrations manganese inhibits plant growth.

Carcinogenicity. There is currently no evidence to suggest that this chemical is carcinogenic.

Environmental Fate. Manganese is an essential nutrient for plants and animals. As such, manganese accumulates in the top layers of soil or surface water sediments and cycles between the soil and living organisms. It occurs mainly as a solid under environmental conditions, though may also be transported in the atmosphere as a vapor or dust.

1 1 1-Trichloroethane

Sources. Used for surface cleaning of steel prior to coating.

Toxicity Repeated contact of 1,1,1-trichloroethane (TCE) with skin may cause serious skin cracking and infection. Vapors cause a slight smarting of the eyes or respiratory system if present in high concentrations.·

Exposure to high concentrations of TCE causes reversible mild liver and kidney dysfunction, central nervous system depression, gait disturbances, stupor, coma, respiratory depression, and even death. Exposure to lower concentrations of TCE leads to light-headedness, throat irritation, headache, disequilibrium, impaired coordination, drowsiness, convulsions and mild changes in perception.

Carcinogenicity. There is currently no evidence to suggest that this chemical is carcinogenic.

Environmental Fate. Releases of TCE to surface water or land will almost entirely volatilize. Releases to air may be transported long distances and may partially return to earth in rain. In the lower atmosphere, TCE degrades very slowly by photooxidation and slowly diffuses to the upper atmosphere where photodegradation is rapid.

Any TCE that does not evaporate from soils leaches to groundwater. Degradation in soils and water is slow. TCE does not hydrolyze in water, nor does it significantly bioconcentrate in aquatic organisms.

Zinc and Zinc Compounds

Sources. To protect steel from rusting, it is coated with a material that will protect it from moisture and air. In the galvanizing process, steel is coated with zinc.

Toxicity. Zinc is a nutritional trace element; toxicity from ingestion is low. Severe exposure to zinc might give rise to gastritis with vomiting due to swallowing of zinc dusts. Short-term exposure to very high levels of zinc is linked to lethargy, dizziness, nausea, fever, diarrhea,

and reversible pancreatic and neurological damage. Long-term zinc poisoning causes irritability, muscular stiffness and pain, loss of appetite, and nausea.

Zinc chloride fumes cause injury to mucous membranes and to the skin. Ingestion of soluble zinc salts may cause nausea, vomiting, and purging.

Carcinogenicity. There is currently no evidence to suggest that this chemical is carcinogenic.

Environmental Fate. Significant zinc contamination of soil is only seen in the vicinity of industrial point sources. Zinc is a relatively stable soft metal, though burns in air. Zinc bioconcentrates in aquatic organisms.

Analysis of Typical Releases

Table 5 summarizes annual US releases of carbon monoxide (CO), nitrogen dioxide (NO_2), particulate matter of 10 microns or less (PM10), total particulates (PT), sulfur dioxide (SO_2), and volatile organic compounds (VOCs). With 1.5 million short tons/year of carbon monoxide, the iron and steel industry emissions are estimated as more than twice as much as the next largest releasing industry, pulp and paper. Of the eighteen industries listed, the iron and steel industry also ranks as one of the top five releasers for NO_2, PM10, PT, and SO_2. Carbon monoxide releases occur during ironmaking (in the burning of coke, CO produced reduces iron oxide ore), and during steelmaking (in either the basic oxygen furnace or the electric arc furnace). Nitrogen dioxide is generated during steelmaking. Particulate matter may be emitted from the cokemaking (particularly in quenching operations), ironmaking, basic oxygen furnace (as oxides of iron that are emitted as sub-micron dust), or from the electric arc furnace (as metal dust containing iron particulate, zinc, and other materials associated with the scrap). Sulfur dioxide can be released in ironmaking or sintering.

Comparison of Toxic Release Inventory Between Selected Industries

The following information is presented as a comparison of pollutant release and transfer data across industrial categories. It is provided to give a general sense as to the relative scale of releases and transfers.

Figure 4 is a graphical representation of a summary of data for the iron and steel industry. The bar graph presents the total releases and total transfers on the left axis and the triangular points show the average releases per facility on the right axis. Industry sectors are presented in the order of increasing total releases. The graph is meant to facilitate comparisons between the relative amounts of releases, transfers, and releases per facility both within and between these sectors.

POLLUTION PREVENTION OPPORTUNITIES

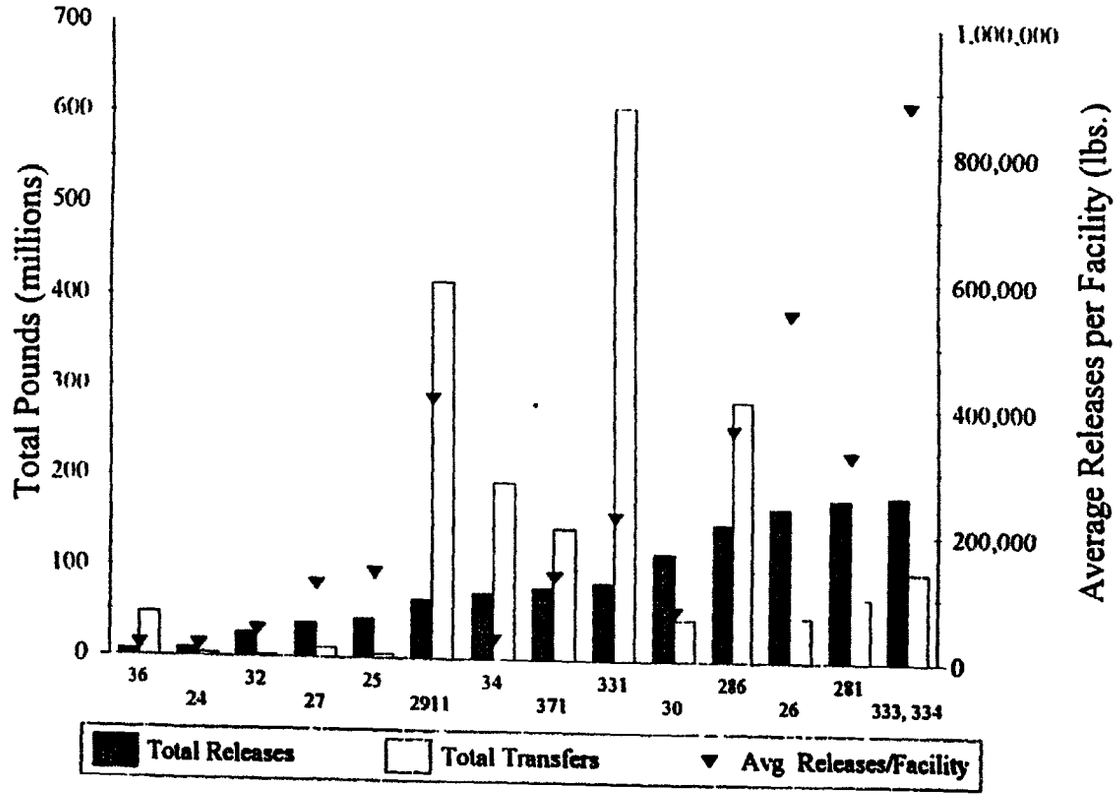
The best way to reduce pollution is to prevent it in the first place. Some companies have creatively implemented pollution prevention techniques that improve efficiency and increase profits while at the same time minimizing environmental impacts. This can be done in many ways such as reducing material inputs, re-engineering processes to reuse by-products, improving management practices, and employing substitution of toxic chemicals Some smaller facilities are able to actually get below regulatory thresholds just by reducing pollutant releases through aggressive pollution prevention policies.

In order to encourage these approaches, this section provides both general and company-specific descriptions of some pollution prevention advances that have been implemented

TABLE 5. POLLUTANT RELEASES (SHORT TONS/PER YEAR)

INDUSTRY SECTOR	CO	NO_2	PM_{10}	PT	SO_2	VOC
U S TOTAL	97,208,000	23,402,000	45,489,000	7,836,000	21,888,000	23,312,000
METAL MINING	5,391	28,583	39,359	140,052	84,222	1,283
NONMETAL MINING	4,525	28,804	59,305	167,948	24,129	1,736
LUMBER and WOOD PRODUCTION	123,756	42,658	14,135	63,761	9,419	41,423
FURNITURE and FIXTURES	2,069	2,981	2,165	3,178	1,606	59,426
PULP and PAPER	624,291	394,448	35,579	113,571	541,002	96,875
PRINTING	8,463	4,915	399	1,031	1,728	101,537
INORGANIC CHEMICALS	166,147	103,575	4,107	39,062	182,189	52,091
ORGANIC CHEMICALS	146,947	236,826	26,493	44,860	132,459	201,888
PETROLEUM REFINING	419,311	380,641	18,787	36,877	648,155	369,058
RUBBER and MISC PLASTICS	2,090	11,914	2,407	5,355	29,364	140,741
STONE,CLAY and CONCRETE	58,043	338,482	74,623	171,853	339,216	30,262
IRON and STEEL	**1,518,642**	**138,985**	**42,368**	**83,017**	**238,268**	**82,292**
NONFERROUS METALS	448,758	55,658	20,074	22,490	373,007	27,375
FABRICATED METALS	3,851	16,424	1,185	3,136	4,019	102,186
COMPUTER and OFFICE EQUIPMENT	24	0	0	0	0	0
ELECTRONICS and OTHER ELECTRICAL EQUIPMENT and COMPONENTS	367	1,129	207	293	453	4,854
MOTOR VEHICLES,BODIES ,PARTS and ACCESSORIES	35,303	23,725	2,406	12,853	25,462	101,275
DRY CLEANING	101	179	3	28	152	7,310

SOURCE U S EPA OFFICE of AIR and RADIATION, AIRS DATABASE, MAY 1995



SIC Range	Industry Sector	SIC Range	Industry Sector	SIC Range	Industry Sector
36	Electronic Equipment and Components	2911	Petroleum Refining	286	Organic Chemical Mfg.
24	Lumber and Wood Products	34	Fabricated Metals	26	Pulp and Paper
32	Stone , Clay , and Concrete	371	Motor Vehicles, Bodies and Accessories	281	Inorganic Chemical Mfg.
27	Printing	331	Iron and Steel	333,334	Nonferrous Metals
25	Wood Furniture and Fixtures	30	Rubber and Misk. Plastics		

Figure 4. Releases and Transfers by Industry

within the iron and steel industry. While the list is not exhaustive, it does provide core information that can be used as the starting point for facilities interested in beginning their own pollution prevention projects. This section provides summary information from activities that may be, or are being implemented by this sector. When possible, information is provided that gives the context in which the technique can be effectively used. Note that the activities described in this section do not necessarily apply to all facilities that fall within this sector. Facility-specific conditions must be carefully considered when pollution prevention options are evaluated, and the full impacts of the change must examine how each option affects air, land and water pollutant releases.

Most of the pollution prevention activities in the iron and steel industry have concentrated on reducing cokemaking emissions, Electric Arc Furnace (EAF) dust, and spent acids used in finishing operations. Due to the complexity, size, and age of the equipment used in steel manufacturing, projects that have the highest pollution prevention potential often require significant capital investments. This section describes pollution prevention opportunities for each of the three focus areas (cokemaking, EAF dust, and finishing acids), and then lists some general pollution prevention opportunities that have been identified by the iron and steel industry.

Cokemaking

The cokemaking process is seen by industry experts as one of the steel industry's areas of greatest environmental concern, with coke oven air emissions and quenching waste water as the major problems. In response to expanding regulatory constraints, U.S. steelmakers are turning to new technologies to decrease the sources of pollution from, and their reliance on, coke Pollution prevention in cokemaking has focused on two areas· reducing coke oven emissions and developing cokeless ironmaking techniques Although these processes have not yet been widely demonstrated on a commercial scale, they may provide significant benefits for the integrated segment of the industry in the form of substantially lower air emissions and wastewater discharges than current operations.

Eliminating Coke with Cokeless Technologies

Cokeless technologies substitute coal for coke in the blast furnace, eliminating the need for cokemaking. Such technologies have enormous potential to reduce pollution generated during the steelmaking process. The capital investment required is also significant. Some of the cokeless technologies in use or under development include:

- *The Japanese Direct Iron Ore Smelting (DIOS) process.* This process produces molten iron directly with coal and sinter feed ore. A 500 ton per day pilot plant was started up in October, 1993 and the designed production rates were attained as a short term average. The data generated is being used to determine economic feasibility on a commercial scale.

- *HIsmelt process.* A plant using the HIsmelt process for molten iron production, developed by HIsmelt Corporation of Australia, was started up in late 1993. The process, using ore fines and coal, has achieved a production rate of 8 tons per hour using ore directly in the smelter Developers anticipate reaching the production goal of 14 tons per hour. If commercial feasibility is realized, Midrex is expected to become the U.S. engineering licensee of the HIsmelt process.

- *Corex process.* The Corex or Cipcor process has integral coal desulfurizing, is amenable to a variety of coal types, and generates electrical power in excess of that required by an iron and steel mill which can be sold to local power grids. A Corex

plant is in operation in South Africa, and other plants are expected to be operational in the next two years in South Korea and India.

Reducing Coke Oven Emissions

Several technologies are available or are under development to reduce the emissions from coke ovens. Typically, these technologies reduce the quantity of coke needed by changing the method by which coke is added to the blast furnace or by substituting a portion of the coke with other fuels. The reduction in the amount of coke produced proportionally reduces the coking emissions. Some of the most prevalent or promising coke reduction technologies include:

- *Pulverized coal injection.* This technology substitutes pulverized coal for a portion of the coke in the blast furnace. Use of pulverized coal injection can replace about 25 to 40 percent of coke in the blast furnace, substantially reducing emissions associated with cokemaking operations. This reduction ultimately depends on the fuel injection rate applied to the blast furnaces which will, in turn be dictated by the aging of existing coking facilities, fuel costs, oxygen availability, capital requirements for fuel injection, and available hot blast temperature.

- *Non-recovery coke battery.* As opposed to the by-product recovery coke plant, the non-recovery coke battery is designed to allow combustion of the gasses from the coking process, thus consuming the by-products that are typically recovered. The process results in lower air emissions and substantial reductions in coking process wastewater discharges.

- *The Davy Still Autoprocess.* In this pre-combustion cleaning process for coke ovens, coke oven battery process water is utilized to strip ammonia and hydrogen sulfide from coke oven emissions.

- *Alternative fuels.* Steel producers can also inject other fuels, such as natural gas, oil, and tar/pitch, instead of coke into the blast furnace, but these fuels can only replace coke in limited amounts.

Recycling of Coke By-products

Improvements in the in-process recycling of tar decanter sludge, a hazardous waste, are common practice. Sludge can either be injected into the ovens to contribute to coke yield, or converted into a fuel that is suitable for the blast furnace.

Reducing Wastewater Volume

In addition to air emissions, quench water from cokemaking is also an area of significant environmental concern. In Western Europe, some plants have implemented technology to shift from water quenching to dry quenching in order to reduce energy costs. However, there are major construction changes required for such a solution.

Electric Arc Furnace Dust

Dust generation in the EAF, and its disposal, have also been recognized as a serious problem, but one with potential for pollution prevention through material recovery. EAF dust is a hazardous waste because of its high concentrations of lead and cadmium Steel companies typically pay a disposal fee of $150 to $200 per ton of dust With an average zinc concentration of 19 percent, much of the EAF dust is shipped off-site for zinc reclamation.

Most of the EAF dust recovery options are only economically viable for dust with a zinc content of at least 15 - 20 percent. Facilities producing speciality steels such as stainless steel with a lower zinc content, still have opportunities to recover chromium and nickel from the EAF dust.

In-process recycling of EAF dust involves pelletizing and then reusing the pellets in the furnace, however, recycling of EAF dust on-site has not proven to be technically or economically competitive for all mills Improvements in technologies have made off-site recovery a cost effective alternative to thermal treatment or secure landfill disposal.

Pickling Acids

In finishing, pickling acids are recognized as an area where pollution prevention efforts can have a significant impact in reducing the environmental impact of the steel mill. The pickling process removes scale and cleans the surface of raw steel by dipping it into a tank of hydrochloric or sulfuric acid. If not recovered, the spent acid may be transported to deep injection wells for disposal.

Large-scale steel manufacturers commonly recover hydrochloric acid in their finishing operations, however the techniques used are not suitable for small- to medium-sized steel plants. Currently, a recovery technique for smaller steel manufacturers and galvanizing plants is in pilot scale testing. The system under development removes iron chloride (a saleable product) from the hydrochloric acid, reconcentrates the acid for reuse, and recondenses the water to be reused as a rinse water in the pickling process. Because the only by-product of the hydrochloric acid recovery process is a non-hazardous, marketable metal chloride, this technology generates no hazardous wastes. This technology is less expensive than transporting and disposing waste acid, plus it eliminates the associated long-term liability. The total savings for a small- to medium-sized galvanizer is projected to be $260,000 each year for U.S based facilities.

To reduce spent pickling liquor and simultaneously reduce fluoride in the plant effluent, one facility modified their existing treatment process to recover the fluoride ion from rinse water and spent pickling acid raw water waste streams. The fluoride is recovered as calcium fluoride (fluorspar), an input product for steelmaking. The melt shop in the same plant had been purchasing 930 tons of fluorspar annually for use as a furnace flux material in the EAF at a cost of $100 per ton. Although the process is still under development, the recovered calcium fluoride is expected to be a better grade than the purchased fluorspar, which would reduce the amount of flux used by approximately 10 percent. Not only would the generation rate of sludge from spent pickling liquor treatment be reduced (resulting in a savings in off-site sludge disposal costs), but a savings in chemical purchases would be realized.

Other areas with pollution prevention opportunities

Other areas in iron and steel manufacturing where opportunities may exist for pollution prevention are listed below, in three categories: process modifications, materials substitution, and recycling.

Process Modification

Redesigning or modifying process equipment can reduce pollution output, maintenance costs, and energy consumption, for example:

- Replacing single-pass wastewater systems with closed-loop systems to minimize chemical use in wastewater treatment and to reduce water use.

- Continuous casting, now used for about 90% of crude steel cast in the U.S., offers great improvements in process efficiency when compared to the traditional ingot teeming method This increased efficiency also results in a considerable savings in energy and some reduction in the volume of mill wastewater.

Materials Substitution

- Use scrap steel with low lead and cadmium content as a raw material, if possible.

- Eliminate the generation of reactive desulfurization slag generated in foundry work by replacing calcium carbide with a less hazardous material.

Recycling

Scrap and other materials are recycled extensively in the iron and steel industry to reduce the raw materials required and the associated pollutants. Some of these recycling activities include:

- Recycle or reuse oils and greases.
- Recover acids by removing dissolved iron salts from spent acids.
- Use thermal decomposition for acid recovery from spent pickle liquor.
- Use a bipolar membrane/electrodialytic process to separate acid from metal by-products in spent NO_3-HF pickle liquor
- Recover sulfuric acid using low temperature separation of acid and metal crystals.

