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Pollution Effects of Abnormal Operations in Iron and Steel Making - Volume I. Technical Report

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Pollution Effects of Abnormal Operations in Iron and Steel Making - Volume 1. Technical Report

by

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PREFACE

This study of the environmental effects of substandard, breakdown, or abnormal operation of steelmaking processes and their controls has been made to provide needed perspective concerning these factors and their relevance to attainment of pollution control. The use of the term Abnormal Operating Condition (AOC) herein, in characterizing any specific condition should not be construed to mean that any operator is not responsible under the Clean Air Act as amended for designing the systems to account for potential occurrence in order to comply with applicable State Implementation Plans or New Source Performance Standards.

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The project was carried out in RTI's Energy and Environmental Research Division under the general direction of Dr. J. J. Wortman. The work was accomplished by members of the Process Engineering Department's Industrial Process Studies Section, Dr. Forest O. Mixon, Jr., Department Manager, Mr. Ben H. Carpenter, Section Head.

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TABLE OF CONTENTS

TABLE OF CONTENTS (cont'd)

LIST OF FIGURES

LIST OF TABLES

INTERNATIONAL SYSTEM OF UNITS AND ALTERNATIVE (METRIC) UNITS WITH CONVERSION FACTORS

Quantity	SI Unit/Modified SI Unit	Equivalent To
mass	kg	2.205 lb
	Mg (megagram = 10^6 grams)	2205 lb
	Mg	1.1025 ton
	Gg (gigagram = 10^9 grams)	
volume	m^3 (cubic meter)	35.32 cf
	dscm (dry standard cubic meter)	
	scm (standard cubic meter: 21°C, 1 atm)	
	ℓ (liter = 0.001 m^3)	
concentration or rate	g/m^3 (grams/m^3)	0.437 gr/ft^3
	mg/m^3 (milligrams/m^3)	0.000437 gr/ft^3
	g/kg	2 lb/ton
energy	J (joule)	0.000948 Btu
	kJ/m^3 (kilojoules/m^3)	0.02684 Btu/ft^3
	MJ (megajoules = 10^6 joules)	
	MJ/Mg	0.430 Btu/lb
		859 Btu/ton
force	kPa (kiloPascal)	0.146 lb/in^2
	1 Pascal = 1 N/m^2 (Newton/m^2)	
area	m^2 (square meter)	10.76 ft^2

1.0 SUMMARY

This report discusses the findings of a study of the effect of abnormal operating conditions (AOC's) on air and water pollution in the iron and steel industry. The purpose of the study was to draw upon available data to describe these conditions and to determine as quantitatively as possible the resulting pollutants attributable to them. The investigation was limited to sintering blast furnace ironmaking, and open hearth furnace, basic oxygen process, and electric arc furnace steelmaking operations and the processes and air and water pollution control equipment associated with these operations. Abnormal operating conditions included startup and shutdown difficulties and upsets of both process and pollution control equipment, plus any unusual deviations in processing from conditions considered for equipment design. AOC's were identified and assessed using data and observations from plant visits, and data from the literature. The assessment was made by estimating, for a generalized steel plant, the increased annual emissions rates and discharges, over and above the rates attainable under specified normal conditions. The efforts so estimated are summarized as follows.

AOC's increased sinter plant windbox annual particulate emissions by 102 percent; and hydrocarbon emissions by 12 percent. Sinter plant product handling AOC's increased particulate emissions by 545 percent.

AOC's increased blast furnace particulate emissions from 53 to 216 percent, while water pollutant increases ranged: 680-24,000 percent for suspended solids, 22,000 percent for cyanides, and 5,900 percent for phenols.

AOC's increased BOP process particulate emissions from 113 to 3,000 percent, while water suspended solids increased 0-418,000 percent.

Based on this analysis, AOC's may be expected to add an additional annual air pollutant emissions load of from one-half to several times the load from non-upset operation. Where water treatment is required, AOC's may add additional discharges estimated at orders of magnitude in excess of standard.

While the environmental impact of AOC's is expected to vary from plant to plant, the AOC's assessed were found to occur to some extent in all plants visited. AOC's appear to be a common problem of importance in the attainment of desired air quality. This initial investigation indicates that there are two types of AOC's: those that can be remedied by applying existing (but not necessarily already applied) technology; and those requiring research and development of suitable controls. Since AOC's have not previously been addressed as a routine part of application of pollution controls, cost data for AOC control are practically non-existent.

Further research appears to be justified, directed in order of judged importance, toward the following areas: 1) additional quantitative data, process and control equipment, 2) blast furnace bell leaks, 3) control equipment bypass at startup, 4) reliability of water recycle systems, 5) external desulfurization of iron, 6) BOP process upsets, 7) better emission factors, 8) sinter plant hydrocarbon emissions control, and 9) blast furnace vacuum filter performance.

This is Volume 1 of the final report. Volumes 2-6 serve as detailed manuals of practice for, respectively, sintering, blast furnace ironmaking, open hearth furnace, electric arc furnace, and basic oxygen process steelmaking. These manuals provide further details concerning the AOC's for each of the processes studied.

2.0 CONCLUSIONS AND RECOMMENDATIONS

The published literature concerning abnormal operating conditions in the iron and steel industry is sparse. Where data and information were found they were usually part of a discussion of operating problems of new pollution control systems rather than being the principle topic of the article. The bulk of the data obtained on cause, effect, frequency, duration, and remedial action for abnormal operating conditions (AOC's) was obtained from the files of pollution control agencies and from the records and data supplied by the steel companies who cooperated in this study.

The total picture of AOC's presented by this report and its five companion volumes has been assembled from a large number of sources, with no one source presenting a complete picture of a typical plant. The model plant generated for this document has been mated with all the major AOC's identified as occurring in plants with similar equipment. Estimates have been made as necessary to complete the evaluation of AOC contributions to increased air and water polluting emissions. On these bases, increased emissions due to AOC's have been shown to be significant when compared to controlled emissions from the same sources. In general, the estimates show increased emissions from AOC's at the minimum levels of frequency and duration to be of the same order of magnitude as controlled emissions. At the maximum condition of frequency and duration, though not all the worst conditions can be expected to occur simultaneously, the estimates of increased pollution are one-half to three orders of magnitude higher than controlled emissions. The implications of this conclusion reach beyond the immediate goal of meeting emission standards to the question of being able to achieve ambient air standards and desired water quality under these conditions.

Virtually no quantitative data on discharge or emission rates during AOC's were found during this study. As a result, estimates were made. Some of the estimates are very sound from an engineering point of view and others weak. Estimates based on complete failure of pollution control equipment are strong provided frequencies and durations are accurate (because uncontrolled emission factors are known). Partial failure estimates are less sound because emission factors for these situations are not available. Partial failure estimates for precipitators can be reasonably well calculated given design data and precipitator theory. The same is not true for fabric filters and scrubbers at least at present. More quantitative AOC emission data are needed.

A necessary step in mounting an effective effort at reducing AOC contributions to environmental problems is to build a data base. The wide variations in AOC record keeping found during control agency visits demonstrates the need to establish a model or standard procedure for obtaining and retaining AOC data, not just for pollution control equipment problems, but also for process problems that increase emissions. Both new and existing sources must be included.

Total or partial failures of pollution control equipment have been identified as significant contributors to increased emissions from AOC's. As opposed to some AOC problems for which there are no ready solutions, there are some effective ways of dealing with control equipment partial failure. Many of the plants visited had spare control equipment capacity or backup for some primary emission sources. Applying this concept to all primary and secondary sources not presently included is a means of effecting AOC emission reductions. This is an available course of action that might be accomplished through enforcement action as opposed to the other AOC's for which additional research is needed to find satisfactory solutions.

For those AOC problems without ready solution, three areas of further research are recommended: development of controls for major AOC's; development of controls with small R&D investment; and development of less costly controls for those AOC's the control of which is now inordinately expensive. These recommendations are discussed in Section 8.

3.0 INTRODUCTION

Air and water pollution standards are generally based upon control of discharges during normal (steady-state) operation. When upsets occur in either the process or its pollution control equipment the abnormal operation may lead to discharges that exceed standards. Iron and steelmaking processes are subject to such upsets, as are other industrial operations. Among the nearly 200 iron and steelmaking plants in the United States, there are pollutant discharge problems under abnormal operation that are important both with respect to environmental severity and technological difficulty. Periods of abnormal operation are becoming recognized as an important factor in the achievement of environmental goals.

There is a need for further information concerning upsets: their identity, cause, resulting discharges, prevention or amelioration.

This study provides an evaluation of pollution problems attributable to abnormal operation, startup, and shut down. It is limited to five processes: sintering, blast furnace ironmaking, open hearth furnace, basic oxygen process, and electric arc furnace steelmaking. The report is issued in six volumes. Volume 1 provides a summary and analysis of more detailed technical data found in Volumes 2 through 6. The latter volumes serve as manuals of practice for use by those who must deal on a day to day basis with environmental problems attributable to abnormal conditions. It is based on available published information, and additional information supplied by iron and steel companies. The evaluation includes comparison of the estimated pollutant discharges under abnormal operation with the estimated discharges under normal operation, discussion of the state-of-the-art technology for handling upsets, and discussion of needs for further research and development.

An abnormal operating condition (AOC) for purposes of this study was considered to be that which departs from normal, characteristics, or steady-state operation, and results in increased emissions or discharges. In addition to abnormal operation, this study includes startup and shut down difficulties of processes and control equipment, substantial variations in operating practice and process variables, and outages for maintenance, either scheduled or unscheduled.

AOC experiences were sought by reviewing reports of upsets made to local, state, and regional pollution control offices. Very little data were found to exist at Control agencies relevant to AOC's. NPDES files offer none, but do serve to identify the plant water handling flow plans. Permit applications provided limited data from which control equipment operating characteristics might be inferred, but seldom if ever contained data relevant to upsets, except for raw gas particulate loadings. Some local agencies had developed upset reporting procedures and thus could provide data from operating experiences. After a preliminary characterization, by engineering analysis, of the processes and their pollution controls, and with the assistance of the American Iron and Steel Institute, steel plants were selected to provide, for each of the subject processes, a range of process and control technology reflecting such factors as plant size and age, type of control, and raw material utilization. Visits were made to 10 plants to observe the processes and their control systems and to obtain available data relating to upsets, their effects, their prevention, and the roles of system design and maintenance.

Three types of information were then developed: the frequency of occurrence of an upset, its duration, and its estimated intensity. The ranges of frequency given in Tables 1-5 (Section 5.0) were developed using both the experience of the plants visited and the data available from Control Agencies. Frequency values thus tend to reflect the performance of more than the number of plants visited. Nevertheless there are data gaps, the data are not always equally representative, and some frequencies are better defined (based on more data) than others.

The duration of an AOC was also developed as a range, sometimes reflecting the punctuality of response to a breakdown, sometimes indicating the seriousness of the underlying cause.

All intensity factors (increased discharge rates) are estimates, since not specific data were found quantifying an AOC per se. Estimates given are based upon the projected reaction of the process control system to the causes of the upset. Ranges are given for the estimates wherever data from the literature of from steady-state operation could be applied.

For each process, the AOC's thus characterized were further investigated to identify causes or suspected causes, and to determine whether corrective methodology is available or needs development.

4.0 ABNORMAL OPERATING CONDITIONS

This section provides descriptions of those AOC's which appear to result in the greatest increases in emissions and discharges. Those described here were selected from more comprehensive lists given in Volumes 2 through 6. They are tabulated in Section 5, where their effects are assessed in terms of increased pollution. Tables referred to in this section are located in Section 5.

4.1 SINTER PLANTS

The most important sinter plant related AOC's identified under this study are shown in Table 1 (Page 24). The process has two main emissions sources, windbox gases from the sintering strand and product handling gases from the sinter breaker, screens, coolers, and associated conveyors. In addition, fugitive emissions result from materials handling and transports.

Generally, operational upsets that increase the dust or hydrocarbon loading of windbox gases will lead to increased emissions even if emissions control equipment continues operations at the same efficiency. Such upsets include inadequate mixing of the feed due to blending practices in the bedding operation, mechanical problems in material transport or proportioning from feed bins. Direct Digital Computer control of the mixing process, to convert the analysis of each material to limestone equivalents, develop a schedule for the bedded pile, and sense operation during the blending and conveying has recently been implemented at one plant with reported improvement in alleviating this problem.[1]

A hearth layer of returned sinter is laid down first to provide a base for the sintering mass and protect the grate bars. When this layer is not uniform, increased amounts of dust pass through. Some plants do not use a hearth layer. Grate bars distort under the thermal and mechanical stress, and the increased openings between them pass extra dusts. Frequent (once a week) maintenance, choice of materials of construction, and protective operating practice can minimize this problem. Most of the cost is reflected in maintenance. Poor sintering can lead to unfused dusts, overburning and underburning at different spots. The sinter will lack uniform quality and there will be increased dust loadings. Causes include too much fine material or varying moisture in the feed, and difficulties in ignition. Hydrocarbon loadings in the windbox gases become excessive when more oils and greases (e.g., from mill scale) are fed then can be adequately burned on the strand. The substitution of petroleum coke can also increase hydrocarbon emissions. The control of hydrocarbons to meet state regulations is a major problem to be overcome in plants when recycle of such materials is practiced. Primarily for this reason, scrubbers and wet ESP's are being considered (and are under test) for use on windbox gases.[2,3]

Electrostatic precipitators (ESP's) are most commonly used for control of windbox gases, although both fabric filters (FF) and scrubbers are also used. Fabric filters are most commonly used for product handling gases, the dust's of which are hard, sharp, and errosive. Each type of control has its characteristic upsets. Both ESP's and FF's are often held inactive during startup until the gases warm up. This is to drive off any condensed moisture within ESP's and prevent damage to insulators and other internal parts. FF's are bypassed to avoid bag-blinding by cold gas contaminants. Both units may be similarly deactivated at shut down. Weekly maintenance requires weekly shut down and startup of these systems.

