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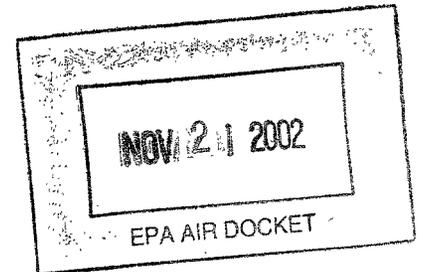
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ENVIRONMENTAL ASSESSMENT OF  
MELTING, POURING, AND INOCULATION  
IN IRON FOUNDRIES

by

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## TABLE OF CONTENTS

	<u>Page</u>
Abstract. . . . .	ii
Figures . . . . .	v
Tables. . . . .	vi
Acknowledgement . . . . .	vii
1.0 SUMMARY. . . . .	1
1.1 PARTICULATE . . . . .	1
1.2 ORGANIC AND INORGANIC . . . . .	.2
2.0 CONCLUSIONS. . . . .	5
3.0 INTRODUCTION . . . . .	6
4.0 PROCESS ANALYSIS . . . . .	7
4.1 MELTING METHODS . . . . .	10
4.1.1 The Induction Furnace. . . . .	11
4.1.2 The Electric Arc Furnace . . . . .	12
4.1.3 Cupola Furnaces. . . . .	15
4.1.3.1 The Hot Blast Cupola. . . . .	16
4.1.3.2 The Divided Blast Cupola. . . . .	17
4.1.3.3 The Gas Cupola. . . . .	18
4.1.3.4 The Oxygen Enriched Blast Cupola. . . . .	18
4.2 THE NODULARIZING PROCESS. . . . .	19
4.3 POURING . . . . .	22
5.0 WASTE STREAM CHARACTERISTICS . . . . .	25
5.1 SOLID WASTES. . . . .	25
5.2 WATER EFFLUENTS . . . . .	25
6.0 ENVIRONMENTAL DATA ACQUISITION. . . . .	27
6.1 SAMPLING AND ANALYTICAL STRATEGY . . . . .	27
6.2 TEST SITE SELECTION. . . . .	28
6.3 SOURCE ASSESSMENT SAMPLING SYSTEM ACQUISITION OF SAMPLES. . . . .	30
6.3.1 Sampling at Foundry "P" . . . . .	30
6.3.2 Sampling at Foundry "I" . . . . .	31
6.3.3 Sampling at Foundry "C" . . . . .	31
6.3.4 Sampling at Foundry "E" . . . . .	31
7.0 ENVIRONMENTAL DATA ANALYSIS . . . . .	33
7.1 COMPARISON SUMMARY OF RESULTS. . . . .	33
7.2 ANALYSIS OF SASS TRAIN SAMPLE OF POURING EMISSIONS . . . . .	37
7.2.1 Total Particulate Loading . . . . .	37
7.2.2 Level 1 Organic Analysis. . . . .	39
7.2.3 Level 1 Inorganic Analysis. . . . .	44

## ABSTRACT

Four foundry processes, (cupola melting, electric arc furnace (EAF) melting, magnesium inoculation, and pouring) were studied to determine if potentially hazardous organic air pollutants are generated by these processes and pass through commonly used air pollution control systems. EPA/IERL-RTP Level 1 assessment methodology was used to determine within a factor of 3 amounts of a wide range of chemical compound classes in the stream sampled. This information can be used in setting priorities for future research efforts.

Samples were obtained before any emissions control devices for fume generated during inoculation and pouring, and after the control devices (baghouses) for emissions from the cupola and EAF. Source and control technology characterization, as utilized by the Industrial Environmental Research Laboratory, involves determining which of a large number of waste streams and/or pollutants should be given further chemical analyses or monitoring. Many of these pollutants are not regulated but are potentially important. In order to satisfy this engineering need, a methodology was developed which utilizes the concept trigger values, Multimedia Environmental Goals (MEGs), to suggest when further analyses should be undertaken. If a pollutant is or could be present at a concentration higher than the trigger value, then that substance is felt to warrant priority for further analysis. The term "severity" is used to denote the extent to which the trigger value is exceeded -- by dividing the concentration of a particular pollutant found in a waste stream by the appropriate trigger value (MEG). Other information such as bioassay results would supplement such severity calculations.