DESCRIPTION OF THE MARIUPOL ILLICH IRON AND STEEL PLANT.

Overview.

The Mariupol Illich Iron and Steel Plant is one of the largest steelmaking plants in the Oblast with a complete metallurgical cycle. Figures 5 and 6 provide an overall process flowsheet of the operation and a general material balance, respectively. Photographs of the entrance to the facility are shown in Figures 7 and 8.

The plant consists of:

- Agglomeration plant with 12 agglomeration units;
- Blast-furnace shop with 5 blast furnaces with a total capacity of 8147 cubic meters;
- Open-hearth mill with the capacity 900 tons (3 furnaces) and 650 tons (3 furnaces);
- Oxygen shop with 3 converters-160 tons each;
- Slabbing mill "1150";
- Sheet rolling mill "1700" and "3000",
- Cold rolling mill;
- Pipe arc welding shop;
- Gas cylinder shop;
- Repair and accessory shops.

The energy-producing system of the plant (heat and electric power plants, boiler houses) has 21 hot water heaters with different degrees of production capacity. The plant has machinery for the complete processing of metallurgical slags. The plant produces commercial cast iron, different brands of steel in slabs and ingots, metal sheets of cold rolling and hot rolling, hot rolled pipes and welded pipes, cylinders for compressed gases, building materials from metallurgical slags.

Iron ore, coke, lime, agglomerate, manganese ore are the raw materials for the primary production Metallurgical coke, petroleum residue, natural and blast furnace gases are the fuel In 1989, 11 3 million tons of agglomerate, 5.1 million tons of cast iron, 6 3 million tons of steel, 7.7 million tons of rolled products were manufactured by the facility. During subsequent years, due to industry recession , the amounts of production manufactured by the plant decreased steadily and in 1995 production capacities fell to

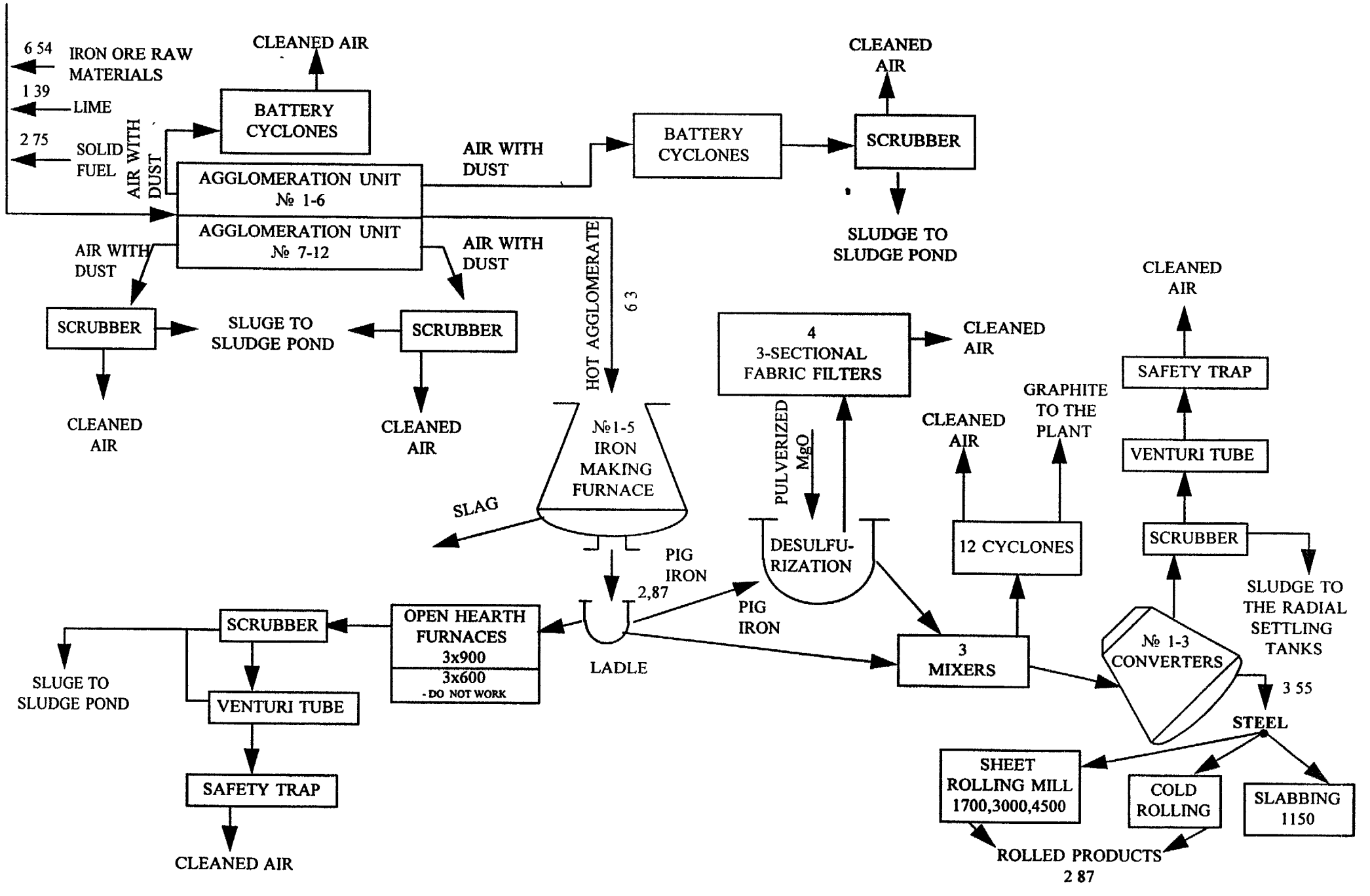


Figure 6. Material Flows in million tons during the 10 months of 1996

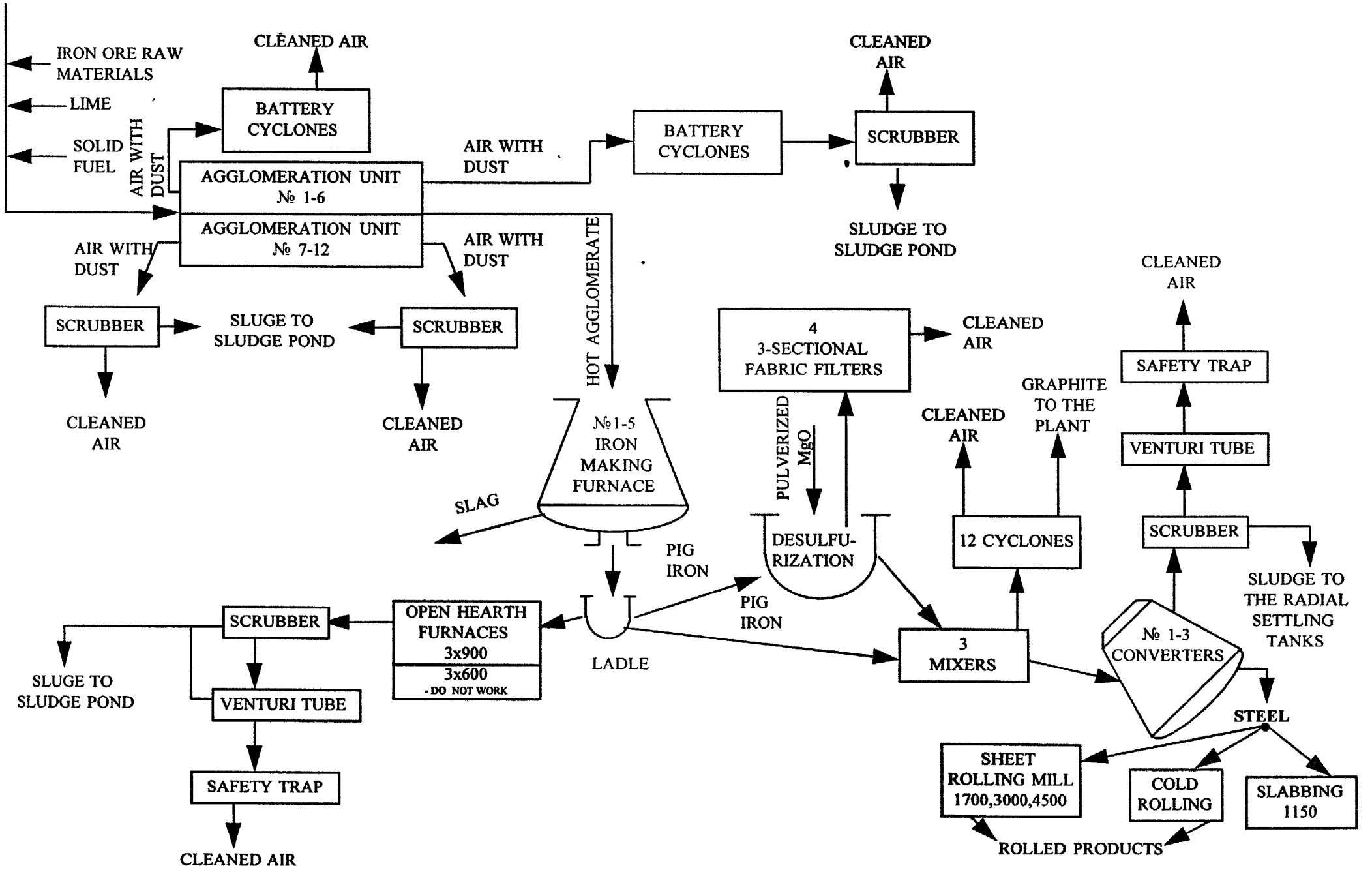


Figure 5. Illich Plant Flowsheet.

- Agglomerate - 7.107 million tons (a 37.1% reduction over 1989 productivity);
- Pig iron - 3 208 million tons (a 37.1% reduction),
- Steel - 4.4 million tons (43.2%);
- Rolled products - 4.5 million tons (41.5%)

During the first 10 months of the current 1996 year the following amounts of products were manufactured by the plant:

- Agglomerate - 6.383 million tons;
- Pig iron - 2.877 million tons;
- Steel - 3.577 million tons;
- Rolled products - 2.871 million tons.

Agglomeration.

The agglomeration plant, which is a part of the Illich Iron and Steel Plant, is designed for the processing of pulverized ore, concentrates and sludge from the gas purification of the blast furnace, steel and oxygen shops, scale from the rolling mills and other ferriferous materials (refer to Figure 9)

During the production of agglomerate the following raw and other materials are used in the agglomerated charge· iron ore raw materials (concentrate, agglomerated ore, sifting of the agglomerate from the blast furnace shop, blast furnace dust, dross, sludge, manganese ore, manganese sludge) ,return sludge, limestone, dolomitic limestone and solid fuel (coal brand AS and coke fines).

The agglomeration plant consists of 2 lines, each equipped with 6 agglomeration units (brand AKM 85/160). In all, there are 12 agglomeration units at the plant (the 1st line - agglomeration units 1-6, the 2nd line - agglomeration units 7-12). On the average, 8 out of 12 units are in operation. The productivity of the agglomeration plant is less than 8 million tons of agglomerate per year, while the rated capacity is 12 million tons per year.

Both lines on the agglomeration plant are equipped with gas purification systems, both on the cold and hot sides. Gas purification systems of the first line were put into operation in 1966, and the second line in 1969.

On the cold side, the 1st line is equipped with a battery of cyclones (brand BC 540) and scrubbers; the 2nd line is equipped only with scrubbers (Figures 10-15) On the hot side both lines are equipped with gas purifying facilities - a battery of cyclones (brand BC 800) and scrubbers (Figures 16-20) The scrubbers are in unsatisfactory conditions; they are heavily corroded and often stopped for unplanned repairs.

At present the reconstruction of the gas-purifying facilities of the cooling area of agglomeration unit #6 is under way and on the 2nd line, an aspiration system is being reconstructed with the installation of electrostatic precipitators made by a French company "Spake" These will replace the existing battery cyclones (refer to Figure 21).

Blast Furnace Shop.

There are 5 blast furnaces (#1-5) at the Illich Iron and Steel Plant that produce pig iron. Ore, agglomerate, pellets and flux are used during its production, with the coke and natural gas used as fuel (refer to Figure 22-28). The pig iron, in ladles, then goes either to the desulfurization installation or directly to the production of steel. Slag that is generated during the process of smelting is granulated for future utilization. Gas-cleaning facilities were installed during the construction of blast furnaces (Figure 28-29). The gas cleaning is carried out in 2 steps: in the 1st step- large fractions of blast furnace dust are deposited into railway cars which are sent to the agglomeration plant and is used as an admixture to the agglomerate; in the 2nd step, the gas is scrubbed. Dust catching and gas cleaning units from the blast furnaces 2,3,5 do not work properly and only intermittently (refer to Figure 31).

Desulfurization.

The cast iron desulfurization department is incorporated into the blast furnace shop (refer to Figure 32) The installation has one line designed for 5 deposits (ladles), but only 4 of them operate (Figure 33) Desulfurization takes place with the pulverized MgO supply (Figures 34-36) The facilities have 2 exhaust fans (one exhaust fan for two gas outlet hoods). (Refer to Figures 37 through 39). Gas-purifying facilities are three-sectional fabric filters (brand FRKI-90, made in Romania in 1988). They were installed in 1994 (2 filters are in operation, 2 filters are at the storage facilities) and were put into operation in March 1996 (refer to Figures 40 through 43) Flying hot particles are responsible for damaging filter bags (Figure 44). The plant purchased new filtering fabric, but the new filter bags have not yet been installed. One of the hoods over the desulfurization unit is shorter in size. Practically speaking, the process of desulfurization is not employed on a continuous basis and only when there is the order from the converter shop. Normally, 50 ladles are operated and the cast iron cools off and crusts, and desulfurization can not be conducted according to the normal design basis.

Mixer Department.

Discharge of slag from the pig iron ladle, pouring of the pig iron into the mixer, discharge of the pig iron from the mixer into the steel ladle are the basic operations. Two mixer departments at the Illich Iron and Steel Plant (in the open hearth and converter shops) are not equipped with gas cleaning operations.

There are 3 mixers in the converter shop (Figures 45-46) At present, the dust content of the gases discharged through the aeration outlet in the mixer department is 800 mg/c.m (Figures 47-49) The floor in the mixer department is covered with a thick layer of graphite (refer to Figures 50 and 51).

A group of 12 cyclones is installed behind the mixers; the cyclones work unsatisfactorily and catch 15-20% of the flying graphite (see Figures 52-53) .At present the Illich Plant does not send the recovered graphite to the graphite plant.

Converter Department.

Three converters (160 tons each) are installed in the converter department (Figure 54). Converter #1 is inoperable During the audit there was emergency situation at converter #2 (see Figure 55) Only converter #3 was working at that time (Figures 56-58).

Converter #3 has a two-step system of gas cleaning. The first stage is a conventional scrubber, the second step is a Venturi scrubber, followed by two safety traps. There are only scrubbers behind converters #1 and 2 (see Figures 59-62). The sludge water from the scrubbers of the converter shop goes to radial settling tanks.

Figure 7. Central entrance to the Illich Iron and Steel Plant.

Figure 8 - Central office of the Illich Iron and Steel Plant.

Figure 9 - Building of the first unit of the agglomeration plant.

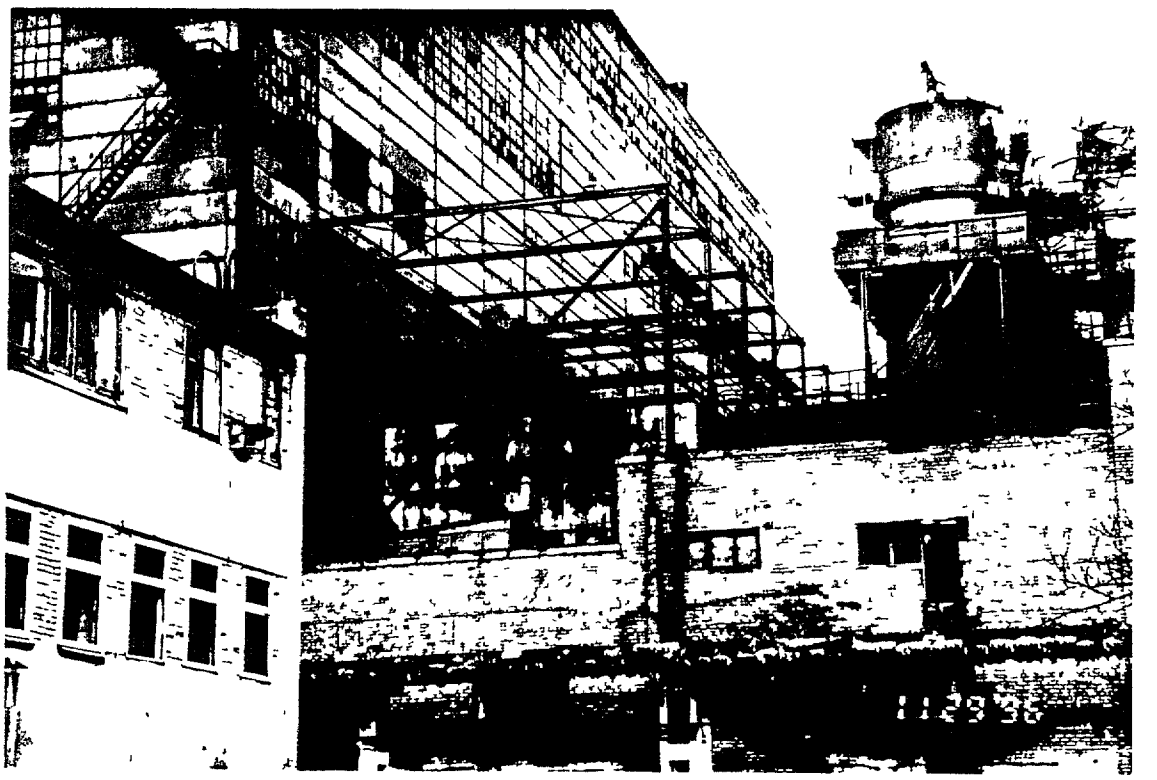


Figure 10 - Gas purification on the cold side of agglomeration building #1, battery cyclones and wet scrubbers.

Figure 11 - Gas purification on the cold side of agglomeration building #1, battery cyclones and wet scrubbers.