Some ESP controls include heaters for insulators; these may be turned on ahead of startup. Solid-state transformer-rectifiers may permit initial operation at low voltage, preventing damage while accomplishing partial collection of particulates. Design of ESP's with individually isolatable chambers allows system start up without complete ESP shut down. The costs of retrofitting these features would have to be determined on an individual basis.

Startup and shut down of fans for control equipment involves changing the position of dampers. The resulting changes in air flow usually reentrain dusts settled within the ducts, leading to increased emissions. No complete remedy for this upset has been identified. Electrical equipment upsets for

ESP's include broken electrodes, transformer-rectifier set failure due to overheating, insulator failure, and abnormal rapper operation. Inspection and maintenance on a regular basis, with a suitable spare parts inventory, are required to minimize increased emissions from these causes.

The efficiency of collection of an ESP decreases with increases in dust resistivity.[4] The increase is brought about by adopting a feed mix chosen to produce a sinter of higher basicity than that for which the control unit was designed. A basicity may be set such that resistivity will exceed the capability of an ESP to collect particulates efficiently, in which case, an alternative control technique will be required.

Upsets in the handling of collected dusts include conveyor belt overloads, screw conveyor breakdowns, and dust bridging in hoppers. These have been alleviated by replacing the conveyor system with redesigned units. The costs would have to be determined for a particular system.

Wet ESP's are believed to have many of the same upsets as dry ones. Although none were observed in operation, they are candidate controls for future use and their upset characteristics were obtained from pilot plant test reports.[5,6]

Fabric filters used to control windbox gases are bypassed at startup and shut down to prevent bag-blinding. Other problems include torn bags, shut downs for major repairs, fan failures, and bypasses when inlet gases show temperature excursions (seldom for sinter plants). Fan blades with scroll liners resist abrasion, and fan wheels with replaceable plates are easier to maintain.[7] Upset experiences surveyed under this study are shown in Table 1.

Scrubbers used in sinter plants need erosion resistant (ceramic) linings, and water pipes need to be lined with rubber or other resistant material.[7] The equipment cost may amount to an addition 25-50 percent, which is returned in the form of longer equipment life. Increased emissions result from excess oil in the strand feed, low water flow, demister failure, and plugged sprays. Maintenance of the recycle water system affects scrubber performance; pH control is necessary but not sufficient. Often scrubber waters are combined with those from blast furnaces for final treatment and disposition. In any event, upsets (clarifier failure, high sump levels, low sludge densities, and excessive overflow of recirculating water) can increase the discharge of suspended solids and other water contaminants. Costs of avoiding such upsets depend upon the particular system and range from the costs of redundant pumps to the costs of complete renovating of the system to provide an adequately designed installation.

4.2 BLAST FURNACES

The most important blast furnace related AOC's identified in this study are shown in Table 2 (Page 30). The withdrawal of hot metal can yield increased emissions often related to the furnace operation. The hot iron at the start of the cast yields emissions at rates which are relatively low and increase with agitation and temperature. Slag is withdrawn at the end of the cast. Limey slag leads to excessive fumes and sulfide emissions. Such a slag may be employed at startup to coat hearth and bosh walls and protect against breakouts. After startup, the slag volume is decreased. To remove sulfur with a low slag volume, the slag must be made more basic, hence the temperature must be raised to make the slag flow properly.

Furnace top bleeders are opened at the startup of the blast furnace campaign (once a year or so) until the existing gases show no oxygen and can be cleaned and burned in the stoves. This is done to avoid explosions and no control technology is in use. Bleeders are opened during shut down to release furnace gases from an ore blank or burden quench. They may open during power failures and furnace slips. The result of bleeder opening is the emission of raw, dust-loaded furnace gases.

Furnace slips (or kicks) occur when the furnace burden builds up in a way which retards gas flow. This bridging of material can occur because of improper heat distribution in the furnace, too small size distribution of burden, or improper slag chemistry. A slip is operator-induced, that is the operator sees the blast pressure buildup as the bridging-sealing action takes place. He diverts the blast and the weight of the burden causes the bridge to collapse, slipping the furnace. A kick results when the pressure buildup is rapid, unnoticed, or will not release, and the gas eventually blows through the bridge-seal, blowing the bleeders on the furnace. High-alkali burdens are especially important contributors to slipping. One of the most effective ways to decrease the alkali content of the burden is to decrease the proportion of those materials which are the principal sources of the alkali. Factors that induce good performance in blast furnace operation are also conducive to reducing AOC from slips and kicks.

Bleeder valves, once opened, must be closed manually on many furnaces. Automatic reset controls should help reduce the open-time to a minimum. Partial emissions control during slips might be accomplished by venting through the equalizer, with feed-back control from pressure sensors to open the venturi scrubber throat and, if necessary, the associated vents.[7] Alternatively, two scrubbers might be used in series, with a slip vent between them. This system would vent partially cleaned gas and equipment life would be longer. Installed on a new furnace, a scrubber and equalizer might cost $900,000; the scrubbers with control vent, $1 million. Installation on existing systems might be limited by lack of space.

Certain furnace repairs require backdrafting--furnace gases are drawn back through the tuyeres to a stove and burned or vented through a special backdraft stack. Emission of gas and particulate matter from the opening of relief valves and backdrafting occur primarily during the first 15 minutes. Visible emissions result during this time.

Power failures, if prolonged, can result in severe damage to the furnace with accompanying increased emissions. Residual water in the tuyeres, coolers, bosh plates, and stack plates may boil out and the metal melt. Bleeders may be opened to release gases formed when water leaks develop in copper coolers. Condensation of vapors in gas mains may cause infiltration of air and explosions.[8] Preventive measures include an auxiliary power source, steam-driven pumps, overhead reserve water storage, and operator training for emergency reaction.

Breakouts are caused by failure of the walls with resulting outflow of liquid slag or molten metal and increased emissions. Slag breakouts can be chilled with water and the hole plugged with fireclay. Iron breakouts often stop only upon drainage of the furnace. Most iron breakouts have occurred in furnaces lined with carbon, and have occurred mainly while learning to use this material.

Charging dusty material involves loading, transport, and unloading of skip cars (some 600/day). Friable, dry material yields fugitive dust under such handling. A second screening of pellets, sinter, and coke in the blast furnace stockhouse may alleviate the emissions considerably. Water sprays may help. Extra costs for such control include the screening and spraying equipment and the labor involved.

Furnace stoves can become plugged with dusts, requiring bypass of the stove until it is cleaned. Better gas cleaning can reduce the frequency of plugging. No single methodology (or cost) applies. Dust catchers also become plugged, and are blown clear during shutdowns. The resulting dusts can be partially suppressed with steam and water.

Carbon black can result from the partial burning of tuyere-injected fuel oil and can accumulate in scrubber waters, and float on the surface of the clarifier. The cause may be excessive fuel oil rates, non-uniform distribution of oil among the tuyeres, an improperly centered oil lance in a blowpipe, or excessive use of mill scale in the burden. Detergents added to the water may help to settle the carbon black.

Bell leaks result from lack of complete closure of the bell, due to limitations in machining, and the effects of usage.[9,1] Corrective measures may include the application of new control technology, e.g., equalizers or alternative furnace top designs. This problem warrants further investigation.

Increased emissions into the casthouse occur under several AOC's. A hard blow through the tap hole is employed at shut down to remove as much iron and slag as possible from the furnace. Molten iron may be flushed to the ground to empty the salamander. A slow cast may result from a small tap hole, or be due to limey slag. Cold metal (relative to desirable temperatures) due to low silica and high sulfur within the furnace caused increased emissions of kish during the cast. Wet tap holes are rare, but do add to increased emissions. Tap hole enlargement can increase the flow of hot molten mass. This can often be corrected by use of different materials, e.g., anhydrous clay instead of water-based clay. These process and operations related AOC's are perhaps more amenable to control, generally through control, of cast house emissions, than by adjustment of so much of the operating practice. Such general control is not practiced commonly in this country.

Scrubbers for blast furnace gases incur plugged nozzles and worn internals, and if back pressure results, the furnace bleeders may open to allow the large bell to close. This leads to increased emissions. Corrective actions include nozzle design change, more maintenance and control of the quality of the water supply, especially recirculated water. The costs will depend upon the particular characteristics to be altered (improved).

Water system handling components including pumps and clarifier rakes, are subject to breakdown due to the severity of the service. The result may be discharge of excessive suspended solids, cyanides, and phenols. Redundant pumps, adequate sumps, pipelines equipped with cleanout plugs and blow out connections, and proper choice of materials of construction will help minimize water pollution associated with scrubber operation. None of the observed systems have resolved all their water pollution problems, and further investigation of system design and materials is indicated.

4.3 BASIC OXYGEN PROCESS

Table 3 (Page 33) lists the most important AOC's identified for the BOP during the course of this study. The process related AOC's are listed first as they affect primary emissions from the vessel. Control equipment related AOC's follow as they affect both primary and secondary emissions from the vessel and ancillary operations. The paragraphs that follow briefly describe the cause, effects, and corrective actions for these AOC's. A more detailed discussion of each AOC can be found in the BOP Process Manual also produced under this contract.

Startup of a newly relined vessel necessitates burning-in the tar-bonded refractory vessel lining. Combustion of the volatile matter yields hydrocarbon emissions. These emissions can be vented through the control device attached to the vessel, but collection of these emissions is not necessarily achieved.

When a vessel is taken out of service for relining, the vessel is turned upside down after cooling. The refractory lining is dumped on the ground generating a momentary puff of emissions.

Escape of emissions around the hood skirt or puffing can be caused by rapid vessel reactions or deterioration of the hood panel junctions. A sudden surge in emissions may overcome the available draft and escape. If cracks develop between the hood panels, air inleakage occurs reducing available hood draft. Continual maintenance on the hood and improved process control are possible solutions.

The care used in transferring hot metal from a ladle to the furnace vessel has a big effect on the charging emissions. Use of slow pouring and a proper furnace and ladle angle can reduce charging emissions.

Some BOP shops have relief dampers in their fume capture systems. Excursions in gas temperature coming off the vessel caused by furnace reactions may cause the damper to open to protect attached control equipment. The effect of this AOC can be reduced by stopping the oxygen blow when it occurs and by improved process control.

Foaming and slopping is one result of rapid furnace reactions. It may cause relief dampers to open or at the least cause metal to spill over the vessel side with consequent uncontrolled fume emissions. One plant has reduced the frequency of this problem by revising furnace operating practice.[10] Lance maintenance may also be a factor in reducing these occurrences. Slopping can increase during the life of the furnace lining, the cause being build-up of the bottom resulting in loss of free board for the bath.[35]

Additional emissions during charging may result from improper charge material. Scrap and hot metal quality is the cause. Concrete, water, or oil in the scrap causes increased emissions as does high silicon hot metal. Improved quality control of the charged material can reduce the frequency of this problem.

Steel tapped from the furnace is transported to ingot molds or a continuous caster by ladle. Steel may be emptied from the ladle through a bottom-hole with flow controlled by a stopper rod. When a rod does not seat properly, steel is spilled yielding fume emissions. This AOC may be minimized by improved practice or in some cases, by the use of slide gates to control flow.

Many BOP shops have multiple fan installations providing draft to the vessel. When a fan fails, a spare fan is brought on-line. If the spare fails to start, there will be insufficient draft which results in increased hood emissions. The oxygen blowing rate can, however, be reduced to match draft capacity with emission rate.

Similarly, in many shops adjacent vessels share fan facilities. If the out-of-service vessel is not dampered off, system draft is lost thus producing hood emissions. The dampers used sometimes leak because they are prone to stick open. Attention to control, maintenance, and frequent cleaning of sealing surfaces can minimize this AOC.

Complete failure of primary and secondary emission control systems can be caused by power failures, fan failures, and pump failures. Wastewater treatment can be interrupted by clarifier rake failures. Unless the process also is affected, as may be with power failures, or shut down intentionally, all the emissions escape untreated. Spare capacity in the case of fans, pumps, and clarifiers may prevent this. While spare capacity is frequently found in the case of the primary vessel pollution control systems, the systems for secondary emission control do not typically have spare capacity.

Precipitators and scrubbers are the common emission control devices for the primary vessel emissions. Fabric filters and scrubbers are commonly used to control emissions from the ancillary operations, i.e., charging, tapping, hot metal reladling, external desulfurization.

Manufacturers of precipitators generally recommend a warmup period after a shut down prior to energizing the electrical sets. During this warmup, gases pass through the precipitator untreated. One or more chambers of a multiple-chambered precipitator may be involved. The warmup period may be shortened by use of heat insulation, hopper heaters, and insulator heaters. Also, cold start operation may be possible at reduced voltage when solid state controls are present.

In a multiple fan installation bringing a spare fan into service and shutting down another may upset gas distribution in the precipitator resulting in poor performance. Careful design of plenums and ductwork can minimize this AOC.

Wire breakage, transformer-rectifier (TR) set failure, cracked insulators, and dust removal system breakdown can all cause a portion of a precipitator to be shut down with a resulting increase in particulate emissions. Improved materials of construction and shrouds may reduce wire breakage. Air conditioning the electrical control enclosure may increase the useful life of solid state components in the TR sets.

Cleaning and preventive maintenance can reduce the frequency of problems with insulators. Dust removal problems can be minimized by use of hopper heating, heat insulation, hopper level indicators, and properly used hopper vibrators.

Spray plugging, pump failure, and insufficient conditioning all results in increased dust resistivity and poorer precipitator performance. Chemical control of pH, scaling, and proper material of construction selection can reduce pump and spray problems. Use of steam injection when the gases are too cool to quickly evaporate water improves conditioning.

In the case of scrubbers, plugged sprays or pipes and pump failures reduce the available scrubbing water in turn reducing collection efficiency. As with precipitators chemical control of pH and scaling improves operations.