Significant findings include the identification of compound classes which warrant further analyses: (1) both halogenated aliphatic and halogenated aromatic organic compound classes for all four processes, (2) chromium in pouring, inoculation, and EAF emissions, and (3) arsenic in the cupola emissions. The data indicate the possible presence of small amounts of polynuclear aromatic hydrocarbons in the emissions from all four processes.

FIGURES

<u>Number</u>		<u>Page</u>
4-1	Typical Foundry production flow chart. . . . .	8
4-2	Iron Foundry process flowsheet, emission sources . . . . .	9

## TABLE OF CONTENTS

	<u>Page</u>
7.3 ANALYSIS OF SASS TRAIN SAMPLE OF INOCULATION EMISSIONS . .	44
7.3.1 Total Particulate Loading . . . . .	47
7.3.2 Level 1 Organic Analysis. . . . .	48
7.3.3 Level 1 Inorganic Analysis. . . . .	48
7.4. ANALYSIS OF SASS TRAIN SAMPLE OF CUPOLA EMISSIONS. . . . .	52
7.4.1 Total Particulate Loading . . . . .	55
7.4.2 Level 1 Organic Analysis. . . . .	55
7.4.3 Level 1 Inorganic Analysis. . . . .	58
7.5 ANALYSIS OF SASS TRAIN SAMPLE OF ELECTRIC ARC FURNACE. . . . .	59
7.5.1 Total Particulate Loading . . . . .	59
7.5.2 Level 1 Organic Analysis. . . . .	60
7.5.3 Level 1 Inorganic Analysis. . . . .	63
8.0 DISCUSSION OF RESULTS . . . . .	65
9.0 REFERENCES. . . . .	69
APPENDIX . . . . .	71

## TABLES

<u>Number</u>		<u>Page</u>
A-6	IR REPORT - POURING EMISSIONS, PARTICULATE EXTRACT. . . .	78
A-7	LRMS REPORT - POURING EMISSION, PARTICULATES. . . . .	79
A-8	CALCULATED ESTIMATES FROM LRMS DATA POURING EMISSIONS, PARTICULATES. . . . .	80
A-9	LC ANALYSIS REPORT, SAMPLE NO. I-XR . . . . .	81
A-10	IR REPORT - INOCULATION EMISSIONS, AIR - I-XR . . . . .	82
A-11	LRMS REPORT: INOCULATION EMISSIONS, AIR. . . . .	84
A-12	LC ANALYSIS REPORT, SAMPLE NO. I-PARTICULATE. . . . .	85
A-13	IR REPORT - INOCULATION EMISSIONS, PARTICULATE EXTRACT. .	86
A-14	LRMS REPORT: INOCULATION EMISSIONS, PARTICULATES . . . . .	87
A-15	LC ANALYSIS REPORT, SAMPLE NO. C-XR . . . . .	88
A-16	IR REPORT - CUPOLA EMISSIONS. . . . .	89
A-17	LRMS REPORT: CUPOLA EMISSIONS. . . . .	91
A-18	LC ANALYSIS REPORT, SAMPLE NO. E-XR . . . . .	92
A-19	IR REPORT - ELECTRIC ARC FURNACE EMISSIONS. . . . .	93
A-20	LRMS REPORT: ELECTRIC ARC FURNACE EMISSIONS. . . . .	95