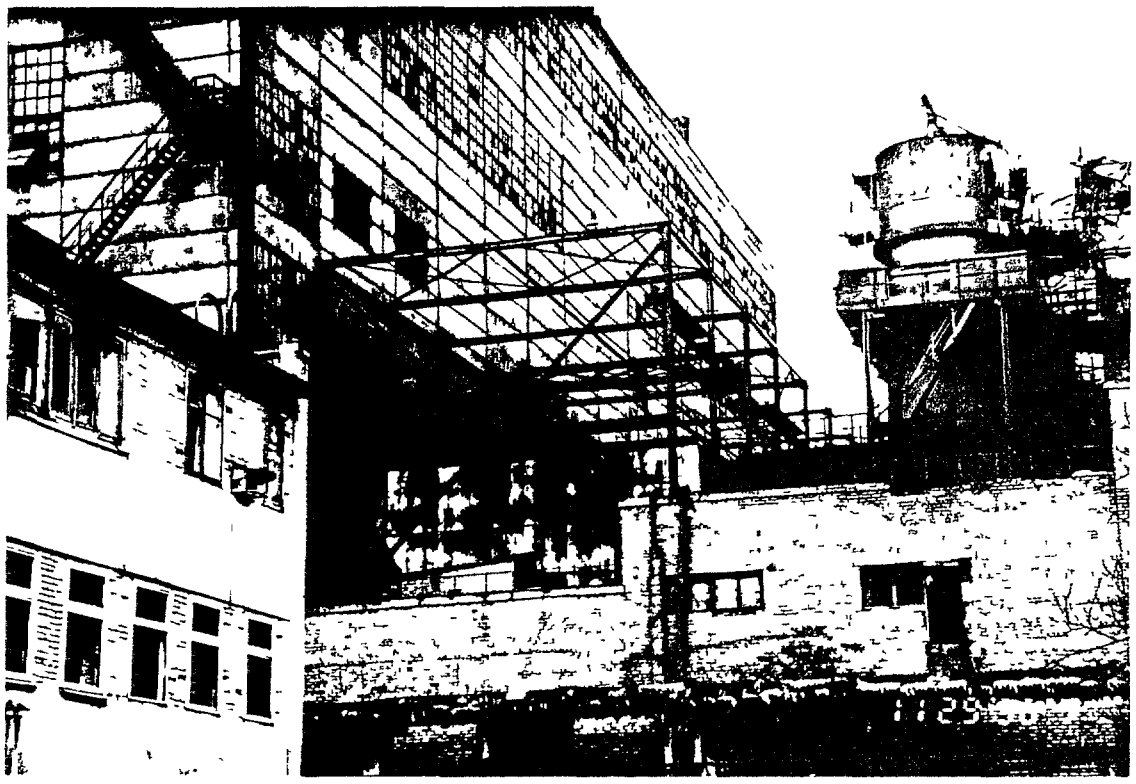


Figure 12 - Gas purification on the cold side of agglomeration building #1, battery cyclones and wet scrubbers.

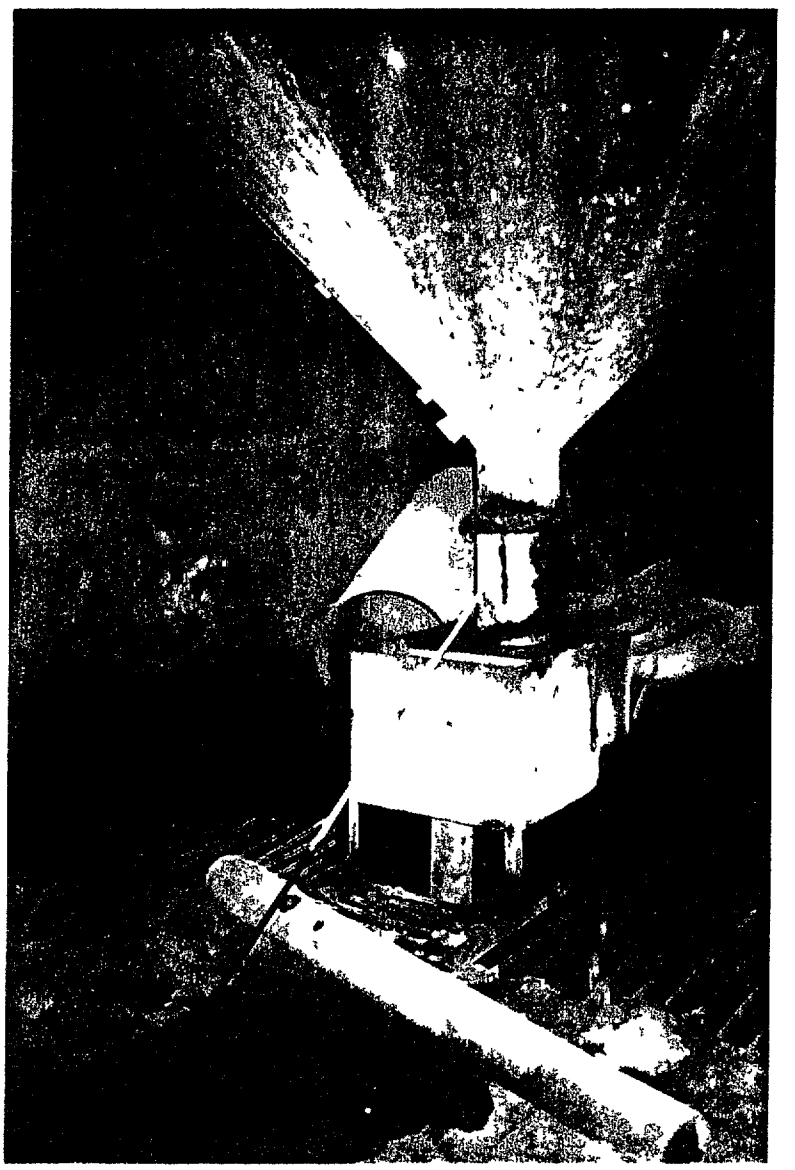


Figure 13- Discharge of the sludges from the scrubber.

Figure 14 - Smoke stack on the cold side of agglomeration building #2.

Figure 15- Smoke stack on the cold side of agglomeration building #1.

Figure 16- Gas purification on the hot side.

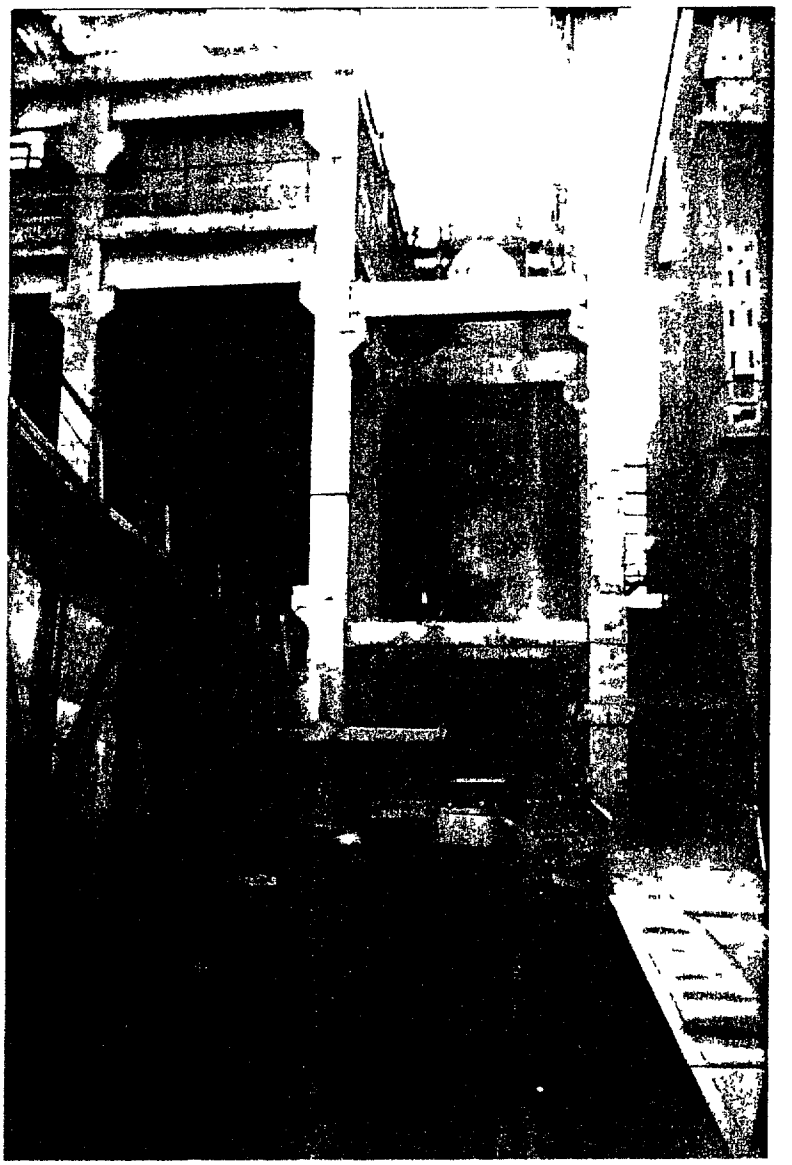


Figure 17- Gas purification on the hot side.

Figure 18- Gas purification on the hot side, battery cyclones.

Figure 19- Gas conduit of the gas purification system on the hot side.

Figure 20- Smoke stack on the hot side.

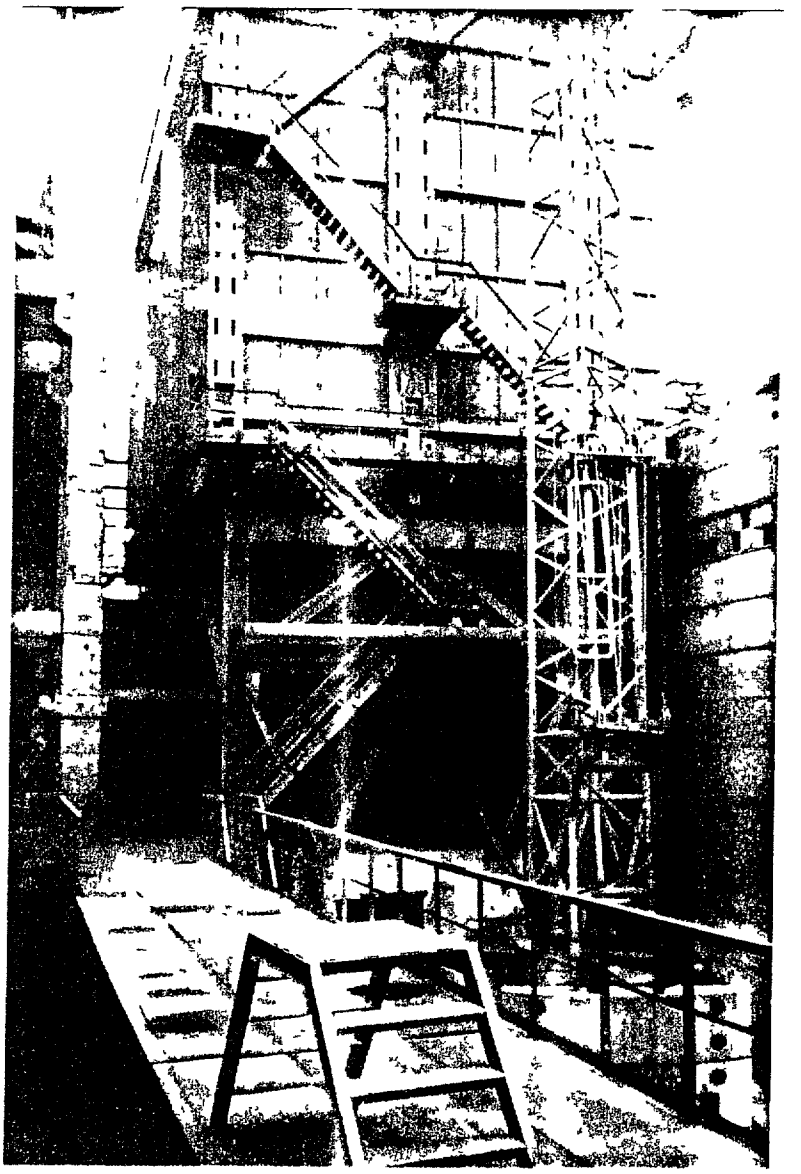


Figure 21- Agglomeration building#2, company "Spake" installs electrostatic precipitators at this place.