A plugged demister reduces available draft allowing emissions to escape the hood. Frequent flushing and preventive maintenance can minimize this AOC. Use of a centrifugal demister may also avoid the problem.

Spills to the sewer can result from unbalanced water flow in recirculating systems and during acid cleaning operations to remove scale. Sufficient surge capacity and better coordination of recycle system operation solves unbalanced flow problems. Acid spills can be avoided by careful planning to capture and neutralize waste acid. Care must be taken to avoid leaving an obscure valve open or forgetting where a certain pipe goes.

In closed hood systems, carbon monoxide is generated during the oxygen blow. Most U.S. plants do not save this gas, but choose to flare it as it is produced. When the flare igniter fails, the gas is released unburned. Immediate igniter repair is necessary. Considering the present energy concerns, a better choice would be to store and use the gas as fuel (7,500,000 joules per standard cubic meter ~ 200 BTU per standard cubic foot). The estimated cost of a gas recovery facility in a new plant is about $10 million for a two 227 metric ton vessel shop.[11]

Common problems of fabric filters include bag breakage, plugging, and bag cleaning system failures. Bag breaks result in direct discharges for a portion of the waste gas stream. Plugging or bag cleaning system failure will cause partial or total loss of system drafts. Provision of spare compartments, frequent inspection, and preventive maintenance are the ways to minimize the effects of these AOC's. Poor initial system design may play a large role in these AOC's.

Dust removal system breakdown can also cause partial or total failure. Appropriate action includes those things suggested for precipitators as well as those things listed in the previous paragraphs.

Open bypass dampers may result from high temperature caused by cooling failure (potential to damage bags) or high pressure drop. The effect is direct discharge of emissions to the atmosphere. Frequent equipment inspection and preventive maintenance are the recommended corrective actions.

4.4 ELECTRIC ARC FURNACES (EAF)

The major identified electric arc furnace related AOC's are shown in Table 4 (Page 39). Burn-in relates a new or newly lined vessel into service. When needed, as for example with tar-bonded refractories, burn-in is accomplished by putting burning coke into the furnace and operating the oxygen lance. Excessive carbonaceous emissions reach the control device, and increased outlet loadings result. Burn-in occurs after 100-200 heats. Where control by total building evacuation is practiced, increased emissions may be relatively minor.

Several furnace reactions can occur during the normally turbulent conditions of steel scrap melting and furnace backcharging if the scrap has excessive oil, grease, water, dirt, concrete, or ice. Shops with a canopy hood (CH) will capture a portion of the escaping fume. Corrective measures include reducing the oxygen blowing rate, or the electrical power input, and increasing the furnace draft. Careful selection of scrap and proper storage are preventive measures.

The general level of emissions from an EAF goes up as the quality of the scrap goes down, even in the absence of severe furnace reactions. Poor quality scrap can lead to a one-third increase in loadings, with increased emissions from the overloaded controls. The extent to which scrap quality can be controlled varies from shop to shop.

Shops which rely on manually placed lances for oxygen injection can experience the varying emissions rates that accompany changes in lance position. Excessive blowing rates also increase emissions. The upset is perhaps most pronounced where direct shell evacuation (DSE) control systems are used. This control system requires that an elbow be attached to the furnace roof and that this elbow be aligned with a fixed duct for fume collection. A gap is left to admit combustion air. When the furnace is tilted, e.g., under conditions of foaming slag, misalignment of the duct occurs and substantial emissions escape.

Running stoppers and ladle breakouts have been described under BOF's. Pit or charging explosions can occur when molten steel or slag contacts water. These are accidents that may lead to increased emissions a few times a year.

Fume-capture systems generally include emergency relief or bypass dampers for pressure relief and temperature protection. Pressure and temperature excursions do not appear to be common because of the comparatively lesser decarburization and lower oxygen injection rates, and substantial quantities of dilution air used for baghouse systems.

The commonly used control system is a fabric filter. Its upsets include stack puffs and bag failures as described for sinter plants.

4.5 OPEN HEARTH FURNACE (OH)

The most important open hearth furnace related AOC's identified under this study are shown in Table 5 (Page 40). Either electrostatic precipitators or scrubbers are used to capture particulate emissions. Since fossil fuels are fired as an energy source process, sulfur and nitrogen oxides are also emitted. Neither of these techniques has been addressed as a separate subject. Some removal of SO_x and NO_x may occur in the particulate control devices. No data are available.

Control devices may be bypassed during startup when the furnace is brought up to temperature by preheating with natural gas, the furnace being drafted through the waste heat boiler and out the furnace stack, bypassing the control device. After 12 hours oil may be fired for two to three hours as needed to make the system hot enough to provide hot gas to the control device. About 24 hours of heating are required at startup before iron and scrap can be charged to the furnace to begin steelmaking.

Control of emissions during this period now depends upon proper oil atomization, and employing proper air to fuel ratios in the combustion of the fuels used. Poor oil atomization may occur at any time and with a corresponding increase in hydrocarbon emissions.

Plugged checkers cause low intake air temperature of volume and thus poor combustion. Causes are due to poor cleaning practice and/or excessive dust, soot and slag carryover. Of course, checkers normally plug eventually. To be considered an abnormal operating condition, the checkers should plug and require cleaning more often than normal for the shop.

Poor combustion can be caused by poor reversing practice, excessive fugitive air intake, or an oxygen/fuel ratio problem. These problems are corrected by returning to correct operating practice.

Furnace emissions through the furnace doors are the result of a high furnace pressure, which in turn may be caused by insufficient draft, plugged checkers or active furnace conditions such as hot metal addition, some alloy additions, and the lime boil. The condition may be improved by either reducing the rate of fuel input or oxygen blowing or by increasing the draft.

Molten steel escaping the furnace through an improperly sealed tap hole and spilling onto the shop floor causes a loss of steel, safety problems, and emissions within the building. If a tap hole breakout occurs, it is likely to be controlled within the half-hour.

The cleaning of checkers is generally accomplished by blowing air or steam. The ensuing dust is generally routed through the control device, slightly increasing emissions due to the high particulate loadings. An alternative is to hand draw the equipment, collecting the dust by hand from the bottom of the flue.

Boil-out from an OHF is due to occasional violent furnace reactions caused by hot metal additions, highly oxidized scrap, a violent lime boil, or high silicon hot metal.

Ladle reactions occur due to excessive FeO in the bath, a rapid tap, or a furnace overcharge. Both blowing oxygen at too high a rate and blowing at a high carbon content (> 0.3) can overwhelm the furnace control system. The result is loss of steel yield due to excessive reaction products, high particulate loadings and gas rates to the control device and furnace puffing.

Breakouts can occur in either the furnace or the ladles. Corrective action is to contain the spill with bags; preventive action is close attention to the conditions of the vessels and prompt repair when necessary.

Pit explosions occur in the slag pit or in the vessel and are generally due to the presence of water. The explosion usually shake the building sufficiently to stir up settled dust resulting in some dust emissions from various building openings. The only recommendation for reducing these occurrences is to avoid water leaks and spills. Unfortunately, water in the vessel may enter with the scrap.

A running stopper has previously been discussed (Section 4.3).

If the waste heat boiler fails and is not cooling the process emissions, some shops must bypass the control device. Emissions would be from the single furnace affected and would amount to uncontrolled emissions for the duration of the AOC.

The ESP bypass at startup, stack puffs, unbalanced flow, and wire breakage problems have previously been discussed (Section 4.1). One cause of primary collection system shut down is a catastrophic utility failure. A power failure that affects both the process and control equipment causes both to shut down and, therefore, the immediate environmental effect is small. If, however, power failure leads to the failure only of the control equipment, the OHF operator will have the option of shutting down or continuing the heat. As the control devices are generally retrofits, the OHF process can sometimes operate without controls, though at a reduced rate. In addition, the plants emergency power system may be available to the process and not to the control device.

Scrubber related upsets have been discussed under Sinter Plants and Blast Furnaces.

5.0 ENVIRONMENTAL EFFECTS OF ABNORMAL OPERATION

The effects of abnormal operating conditions were assessed by estimating, within the limits of available data, the attendant increased discharge of pollutants. Three factors are required to characterize each condition: the pollutant discharge rate, the duration of the abnormal condition, and the frequency with which it occurs. Pollutant discharge rates are expressed in the following units:

sinter plant:	g/Mg of strand feed*
blast furnace:	g/Mg of hot metal produced, or g/Mg of hot metal per cast
steelmaking:	g/Mg of steel per heat, or g/Mg of steel per blow.

The duration of each occurrence of an AOC is expressed in hours, minutes, or days, as appropriate. Duration often varied from plant to plant, hence a range is given. The frequency is expressed as the number of occurrences of an AOC per week, month, or year, and a range of frequencies is given as available.

Complete specific data, taken during AOC's do not exist. Discharge rates shown are generally estimates, based on effects of bypassing the control systems with gases carrying measured raw dust loadings, or on effects of likely reductions in operating efficiency of the process or control device as well as the frequency, was based on actual operating experience whenever possible, and estimated when no record of experience was available.

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*or kg/Mg, or Mg/Mg as dictated in the magnitude of the discharge rate.

5.1 SINTER PLANTS

Table 1 summarizes the estimates of these three factors by AOC for sinter plants. The main process emissions sources are covered: windbox gases and product handling. The latter includes the sinter breaker, screens, coolers, and associate conveyors. Only those AOC's believed to result in the most discharges are included. Process related AOC's are listed under windbox gases because these gases receive the attendant increased emissions. Since windbox gases are controlled by ESP's, fabric filters, or scrubbers, AOC's are listed for all three of these controls. Estimates are shown for the wet ESP by analogy since although none were observed in full-scale use, several are expected to be adopted. Where these or scrubbers are used, water treatment AOC's can be expected to occur. Almost all the product handling gases are controlled with fabric filters, and only AOC's for this device are listed in the table.

The increased emissions rates are given relative to the sinter plant strand feed rate because several regulations employ these units.

The increased emissions rate from an improperly formed hearth layer is based on half the EPA Region V estimate of > 50 kg/hour for five minutes, applied to a sinter plant with a strand feed of 220 Mg/hour (240 tons/hr). The rate under operator error is based upon bypass at shut down of a windbox control of 400 Mg/scm particulate loadings. This loading is below the 450-700 Mg/scm reported by Steiner for this gas.[12] The inadequate mixing of feed results in fugitive emissions (from pug mills) estimated at 130 g/Mg of strand feed. Excess air leakage into the system sufficient to give an increased emission rate of 130 g/Mg was assumed. The same rate was set for dust-bridging in ESP hoppers. Grate bar distortion was estimated using a 50 percent increase over the minimum dirty gas particulate loading of 450 g/Mg with no decrease in efficiency of the control device. The loading applied (675 g/Mg) is less than the top of the range reported for these gases, 700 g/Mg.[12] An equal rate was used for excess loading of gases due to poor sintering. Uncontrolled screening of sinter results in fugitive emissions set at 955 g/Mg, equal to the high rate from uncontrolled windbox gases. Excess hydrocarbon emissions from petroleum coke (reported in EPA Region V) were set at twice the controlled rate of 120 g/Mg.

TABLE 1. SINTER PLANT ABNORMAL OPERATING CONDITIONS. ESTIMATED DURATION, FREQUENCY, AND POLLUTANT DISCHARGE RATES

Abnormal Operation by Source and System	Ref.	Discharge Rate Particulates Unless Otherwise Noted	Duration	Frequency
		g/Mg Strand Feed	Hours	
WINDBOX GASES				
A) Process Related				
1. Improperly formed hearth layer	19	110	0.08	≥ 1/month
2. Shut down NO DATA				
3. Operator error, pol. control shut down	19,12	546	0.6	2/yr
4. Inadequate mixing of feed	20	130	1-10	0-4/yr
5. Excess air leakage into sys.	21	130	84	0-≥ 3/yr
6. Grate bar distortion	20	101	≤ 84	≥ 6/yr
7. Excess loading of gases by poor sintering	12	101	≤ 24	≥ 12/yr
8. Uncontrolled screening under equip. bndn.	20	956	≥ 40	≤ 1/yr
9. Substitution of petroleum coke	19	240 (hydrocarbons)	8-24	≤ 2/month
B) Control Equipment Related				
ESP Used				
1. Cold start w/ESP off	12	614-956	≤ 1	≥ 1/week
2. Settled dust reentrainment at startup and shut down	19,21	956	0.08	≥ 2/week
3. Dust overload, conveyor belt	20	100	≤ 1	≤ 4/day
4. Excessively high particulate resistivity	12,13	129	Persistent	Continuous
5. Dust overload, conveyor belt at shutdown	12	100	≤ 1	≥ 1/week

TABLE 1. (cont'd)

Abnormal Operation by Source and System	Ref.	Discharge Rate Particulates Unless Otherwise Noted	Duration	Frequency
		g/Mg Strand Feed	Hours	
6. ESP shut down before process, and bypassed	22	614-956	≤ 1	≥ 1/week
7. Transformer-rectifier failure	12	100	72	≥ 1/yr
8. Screw conveyor breakdown	21	614	1-4	≤ 7/yr
9. Dust bridging in hoppers	20	130	1-2	≤ 1/week
10. Loss of chamber, e.g. insulator fails	20	122	4-48	2/yr
11. Broken electrodes	20	100	3-48	≥ 3/yr
12. Abnormal rapping, heating		100	168	≥ 1/yr
13. Reduced voltage	12	150	24-48	1-2/month
14. Excess oil in feed	20	44-330 hydrocarbons	48	1/month
Fabric Filter Used				
1. Cold start w/baghouse bypassed	12	614-956	≤ 1	≥ 1/week
2. Baghouse shut down ahead of process	22	614-856	≤ 1	1/week
3. Excess oil in feed	20	44-330 hydrocarbons	48	1/month
4. Torn bags	20	410	24-168	1-3/yr
5. Shutdown for major repairs	20	614-956	5 weeks	---
6. Fan Failure	12	614-956	5-97	≤ 5/yr
Scrubber Used				
1. Excess oil in feed	20	44-330 hydrocarbons	48	1/month
2. Low water flow	21	220-440	3-24	1-6/yr
3. Demister failure		220-440	24-72	1/yr
4. Plugged sprays	21	546-682	1-8	1-4/month
5. Low pH		Daily Limited Exceeded		12/yr