## TABLES

<u>Number</u>		<u>Page</u>
7-1	SUMMARY OF PARTICULATE DATA. . . . .	33
7-2	SUMMARY OF ORGANIC EMISSIONS . . . . .	34
7-3	ORGANIC EXTRACTABLES . . . . .	35
7-4	SUMMARY OF SAMPLING DATA . . . . .	36
7-5	PRODUCTION DURING SAMPLING . . . . .	36
7-6	UNCONTROLLED PARTICULATE FROM POURING . . . . .	38
7-7	SUMMARY OF SAMPLING DATA FOR POURING . . . . .	38
7-8	SUMMARY OF ORGANICS FROM POURING EMISSIONS . . . . .	40
7-9	ORGANIC EXTRACT SUMMARY TABLE, SAMPLE NO. P-XR (XAD-2 RESIN) POURING EMISSIONS . . . . .	41
7-10	ORGANIC EXTRACT SUMMARY TABLE, SAMPLE NO. P-PART. POURING EMISSIONS, PARTICULATE . . . . .	42
7-11	COMPARISON OF ORGANIC CONCENTRATIONS WITH MEG RANGES POURING EMISSIONS. . . . .	43
7-12	METAL CONTENT OF COMPOSITE POURING DUST. . . . .	45
7-13	PARTICULATES FROM INOCULATION. . . . .	47
7-14	SUMMARY OF SAMPLING DATA FOR INOCULATION . . . . .	48
7-15	SUMMARY OF ORGANIC VAPOR ANALYSIS FROM UNCONTROLLED INOCULATION. . . . .	49
7-16	ORGANIC EXTRACT SUMMARY TABLE, SAMPLE NO. I-XR (XAD-2 RESIN) INOCULATION EMISSIONS. . . . .	50
7-17	ORGANIC EXTRACT SUMMARY TABLE, SAMPLE NO. I-PARTICULATES INOCULATION EMISSIONS, PARTICULATE EXTRACT . . . . .	51
7-18	METAL CONTENT OF INOCULATION SMOKE . . . . .	53
7-19	SUMMARY OF SAMPLING DATA FOR THE CUPOLA EMISSION TEST. . . . .	55
7-20	SUMMARY OF ORGANIC VAPOR ANALYSIS FROM CUPOLA EMISSIONS. . . . .	56
7-21	ORGANIC EXTRACT SUMMARY TABLE, SAMPLE NO. C-XR (XAD-2 RESIN) CUPOLA EMISSIONS . . . . .	57
7-22	SUMMARY OF SAMPLING DATA FOR ELECTRIC ARC FURNACE EMISSIONS. . . . .	60
7-23	SUMMARY OF ORGANIC VAPOR ANALYSIS FROM THE ELECTRIC ARC FURNACE. . . . .	61
7-24	ORGANIC EXTRACT SUMMARY TABLE, SAMPLE NO. E-XR (XAD-2 RESIN) ELECTRIC ARC FURNACE . . . . .	62
7-25	METAL CONTENT OF FILTERED EAF EMISSIONS. . . . .	63

8-1	PERCENTAGE OF EACH COMPONENT IN SAMPLES. . . . .	66
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### APPENDIX

A-1	LC ANALYSIS REPORT, SAMPLE NO. P-XR. . . . .	72
A-2	IR REPORT - POURING EMISSIONS, AIR . . . . .	73
A-3	LRMS REPORT: POURING EMISSIONS, AIR . . . . .	75
A-4	CALCULATED ESTIMATES FROM LRMS DATA - POURING EMISSIONS, AIR. . . . .	76
A-5	LC ANALYSIS REPORT, SAMPLE NO. P-PARTICULATE . . . . .	77

## 1.0 SUMMARY

This report presents the results of an environmental sampling program for four processes used in iron casting: cupola melting, electric arc furnace melting, inoculation with magnesium, and pouring.

The iron casting industry ranks sixth in value added by manufacturing among all manufacturers. There are 1,367 foundries that can cast a total of 17 million megagrams (Mg) (19 million tons) of iron per year. Sand constitutes 75 percent of the solid waste produced. Although significant progress has been made in eliminating the smoke output of foundries, assessments of organic emissions have not been made.

The present study is a follow up of the study "Environmental Assessment of Iron Casting"<sup>1</sup> which investigated the shakeout of green sand and phenolic-isocyanate core molding.

### 1.1 PARTICULATE

Only the pouring and inoculation processes were sampled before emission control devices. The results of particulate analysis were:

<u>Category</u>	<u>Pouring</u> <u>g/Mg</u>	<u>Inoculation</u> <u>g/Mg</u>
< 1 $\mu\text{m}$ dust	6.72	15.36
1-3 $\mu\text{m}$ dust	1.07	21.29
3-10 $\mu\text{m}$ dust	7.44	7.97
> 10 $\mu\text{m}$ dust	31.55	11.07
Probe rinse	19.84	
TOTAL	66.63	55.69

Emissions from cupola and electric arc furnace (EAF) melting of iron were sampled after passing through a baghouse control device. The particulate matter in these emissions were below the detection limit of the test method (0.2 mg/dsm<sup>3</sup>).