Figure 22 - Blast furnaces #1-5

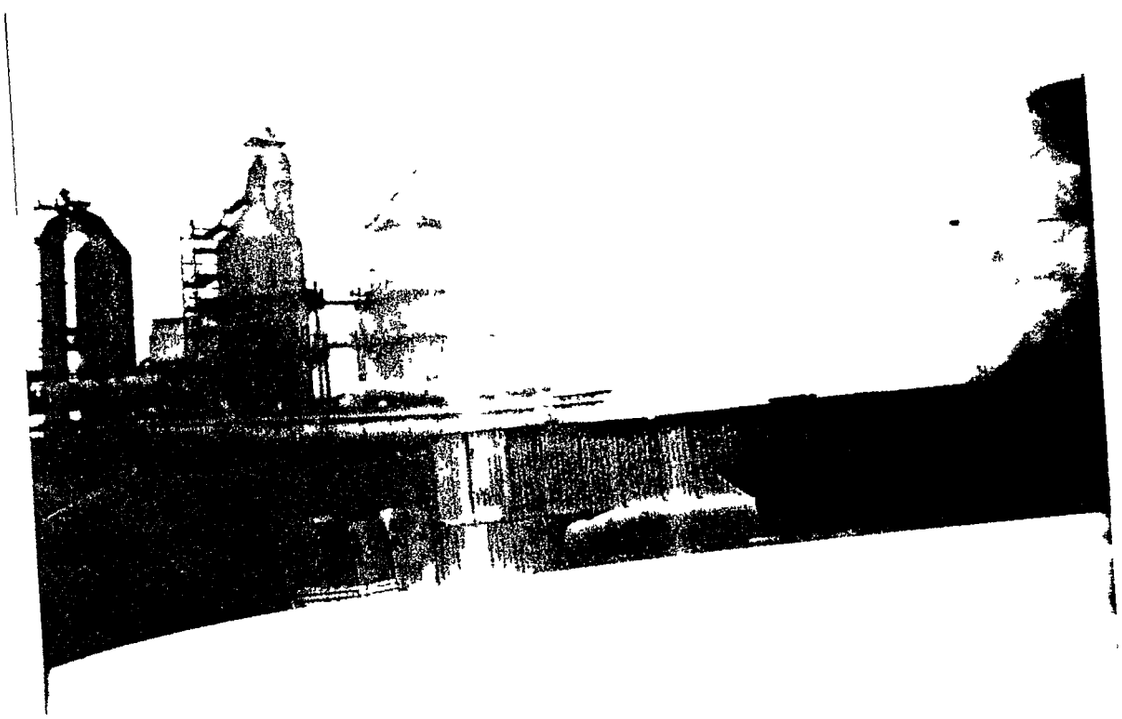


Figure 23 - Blast furnaces #1-5

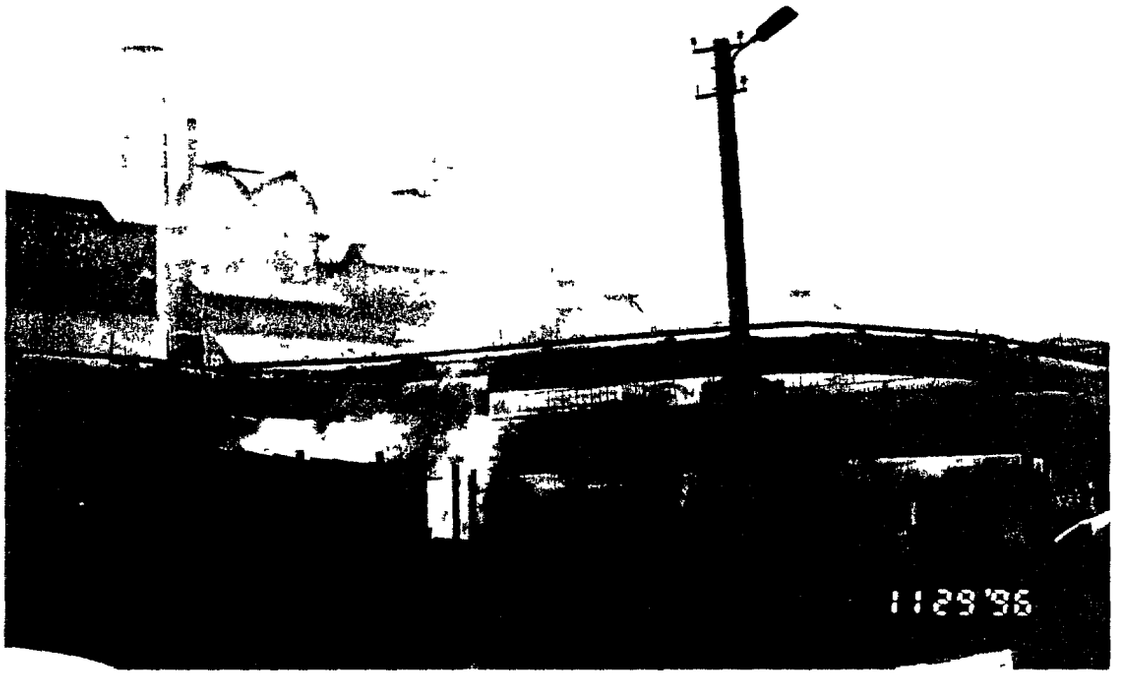


Figure 24 - Blast furnaces #1-5

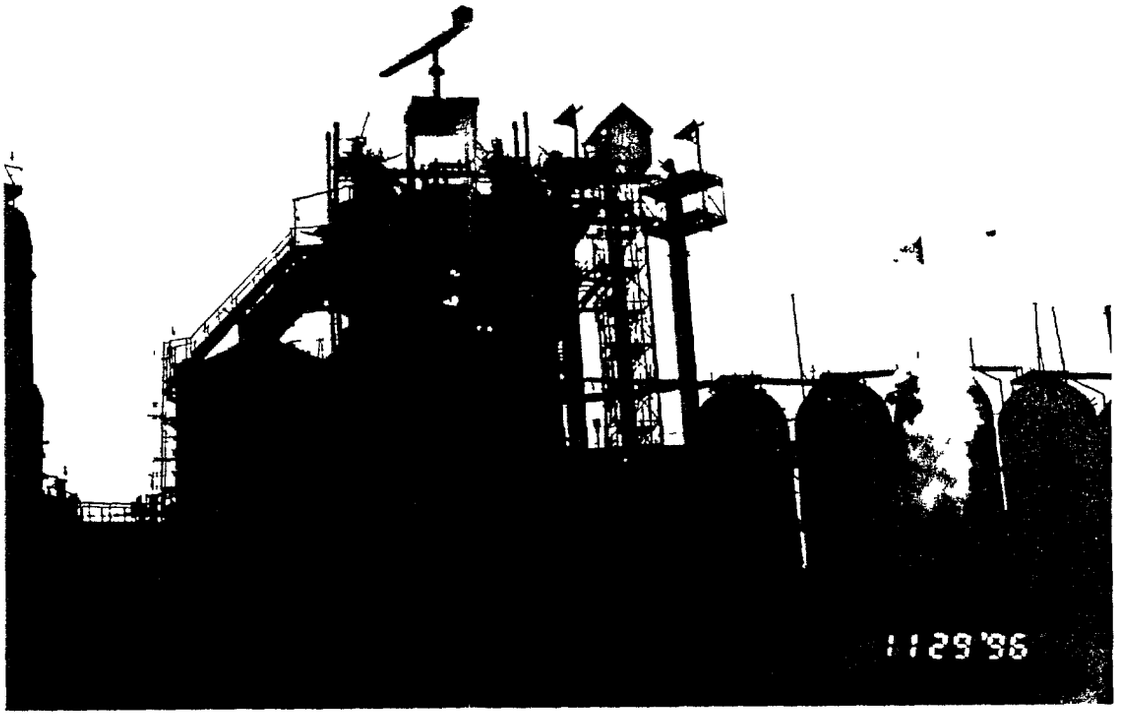


Figure 25 - Blast furnaces #1-5

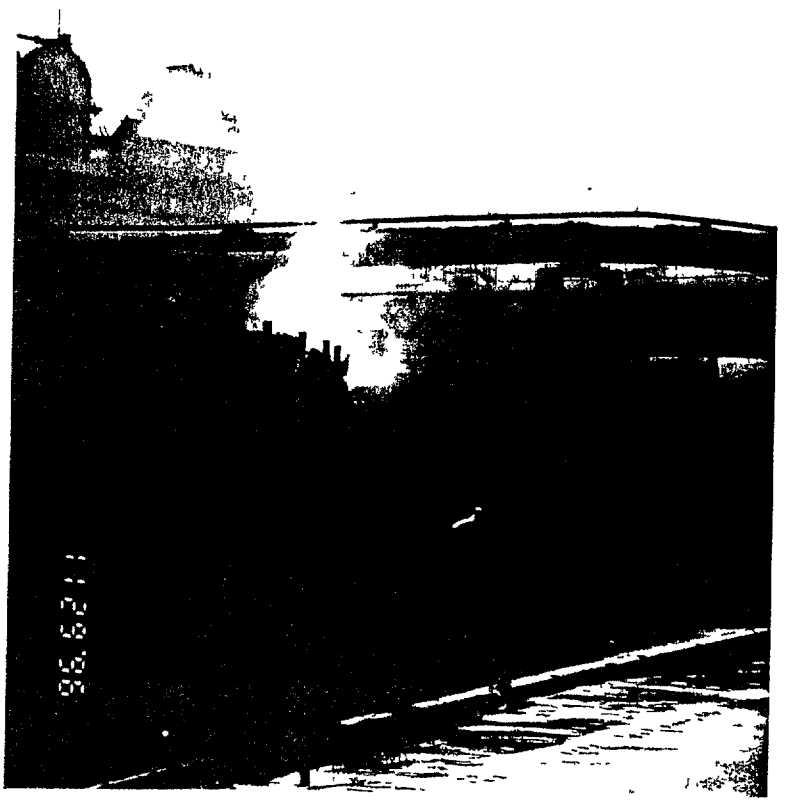


Figure 26 - Blast furnaces #1-5

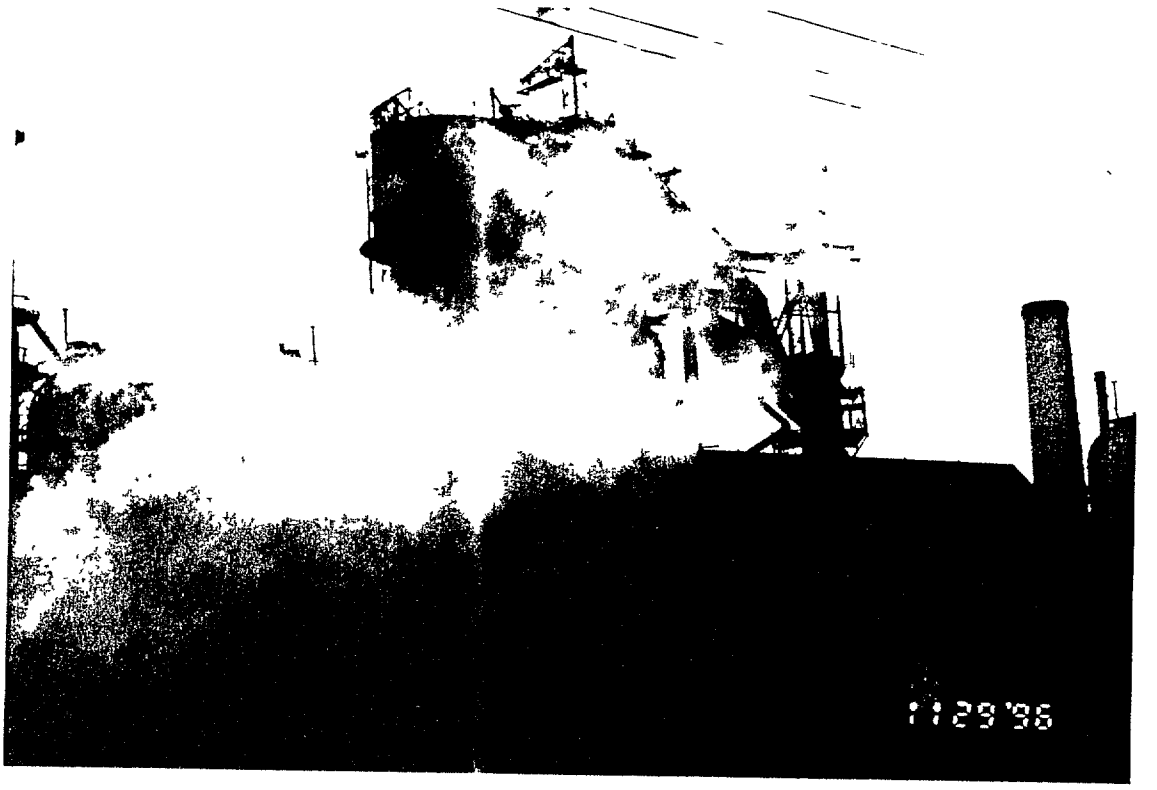


Figure 27 - Blast furnace #5 (capacity- 2000c.m.)

Figure 28 - Blast furnace #5 (capacity- 2000c.m.)

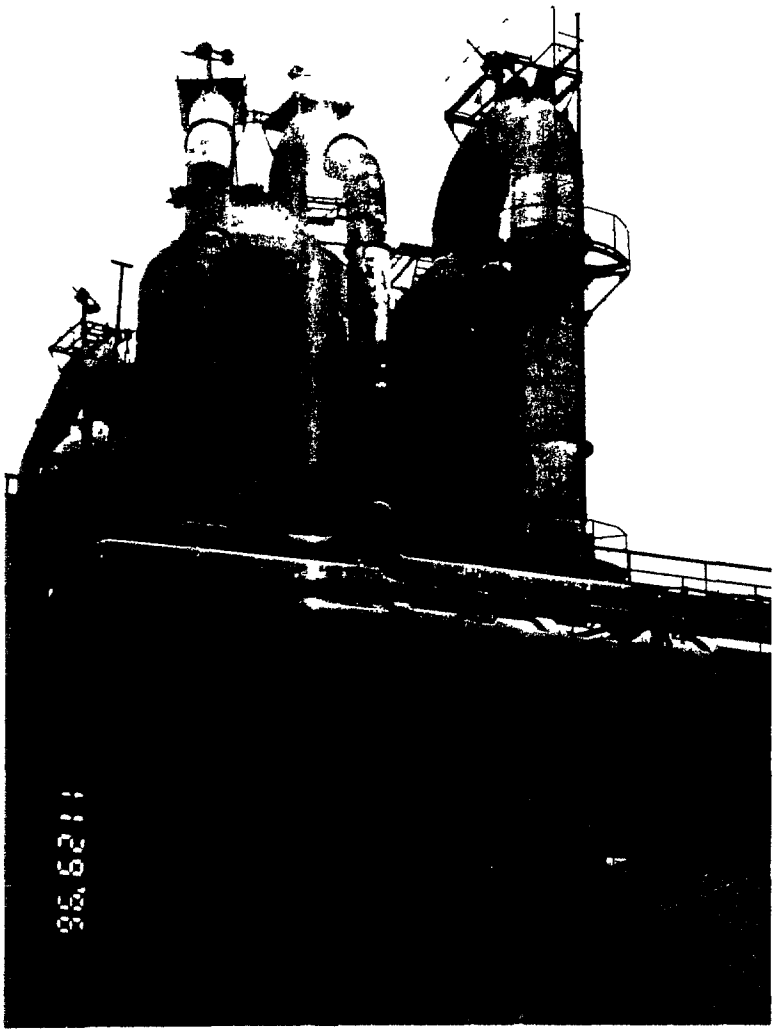


Figure 29 - Gas purification of the exhaust gases of blast furnace #5.

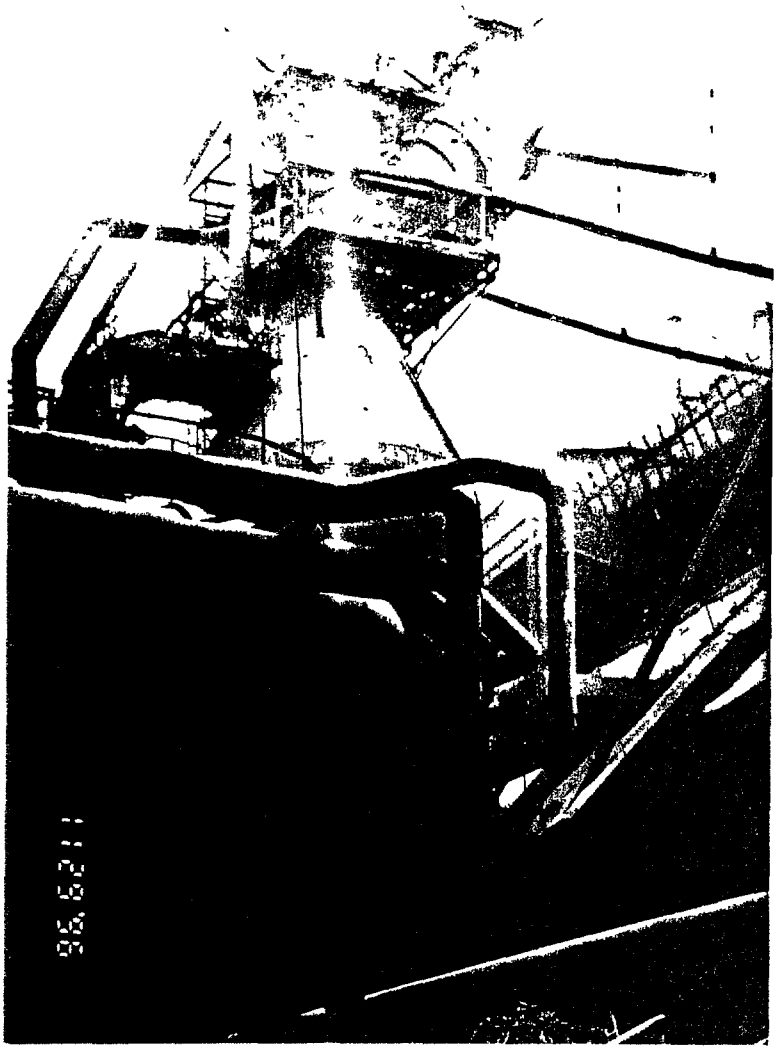


Figure 30 - Gas purification of the exhaust gases of blast furnace #5.

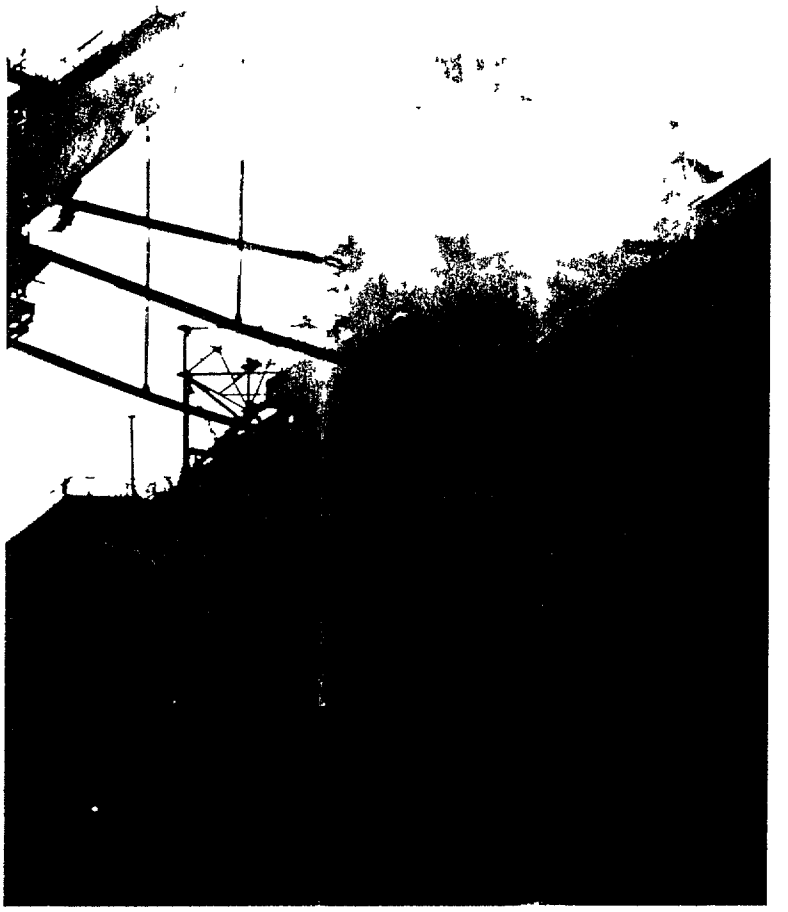


Figure 31 - Blast furnace #5, discharges from the unit for materials feeding.

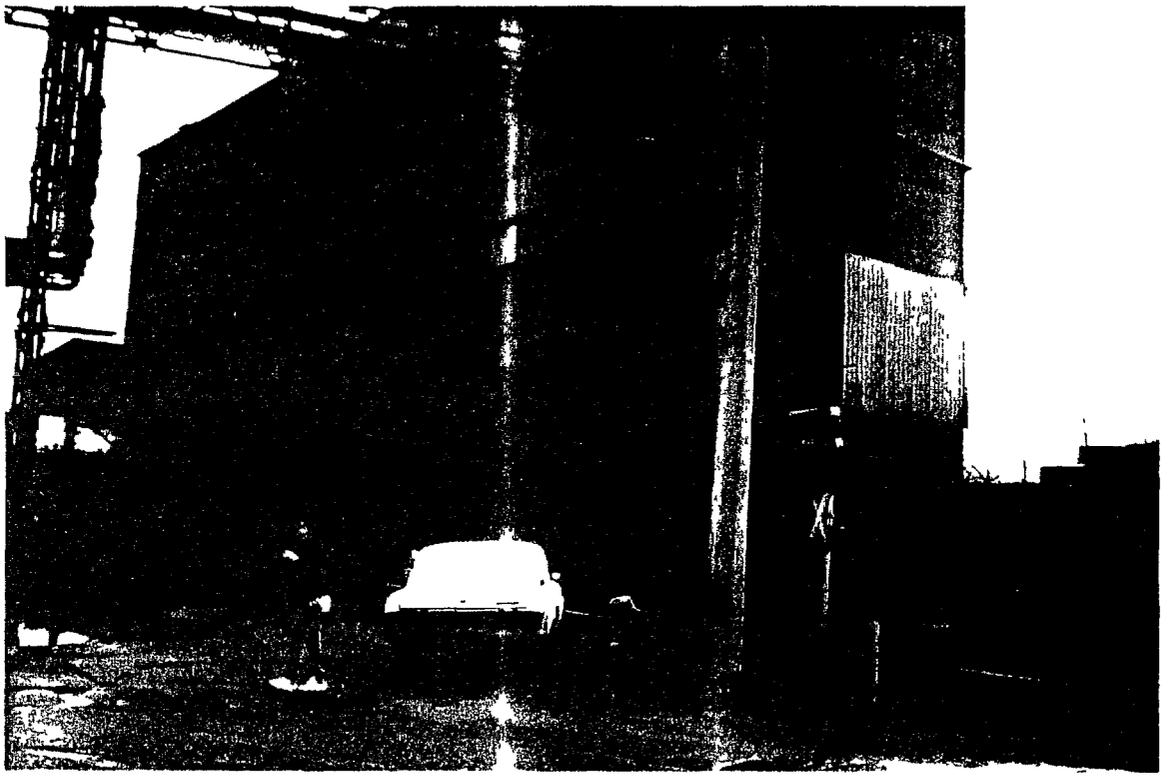


Figure 32 - Desulfurization building.

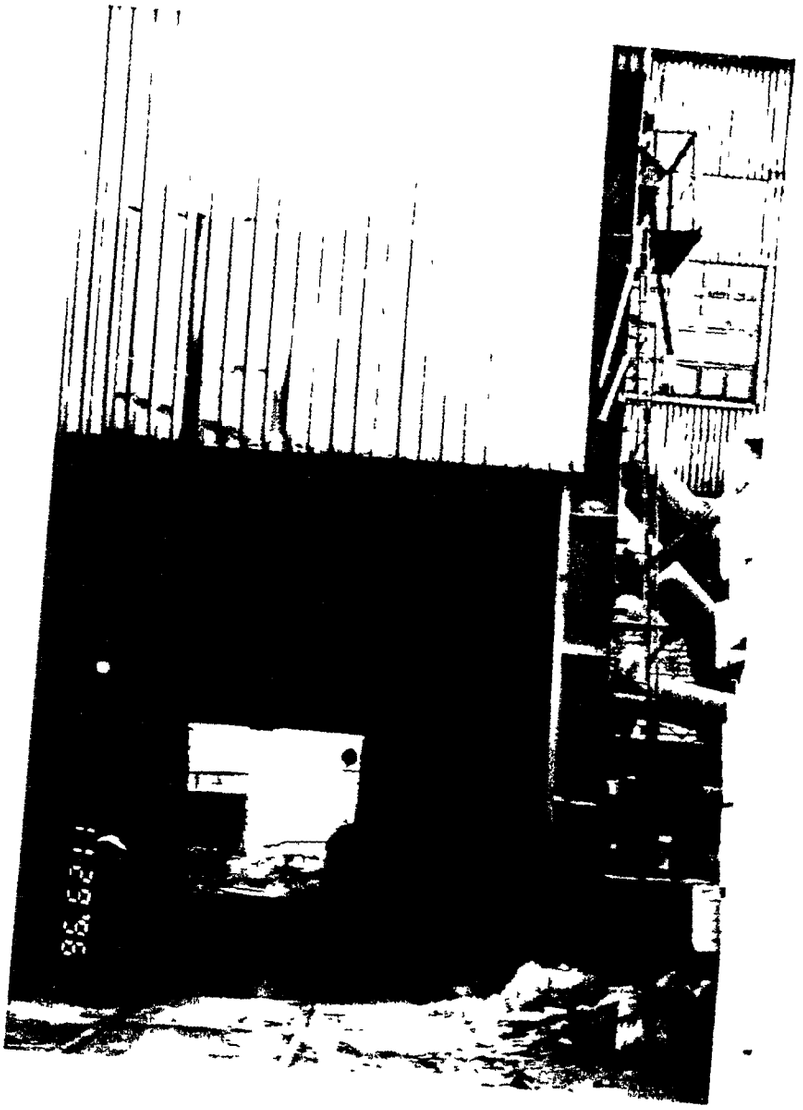


Figure 33 - Places for the ladles in the desulfurization shop.