TABLE 1. (cont'd)

Abnormal Operation by Source and System	Ref.	Discharge Rate Particulates Unless Otherwise Noted	Duration	Frequency
		g/Mg Strand Feed	Hours	
Wet ESP Used				
1. Cold start with ESP off	12	614-956	≤ 1	≥ 1/week
2. Settled dust reentrainment	19,21	956	0.08	≥ 2/week
3. Excessively high dust resistivity	12,13	129	Persistent	Continuous
4. ESP shut down before process, bypassed	22	614-956	≤ 1	≥ 1/week
5. Transformer-rectifier failure	22	100	72	≥ 1/yr
6. Loss of chamber, e.g., insulator fails	20	122	4-48	2/yr
7. Broken electrodes	20	100	3-48	≥ 3/yr
8. Reduced voltage	12	150	24-48	1-2/month
9. Excess oil in feed	20	44-330 hydrocarbons	48	1/month
10. Plugged sprays	21	546-682	1-8	1-4/month
11. Low water flow	21	220-440	24-72	1/yr
12. Discharge drain water w.o. treatment		75-116	24	2/month
WATER TREATMENT				
1. Clarifier failure	20	75-116	24-120	1/yr
2. High sump level	20	75-116	12-24	1-6/yr
3. Low sludge density		75-116	24-72	1/yr
4. Excessive overflow recirc. water	20	75-116	24	1/month

TABLE 1. (cont'd)

Abnormal Operation by Source and System	Ref.	Discharge Rate Particulates Unless Otherwise Noted	Duration	Frequency
		g/Mg Strand Feed	Hours	
PRODUCT HANDLING GASES				
Fabric Filter Used				
1. Excessively open hoods	20	500-700	≤ 84	2/yr
2. Bypassing, cold start	20	5000	1	≥ 1/week
3. Torn bags	20	410	24-168	1-3/yr
4. Fan failure	12	5000	5-97	≤ 5/yr

A cold startup usually is done without either the fabric filter or ESP turned on, at least for existing controls of these types. Similarly, the control may be shut down ahead of the process. The increased emission rates were based on the range of particulate loadings reported for untreated gases.[12] Settled dust reentrainment was set at the 700 g/Mg dirty gas loading rate. Conveyor belt dust overlaods yield fugitive emissions estimated at 100 g/Mg burden. This value is set low in consideration of the larger particulates fraction involved. High resistivity particulate rates are based on a 10 percent loss in control efficiency with a 450 g/Mg dirty gas loading. Screw conveyor breakdown rates are set at the same level. Rates for ESP insulator failures, 122 g/Mg, are set at a 90 percent increase over controlled emissions. For this purpose, "control" rates were considered to be 65 g/Mg. Broken electrode (ESP) rates are estimated at only 100 g/Mg, the same as for rapper and heater problems.

Reduced ESP voltage emission rates are set at 150 g/Mg, based on the principles of ESP operation.[13]

Hydrocarbon emission rates from excess oil in sinter strand feed is estimated at 44 to 330 g/Mg, based on opinions expressed by plant operating personnel.

Torn bags (fabric filter rates (410 g/Mg) are set at three-fourths the minimum loading of dirty windbox gases. This is high, but reported incidents indicate that torn bags are either a severe problem or a very minor problem. The baghouse fan failure emissions rate is based on dirty gas emissions from continued operation.

Wet ESP emission rates were assigned by analogy since none were found in use, but this system is favored for future use.

Discharges from water treatment AOC's are based on raw wastewater loadings.[14] Only suspended solids values are shown.

5.2 BLAST FURNACE

Table 2 shows the estimated discharge rates, duration, and frequency for blast furnace AOC. A fundamental factor used for these estimates is the dirty gas loading, 42 kg of dust per Mg of hot iron produced.[15] Increased emissions at startup due to excessive lime in the slag were taken at 10 to 20 percent of the basic value. The emissions rate from open bleeders during startup is based on a wind rate of 13 percent of normal.[16] Lindau et. al. show the 0.17 kg/Mg increased emissions used for blowing through the tap hole.[17] The same source was used for emission rates during extended startup, which presents the problem of tap hole failure at full wind rates. Excess slips during startup were considered to result in open bleeders at an average wind rate of 13 percent; the frequency is 0-2 per day for a 3-day average startup. The same average rate is used for open bleeder valves during shut down. The back-drafting emission rate was estimated at 0.01 of the normal rate for dirty gas (0.1 of normal gas flow x 0.1 of the normal loading) since the gases are in reverse flow and do not (fluidize" the solids in the furnace. Water and power failure rates assume an induced draft rate equal to 10 percent of the normal wind rate which gives negligible emission rates compared to fugitive emissions set at 0.5 kg/Mg.

The rate for charging of dusty material is based on the fugitive emissions rate applied 0.035 to 0.07 fraction of the operation time. Rates under plugged stoves are based on clean gas loadings of 0.11 to 2.3 g/scm.[18]

The carbon monoxide (CO) release rate under loss of ignition of bleeders for plugged gas lines is based on a 20 percent bleed of the 3890 scm/Mg wind gas at 35 percent CO. Carbon black is taken as a fugitive emission equal to 8-12 gms/Mg of hot metal produced.

Bell leakage rates were estimated using an average bell service life of 5 years.[9] Slow casts yield increased fugitive emissions from tapping and pouring into ladles. Lindau's measured rate of 0.59 kg/Mg is used for the additional 10-60 minutes of the cast. Cold metal cast emission rates are estimated as the difference between high and low rates measured at the DOFASCO Blast Furnace No. 1 in 1976 (0.364-0.15 kg/Mg).

TABLE 2. BLAST FURNACE ABNORMAL OPERATING CONDITIONS. ESTIMATED DURATION, FREQUENCY, AND POLLUTANT DISCHARGE RATES

Abnormal Operation by Source and System	Ref.	Discharge Rate kg/Mg raw iron	Duration Hours	Frequency
FURNACE				
1. Excessive lime in slag, bleeders open	15	4-8	12-24	1/3-4 yrs
2. Dirty gas bleeders open	16	5.5	12-24	1/3-4 yrs
3. Extended startup	17	0.5	1-4 for 12 days	1/3-4 yrs
4. Excessive slips, startup	15	5.5	15 sec	6/3-4 yrs
5. Bleeder valve open, shut down	15	5.5	16-24	1/3-4 yrs
6. Severe burden slips	23	37-63	5-30 sec	1-50/month
7. Backdrafting		0.21	2 hr-7 days	4-50/month
8. Water and power failure	17	0.5	1-3 days	1/6 or more months
9. Breakouts	17	0.5	≤ 30 min	1/2 yrs
10. Charging dusty material		18-35 gms	5-10 sec	600 chgs/day
11. Stove plugging		0.21-4.600 kg	1/day for 21 days	1/yr
12. Loss of ignition on clean gas bleeder		340 kg CO/Mg	1-4	1/month
13. Formation of carbon black		8-12 gm/Mg	3 months	1/yr
14. Unplugging dust catcher		42 kg	1-8	1-8/yr
15. Leaks from bells		0.3	Continuous	Continuous

TABLE 2. (cont'd)

Abnormal Operation by Source and System	Ref.	Discharge Rate kg/Mg raw iron	Duration Hours	Frequency
CASTHOUSE				
1. Blowing through tap hole	17	0.17	12-48	1/3-4 yrs
2. Hard blow, tap hole, at shut down	17	0.5	15-45 min	1/3-4 yrs
3. Iron flush to ground, shut down	17	0.5	0.5 hr	1/3-4 yrs
4. Slow cast	17	0.59	10-60 min	1-5/week
5. Cold metal		0.21/Mg per cast	40 min	1-2/week
6. Hot, limey slag	17	0.5 kg/Mg per cast	15-45 min	2-7/week
7. Wet tap hole, trough, runner		0.5	5-20 min	1/3 months
8. Tap hole enlargement		0.5	20-45 min	8/day
CONTROLS				
1. Scrubber problems		42	Bleeder 10 sec 4 times/hr for 0.2-48 hours	3-4/yr
WATER TREATMENT				
1. Loss of water pump		SS 5-39 kg/Mg cyanide 0-32 gm/Mg phenol 0-13 gm/Mg	0.5-6 hrs	1-6/month
2. Clarifier rake failure		SS 0.25 kg/Mg cyanide 13 g/Mg phenol 6.5 g/Mg	1-3 days	1-2/yr

Plugged scrubbers, leading to open bleeders are assessed using a 10 second emission from the bleeder four times per hour for from 0.2 to 48 hours.

Water treatment AOC's that increase discharges of high waste loaded water are assessed using data from four plant tests and assuming BATEA standards are normally met. The data are as follows:

Pollutant	Range of Discharge Untreated Waste g/Mg	BATEA Discharge Rate g/Mg
Suspended solids	5-39 kg	0.005 kg
Cyanides	0-32 g	0.13 g
Phenols	0-13 g	0.26 g

Rake failure discharge increases assume a 50 fold increase over BATEA rates.

5.3 BASIC OXYGEN PROCESS (BOP)

Estimates of particulate emissions from BOP steelmaking, shown in Table 3, are based on literature reports of uncontrolled emission rates from the BOP vessel and secondary operations. The total range of reported vessel emissions is 6 to 20 kg/metric ton (Mg) of raw steel. For open hood vessels, the assumed emission factor is 20 kg/Mg; for closed hood vessels it is 10 kg/Mg.

Charging emissions are reported to range from 0.15 to 0.2 kg/Mg of hot metal charged.[24] They were assumed to be 0.13 kg/Mg in Table 3 (assuming 70 percent hot metal charge). Reports of tapping emissions range from 0.08 to 0.1 kg/Mg of raw steel with the assumed value of 0.1 kg/Mg.[24] Hot metal transfer was assumed to be in the range of 0.25 to 0.35 kg/Mg of raw steel.[24] Uncontrolled flux handling emissions were assumed to be 0.75 kg/Mg of raw steel. All the particulate emission calculations in the tables are based on the above assumed values plus other assumptions related to capture and control efficiency of exhaust systems as noted in the following paragraphs.

For burn in the vessel (218 Mg/heat) is assumed to contain about 318 to 363 Mg of tar-bonded refractory. Loss on ignition from tar-bonded brick is about 6 percent of which half is volatiles. The factor in Table 3 assumes

TABLE 3. BASIC OXYGEN STEELMAKING PROCESS ABNORMAL OPERATING CONDITIONS. ESTIMATED DURATION, FREQUENCY, AND POLLUTANT DISCHARGE RATES

Abnormal Operation by Source and System	Ref.	Discharge Rate kg/Mg·heat (kg/Mg·blow)	Duration minutes (fraction of blow time)	Frequency
PRIMARY VESSEL EMISSIONS				
1. Burn in on startup	25	1.5-1.7 kg/Mg·occurrence	10-120	1/2-2/month
2. Vessel dump on shut down	25		1	1/2-2/month
3. Puffing at hood	25,26	(1.0)	(0.05-1.0)	2/day
4. Improper ladle to vessel transfer	25	0.26	1 heat	1/day
5. Relief damper opening	25,26	(2.0)	(0.02-1.0)	1-10/month
6. Foaming and slopping	25,26	(4.0)	(0.05-0.25)	2/week-25% of heats
7. Pit or charging explosions	25-27		20 sec	Pit - 3/yr Charge-1/yr
8. Improper charge material	27	0.13	1 heat	2/week
9. Running stopper	25,27	0.1	1 heat	3/month
10. Insufficient draft on startup	25,26	6.7	180	0-3/yr
11. Draft loss	25-27	2.0	24880	1/month-1/yr
12. Stack puff on startup	25		1-60	1/week-1/yr
13. Dampers stuck or jammed	25,26	2.0	60-1440	1/month-2/yr
14. Power failure	25,26	10-20	0.5	3/yr-1/5 yr
Primary-ESP Used				
1. Precipitator warmup (1 chamber)	25-26	(2.5)	(0-0.5)	1/week-1/month
2. Unbalanced flow among fans	25-26	1.0	720-960	1/week-1/yr
3. Wire breakage	25-27	1 wire 0.07 2 wires 0.14	480-20160	2-12/yr
4. Sprays plugged or corroded	25-27	1.0	1440-4320	3/week-1/month

TABLE 3. (cont'd)

Abnormal Operation by Source and System	Ref.	Discharge Rate kg/Mg·heat (kg/Mg·blow)	Duration minutes (fraction of blow time)	Frequency
5. Insufficient conditioning	26,27	(1.0)	(0.05-0.4)	1/heat
6. Pump failure, corroded, or eroded	26,27	1.0	120-480	3/yr
7. Transformer-rectifier set failure	26,27	0.07	120-43200	1/yr-1/2 yr
8. Cracked insulator	25-27	0.07	60-720	2-4/yr
9. Dust removal breakdown	25-27	0.14	60-480	1/week-1/2 month
<u>Primary-Scrubber Used</u>				
1. Rake failure	25-27	Open hood 20.0 Closed hood 10.0	1440-4320	0-2/yr
2. Sprays corroded or plugged	25-27	Open hood 1.0 Closed hood 0.5	60-420	3/week-1/2 month
3. Plugged or corroded pipes	25-27	Open hood 1.0 Closed hood 0.5	180	6/yr
4. Pump failure, corroded, or eroded	25-27	Open hood 2.0 Closed hood 1.0	120-480	6/yr
5. Plugged or failed demister	26,27	Open hood 2.0 Closed hood 1.0	4320	1/yr
6. Drum filter failure	25			
7. Acid cleaning scrubber overflow		$pH < 6.0$	10-180	1/yr
8. Unbalanced water level	25		60	6/yr
9. Failure to flare gas (closed hood only)	25-27	110 SCM CO/Mg·blow	(1.0)	3/yr/2 vessel
10. Loss of instrument air (closed hood)	25-27	(10.0)	(0.025-0.035)	6/yr/2 vessel

TABLE 3. (cont'd)

Abnormal Operation by Source and System	Ref.	Discharge Rate kg/Mg·heat (kg/Mg·blow)	Duration mintues (fraction of blow time)	Frequency
Secondary Emissions-Fabric Filter Used				
System Failure				
1. Charging	25-27	0.13	30-18720	30/yr
2. Tapping	25-27	0.1		
3. Hot Metal Transfer	25-27	0.25-0.3	60-5760	18-47/yr
4. Flux	26,27	0.75 kg/Mg·day	120-180 (1 day)	1-8/yr
Bag Breakage or Plugged				
1. Charging	25-27	0.0002	780-5760	3-6/yr
2. Tapping	25-27	0.0001	780-5760	3-6/yr
3. Hot Metal	25-27	0.0005	780-5760	3-6/yr
Shaker or Reverse Air Failure				
1. Charging	25-27	0.013	120-1020	4-6/yr
2. Tapping	25-27	0.01		
3. Hot Metal	25-27	0.035		
Open Bypass Damper				
1. Charging	25-27	0.13	480	1/yr
2. Tapping	25-27	0.1		
3. Hot Metal	25-27	0.25-0.35		
Dust Removal Breakdown	25-27	10 to 100% of open bypass	60-480	1/week-1/2 month

1 percent volatized during burn in producing 1.5 to 1.7 kg/Mg of vessel capacity per burn in.