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The research was conducted in the Process and Chemical Engineering Division and the Chemistry and Life Sciences Group of the Research Triangle Institute. Dr. C. W. Westbrook served as project supervisor and Dr. Van H. Baldwin, Jr. was the principal investigator. Dr. Robert Handy directed the chemical analysis effort and Messrs. Frank Phoenix and Thomas Allen of Entropy Environmentalists directed the plant sampling effort.

The sampling program could not have been accomplished without the generous help of managers and engineers at certain foundries who wish to remain anonymous. Mr. William B. Huelsen and other staff at the American Foundrymen's Society gave invaluable assistance in these arrangements.

The assistance of Mr. Robert C. McCrillis, EPA Project Officer, is gratefully acknowledged.

lished or proposed are assigned MEG values reflecting the most stringent standards or guidelines for that potential medium. However, these values need updating and revision -- for example, incorporation of the latest criteria and CAG potency values. A revised (Phase II) methodology for calculating trigger values was developed based on peer review recommendations, but all the suggested changes were not incorporated due to time, policy, and funding considerations. If a revised set of trigger values is developed based on a peer-reviewed Phase II methodology, the severity calculations in this report should be re-evaluated.

In this report, the trigger value for a particular chemical class is taken as the lowest value for any compound in that class. This is a conservative approach environmentally since it assumes all of the material found in a compound class is the one compound most detrimental to the environment. This report, a severity of less than 10 is taken as a low priority for further investigation while a severity of at least 100 would be required before assigning a high priority rating.

Level 1 results may be used for estimating emission factors in the absence of more quantitative data.

This study indicated that most emissions do not warrant further chemical/biological analyses but some, notably halogenated hydrocarbons might. In general, no calculated severities were greater than 10. By process, the items are summarized in the following table suggested for further analyses.

## 1.2 ORGANIC AND INORGANIC

This study followed the EPA/IERL-RTP Level 1 methodology, a screening approach which searches for a wide range of chemical compound classes in the stream sampled. Accuracy of the results is expected to be within a factor of 3.

Source and control technology characterization, as utilized by the Industrial Environmental Research Laboratory, involves determining which of a large number of waste streams and/or pollutants are not regulated but are potentially important. In order to satisfy this engineering need, a methodology was developed which utilizes the concept trigger values, Multimedia Environmental Goals (MEGs), to suggest when further analyses should be undertaken. If a pollutant is or could be present at a concentration higher than the trigger value, then that substance is felt to warrant priority for further analysis. The term "severity" is used to denote the extent to which the trigger value is exceeded -- by dividing the concentration of a particular pollutant found in a waste stream by the appropriate trigger value (MEG). Other information such as bioassay results would supplement such severity calculations.

These trigger values (MEGs) are generally calculated using simplified formulae based upon commonly-available health and ecological information. Thus, it should be made clear that neither the trigger values or the resulting severity ratios have any utility for risk assessment; they are purely an R&D and engineering tool aimed at suggesting, in an orderly fashion, which waste streams and pollutants warrant priority for further chemical analyses. They are also aimed at reducing the cost of analyses, by avoiding the rather costly, impossible problem of continuing to analyze for everything. Although the MEG values may provide a basis for rough relative ranking of chemical compounds or streams, it is inappropriate to assume that the values (other than those reflecting Federal standards and guidelines) can be considered as acceptable or "safe" severities as calculated by the procedures utilized in this report should be considered as deserving of further evaluation.

MEGs provide a means of 1) keeping track and organizing into classes a rather substantial established list of pollutants of concern plus a rapidly expanding number of new pollutants of concern and 2) providing trigger values for decisions on further analyses. Methodologies for derivation of the trigger values are described in other EPA reports.<sup>17 21</sup> For example, chemicals for which Federal standards or guidelines have already been estab-

## 2.0 CONCLUSIONS

This study of pouring, inoculation, cupola furnace melting and electric arc furnace melting, a Level 1 assessment, indicated that most emissions would not need further quantitative analyses; but some, notably halogenated hydrocarbons do exceed DMEG values.