Figure 34 - Gas exhaust hoods and supply of pulverized MgO.

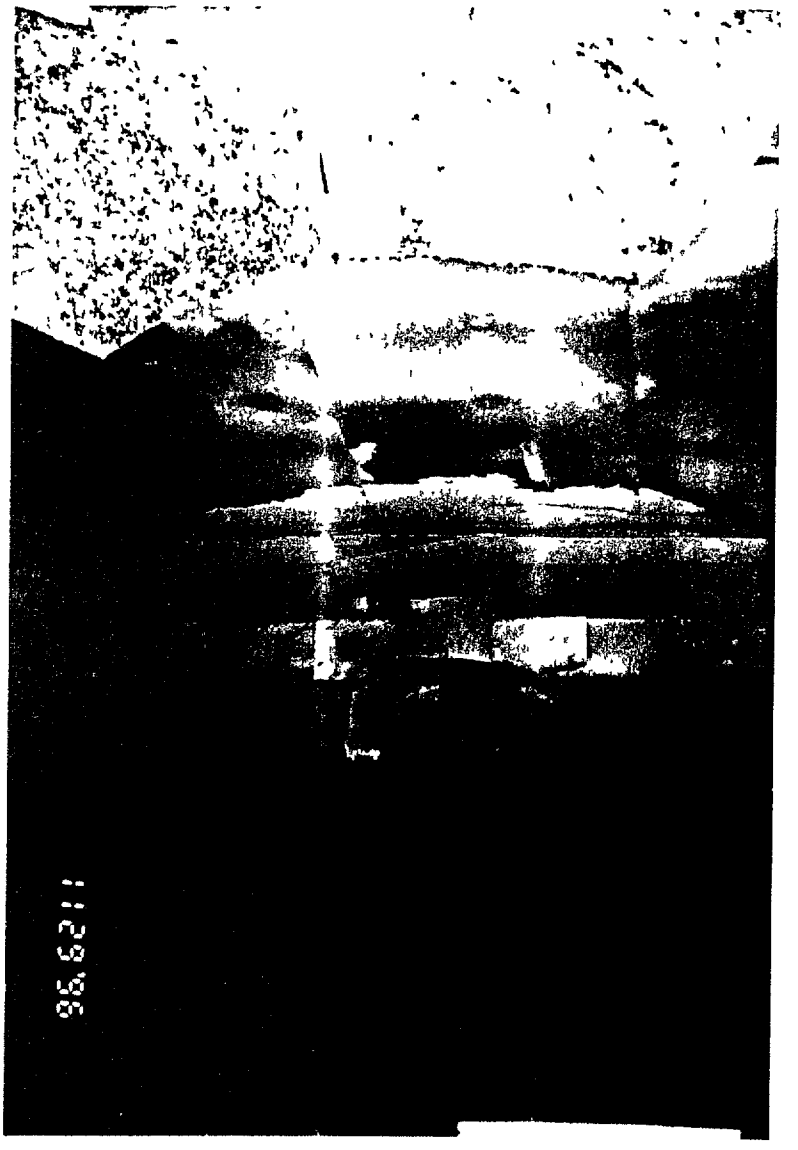


Figure 35 - Gas exhaust hoods and supply of pulverized MgO.

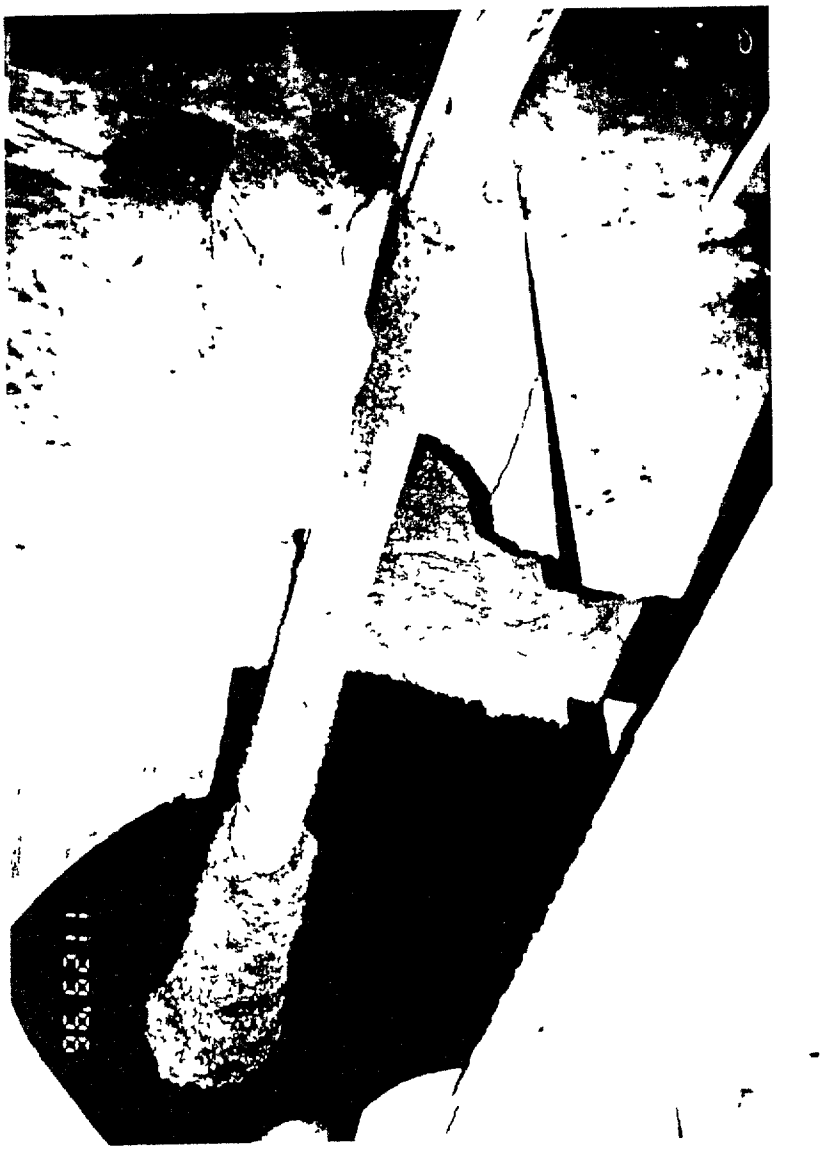


Figure 36- Supply of pulverized MgO.

Figure 37 - Exhaust fans of the gas purification system in the desulfurization shop, one exhaust fan for two places.

Figure 38 - Exhaust fans of the gas purification system in the desulfurization shop, one exhaust fan for two places.

Figure 39 - Exhaust fans of the gas purification system in the desulfurization shop, one exhaust fan for two places.

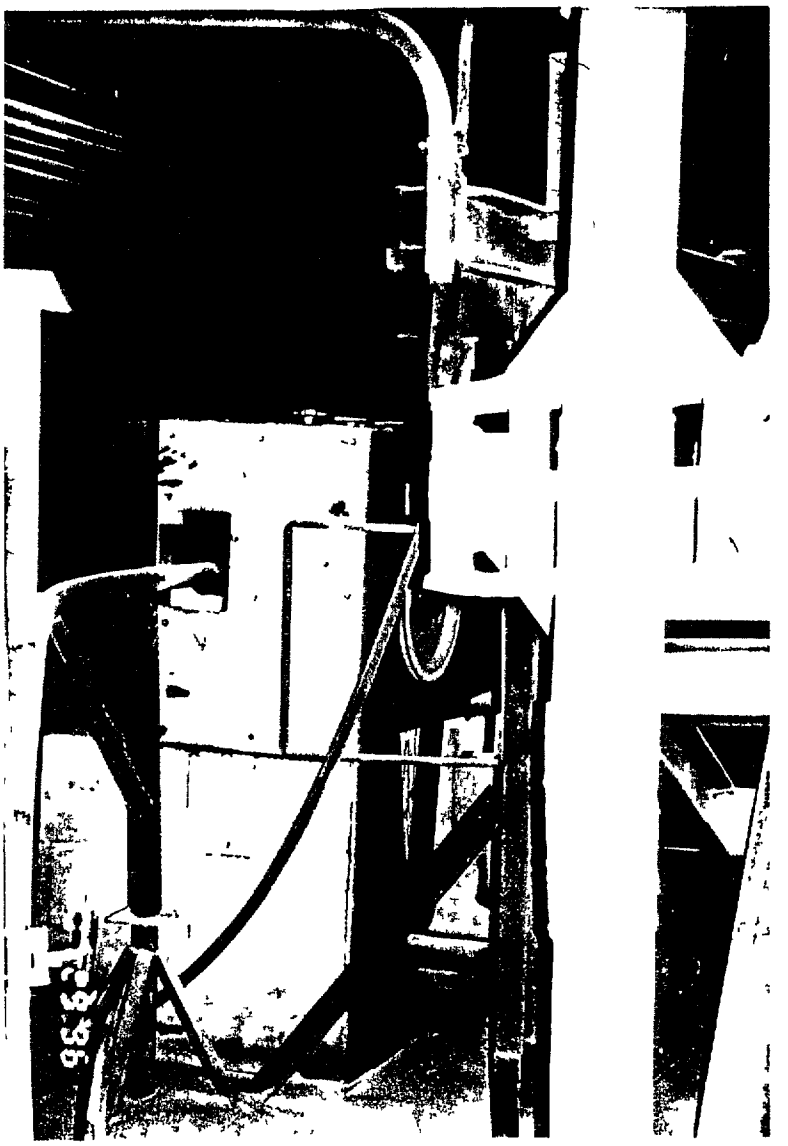


Figure 40 - Gas purification shop.

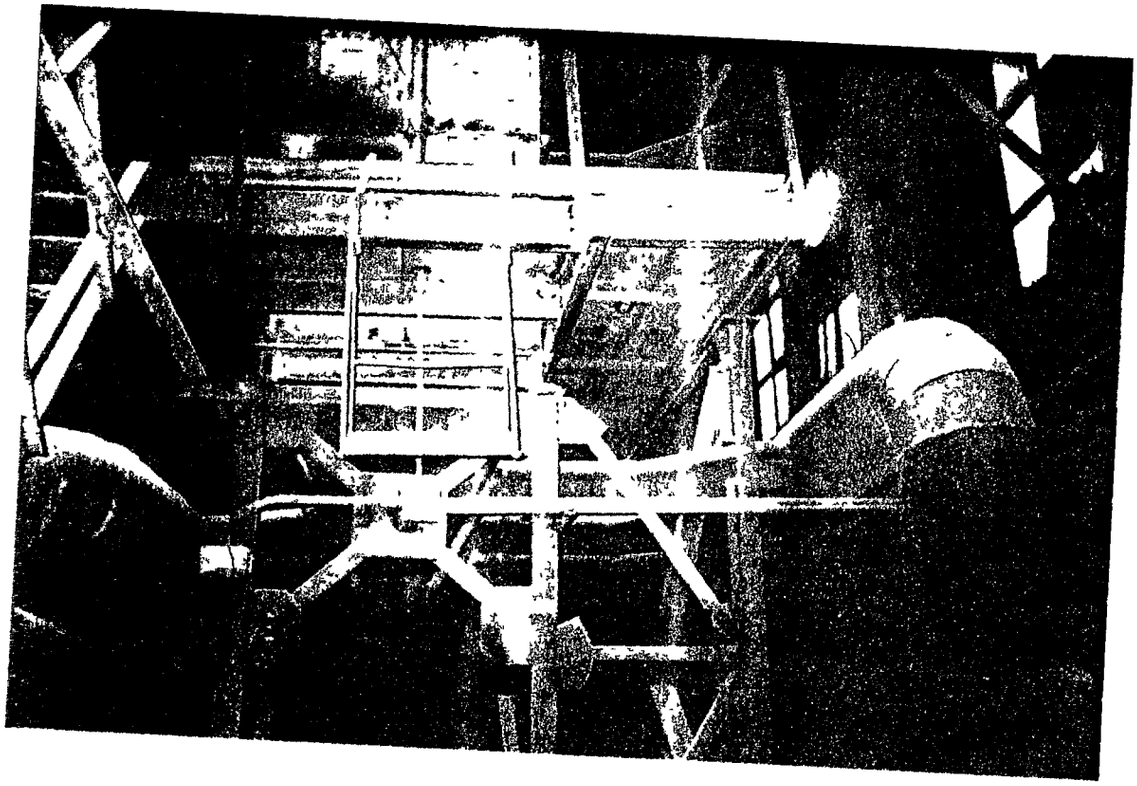


Figure 41 - Gas purification in fabric 3-sectional filters.

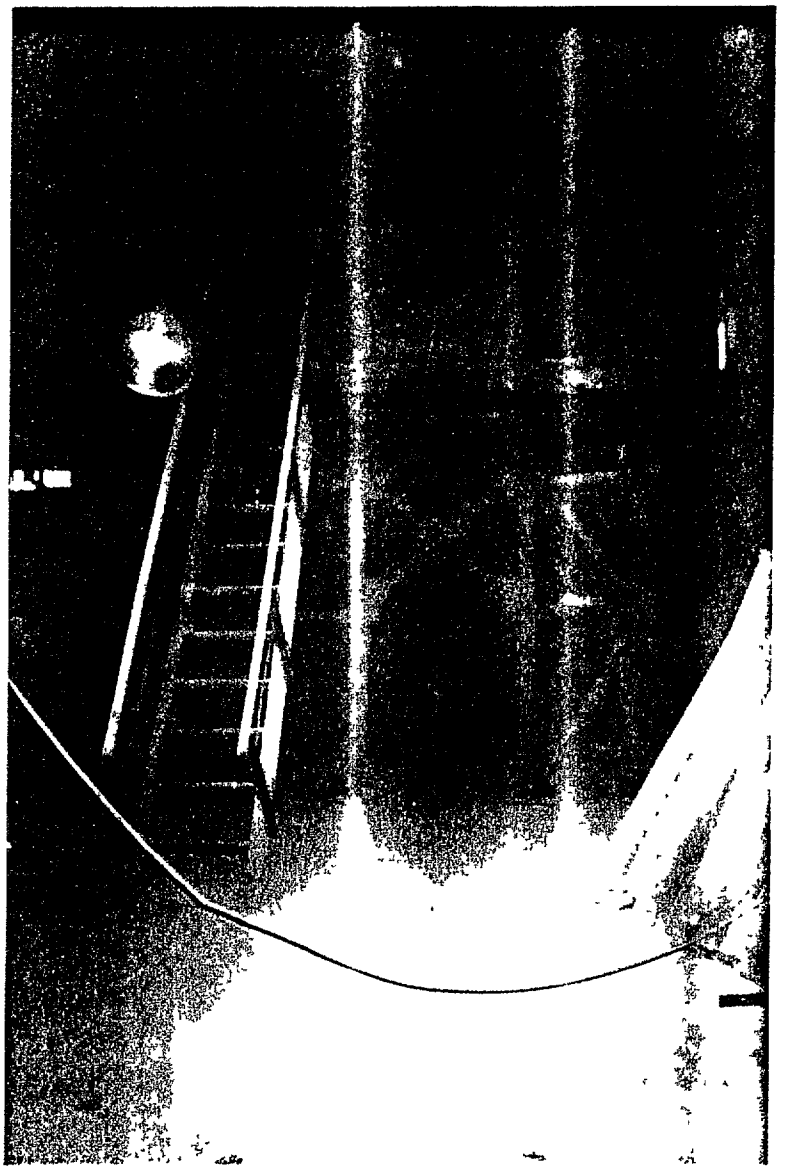


Figure 42 - Gas purification in fabric 3-sectional filters.

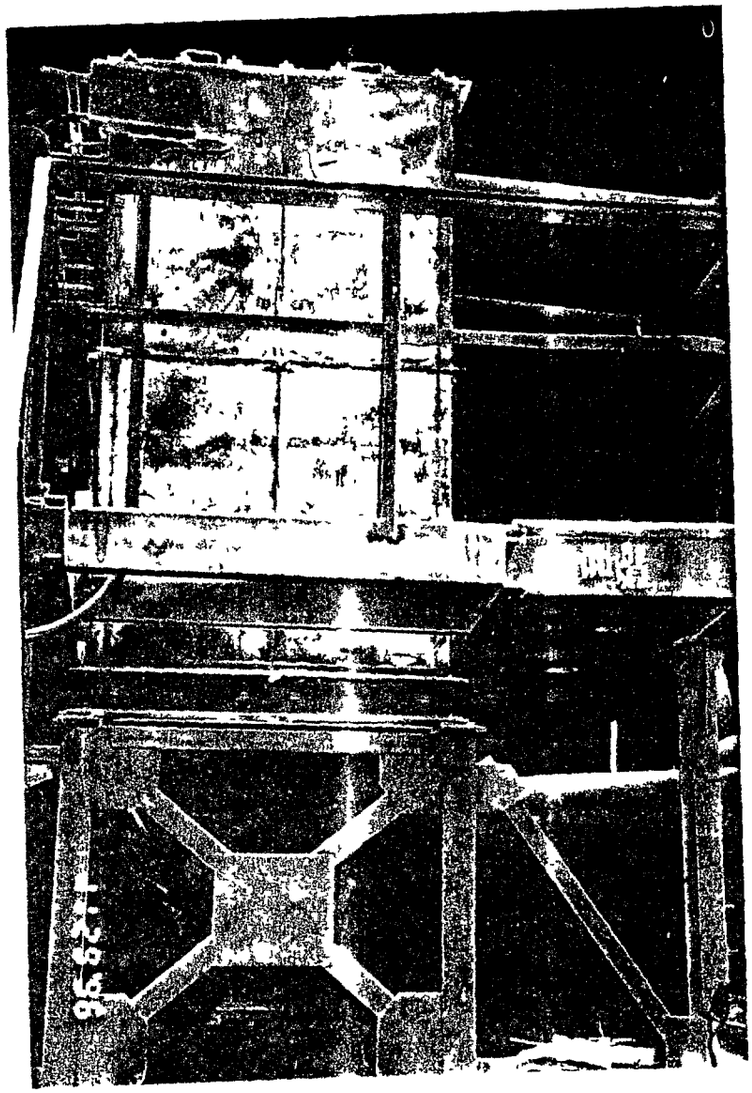


Figure 43 - Gas purification in fabric 3-sectional filters.