The hood puffing factor assumes a 5 percent loss of hood capture efficiency during puffing. Improper ladle to vessel transfer assumes particulates to be emitted at twice the normal uncontrolled charging rate. Relief damper opening assumes all the uncontrolled emissions pass directly to the atmosphere for the period of the AOC.

Foaming and slopping assumes the hood reaches only 80 percent capture efficiency of fumes during the AOC. Improper charge material is assumed to release particulate equivalent to the normal uncontrolled charging emission rate. The factor for a running stopper was estimated to be equal to normal furnace vessel tapping emissions.

The insufficient draft factor was calculated by assuming one of three fans serving a furnace hood would fail to start. The loss of draft was estimated at 30 percent and hood losses estimated at 30 percent (if blowing rate were simultaneously reduced, the factor would be reduced because not as much draft would be required to capture the emissions).

For the case of a damper being jammed open, a 10 percent flow loss to the non-operating hood was estimated to reduce operating hood capture efficiency by 10 percent. As in the case of a fan failing to start, reducing blow rate would reduce the factor.

Power failure was assumed to interrupt the process shutting down the vessel and control system. The emissions result from an estimated 30 seconds of uncontrolled residual emissions after the process shuts down.

The precipitator warmup factor is based on a eight-chambered precipitator, one chamber of which is being brought on-line. Therefore, one-eighth of the process emissions would be uncontrolled for that period. Unbalanced flow among fans was assumed to reduce precipitator efficiency by 5 percent from a base efficiency of 98.5 percent.

For wire breakage the precipitator condiguration was assumed to be eight chambers by four fields in the direction of gas flow giving 32 electrically isolatable sections. One wire failure takes one section out of service.

Base precipitator efficiency was 98.5 percent for a specific collection area of 80.9 square meters per actual cubic meter per second. The Deutsch equation was used to calculate the reduced efficiency in the affected chamber.

Corroded and plugged sprays were assumed to cause a 5 percent reduction in efficiency from a base of 98.5 percent. The same assumption was applied to insufficient conditioning and pump failure. Transformer-rectifier set failure, cracked insulator, and dust removal system breakdown factors were calculated the same as for wire breakage, except that dust removal system failure assumed two sections out of service instead of one.

For clarifier rake failure, once through scrubbing water with no terminal treatment was assumed, giving suspended solids of 20 kg/Mg of raw steel for open hoods and 10 kg/Mg for closed hoods. Spray problems and corroded or plugged pipes were assumed to reduce scrubber efficiency by 5 percent. Pump failure with no spare was assumed to be 10 percent efficiency reduction. A plugged demister reduces hood draft; in this case 10 percent reduction was estimated.

Unflared carbon monoxide emissions were estimated on the basis of 3.1 standard cubic meter per minute of oxygen blown per metric ton of raw steel. For a twenty minute blow and all oxygen reacting with carbon, and 10 percent combustion of CO to CO_2, the emission factor is 110 scm/Mg of raw steel. This factor would be reduced by 50 percent or more if a CO storage facility is used.

Loss of instrument air is treated the same as a power failure. The blow wuld be interrupted, but 30 seconds of residual emissions was assumed.

For bag breakage in secondary emissions collectors a collector size was estimated on the basis of 4300 actual cubic meters per minute hood exhaust and an air-to-cloth ratio of 1.5 cm per second. With 644 total bags one bag break was estimated to release 1/644 of the total particulate load.

Shaker or reverse air failure was assumed to affect only one compartment (total of eight). Taking this compartment out of service was estimated to reduce available hood draft by 10 percent. Dust removal system breakdown could affect one or more compartments producing anything from 10 percent draft loss to complete system failure.

Fan failures in secondary control systems generally mean complete system failure because spare fans are typically not provided.

5.4 ELECTRIC ARC FURNACE STEELMAKING

Table 4 shows the estimated increased discharge rates, duration, and frequency for Electric Arc Furnace AOC's. Raw gases from the process were set at 10-15 kg of particulate per Mg of steel per heat.[28,29,30] Burn-in emissions were considered to be hydrocarbons from the partial combustion of new tar-bonded ceramic furnace linings. Abnormal furnace reactions were assessed using an 85 percent capture of dirty gas loaded at 10 kg/Mg per heat. Poor scrap was expected to result in 33 percent greater particulate loading of the gases with 0.1 of this increase passing through the control device. Improper oxygen lance practice is expected to increase emissions only from direct shell evacuation systems: the rate is based on escape of 4 percent of the loading 10 percent of the time. Capture duct misalignment emissions are based on escape of 0.5 to 0.8 of the total gas loading. Fugitive emissions (e.g., running stoppers, ladle breakout, charging explosions) are based on 0.5 kg particulates/Mg per heat.

Relief damper openings yield emitted dirty gas at 10-15 kg/Mg x heat. Stack puffs are based on the same rate. Bag failures are rated very conservatively using 0.01 of the raw gas loading.

Bag failures are presumed to be corrected as detected, and are assessed at 0.01 of the raw gas loading.

5.5 OPEN HEARTH STEELMAKING

Table 5 provides rough estimates of increased discharges from Open Hearth Steelmaking AOC's. Hydrocarbon emissions increase during startup, times of poor oil atomization, plugged checkers, or poor combustion. A discharge rate of 240 gms/Mg x heat was selected by analogy with sinter plant excess oil charge usage. Raw untreated gases were set at 5-10 kg/Mg of product x heat. Fugitive emissions (e.g., breakouts, running stoppers) are estimated using 0.5 kg/Mg x heat or 0.5 kg/Mg x ladle, this being the rate measured by Landau from blast furnace cast house AOC's of similar type.[31] Fugitive emissions

TABLE 4. ELECTRIC ARC STEELMAKING PROCESS ABNORMAL OPERATING CONDITIONS. ESTIMATED DURATION, FREQUENCY, AND DISCHARGE RATES

Abnormal Operation by Source and System	Ref.	Discharge Rate	Duration	Frequency
PROCESS RELATED				
1. Burn in	Est.	1.5-1.7 kg/Mg/occurrence	10-120 min	1/1 or 2/mth
2. Abnormal furnace reaction	Est.	1.5 kg/Mg x heat	2-5 min	1/month
3. Poor scrap quality	Est.	0.03 kg/Mg x heat	Till quality is good	
4. Improper lance position	Est.	0.04-0.06 kg/Mg x heat	Till corrected	
5. Capture duct misalignment	Est.	5-12 kg/Mg x heat	10 min	1/day
6. Running stopper	Est.	0.5 kg/Mg/ladle	5-30 min	0-2/day
7. Ladle breakout	Est.	0.5 kg/Mg/ladle	5 min	1/yr
8. Pit or charging explosion	Est.	0.5 kg/Mg/ladle	20 min	1-3/yr
9. Relief damper opening	Est.	10-15 kg/Mg x heat	10-30 min	1/yr
Fabric Filter				
1. Stack puff		10-15 kg/Mg x heat	1-5 min	1-50/yr
2. Bag failure		0.1-0.15 kg/Mg x heat	1-7 days	1/yr

TABLE 5. OPEN HEARTH FURNACE STEELMAKING PROCESS ABNORMAL OPERATING CONDITIONS. ESTIMATED DURATION, FREQUENCY, AND POLLUTANT DISCHARGE RATES

Abnormal Operation by Source and System	Discharge Rate	Duration	Frequency
PROCESS RELATED			
1. Startup	240 g HC/Mg per hour	8-15 hr	1/2-1/mth
2. Poor oil atomization	240 g HC/Mg per hour	---	---
3. Plugged checkers	240 g HC/Mg per hour	2 days	1/month
4. Poor combustion	240 g HC/Mg per hour	10 min	1-50/yr
5. Furnace puffing	0.25-5 kg/Mg x heat	1 hr-persistent	1/week
6. Tap hole breakout	0.15-0.5 kg/Mg x heat	30 min	1/yr
7. Cleaning checkers	0.6 kg/Mg x heat	1-4 hrs	1/month
8. Boilout	0.15-0.5 kg/Mg x heat	1-3 min	1-2/month
9. Ladle reactions			
10. Improper control O_2 blowing	0.5-1 kg/Mg x heat	1-30 min	1/month
11. Breakouts	0.15-5 kg/Mg x heat	15 min	1/month
12. Pit or charge explosion	0.15-5 kg/Mg x heat	1-2 min	1-4/yr
13. Running stopper	0.15-5 kg/Mg x ladle	30-60 min	1-3/month
14. Waste heat boiler failure	Uncontrolled emission 5-10 kg/Mg x heat	15 hrs	1/month
CONTROLS			
1. ESP bypass, startup	5-10 kg/Mg x heat	1-15 hrs	2/month
2. Stack puff	5-10 kg/Mg x heat	1-60 min	1-50/yr
3. Unbalanced flow to ESP	10% additional emissions*	---	---
4. Primary collection system	5-10 kg/Mg x heat	0-15 hrs	.2-3/yr
5. ESP wire breakage	Some 1.4 times controlled emissions	---	---

TABLE 5. (cont'd)

Abnormal Operation by Source and System	Discharge Rate	Duration	Frequency
Scrubber			
1. Clogged sprays	Increased if $L/G \leq 0.6\ \ell/SCM$	1-3 hr	1/8-3/wk
2. Plugged pipes	Increase rate		1-2 month
3. Pump failure	Increase rate		0-1/month
4. Plugged demister	Increase rate	---	---
5. Vacuum filter failure	NO DATA BUT SAID TO BE FREQUENT		
6. Acid cleaning spills	Low pH discharge	10mm-3 hr	1/3 month
Rake failure	5-10 kg/Mg x heat	1-3 days	0-2/yr
Transformer-rectifier failure	Some 1.4 times controlled rate*	2 hrs- 1 month	5-1/yr
Insulator failure	Some 1.4 times controlled rate*	to 3.5% of time	----

*One affected section out of a set of 16 sections.

from furnace puffs were set at 0.05 of the uncontrolled rate. Values for scrubber AOC's, ESP AOC's, and water treatment are selected by analogy with the previously described processes, where possible. No suitable estimates were set for clogged sprays, pump failures, plugged demisters, and vacuum filter failure.

6.0 EVALUATION OF ENVIRONMENTAL PROBLEMS PRESENTED BY ABNORMAL OPERATION

Tables 1-5 provide a basis for projecting the impact of AOC's at a specific plant. The impact would vary from plant to plant due to variations in types of processes and control equipment, to differences in production rates, and to differences in feed components. Emissions and discharge limitations, both daily and average, may be increased, depending on the intensity and duration of the AOC. To provide some perspective as to the probable importance of AOC's, the increased discharges therefrom have been projected for a generalized integrated steel plant rated at 7000 Mg/day raw steel, with two sinter plants, two blast furnaces, and two BOP's.

Table 6 shows the material balance for the plant and the production rates by hour, day, and year. Sinter feed includes a hearth layer. The material mass balance relates iron, scrap, sinter, and sinter feed requirements. The sinter is assumed to contain 62 percent iron. The feed/product ratio, 1.2/0.91 is based on current experience of plants visited. The iron production is based on a material balance, page 457 of reference 15. The ore is assumed to contain 62 percent iron: the pig iron, 93.5 percent iron. The steel production is based on current experience at visited plants. The BOP charge is set at 30 percent scrap, 70 percent molten iron with an 85 percent yield. There are two furnaces. One 220 Mg BOP is in use while the other is under service or on standby. Thirty-two 45-minute heats per day are made at full production.

The sinter usage may be higher than that found at some plants. If trends toward higher basicity sinter and increased pellet usage continue, then the sinter plant production will decrease, relative to the rates shown in this example.

This plant's operation is projected for one year, taken as 350 operating days, during which the most important AOC's are also projected in terms of increased emissions or discharges.

Table 7 identifies the increased pollution by process and source. Discharge rates, duration, and frequencies selected from Tables 1-5 have been used

TABLE 6. DESCRIPTION OF GENERALIZED STEEL PLANT

A. MATERIAL MASS BALANCE[a]

1.2 sinter feed → 0.91 sinter

0.074 scrap + 0.38 coke + 0.006 lime + 0.23 ore + 0.91 sinter → 0.83 iron

0.08 lime + 0.36 scrap + 0.83 iron → 1 steel

B. PLANT DESCRIPTION

Unit	Sinter Plant	Blast Furnace	BOP
Number	2	2	2 (1 spare)
Production rate			
each unit Mg/day[b]	2644	2905	7000
all units, Mg/day	5287	5810	7000
all units, Mg/hr	221	242	292
million Mg/yr	1.850	2.033	2.448
Sinter Strand Feed			
All units, Mg/hr	291		
Million Mg/yr	2.444		
Control Equipment			
	Windbox: ESP	Furnace Gas: Scrubber	Vessel: Open hood w/Scrubber
	Product: Fabric Filter	Casthouse: None	Secondary: Fabric Filter

[a] 1 Mg = 1.1025 ton

TABLE 7. ESTIMATED ANNUAL INCREASED POLLUTION FROM ABNORMAL OPERATION, GENERALIZED STEEL PLANT

	EMISSIONS		DISCHARGES		
	Particulates	Hydrocarbons	Suspended Solids	Cyanide	Phenol
Source	Mg/yr	Mg/yr	Mg/yr	Mg/yr	Mg/yr
SINTER PLANTS[a]					
Windbox Gases					
Process related	14.1	20.1			
P/C equip. related	221.8	35.2			
Subtotal	235.9 (240)[c]	55.3 (443)			
Product Handling Gases					
P/C equip. related	534.3 (96)				
Subtotal , Sinter Plants	770.2 (336)	55.3 (443)			
BLAST FURNACES[b]					
Furnace	172-962 (464-564)	5.6-8.4			
		Carbon Monoxide 987-3949			
Scrubber	0.1-21.6 (0.1)				
Cast house	76-238				
Water Treatment			8.8-3565	0.07-3.7	0.04-1.6
Subtotal, Blast Furnaces	248.1-1221.6 (464-564)	5.6-8.4	8.8-3565 (0.037-522)[c]	0.07-3.7 (0-0.017)	0.04-1.6 (0-0.27)

TABLE 7. (cont'd)

Source	EMISSIONS Particulates Mg/yr	EMISSIONS Hydrocarbons Mg/yr	DISCHARGES Suspended Solids Mg/yr	DISCHARGES Cyanide Mg/yr	DISCHARGES Phenol Mg/yr
BASIC OXYGEN PROCESS					
Primary Vessel Emissions					
Process	36.8-1531.3 (68.4)	2-8.9			
P/C, scrubber and associated water treatment	54.8-382.3 (0.9-10.0)		0-836.9 (0.2)[d]		
Secondary Emissions	4.3-1085 (15.4-16.6)				
Subtotal, BOP	95.9-2999 (84.7-95.0)	2-8.9	0-836.9 (0.2)[d]		
TOTAL, Plant	1114-4991	62.9-72.6	8.8-4402	0.07-3.7	0.04-1.6
		Carbon Monoxide 987-3949			

[a] Based on a controlled emissions rate of 65 g particulates/Mg strand feed and 120 g HC/Mg strand feed.

[b] Based on no startup or shut down during the year.

[c] Numbers in parentheses are the annual pollutant discharges under continued control without any abnormal operation.

[d] Based on one day maximum allowable discharge.

TABLE 8. ESTIMATED EMISSIONS AND DISCHARGES FROM ABNORMAL OPERATION

GENERALIZED STEEL PLANT: TWO SINTER PLANTS

AOC	Total Emissions, Mg/yr 10^{-6}[RatexMg/hrxDuration(hr)xTimes/yr)		Equivalent Controlled Emissions[a] Mg/yr	Net Increased Emissions Mg/yr
PROCESS RELATED				
Windbox Gases				
1. Hearth layer	110x291x.0.08x12	0.030	0.018	0.012
3. Operator error	546x291x0.6x2	0.19	0.023	0.17
4. Inadequate feed mix	130x291x10x4	1.5	0.75	0.75
5. Excess air leaks	130x291x84x3	9.52	4.76	4.76
6. Grate bar distortion	101x291x84x6	14.8	9.52	5.27
7. Poor sintering	101x291x24x12	8.47	5.45	3.02
8. Use of petroleum coke or oily feed material	240x291x24x24	40.2	20.1	20.1 (HC)
Total annual increase, Particulates				14.1
HC				20.1
CONTROL EQUIPMENT RELATED				
ESP				
1. Cold start	956x291x1x50	13.9	1.0	12.9
2. Dust reentrained	956x291x0.08x104	2.3	0.1	2.2
3. Dust overload	Assumed not to occur, this plant			
4. High resistivity	129x291x24x350	314	159	155
5. Dust overload, shut down	100x291x1x50	1.5	1.0	0.5
6. ESP shut down	956x291x1x50	13.9	1.0	12.9
7. Transformer-rectifier failure	100x291x72x1	2.1	1.4	0.7
8. Screw conveyor breakdown	614x291x4x7	5.0	0.5	4.5
9. Dust bridging	Assumed not to occur, this plant			

TABLE 8. (cont'd)

AOC	Total Emissions, Mg/yr 10^{-6}[RatexMg/hrxDuration(hr)xTimes/yr]		Equivalent Controlled Emissions Mg/yr[a]	Net Increased Emissions Mg/yr
10. Loss of chamber	122x291x48x2	3.4	1.9	1.5
11. Broken electrodes	100x291x48x3	4.2	2.8	1.4
12. Abnormal rap	100x291x168	4.9	3.2	1.7
13. Reduced voltage	150x291x48x24	50.3	21.8	28.5
14. Excess oil, hydrocarbons	330x291x48x12	55.3	20.1	35.2 (HC)
Total annual increase, Particulates				221.8
HC				35.2
PRODUCT HANDLING				
CONTROL EQUIPMENT RELATED				
Baghouse				
1. Excessively open hoods	700x291x84x2	34.3	1.2[b]	33.1
2. Bypassing, cold start	5000x291x1x50	72.7	0.4	72.3
3. Torn bags	410x291x168x3	60.1	3.6	56.5
4. Fan failure	5000x291x50x5	364	1.9	362.1
5. Screen breakdown	956x291x40x1	11.1	0.76	10.3
Total increased particulates				534.3 Mg
Percent Increase[c]				
Windbox: Particulates	100(24.3 + 221.8)/240	= 102		
HC	100(20.1 + 35.2)/443	= 12		
Product Handling: Particulates	100(534/96)	= 545		

[a]Based on a controlled emissions rate of 65 g particulate per Mg of strand feed and 120 g hydrocarbons per Mg of strand feed. The use of the HC standard is indicated by (HC).

[b]Based on a controlled emissions rate of 25 g particulate per Mg of strand feed.

[c]Percent increase based on controlled emissions for an entire year of 240 Mg for windbox particulates, 443 Mg/yr for windbox hydrocarbons, and 96 Mg/yr for product handling particulates.

TABLE 9. ESTIMATED EMISSIONS AND DISCHARGES FROM ABNORMAL OPERATION

GENERALIZED STEEL PLANT: TWO BLAST FURNACES

AOC	Total Emissions Mg/yr Particulates 10^{-3}xkg/MgxMg/hrxDuration(hr)xTimes/yr		Equivalent Controlled Emissions Mg/yr	Net Increased Emissions Mg/yr
FURNACE				
1. Excessive lime in slag, bleeders open	(4-8)x242x(12-24)x1	11.6-46	0.7-1.4	10.9-44.6*
2. Dirty gas bleeders open	5.5x242x(12-24)x1	16-32	0.6-1.3	15.4-30.7*
3. Extended startup	0.5x242x(1-4)x12	1.5-5.8	0	1.5-5.8*
4. Excess slips, startup	5.5x242x15/60x60x6	0.03	0	0.03*
5. Bleeders open, shut down	5.5x242x(16-24)	21.2-32	0.9-1.2	20.3-30.7*
6. Severe burden slips	(37-63)x242x(5-30/3600)x 12-600	0.15-76.2	0.001-0.3	0.15-75.9
7. Backdrafting	0.42x242x(3)x(4-50)x12	14.6-183	7.8-97.6	3.5-43
8. Water and power failure	0.5x242x(24-72)x(1-2)	3.9-17.4	1.3-7.8	1.6-9.6
9. Breakouts	0.5x242x0.5x1	0.06	0	0.06
10. Charging dusty material	(0.018-0.035)x242x5-10/ 3600x600x350	1.3-4.9	0	1.3-4.9
11. Stove plugging	(0.21-4.6)x242x21x1	0.22-23.3	0	0.22-23.3
12. Loss of ignition, clean gas bleed	340x242x(1-4)x12	987-3949	Carbon monoxide	987-3949
13. Formation of carbon black	(0.008-0.012)x242x24x120	5.6-8.4	Hydrocarbons	5.6-8.4
14. Unplugging dust catcher	42x242x(1-8)x(1-8)	10.2-653	0.05-3.5	10.1-650
15. Leaks from bells	0.3x242x24x350	610	455	155
Total annual increase, particulates	with startup, shut down			220-1074
	without startup, shut down			172-962
HC				5.6-8.4

TABLE 9. (cont'd)

AOC	Total Emissions Mg/yr Particulates 10^{-3}xkg/MgxMg/hrxDuration(hr)xTimes/yr		Equivalent Controlled Emissions Mg/yr	Net Increased Emissions Mg/yr
CASTHOUSE				
1. Blow through taphole	0.17x242x(12-48)	0.5-2.0	---	0.5-2[a]
2. Hard blow, tap hole, shut down	0.5x242x(0.25-0.75)	0.03-0.09	---	0.03-0.09[a]
3. Iron flush to ground, shut down	0.1x242x1.5	12	---	12[b]
4. Slow cast	0.59x242x(0.17-1)x(12-60)	0.3-8.6	---	0.3-8.6
5. Cold metal	2x0.21x533Mg/castx(50-100)	11.2-22.4	---	11.2-22.4
6. Hot limey slag	2x0.5x533x(100-350)	53.3-187	---	53.3-187
7. Wet tap hole, trough, runner	2x0.5x533x4	2.1		2.1
8. Tap hole enlargement	0.5x242x(0.33-0.67)x4x90	14.3-29	5.7-11.7	8.6-17.3
Total annual increase, particulates	with startup, shut down			88-252
	without startup, shut down			75.5-238
CONTROLS				
1. Scrubber problems	42x242x40/3600x(0.2-48)x(3-4)	0.07-21.7	0-0.1	0.07-21.6
WATER TREATMENT				
1. Loss of water pump	SS (5-39)x242(0.5-6)x(12-72)	7.3-4078	0.007-522	7.3-3556
	Cyanide 0-0.032x242x(0.5-6)x (12-72)	0 -3.3	0-0.013	0-3.3
	Phenol 0-0.013x242x(0.5-6)x (12-72)	0-1.4	0-0.03	0-1.35

TABLE 9. (cont'd)

AOC	Total Emissions 10^{-3}xkg/MgxMg/hrxDuration(hr)xTimes/yr	Mg/yr Particulates	Equivalent Controlled Emissions Mg/yr	Net Increased Emissions Mg/yr
2. Clarifier rake failure	SS 0.25x242x(24-72)x(1-2)	1.5-8.7	0.03-0.2	1.5-8.5
	Cyanide 0.012x242x(24-72)x(1-2)	0.07-0.4	0 -0.004	0.07-0.4
	Phenol 0.007x242x(24-72)x(1-2)	0.04-0.24	0 -0.009	0.04-0.23
Total annual increase water		SS		8.8-3565
		Cyanides		0.07-3.7
		Phenol		0.04-1.58

PERCENT INCREASE

Particulates: 100(172 + 76)/464 = 53; 100(962 + 21.6 + 238)/564 = 216

Suspended Solids: 100(8.8/0.037) = 24000; 100(3563/522) = 683

Cyanides: 100(3.7/0.017) = 22000

Phenols: 100(1.6/0.027) = 5926

[a]Startup: once in 3-4 years

[b]Shut down: once in 3-4 years

TABLE 10. ESTIMATED EMISSIONS AND DISCHARGES FROM ABNORMAL OPERATION

GENERALIZED STEEL PLANT: TWO VESSEL BOP SHOP (ONE OPERATING)
OPEN HOOD USING A VENTURI SCRUBBER
FABRIC FILTER APPLIED TO ANCILLARY OPERATIONS

AOC	Total Emissions Mg/yr Particulates[a] 10^{-6} [Rate x Mg/heat x Duration x Times/yr]		Equivalent Controlled Emissions Mg/yr	Net Increased Emissions Mg/yr
PRIMARY VESSEL EMISSIONS				
Process				
1. Burn in	1.5-1.7(218)(6-24) =	2.0-8.9 H_xC_x		
2. Vessel dump on shut down				
3. Puffing at hood	1.0(.05-1.0)(218)(2)(350)=	7.6-152.6	0.2-4.3	7.4-148.3
4. Improper ladle to vessel transfer	0.26(1-3)(218)(1)(350) =	19.8-59.4	0.05-0.15	19.8-59.3
5. Relief damper opening	20(0.02-1.0)(218)(1-10)(12)=	1.0-532.2	0-0.73	1.0-522.5
6. Foaming and slopping	4.0(0.05-0.25)(218)(2-54) (52) =	4.5-612.1	0.03-4.3	4.5-607.8
8. Improper charge material	0.13(1)(218)(2)(52) =	2.9	0.015	2.9
9. Running stopper	0.1(1)(218)(3)(12) =	0.8	0	0.8
10. Insufficient draft on startup	6.7(180)(1heat/45min)(218) (0-3) =	0-17.5	0-0.07	0-17.4
13. Damper stuck or jammed	2.0(60-1440)1/45(218)(2-12)=	1.2-167.4	0.02-2.3	1.2-165.1
14. Power failure	(10-20)(0.5)(1/45)(218) (0.2-3) =	0-0.1	0	0
Total Process		2.0-8.9 H_xC_x		36.8-1531.3
Control-Venturi Scrubber				
1. Rake failure	20(1440-4320)(1/45)(218) (0-2) =	0-837.1	0.2	836.9 (SS)
2. Sprays corroded or plugged	1(60-420)(1/45)(218)(6-156)=	1.7-317.4	0.05-8.9	1.6-308.5