Figure 44 - Burnt-out filter bags.

Figure 45 - Body of the mixer department.

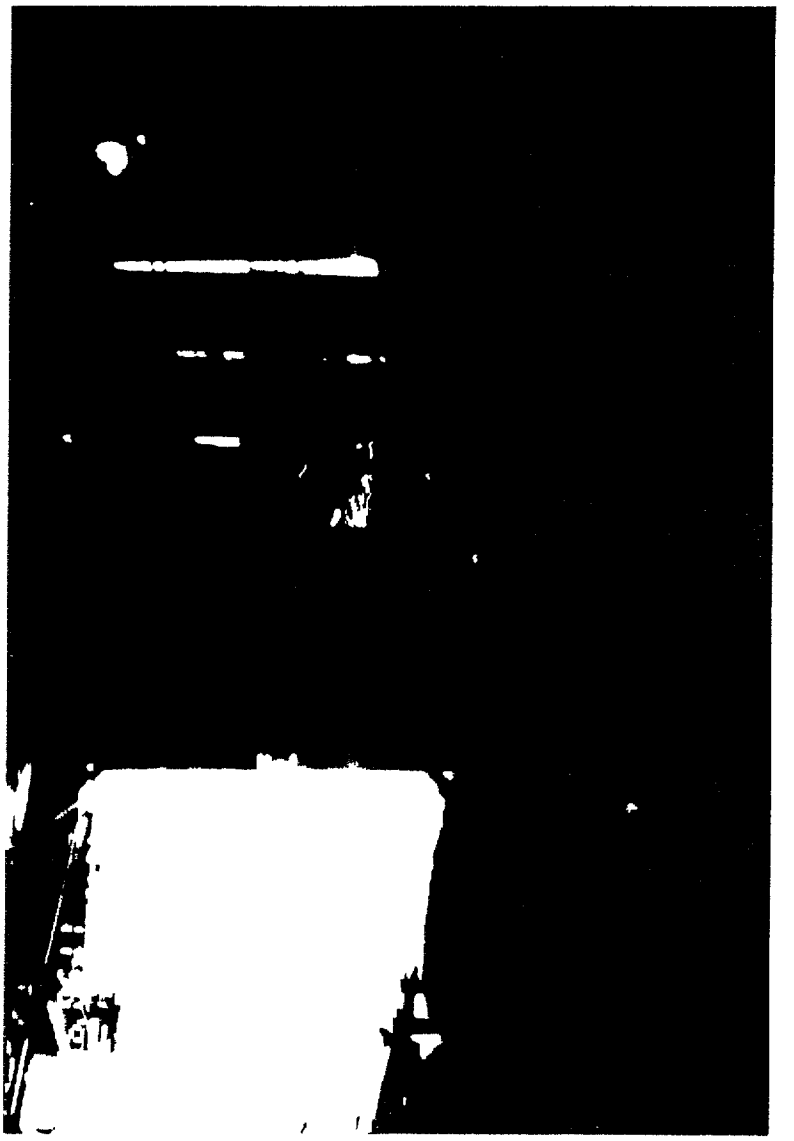


Figure 46 - Pouring of the pig iron into the mixer.

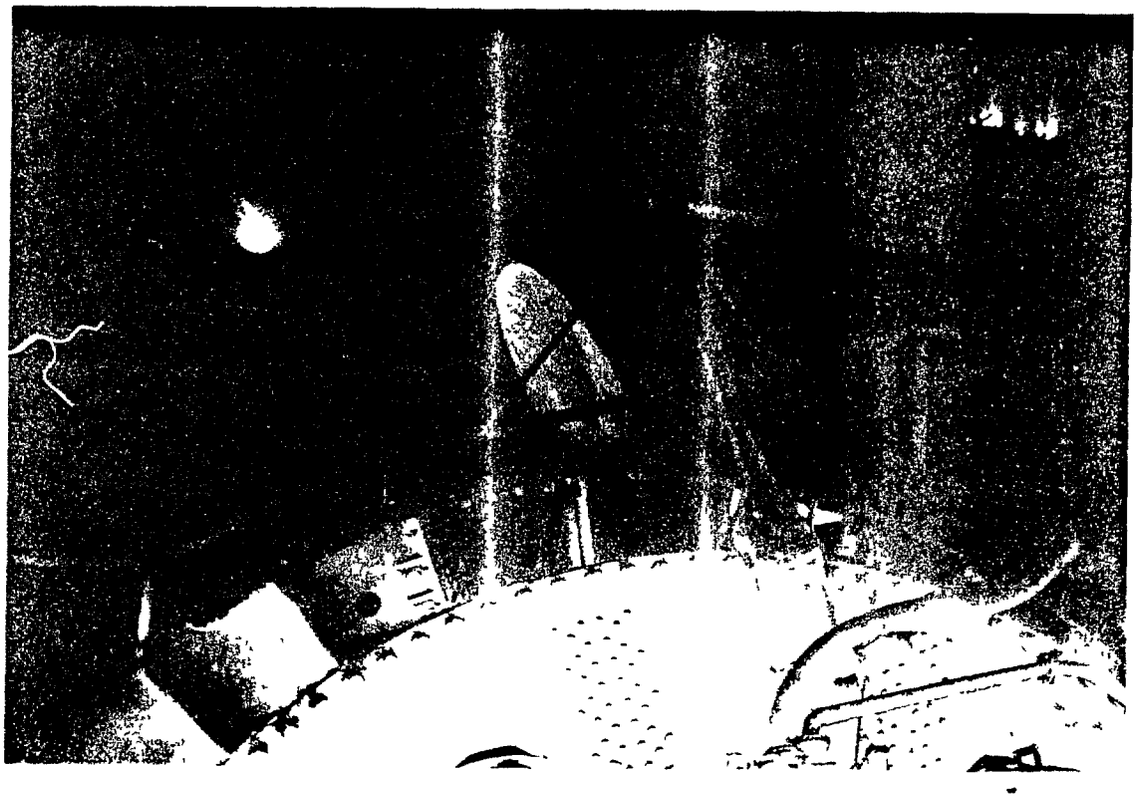


Figure 47 - Mixer at work, the upper hatch is open, all dust-containing discharges get into the building.

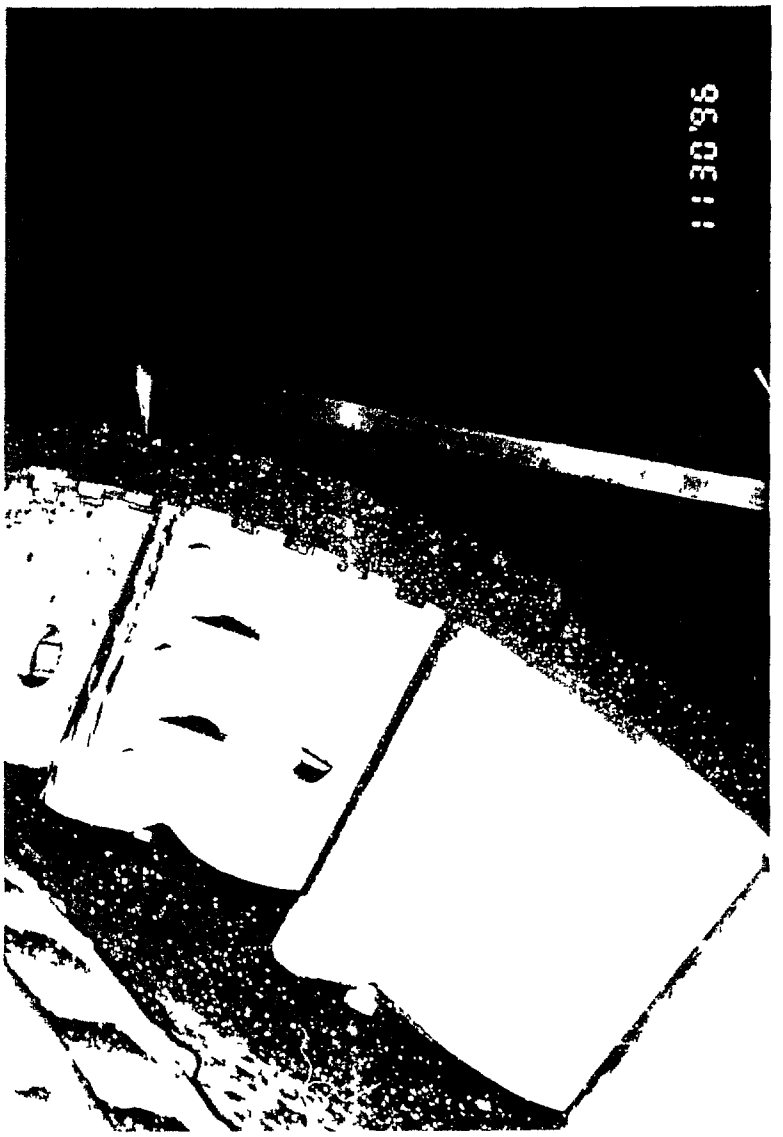


Figure 48 - Mixer at work, the upper hatch is open, all dust-containing discharges get into the building.

Figure 49- Mixer # 3 releases smoke through the aspiration outlet.

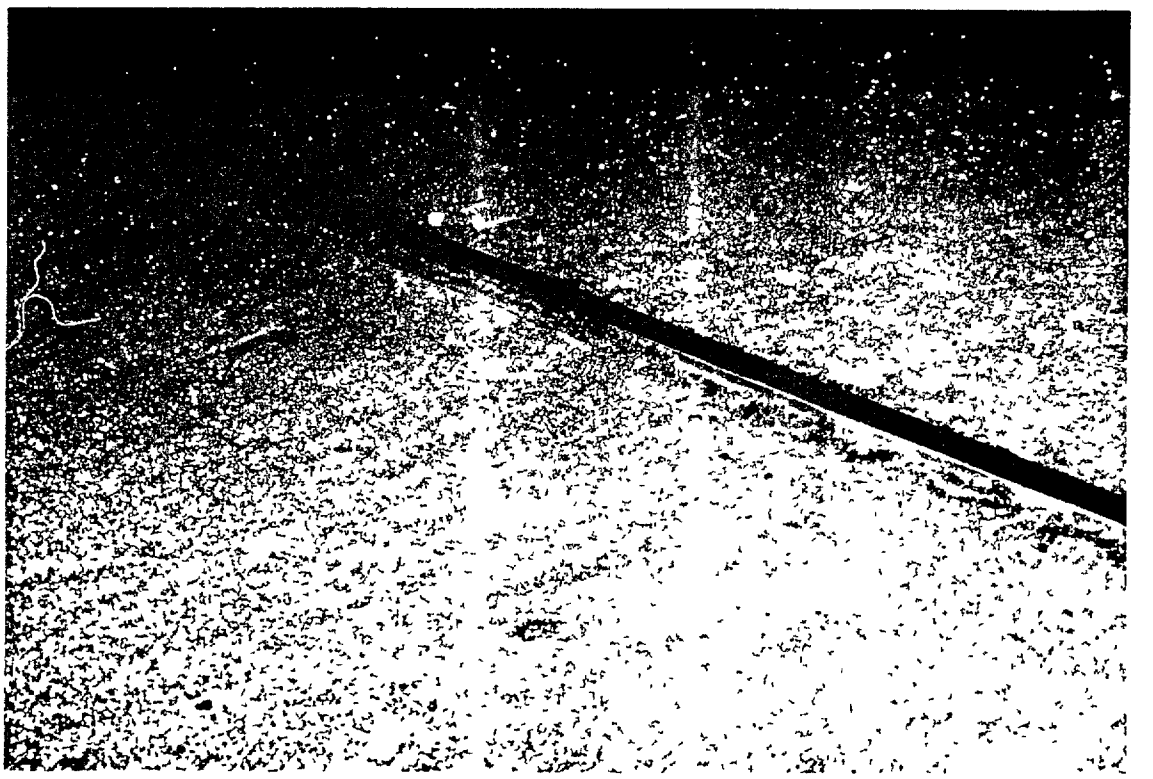


Figure 50 - Floors in the mixer department are covered with a thick layer of graphite.

Figure 51- Piles of graphite in the mixer department.

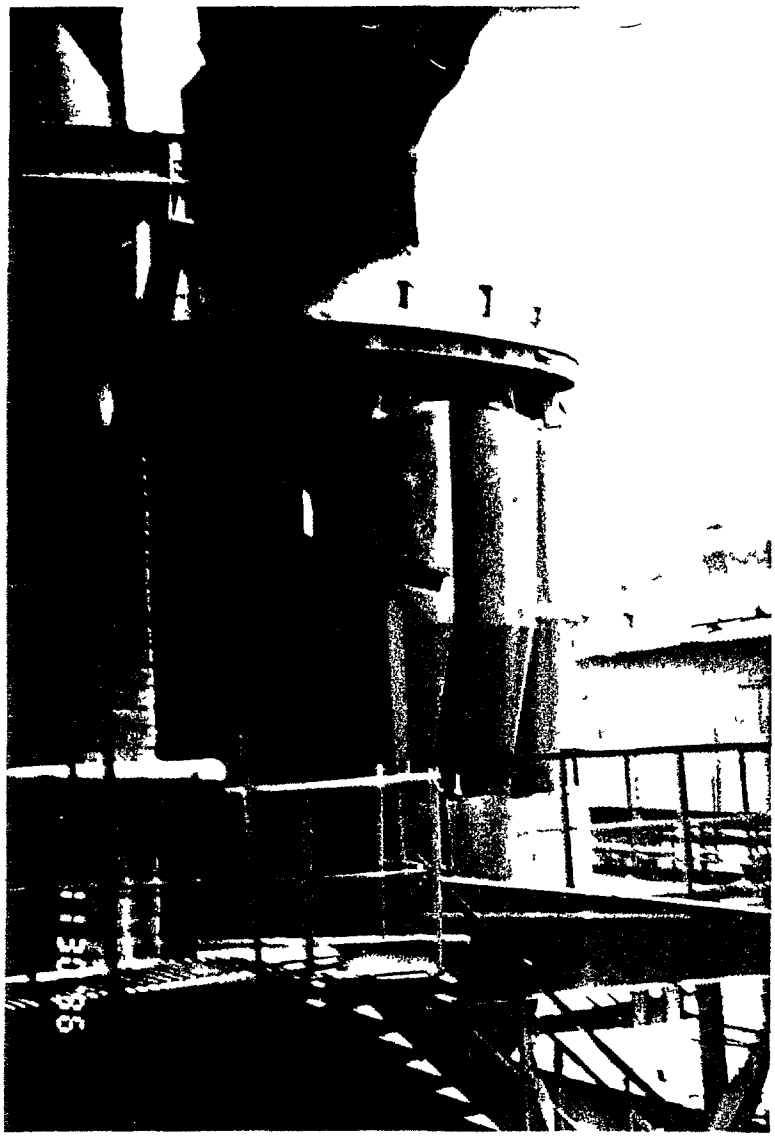


Figure 52 - A 12-cyclone installation behind the mixers to catch graphite.

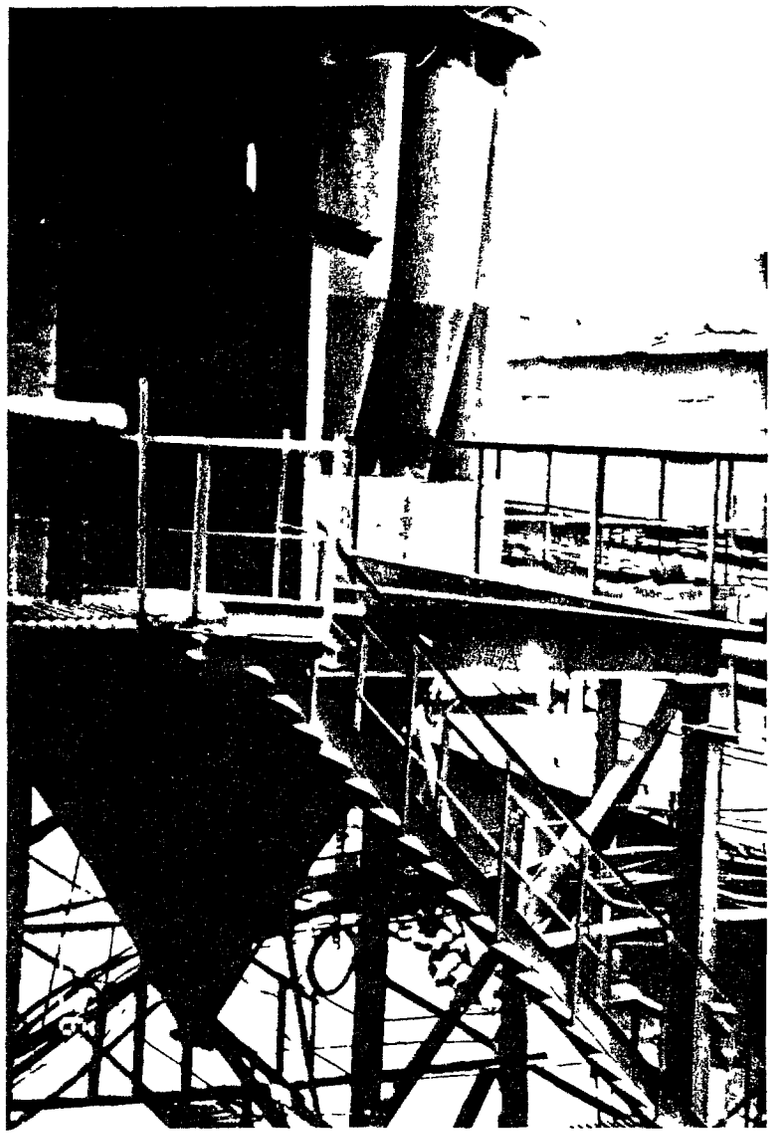


Figure 53 - A 12-cyclone installation behind the mixers to catch graphite.