TABLE 10. (cont'd)

AOC	Total Emissions Mg/yr Particulates		Equivalent Controlled Emissions Mg/yr	Net Increased Emissions Mg/yr
3. Plugged or corroded pipes	1(180)(1/45)(218)(6) =	5.2	0.15	5.0
4. Pump failure	2(120-480)(1/45)(218)(6)=	7.0-27.9	0.10-0.39	6.9-27.5
5. Plugged or failed demister	2(4320)(1/45)(218)(1) =	41.9	0.59	41.3
6. Drum filter failure	NO SUITABLE BASIS FOR ESTIMATE			
8. Unbalanced water level				
Total Control				54.8-1219.2
SECONDARY EMISSIONS				
System Failure				
1-2. Charging & Tapping	0.23(20-18720)(1/45)(218)(30) =	1.0-625.7	0.01-3.1	1.0-622.6
3. Hot metal transfer	0.25-0.35(60-5760)(1/45)(218)(18-47) =	1.3-459.0	0.01-2.3	1.3-456.7
4. Flux handling	0.75(1)(218)(1-8) =	0.2-1.3	0-0.01	0.2-1.3
Bag Breakage & Plugging				
1-2. Charging & Tapping	0.0003(780-5760)(1/45)(218)(3-6) =	0-0.05	0.01-0.19	0
3. Hot Metal	0.0005(780-5760)(1/45)(218)(3-6) =	0-0.8	0.01-0.29	0.5
Shaker or Reverse Air Failure				
1-2. Charging & Tapping	0.023(120-1020)(1/45)(218)(4-6) =	0.1-0.7	0-0.03	0.1-0.67
3. Hot Metal	0.035(120-1020)(1/45)(218)(4-6) =	0.1-1.0	0-0.05	0.1-0.95

TABLE 10. (cont'd)

AOC	Total Emissions Mg/yr Particulates		Equivalent Controlled Emissions Mg/yr	Net Increased Emissions Mg/yr
Open Bypass Damper				
1-2. Charging & Tapping	0.23(480)(1/45)(218)(1)	= 0.5	0	0.5
3. Hot Metal	0.25-0.35(480)(1/45) (218)(1)	= 0.6-0.8	0-0	0.6-0.8
Dust Removal Breakdown				
1-2. Charging & Tapping	10-100% of (0.23)(60-480)(1/45)(281)(1)	= 0.01-0.53	0-0	0.01-0.53
3. Hot Metal	10-100% of (0.23)(60-480)(1/45)(218)(1)	= 0.01-0.58	0-0	0.01-0.58
Total Secondary Emissions				4.32-1085

PERCENT INCREASE

Particulates: 100(95.9/847) = 113; 100(2999/95) = 3157

Suspended Solids: 100(836.9/0.2) = 418,000

[a]Emissions for BOP Shop are appropriately calculated here on a per-heat basis using 218 Mg per heat, which is equivalent to the 292 Mg/hour production given in Table 6.

to calculate the total annual emissions during AOC's for each of the model plant's processes. For clarity, the calculations used for each AOC are presented in Tables 8, 9, and 10. As a means of demonstrating the potential net effects of AOC's on the environment, equivalent controlled emission levels have also been calculated. The net potential increases in emissions due to AOC's are presented in the last column as the difference between AOC and controlled emissions.

The basis for calculation estimates of controlled emissions was established by considering New Source Performance Standards, Effluent Guideline Limitations, proposed or discussed potential standards, and outlet concentrations achievable with high efficiency control devices as discussed in the following paragraphs.

Controlled sinter plant windbox particulate emissions were set at 65 g/Mg of strand feed; hydrocarbons, at 120. Product handling controlled particulate emissions were also set at 65 g/Mg.

Controlled blast furnace particulate emissions were set at 224 g/Mg, based on 0.11 g/scm of cleaned gases given in the Effluent Guidelines. Water discharge limits were set at 0.005 kg/Mg suspended solids, 0.13 g/Mg cyanides, and 0.26 g/Mg phenols, based on the best available technology economically achievable.[14]

For the BOP, there is a New Source Performance Standard of 50 milligrams per dry standard cubic meter. Since it is stated as a concentration, a variation in the amount of gas produced by the process causes the allowable maximum emission rate to vary. The model plant uses an open hood capture system tied to a venturi scrubber. Based on an uncontrolled particulate rate of 20 kg/Mg of raw steel and a dry gas rate of 102 standard cubic meters per second, the controlled emission rate is 0.028 kg/Mg of raw steel. For discharged wastewater suspended solids, the current Effluent Guideline is 0.0101 kg/Mg of raw steel (30 day average).

No emission standards presently exist for secondary processes, i.e., charging, tapping, hot metal transfer, and flux handling. For these operations a controlled emission rate was calculated on the basis of a control device efficiency of 99.5 percent, which is readily achievable. The uncontrolled emission rates were reported previously in the discussion pertaining to Table 3.

6.1 ESTIMATED INDIVIDUAL EFFECTS OF AOC, MODEL PLANT

Tables 8, 9, and 10 show the estimated increased annual discharges for each AOC considered in assessing the model plant.

6.2 DISCUSSION

The interpretation of the results relates, of course, to the generalized steel plant. For the sinter plant windboxes, AOC's increased annual particulate emissions by an estimated 102 percent, and hydrocarbon emissions by 12 percent. Particulates emitted from product handling showed an estimated 545 percent increase.

For the blast furnaces, two levels of AOC were considered for which the estimated increased particulate emissions ranged from 53 to 216 percent of controlled emissions. Estimated suspended solids increase ranged from 680 to 24000 percent; cyanides, 22000 percent; phenols, 5900 percent.

For the BOP process, two levels of AOC were also considered, so that estimated increased particulates ranged from 113 to 3000 percent; suspended solids, 0-418,000 percent.

Based upon this analysis, AOC's add an additional annual air pollutant emissions load estimated at from half to several times the load from non-upset operation. Where water treatment is required, AOC's add additional discharges estimated at substantial levels in excess of standards.

7.0 COST OF PREVENTING OR MINIMIZING ABNORMAL OPERATING CONDITIONS

Essentially no cost data relevant to preventing or minimizing AOC's were acquired under this study. AOC's appear not to have been addressed in budgets and plans developed to date for pollution control. While entire new systems have been built partly to remedy an existing problem, the AOC aspect of current controls have not been identifiably addressed.

Consideration of costs relating to AOC's involves a myriad of factors; design possibilities and priorities, operating techniques, availability of capital and regulatory practices are some of the most important. Process equipment and control equipment should be considered separately, as the operating philosophies differ markedly between the two.

Process Related AOC's - Costs

It is fairly certain that production equipment is designed to be as reliable as is economically feasible, at least to the extent of knowledge at the time. It is also likely that the equipment will be operated to prevent damage and maximize production. With economics as the primary consideration, the decisions which must be made have a common basis.

The most important question concerning the cost of process related AOC's is the extent to which the operator is willing to curtail production in order to prevent or minimize emissions due to AOC. Many process related AOC's which cause emissions are also undesirable from an operation standpoint; the AOC's may be dangerous, cause equipment damage or loss of product, or fill the shop with smoke. If production is to be curtailed, there is a great deal of economic incentive for the steel company to prevent AOC's. If not, the economic incentive to prevent AOC's is lacking and other factors, of uncertain impact, dominate.

Many process related AOC's are to some extent controlled by the production rate of the process. The equipment is under more load and requires more maintenance, operations must be more precise, and in general the system is less able to adjust to deviations from normal conditions.

The effect of all these considerations on the cost of preventing AOC's is difficult to quantify. First a starting point must be identified. This section assumes that the AOC's associated with a process designed to be economically reliable is the basis for comparison. If the AOC causes the process to shut down or curtail production in addition to causing emissions, preventing the AOC becomes a question of how much must be spent to maintain operations. Each situation has many solutions, and the criteria for judging vary from place to place and from time to time.

If the AOC does not directly interfere with the process, preventing the AOC costs the shop money. Here regulatory pressures and "good citizen" considerations dominate and the results cannot be predicted. Based on visits during this project, regulatory efforts are still concentrated on achieving primary control, and effort is spent on AOC's only if the environmental effect is striking.

Control Equipment Related AOC's

The prevention of control equipment AOC's in most cases costs the steelmaker money without any benefit to the balance sheet. The reliability of the control equipment in a shop depends on several factors:

1. the quality of the design information on the job to be done and on the design philosophy,
2. the steelmaker's willingness to spend capital (and the availability of capital) at the time the equipment is purchased,
3. the steelmaker's willingness to properly man and operate the equipment, and
4. the occurrence of changes in the process; i.e., fuels, raw materials, operating conditions.

Of first importance for control equipment design is a set of good specifications. The equipment designer must know what the equipment is to collect; that is, dust loadings, composition, variability, size range, resistivity, gas rate, gas composition, and similar variables. This information is not always easily obtained, particularly for an installation that hasn't yet been built. Bad information will lead to an inadequate design and increased problems with reliability.

The design philosophy is also very important. Compromises must be struck between the competing desires to achieve the lowest possible capital cost and lowest operating cost. Generally these goals are mutually exclusive. The eventual design can be conservative, easy to operate and maintain, and well instrumented (and expensive) or low in capital cost or anything in between. Obviously, AOC's are more likely (but not certain) for the stripped down design.

This study provides strong indications that conventionally designed control equipment will be subject to a sufficient number of AOC's to double at least the annual emissions therefrom that might be expected on a non-AOC basis.

8.0 NEEDS FOR FURTHER RESEARCH AND DEVELOPMENT

8.1 TECHNOLOGY NEEDS

This section of the report addresses the needs for further research and development (R&D). The need is established by classifying each of the most serious AOC's according to the type of corrective measure: existing technology applies or new technology needed. Table 11 provides this categorization. AOC's are listed here in order of decreasing importance, for those processes considered in the general example of Section 6. The order may differ from plant to plant, however the AOC's listed should be important wherever they occur. Table 11 identifies AOC's for Electric Arc and Open Hearth furnaces, but does not rank the major AOC's since these processes were not considered in the general example.

Based upon review of Table 11, further R&D needs were ranked in the following order: 1) additional quantitative process and control equipment data, 2) blast furnace bell leaks, 3) control equipment by-pass at start-up, 4) reliability of water recycle systems, 5) external desulfurization of iron, 6) BOP process upsets, 7) better emissions factors, 8) sinter plant HC control, and 9) vacuum filters.

8.2 STATE-OF-ART APPLICATIONS AND COSTS

As shown in Table 11, there is considerable need to consider application of existing technology. For this reason, a three-year program of study is recommended to determine what can be accomplished by use of state-of-the-art design technology and to provide adequate cost information. An estimated two man-year per year level of effort plus testing would be required.

In addition to this program, several areas of needed research are evident. These are discussed in detail in the following sections.

TABLE 11. CORRECTIVE MEASURES FOR ABNORMAL OPERATING CONDITIONS

Process	AOC	% of AOC Emissions	Existing Technology Applied	Research/ Development Needed
SINTER PLANT WINDBOX				
Process Related	Grate bar distortion	34	x	x
	Excess air leaks	34	x	
	Poor Sintering	21	x	
	Excessive HC in feed	100 (HC)	x	x
Control Eq. Related	High resistivity sinter to ESP	70		x
	Reduced voltage on ESP	13		x
	Cold start--P/C off at start up	6		x
	P/C shut down before process	6		x
	Excessive HC, oil	100 (HC)	x	
Product Handling Control Eq. Related	Fan failure	68	x	
	P/C bypass, start up	13		x
	Torn bags	11	x	
	Excessively open hoods	6	x	
BLAST FURNACE				
Furnace	Bell leaks	90		x
	Bleeders open (shut down)	12	x	
	Unplugging dust catcher	6	x	
	Bleeders open (starters)	9		x
Desulfurization				
	External desulfurization	100		x
Casthouse	Cold metal	15	x	
	Hot limey slag	70	x	
	Tap hole enlargement	11		x
Scrubber	Operating problems	100		x

TABLE 11. (cont'd.)

Process	AOC	% of AOC Emissions	Existing Technology Applied	Research/ Development Needed
Water Treatment	Loss of water pump	83 (SS) 90 (CN) 85 (Phenol)	x	
	Clarifies rake failure	17 (SS) 10 (CN) 15 (Phenol)	x	
BASIC OXYGEN FURNACE				
Process	Improper ladle-vessel transfer	54	x	x
	Puffing at hood	20		x
	Foaming and slopping	12	x	
	Burn-in	100 (HC)		x
P/C, Scrubber and Water Treatment	Plugged demister	75	x	x
	Pump failure	13	x	
	Plugged pipes	9	x	x
	Rake failure	100 (SS)	x	
Secondary	Charge-tap	23		x
	Hot metal transfer	30		x
	Open bypass damper	26		x
	Bag breakage plus hot metal	12	x	

TABLE 11. (cont'd.)