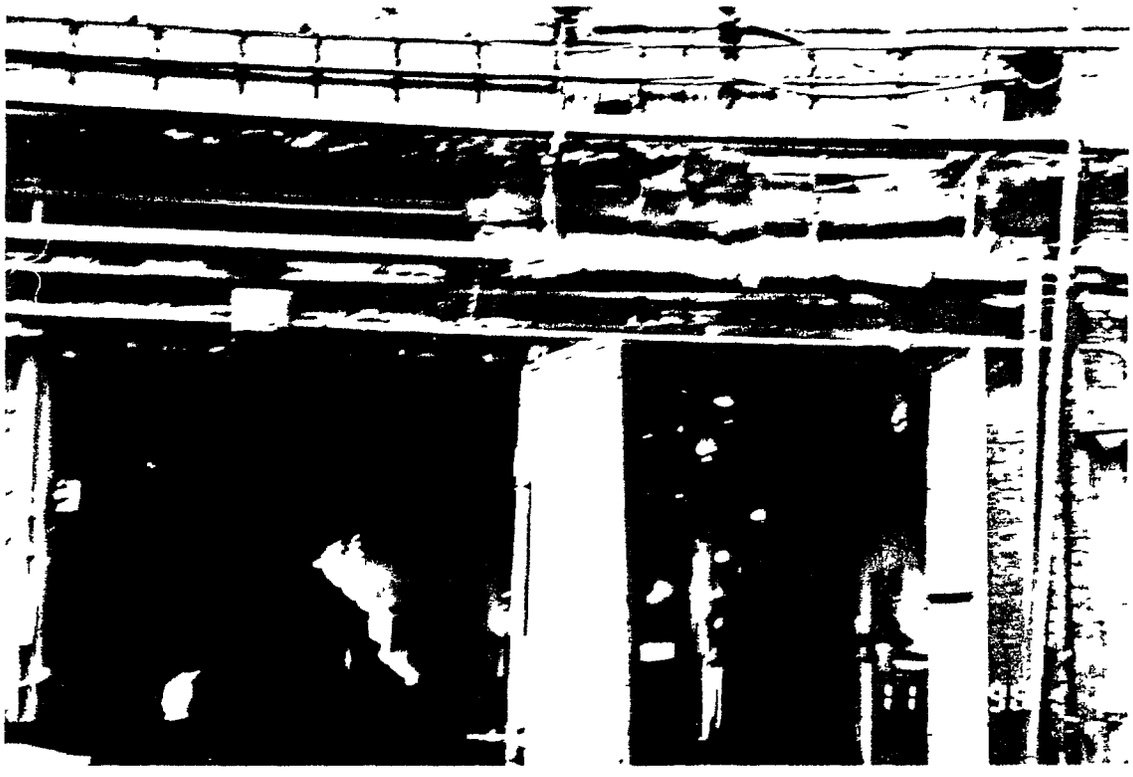


Figure 54- Converter Department.

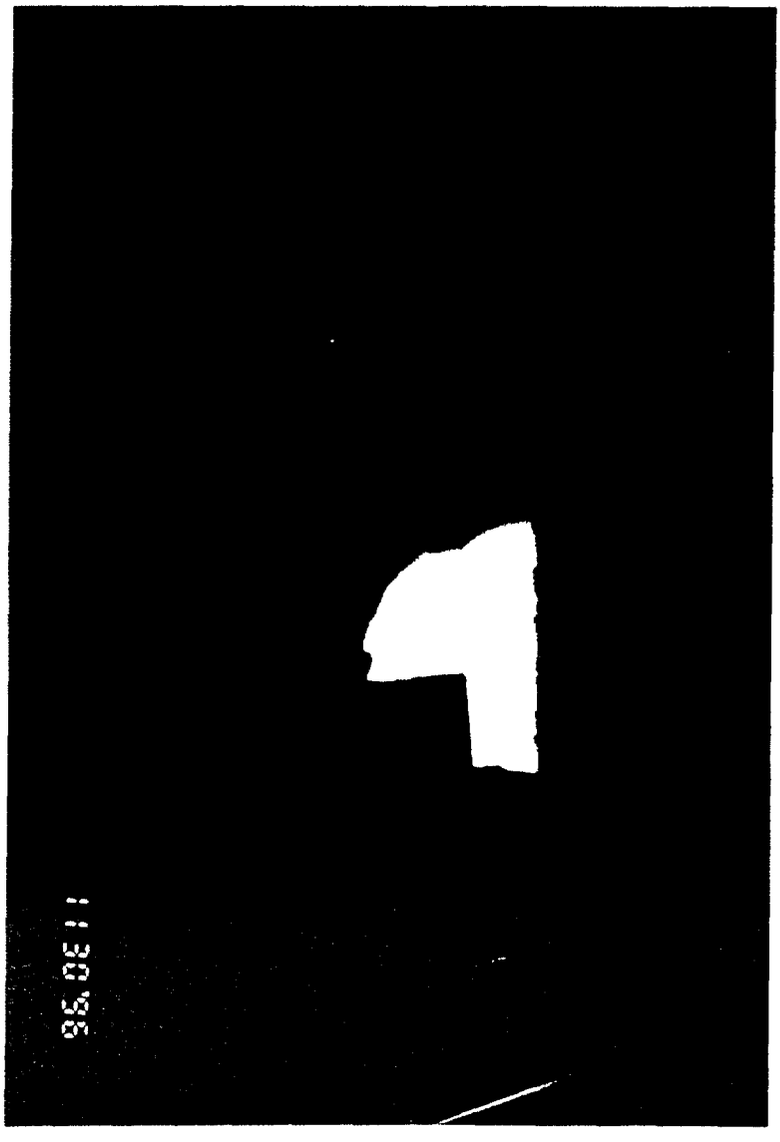


Figure 55 - Emergency Shutdown at converter #2.

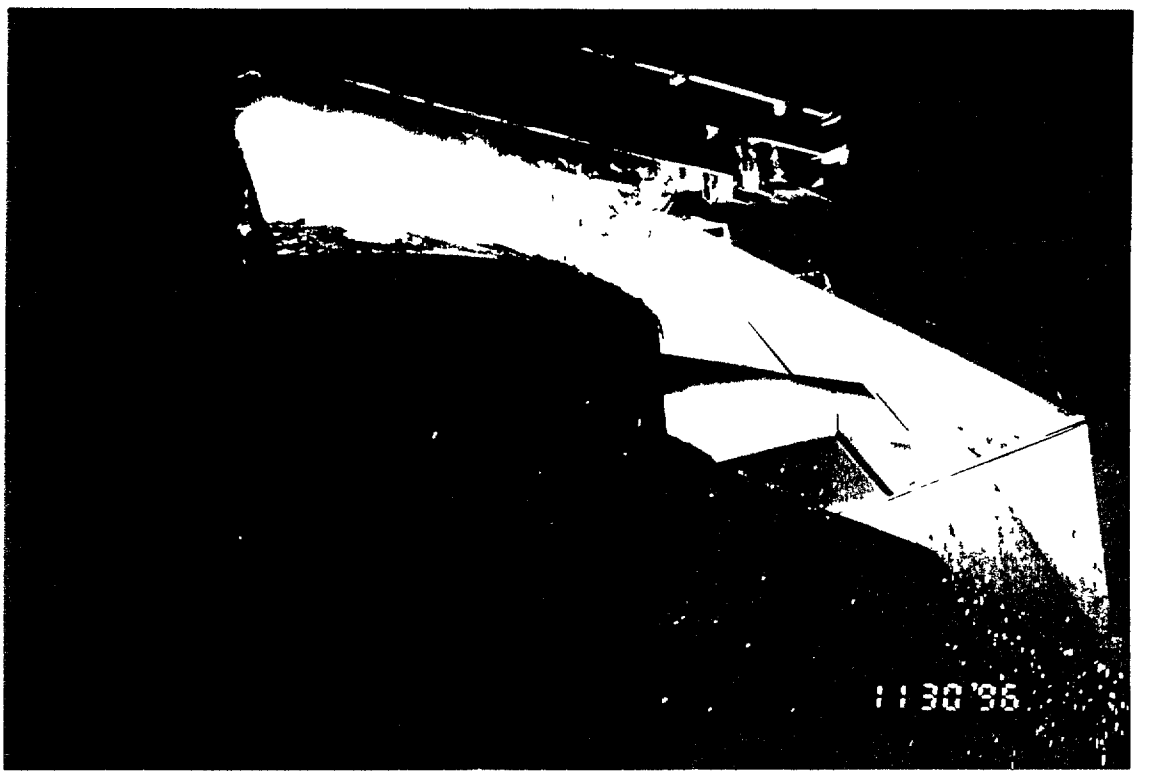


Figure 56- Converter #3 at work.

Figure 57- Converter #3 at work.

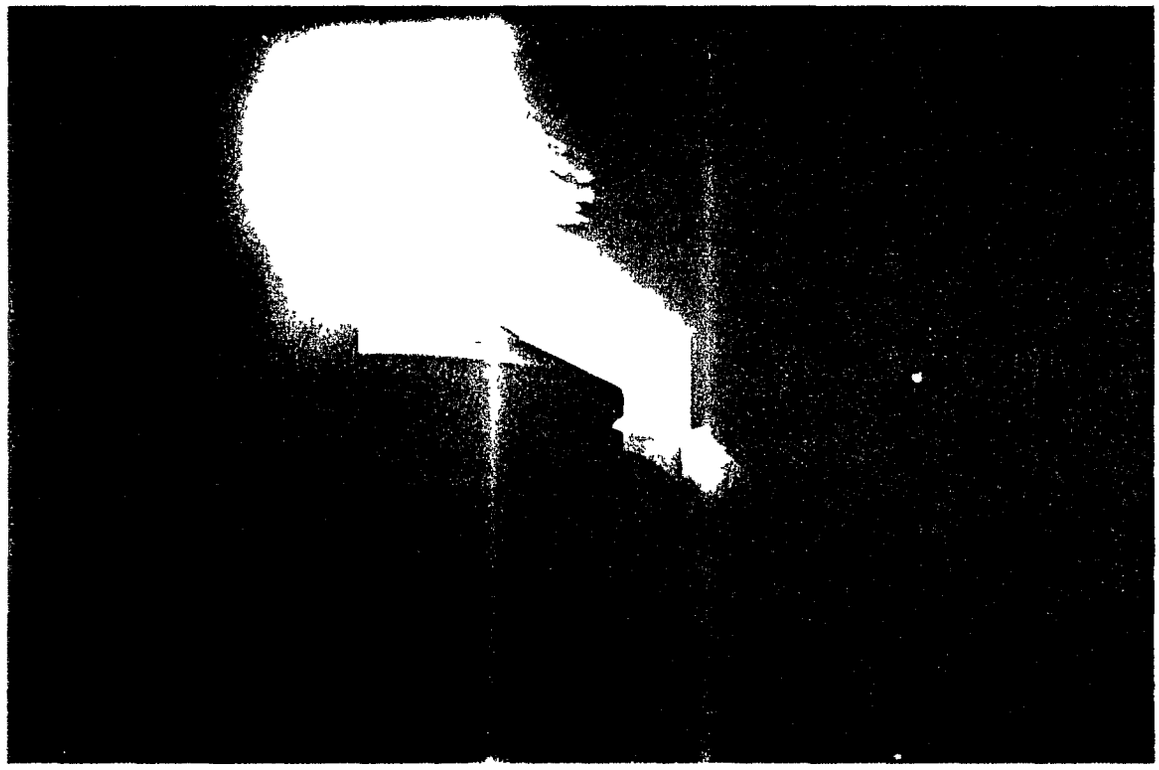


Figure 58- Converter #3 at work.

Figure 59- Smoke stacks of the converter shop.

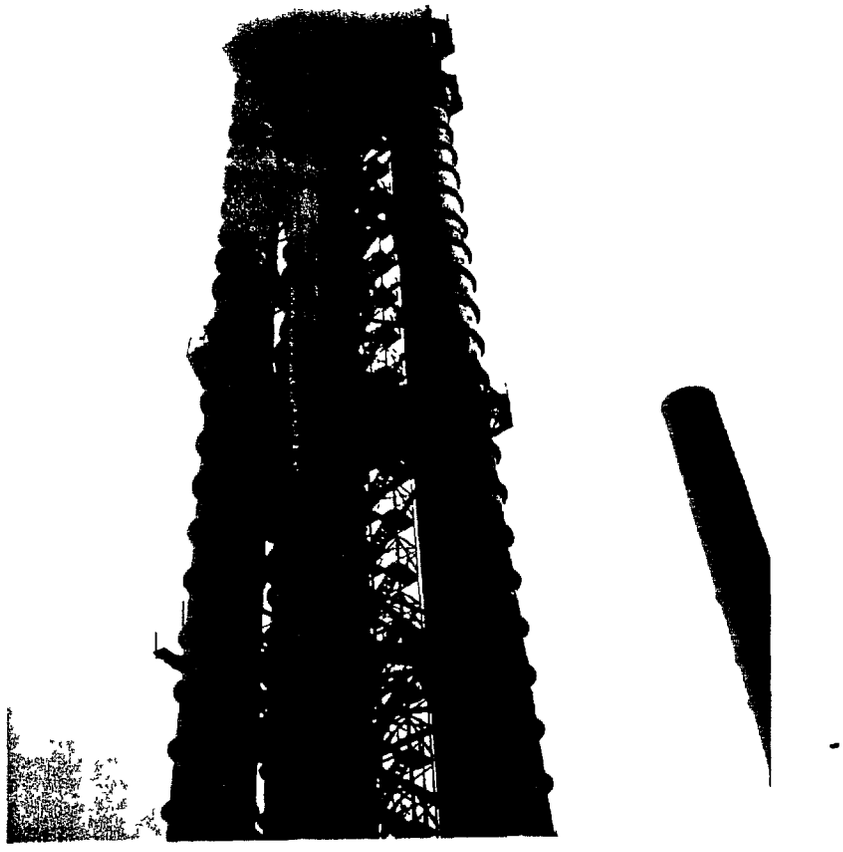


Figure 60 - Discharges into the atmosphere through the smoke stacks of the oxygen- converter shop.

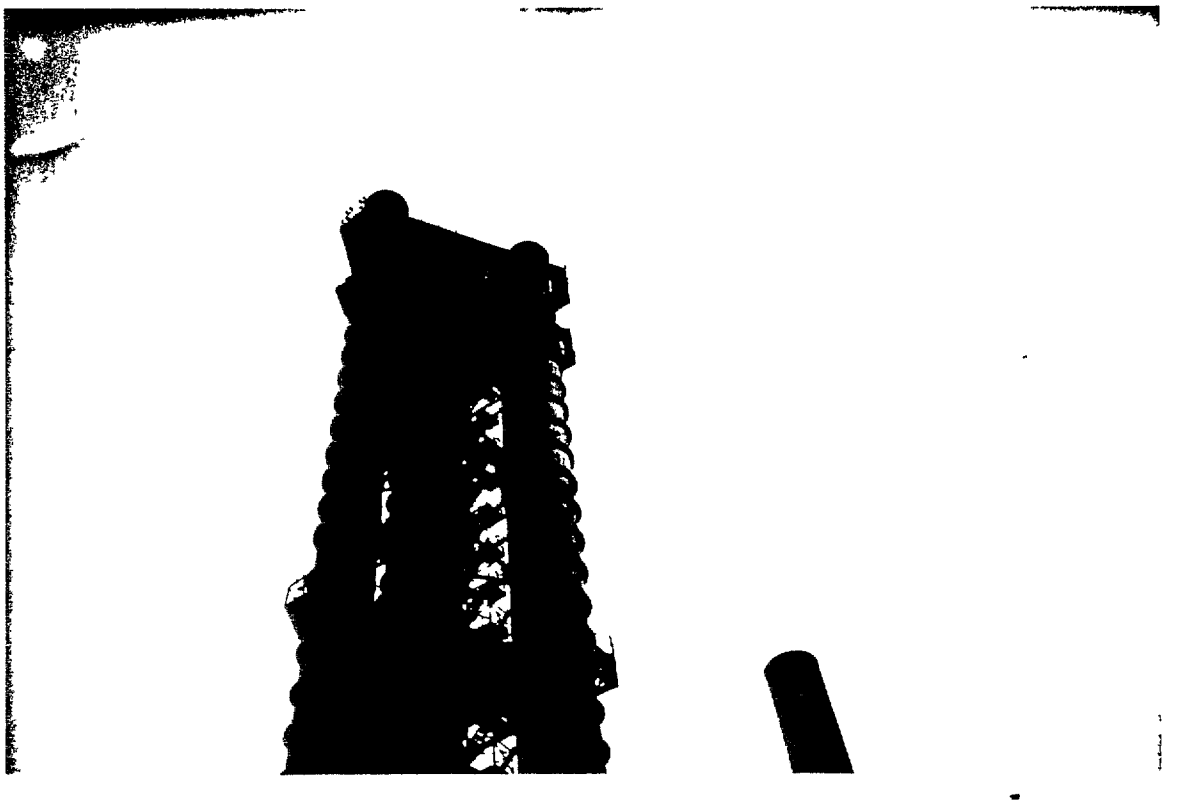


Figure 61 - Discharges into the atmosphere through the smoke stacks of the oxygen-converter shop.

RELEASES AND WASTES OF THE ILLICH IRON AND STEEL PLANT

Overview.

The subject facility is situated in the northern part of the city of Mariupol, in the Illichevski district. The plant covers the area of 950 hectares and is surrounded by residential areas in the south, east and south-west.

The following substances are released into the air by the plant operations

- suspended substances - from sources of the agglomeration plant, blast furnace, open hearth, converter and other shops,
- carbon monoxide and sulfur dioxide - from the agglomeration plant, blast furnace and converter shops. and also from the rolling mills that use blast furnace gas as a fuel,
- nitrogen oxides - from the agglomeration plant, open hearth shop and all the shops that consume fuel,
- hydrogen sulfide - from the slag processing unit

The releases of hazardous substances into the atmosphere can largely be attributed to

- the agglomeration plant - about 70% of all releases,
- the blast furnace shop - approximately 10%;
- the open heath and converter shops - 10%

The agglomeration plant and blast furnace shop are the basic polluters of the air (data obtained from the Ministry of Environmental and Nuclear Safety - Donbass)

Gross releases of hazardous substances by the sources of the Iron and Steel Plant in 1989 and 1995 amounted to 396 and 216 thousand tons per year respectively In 1995 out of the 216 thousand tons, 25 thousand tons were solid substances, with the remainder being gaseous substances From 1990 to 1995 the gross releases from the plant decreased by 45% due to reduced operations It is expected that in 1996 the gross releases of pollutants into the atmosphere will amount to 229 thousand tons In comparison to U S based plants, these estimates are 24 times higher than the largest plant (refer back to Table 4), even at their reduced level of productivity

At the Illich Iron and Steel Plant, wet gas scrubbers are installed almost everywhere. Based on 1996 data, 120 thousand tons of sludge went into the sludge pond from the agglomeration plant, blast furnace and converter shops 45 thousand tons- from the agglomeration plant, 50 thousand tons- from the blast furnace shop, 25 thousand tons - from the oxygen shop The sludge ponds are overflowing with sludge eminating from different production mixes which complicates recycling opportunities At present there is as much as 5 million tons of

non-utilized sludge in the sludge pond (Figure 63) The construction of a ferriferous sludge dehydration shop is essential in addressing the issue of the sludge recycling. The cost of this project is about 150 million USA dollars. Some of the engineering design has been done by the plant, however they have not examined the economic feasibility in detail and no sources of financing have been identified.

There is a large number of unorganized sources of pollutant discharges in addition to those already noted. The bulk processing department where there are no dust-collecting installations is an example of such sources of discharge (refer to Figures 64-67)

Agglomeration.

Dusts generated both from feeding and discharge operations in the agglomeration department are a major source of pollution The significant amount of the agglomeration plant releases discharged during the cooling and sintering operations are sent directly to discharge stacks without any gas cleaning

The agglomeration plant may be described as the largest single air pollution for the facility In 1995 the releases of the agglomeration production reached 174 thousand tons per year, with the gross releases of the plant being 216 thousand tons per year

In the US, these operations have been substituted for the direct coal dust supply into the blast furnaces Most agglomeration production in the US has been terminated U S experience further shows that when wet scrubbing is substituted for dry gas cleaning, the amounts of the releases are reduced significantly This method is recommended for the Illich Plant

Special attention must be paid to the limestone crushing department, which is a part of the agglomeration plant. The Illich Plant obtains burnt limestone from "Azovstal" (town of Mariupol) The quality of limestone is unsatisfactory, because it contains a high percentage of silicone, hence the basicity of limestone does not conform to steelmaking standards There are 6 hammer crushers in the shop which work simultaneously and large amounts of lime dust are released during their operation The ventilation system practically does not work, hoods over the hammer crushers are corroded, gas conduits need repairing , there is no exhaust fan Gas purification is carried out in 4 low pressure wet scrubbers. Enormous amounts of sludge are generated but there are no official estimates.

Note. The audit team filmed the releases from the hammer crushers while conducting the audit. The operation is highly hazardous from a worker safety standpoint.

Blast Furnace Production.

Dust of charge components and gases with high contents of carbon monoxide, sulfur compounds and nitrogen oxides are the main pollutants in the blast furnace operation. Emissions are generated during the intake, processing of charge materials and the output of smelting products (pig iron and slag) Casting yards of blast furnaces, skip pits, units for the materials loading are the main sources of discharge of these hazardous substances. The blast furnace shop is the second largest source of emissions In 1995 the gross amount of

pollutants discharged into the atmosphere amounted to 17 2 thousand tons per year from this operation. Based on US experience, places with high dust emissions are equipped with appropriate hoods for the localization of harmful materials and ventilation devices with subsequent air purification in electrostatic precipitators and fabric filters At present, the dust content of gases discharged through the aeration outlets of casting yards during the pouring of metal from the blast furnaces is 2-4 g/c.m, which is well above Ukrainian maximum permissible levels

Desulfurization.

The pig iron desulfurization unit,although existing, does not function properly During the audit it was obvious that high speed dust-gas mixtures being sucked off from ladles where desulfurization takes place, were being emitted directly into atmosphere. Hot particles burn the filter bags and hence the fabric filters are operating at greatly reduced efficiencies To solve this problem and secure normal operational conditions of filters, every dust removing installation must be equipped with an individual exhaust fan and it is necessary to enlarge the diameter of the opening in gas outlets in order to reduce the speed of the gaseous mixture A gravity settling system preceding the fabric filters would also be desirable

Mixer Department.

In the US there are no problems connected with the purification of exhaust gases in mixer departments because pig iron is transported from blast furnaces in mixer wagons However at the Illich plant the operation consists of discharging the slag from the blast furnace ladle, pouring of the pig iron into the mixer, and then discharging the pig iron from the mixer into steel ladles This results in a large release of dusts and fumes into the workroom It is possible to reduce the releases of ferriferous dust and sublimates during the pouring of pig iron into the mixer and its discharge from the mixer by means of periodical feeding of nitrogen directly to the place of dust release But it is impossible to accomplish it without the construction of a nitrogen-compressor plant

Cyclones are used to purify gases from the graphite-bearing dust They catch only about 20% of the dust. At present, the dust content of the gases discharged into the aeration outlet in the mixer department is about 800 mg/m^3 which is about ten times above Ukrainian permissible discharge limits.

It is essential to install a hood at the discharge of the slag and a device for catching gaseous releases over the nose of the mixer in order to place the exhaust as close as possible to the place of dust accumulation using the side shields for the reduction of air inleakage A cylindrical hood with a slot for the spout of the mixer in the place where pig iron is discharged should be installed

Converter.

In the US there are two options for dealing with dust emissions during the unloading of converters· the first one is to catch and purify gas emissions, the second option is to improve the technology of converter loading and metal scrap preparation Systems of local gas

suctions are sometimes combined with partial or full ventilation of the shop to suppress non-organized discharges. During the construction of the ventilation system efforts were taken to minimize the amount of the air that is drawn in Semi-hermetic covers with slide doors for the heaping up of scrap metal and pouring of the pig iron are also used. The process of guniting at the Illich Plant takes place with a horizontally-inclined converter At the same time, the generated flue gases enter the shop and are discharged into the atmosphere through the aeration outlet In 1995 the gross releases of hazardous materials for the converter shop amounted to 2.8 thousand tons per year It is recommended to introduce vertical guniting At the same time gases that are generated will get into the existing gas-purifying facilities of the converter. Estimated costs are covered in the next section

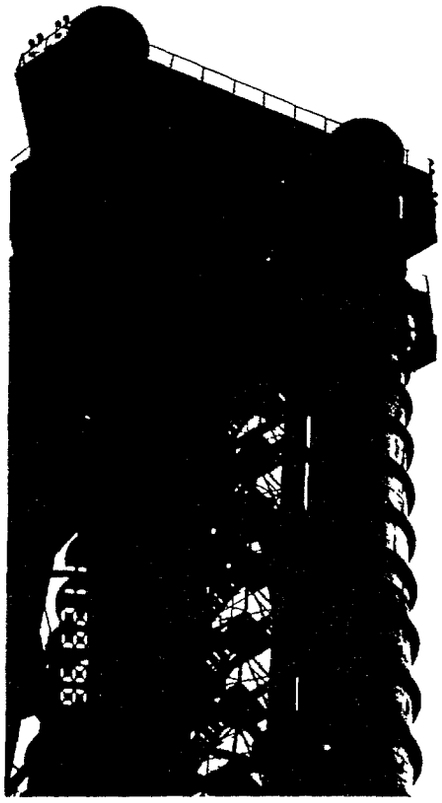


Figure 62 - Discharges into the atmosphere through the smoke stacks of the oxygen-converter shop.

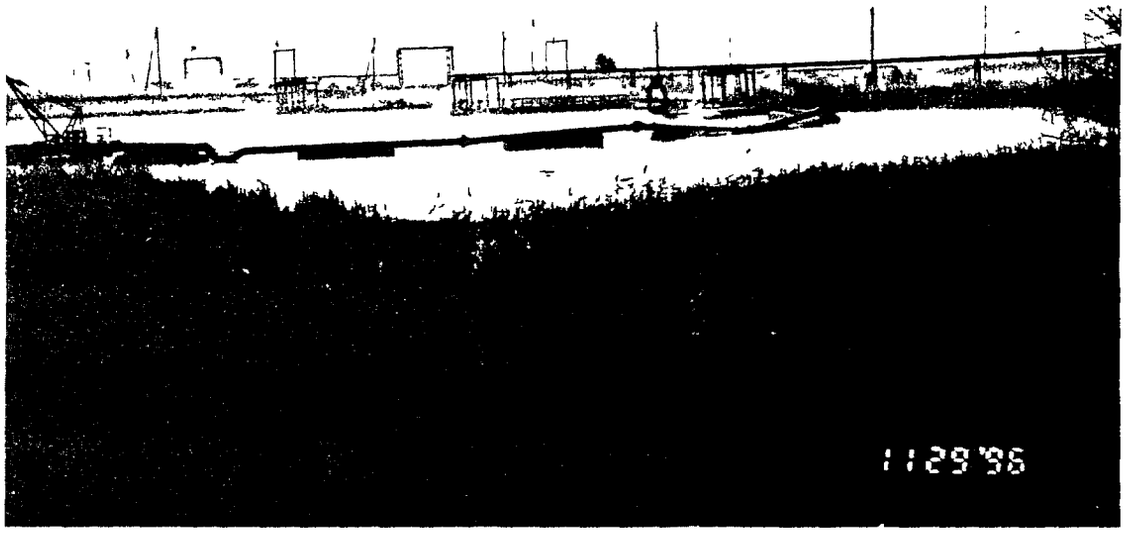


Figure 63 - Sludge pond of the agglomeration plant.

Figure 64 - Department of bulk materials, overturning of cars, no dust collecting installations.

Figure 65 - Department of bulk materials, overturning of cars, no dust collecting installations.

Figure 66 - Department of bulk materials, piles of dust, no dust collecting installations.

Figure 67 - Department of bulk materials, piles of dust, no dust collecting installations.

RECOMMENDATIONS

Overview and General Recommendations.

Approximate investments to reduce overall pollution discharges to conform to Ukrainian environmental standards amount to 100 million US dollars Providing funds are available, this program could be implemented over a 15 year period. If the complete set of recommended measures is implemented, the gross amount of discharges and releases at the facility could be reduced by 112 4 thousand tons per year.

A summary of the most capital-intensive measures aimed at the reduction of discharges is given below

Agglomeration.

The following are the most capital-intensive measures aimed at the reduction of discharges at the agglomeration plant.

- Introduction of the technology of sintering of the agglomerated charge which is prepared beforehand to the agglomeration process Agglomerated charge is averaged out as to its content in the screens and is supplied in accordance with the technology This sintering technology was previously employed at the Illich Plant It is recommended to return to this technology. As a result, releases of dust will be reduced by 2700 tons per year The dust emissions into the collector of the agglomeration unit will be reduced by 3-4 times To introduce this technology on all 12 agglomeration units would cost about 12 million US dollars

- Modernization of wet gas scrubbing operations including the reconstruction of a sludge removal system, installation of automatic intake sprayers, set-up of water regime of scrubbers, recovery of deflectors over corner sprayers The cost of this modernization project is 1 million dollars The same measures have already been carried out at agglomeration units #3, 6, 12.

- Reconstruction of gas-purifying facilities of agglomeration units # 1-6 and 7-12 (cooling zone) and aspiration systems at units # 6,7,8,9 with the installation of electrostatic precipitators made by "Spake" company (France). Dry dust removal is envisaged It can be carried out by conveyers "Redler" ("Spake"). At present, building and assembling works are underway at gas-purifying facilities behind agglomeration unit # 6 and aspiration system B-9 After the construction of electrostatic precipitators, the reduction of dust releases into the atmosphere will be about 11500 tons per year. This reconstruction requires attracting 50 million USA dollars in investments

Blast Furnaces.

At present blast furnaces # 2-5 are equipped with installations purifying discharges of units for materials loading that include a wash gas pipeline (diameter 600 mm) that has radial sprayers and a safety trap The installations do not work effectively and modernization is needed on all 5 blast furnaces that requires 500,000 US dollars of investment

Twenty million US dollars are necessary to introduce aspiration with dust removal from the discharges of casting yards of blast furnaces # 2-5 in the electrostatic precipitators These funds are indispensable for the construction of a dust elimination system This system includes

- installation for a cover of the chutes for the pig iron made from sheet iron and fettled by heat-resistant gunite;
- installation of a cover for the place of discharge of pig iron and slag into the ladle;
- system of exhaust gas conduits from pig iron tapping holes, from the above-mentioned covers,
- a dust elimination installation to capture dust from the discharges of casting yards that include electrostatic precipitators, ventilator, noise suppressor, smoke-stack and a control house

The system of dust elimination from the discharges in the casting yards works in the same mode as blast furnaces continuously, during the year with variable productivity- maximum (600,000 c m. per hour)- at the moment when pig iron is poured (11-14 times a day-40-50 minutes), at other times with minimum productivity (80, 000 c m per hour) during the work of the partially regulated ventilator that is idling The dust content in the gases after they have been purified would be 50 mg/c m (initial dust content is 1-5 g/c m.)

Desulfurization.

An investment of 200,000 US dollars is needed to complete the construction and repair of releases from the gas purification installation in 3-sectional fabric filters in the desulfurization unit, and also to reconstruct suction units and to equip every dust remover with individual exhaust fans

Mixer Department.

Every mixer department should be equipped with a system that captures exhaust gases, along with a gas cleaning. This should include

- installation of a fixed hood over slag discharge operations,
- installation of an improved ventilation system over the nose of the mixer ,

- cylindrical hood device with a slot for the nose of the mixer on the spot where pig iron is discharged

Due to the periodicity of the processes of discharge and pouring of pig iron, an installation based on forced-draft with variable drive is needed.

Approximately 4.5 million US dollars are necessary to carry out these measures

Converter Shop.

There are three centrifugal pumps that supply water for gas scrubbers that are designed to capture dust from the converters. During the audit, backpressure readings on these pumps showed about 16.8 KPa, which provides about 400 c m per minute These pumps are undersized for the application and should be providing almost double the flow capacity in order for the scrubbers to operate at their rated removal efficiency of 90% These pumps should be replaced with larger units that can provide a backpressure of 25 to 28 KPa

If this recommendation were implemented, dust emissions to the atmosphere could be reduced by as much as 120 tons per year This would require an investment of about 4 5 million U S dollars

An additional pollution prevention measure in this part of the operation concerns the practice of vertical guniting At present, the facility employs the practice of guniting with a horisontaly - inclined converter Flue gases escape into the workplace and atmosphere through aeration ports If vertical guniting were implemented, flue gases would efficiently be sent to gas cleaning operations Conservative estimates show that the proposed upgrading could reduce air emissions by as much as 100,000 tons per year This proposal would require about 5 million U S dollars in investment

Closing Remarks

Although significant pollution prevention measures were identified in this audit, no detailed economic feasibility studies could be implemented The facility management has not provided sufficient information or level of cooperation at this point to assess the economic viability of some of the pollution prevention measures It is recommended that the facility examine some of the recommendations first by examining the potential dollar savings to their operation These dollar savings can be broken into two general categories, namely reductions in environmental fines and penalties, reduced costs associated with feed materials conservation through recycling Once these incentives are defined on a dollar basis, the economic attractiveness of each recommendation can be viewed in terms of the return period for the investment. As examples and also for recommendation as pilot programs for USAID or the World Bank potential funding, the following demonstration projects are recommended

RECOMMENDED PILOT DEMONSTRATION PROJECT AIMED AT POLLUTION PREVENTION.

Demonstration pilot project aimed at the pollution reduction at the blast furnaces (gas-purification of the units of materials loading into the blast furnace).

At present, blast furnaces #2-5 are equipped with installations that clean the air emissions from feeding operations However, due to the low water pressure supplying sprayers to scrubbers, the operation is ineffective.

Modernization of one of these installations is recommended as a pilot demonstration Potentially it would reduce the dust emissions from one blast furnace by 150-200 tons per year.

It is recommended to place a pilot installation at blast furnace#5 This demonstration involves the installation of a high-pressure pump to increase the backpressure of water needed fed to radial sprayers and it will provide sufficient sprinkling of the dirty blast furnace gas.

The following specific tasks would be needed

- Purchase and install a high-pressure pump with discharge of 5 c m /per hour that provides a 50-meter rise of water and up to 3 atmospheric pressures on sprayers
- Cut the existing gas pipeline with sediment (diameter 600 mm, length 70 meter)
- Manufacture and install 3 radial sprayers that work under pressure
- Manufacture and install 2 ejectors that will create circulation of gases in the gas pipeline in order to avoid sedimentation on it
- Install start-up valves regulating water supply that are phased in with the work of the units for material feeding

Blowing of the units for materials loading into the furnace with semi-clean blast furnace gas after every loading of charge is envisaged This will be done in order to avoid the generation of sediments on the gas conduits (at present this measure is not carried out at the existing installation)

The demonstration would reduce dust emissions by 150-200 tons per year for one furnace, and reduce of carbon monoxide releases- 1650 tons per year (for all blast furnaces)

The cost of this pilot installation is 50,000 US dollars, including manufacturing, assembling, purchase of a pump and gas conduit and start-up of the system

The economic incentives for this recommendation are as follows The upgrade will eliminate

the need for the annual replacement of the gas pipelines that are fouled by sediments due to current practices The cost of the gas pipeline replacement is 36,000 grievnas which amounts to 19,355 US dollars (exchange rate is 1 86) (The cost of the pipeline itself is 18,000 grievnas and another 18,000 for the cost of the labor) The implementation of this project will also enable the plant to use 330 tons per year of carbon monoxide (for one blast furnace) which can be readily recovered The annual profit of this utilization amounts to 28,000 grievnas or 15,054 US dollars.

The reduction of dust emissions will also result in a reduction of money environmental fines in the amount of 38,000 grievnas per year or 20,430 US dollars

The total benefit to the plant from this project will be 54,840 US dollars

Hence the return on investment will be about 11 months

Substitution of Pollution Control Equipment Behind the Hammer Crushers at the Agglomeration Plant of the Illich Iron and Steel Plant.

At present there are 4 low-pressure scrubbers that capture lime dust. They are located behind the hammer crushers in the limestone crushing shop These units do not operate properly and lime dust in large quantities is discharged into the crushing shop The ventilation system does not work because gas conduits are corroded and must be replaced The hoods above every hammer crusher must also be replaced

The dismantling of the existing scrubbers and the installation of a dry gas cleaning system comprised of fabric filters on the place of the scrubbers is proposed. As a result, lime dust releases would be reduced, and the amount of sludge in the agglomeration plant would be reduced as well as a conservation of water now used for wet scrubbing.

While implementing this project, the existing hoods above the crushers and gas conduits must be replaced in addition to the installation of fabric filters A new exhaust fan must also be installed.

Following measures are incorporated into the cost of the project

- dismantling of the existing hoods, gas conduits and scrubbers,
- manufacturing and assembling of hoods and other optional equipment,
- manufacturing and assembling of filters,
- purchase and assembling of the exhaust fan;
- start-up work

Approximately 680,000 US dollars are required for the implementation of this project

At present, the average dust content of the exhaust gas-dust streams is 17 g/m^3 After the implementation of the project, the dust content after cleaning will be 20 mg/m^3 The

reduction of dust emissions will be 10 8 thousand tons per year. The reduction of money paid by the plant for the pollution of the environment will amount to 2 07 million grievnas or 1 11 million US dollars (exchange rate is 1.86)

The proposed project secures the normal sanitary conditions at the workplace

Due to the substitution of wet gas cleaning operations by dry gas cleaning proposed in this project, the consumption of recycling water is reduced by 32 million m^3 per year The consumption of make-up water is reduced by 1 6 million m^3 per year The cost of one cubic meter of make-up recycling water is 0 38 grievnas Hence, the resulting savings will amount to 608,000 grievnas or 326,880 U S dollars.

This project could result in a payback period of less than one year, with a yearly operational savings of 1,436 million U S dollars