Process	AOC	Existing Technology Applied	Research/ Development Needed
ELECTRIC ARC FURNACE	Burn-in		x
	Capture duct misalignment	x	
	Running stopper	x	
	Ladle breakout	x	
	Relief damper opening		x
	Poor furnace operation	x	
Control Equipment	Stack puff		x
	Bag failure	x	
OPEN HEARTH FURNACE	Start up		x
	Plugged checker	x	
	Furnace puffs	x	
	Ladle reaction	x	
	Waste-heat boiler failure	x	
	Poor furnace operation	x	
Control Equipment	Control bypassed		x
	ESP malfunction	x	
	Plugged demister	x	x
	Rake failure	x	
	Loss of pumps	x	

8.3 ADDITIONAL QUANTITATIVE DATA, AOC'S

In the course of this study, numerous visits and calls were made to pollution control agencies to obtain data on steelmaking AOC's. Most of the jurisdictions visited or called had some regulation related to reporting of malfunctions, breakdowns, startups, and shut downs of pollution control equipment. Beyond that the similarity ends. The procedure for reporting varied greatly as did the procedures for recording and retaining data.

Some of the variation in reporting and recording is due to differences in the regulations. Country-wide NPDES requirements make it necessary for all companies discharging water pollutants in excess of their effluent guideline limitations to report these upsets within five days of the occurrence. The nature, cause, and duration of the occurrence must be reported. This system produces data because the companies are required to monitor their outfalls.

No counterpart of this system exists in the case of air pollutant emissions. In the long term, it may be possible to produce this kind of data because continuous monitoring is required for new sources. However, at present most of these sources are existing and not subject to this requirement. The air pollutant AOC data is gained primarily through self-reports by industry or chance observations by local enforcement personnel. This means the data is less consistent from place to place, varying according to the staff competence, level of staffing, and conscientiousness of the companies within their jurisdiction.

It is proper to point out that many of the local pollution control agencies have their hands full with efforts to obtain compliance from continuously emitting sources. Those in heavily industrialized areas, typical for steel plant locations, were especially busy in this regard. As a result little time is left to deal with reports of abnormal operating conditions. Nevertheless, at least one agency in this position does find or take the time to carefully document the occurrences and retain the records in such a form as to make review or study a relatively simple matter. Given these records it is possible to review and identify sources where chronic AOC's are contributing significantly to increased emissions and where remedial action is in order.

The Air Pollution Control Agency for Erie County, New York is the agency referred to. Their Law, Rule 10, pertaining to operation and maintenance of pollution control equipment is as follows:

RULE 10 OPERATION AND MAINTENANCE

10.1 PERFORMANCE

Historical Note: Section added and filed March 1967 as 6.3.1; Renumbered October 30, 1974, filed November 4, 1975.

a. Air Cleaning devices shall be selected so as to afford the highest efficiency or the lowest discharge rate that is reasonable and practicable. Reasonableness and practicability shall take into account cost, the air contaminant concentration in the emission gas stream, particle characteristics and other properties of the contaminant and of the emission gas stream, and applicable provisions of this Code.

Historical Note: Section added and filed March 1967 as 6.3.2; Renumbered October 30, 1974; filed November 4, 1974.

b. All devices used to effect compliance with these Rules shall be installed, operated and maintained so as to minimize the emission of air contaminants.

10.2 SHUTDOWN OR BREAKDOWN OF CONTROL EQUIPMENT

Historical Note: New sections 10.2 a, b, c, d; 10.3 added October 30, 1974; filed November 4, 1974.

a. In case of an intended shutdown of any control equipment, the operator shall notify the Commissioner at least one County work day in advance of the shutdown.

b. In the case of a malfunction, upset, or breakdown of any operation or control equipment which malfunction, upset or breakdown causes or is likely to cause any applicable Air Pollution rule to be violated, the operator shall notify the Commissioner immediately and shall undertake immediate actions to remedy the malfunction, upset or breakdown in as short a time as possible.

c. The operator shall, at the time of the notification, or as soon thereafter as possible, inform the Commissioner of the cause as well as the estimated duration and amount of emissions associated with the shtudown, or malfunction, upset or breakdown.

d. If the operator wishes to temporarily continue operating the source while the control equipment is inoperative or malfunctioning, he must obtain authorization from the Commissioner. The Comis sioner may allow such operations for limited time periods if he determines that it will not seriously endanger the public health, welfare or comfort. If the Commissioner determines that the emissions are likely to create an immediate public health hazard or nuisance, he shall so advise the operator and the operator shall take immediate steps to abate the emissions by shutdown or other appropriate actions.

e. If the Commissioner determines that the frequency of breakdowns is excessive, he may direct a source owner to take actions which reduce the frequency of breakdowns.

10.3 COMPLIANCE

If and only if the operator completely complies with all provisions of this Rule, emissions in excess of those allowed in the other Rules of this article shall not be considered violations.

Passed by Board of Health: October 30, 1974

Effective December 1, 1974

The form shown in Figure 1 is used by the Agency to record the reports. Part of the data is entered into a computer file and the hard copy is filed. The data retained in the computer file includes the facility identification number, facility name, source number, source name, date of the occurrence, time, estimated percent collector efficiency loss, the type of collector, and the length of the occurrence. If the cause of the AOC is the needed datum, it may be found on the file copy of the report.

Obviously not all agencies can justify the use of a computer to retain these data. Those with a large number of industrial sources, however, may find it useful and, in the long run, time saving as more effort is put into surveillance activity. The important thing is that the data are recorded and kept on file in a readily accessible manner.

ERIE COUNTY AIR POLLUTION CONTROL DIVISION

BREAKDOWN, SHUTDOWN OR STARTUP CARD

NAME OF COMPANY AND DEPARTMENT		
DATE	TIME	TELEPHONE NUMBER
NAME & TITLE OF PERSON REPORTING		TIME BREAKDOWN STARTED
SOURCE NO. (if known) AND DESCRIPTION OF SOURCE		
HOW LONG IS BREAKDOWN EXPECTED TO LAST?		
CAUSE AND DESCRIPTION OF BREAKDOWN		

ESTIMATED LOSS OF EFFICIENCY? ____________

TYPE OF EQUIPMENT

1.) Baghouse ( )
2.) Scrubber ( )
3.) Cyclone ( )
4.) Precipit. ( )
5.) Aftrbrnr. ( )
6.) Other ( )
Specify ____________

PERSON TAKING CALL ____________

INSPECTOR ____________

SUPERVISOR ____________

DATE ENTERED IN RECORD ____________

CALL BACK ( ) yes ( ) no TIME

TOTAL DURATION:

FACILITY NUMBER: [| | | |]   SOURCE NUMBER: [| | | |]

APC-10 (9/74)

Figure 1. Breakdown, shut down or startup card.

Some agencies require no report of breakdowns or malfunctions unless they exceed some minimum duration for example four or eight hours. Other accept telephone reports and keep no record of the particulars. Any program aimed at reducing the emissions caused by AOC's must of necessity maintain a data file of some sort with which to compare the frequency and duration of future occurrences to determine whether progress is being made.

8.4 ADDITIONAL QUANTITATIVE DATA, FUGITIVE EMISSIONS

At the beginning of the study there was a question as to whether continous discharge of fugitive emissions should be considered an abnormal operating condition. Eventually it was decided not to include the continuous fugitive emissions unless there was an increase in emissions resulting from unusual handling or processing. The difference between the two conditions, however, is not clear because few measurements have been made in either case. There are a few plants in the United States with control devices applied to these secondary (previously fugitive) emission sources. The existence of plants with controls on the secondary sources presents an opportunity to develop and substantiate emissions factors. The areas in which better definition of emission factors is needed include charging, tapping, hot and cold metal handling, hot metal desulfurization, teeming, slag handling, and flux handling in the steelmaking shops (open hearth, electric arc, and BOP). An estimated $80,000-200,000 effort would be required.

8.5 CONTROL FOR MAJOR AOC'S

Sinter Plants

The control of hydrocarbon emissions from sinter plant windbox gases requires further investigation. New technologies for this purpose include windbox gas recycling, the wet ESP, and scrubbers. Other devices under consideration include the steam-hydro scrubber and the venturi scrubber-incinerator combination, both high cost technologies. States have set hydrocarbon emissions limitations at levels which challenge and may defeat these technologies.

A performance-design study should be conducted, to identify the potential capabilities of these technologies for this application. The level of effort is estimated at $70,000-200,000 depending on the amount of experimental work.

Blast Furnaces

In the Blast Furnace Process Manual, Volume 3 of the report from this project, the issue of leaks from the blast furnace bells was addressed. Some limited information available suggest that leaks from blast furnace bells may represent a substantial emission source.

These sources might be significant enough to affect the ability of some air quality control regions to achieve ambient air standards. The task force from AISI reviewing the work of this study question the validity of the estimates of blast furnace bell leaks. In view of these questions and the fact that the information is not substantiated, a program of research to study this topic is appropriate. Such a study might include an attempt to produce an accurate gas balance around the furnace. Because the estimated quantity of gas lost at the bell represents only about 1 percent of the total gas generated for any given furnace it would probably also be necessary to find a measuring technique to apply directly to the leak source. Study of this problem might proceed in two stages: (1) methodology development and (2) tests and measurements. An initial effort in methodology would require some measurements and should be considered at the $100,000-200,000 level.

8.6 CONTROL DEVELOPMENT FOR LOW R&D INVESTMENT

Control Equipment Delayed Start Up and Early Shut Down

The need to have a warmup period for precipitators and fabric filters applied to several processes presents a control equipment oriented startup problem. Prevention of moisture condensation in the control devices is the reason a warmup period is recommended by equipment suppliers. The mixture of condensed water and particulate produces a layer or cake that leads to fabric blinding or deposits that cannot be removed from collecting plates. In addition, condensation on precipitator insulators (insulators used to steady the weighted wire discharge electrodes) provides a conductive path across the insulator that leads to insulator cracking or breaking.

An experimental program is needed to develop equipment or techniques that would allow the use of these devices under startup conditions. If not completely eliminated, perhaps some way of shortening the warmup period may be identified. Preheating, precoating of fabric, reduced voltage energization, and intensive rapping are all potentially valuable steps to solving the startup problem.

Unless the startup problem can be solved, the number of high efficiency control devices available for use at steel plants will be severely limited. Scrubbers and wet electrostatic precipitators do not require warmup periods, but have other drawbacks such as high energy consumption and conversion of potential air pollution problems to potential water pollution problems. For instance, precipitators are not now a good choice for controlling particulate from sinter strands producing high basicity sinter; but one would not want to eliminate the fabric filter option (considering their inherently high efficiency capability) because of the warmup problem. A three year study of this major AOC problem at an estimated $75,000-150,000 per year is recommended.

Rotary Drum Filters

Problems with rotary drum vacuum filters were alluded to in some of the plants visited during this study. No data were found or provided on the frequency and duration of AOC's related to this equipment item, yet some comments indicated it to be a significant problem. The consequences of such occurrences were predicted to be land disposal of water sludge (perhaps resulting in fugitive runoff) or increased suspended solids content in the wastewater system blowdown. Further investigation of this area is suggested. A one year, $20,000-50,000 level of effort is estimated to be required.

8.7 COST REDUCTION FOR PRESENTLY AVAILABLE BUT INORDINATELY EXPENSIVE CONTROLS FOR MAJOR AOC'S

Good design practice in pollution control system installations can minimize the occurrence of some of the AOC's described in this study. Two areas that might specifically benefit from the definition of good design practice are recycle wastewater systems and air pollution control systems for new steelmaking technology, i.e., Q-BOP and top blown BOP with suppressed combustion.

Recycle wastewater systems bring with them the need to consider how to achieve long term reliability. Redundant or spare capacity may be provided in the moving parts of the system. But, in addition, it is also necessary to consider those things that typically cause failures such as scaling, corrosion, and abrasion. These problems can be dealt with through improved selection of materials of construction and/or through steps to reduce the severity of attack. Development of guidelines for a thorough review of the system components and their adequacy would be a useful approach. A one year effort at $65,000-120,000 would be required.

Suppressed combustion BOP fume capture systems are more susceptible to process upsets that exceed the main fume system's capability to capture. Secondary systems are a virtual necessity to avoid violation of air pollution regulations. The secondary systems are relatively new and a more uniform approach to their design is needed. The bottom blown or Q-BOP process requires continuation of nitrogen and/or oxygen flow during the period the vessel is turned down, thus increasing its fume generation potential by comparison to the top blown process. Since this process is expected to gain wide acceptance in the industry, guidelines for the design of the capture and collection systems are essential to preventing installation of underdesigned systems. An estimated $55,000-225,000 level of effort would be required.

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TECHNICAL REPORT DATA
(Please read Instructions on the reverse before completing)

1. REPORT NO.	2.	3. RECIPIENT'S ACCESSION NO.
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16. ABSTRACT The report is the first in a six-volume series considering abnormal operating conditions (AOCs) in the primary section (sintering, blast furnace ironmaking, open hearth, electric furnace, and basic oxygen steelmaking) of an integrated iron and steel plant. Pollution standards, generally based on controlling discharges during normal (steady-state) operation of a process and control system, are often exceeded during upsets in operation. Such periods of abnormal operation are becoming recognized as contributing to excess air emissions and water discharges. In general, an AOC includes process and control equipment startup and shutdown, substantial variations in operating practice and process variables, and outages for maintenance. The volume evaluates the magnitude of pollutants emitted during AOCs. Compared to normal controlled emission rates from the processes, the increases due to AOCs are estimated to be significant. The volume describes the methodology used to gather data for the study and sources of information. Numerous pollution control agencies and manufacturing plants were visited. Though most jurisdictions have regulations requiring reporting of spills, malfunctions, etc., there is a wide variation in the procedures and records kept. Without systematic recordkeeping, it is difficult to determine the causes of problems and identify corrective action.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS		b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group	
Pollution	Oxygen Blown Converters	Pollution Control	13B	13H
Iron and Steel Industry		Stationary Sources	11F	
Abnormalities	Blast Furnaces	Abnormal Operations		
Failure	Openhearth Process	Basic Oxygen Process		
Starting	Electric Arc Furnaces			13A,13A
Shutdowns				
Sintering	Steel Making		13H	

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