Further analysis should be pursued to verify the identification of halogenated hydrocarbons.

Should the presence of halides be confirmed, an examination of halide salt sources in the process and possible modification of raw material input should be investigated. The most probable origin of the halogenated hydrocarbon is through reaction of the organics with molten salts. The most fundamental and economically feasible method of modifying these emissions would seem to be reducing the salt content of the raw materials.

The low resolution mass spectrometer results indicated only a small amount of fused aromatics (no benzo(a)pyrene). These substances had previously been found in NOSH-funded laboratory studies of the pouring operation in which the sand mold was enclosed in a sealed container to facilitate sampling the emissions. In contrast, the present study sampled pouring emissions from exposed molds as is the normal production situation. Thus, it would appear, at least at the foundry tested, that if fused organic vapors are emitted during pouring most are oxidized upon contact with air.

Summary of Level 1 Assessment Results  
for Iron Foundry Pouring Inoculation, Cupola  
Furnace and Electric Arc Furnace

	Pouring <sup>a</sup>	Inoculation <sup>b</sup>	Cupola <sup>c</sup>	Electric Arc Furnace <sup>c</sup>
Halogenated Hydrocarbons	2.7 <sup>d</sup> (21) MP <sup>e</sup>	0.36 (3.6) LP	3.6 (36) MP	2.0 (20) MP
Aromatic Hydrocarbons	1.5 (1.5) LP		3.2 (3.2) LP	1.4 (1.4) LP
Halogenated Aromatics	1.5 (2.2) LP	0.8 (1.2) LP	3.2 (4.6) LP	1.4 (2) LP
Heterocyclic N Compounds	0.38 (3.8) LP		0.31 (3.1) LP	
Amines	0.85 (8.5) LP		0.26 (2.6) LP	0.16 (1.6) LP
Carboxylic Acids	0.73 (2.4) LP			
Arsenic	(f)	13.0 (6.5) LP		
Chromium	>15 (>15) MP	7.1 (7) LP		5.1 (5) LP
Vanadium		>100 (>2) LP		
Silicones		0.8 (1.2) LP		
Lead		>100 (>1.0)LP		

<sup>a</sup> Measurements made before control device (uncontrolled)

<sup>b</sup> Measurements made before control device (baghouse)

<sup>c</sup> Measurements made after control device (baghouse)

<sup>d</sup> Indicates measured concentration in the gas stream ~ mg/m<sup>3</sup> (organics, silicones),  
µg/m<sup>3</sup> (metals)

<sup>e</sup> The number in parenthesis indicates the severity =  $\frac{\text{meas. conc.}}{\text{MEG}}$

Letters indicate low priority (LP) or moderate priority (MP).

<sup>f</sup> Blanks indicate severity <1.

#### 4.0 PROCESS ANALYSIS

The methods of sand casting used in foundries today are sophisticated compared to those of 50 years ago. Nevertheless, the principal processes remain the same. The metal is melted by one of several types of furnaces. The composition of the molten metal produced is controlled by the feed stock composition, melting technique, and post melting treatment. To make a desired object, a model is made of wood, metal or plastic, and placed in a container, which is then packed with sand. Clay and other substances are added to the sand to increase its shape holding ability. After this the model is removed from the mold and molten metal is poured into the cavity and allowed to cool. Once cool, the mold is broken, leaving a cast iron copy of the desired object. A portion of the sand is recovered, mixed with virgin materials and reused.

Upon cooling from the molten state, cast gray iron (iron containing 3 to 5 percent carbon) can form seven basic metallurgical structures. Five of these structures result from the plain metal containing sulfur impurities and the other two result from desulfurized metal. Ordinary cast iron, containing sulfur impurities and frequently silicon and manganese, forms white, perlitic gray, or ferritic gray cast iron depending on the rate of cooling. The white cast iron can be further transformed into either perlitic, or ferritic malleable forms by heat treatment. If the hot metal is desulfurized, either perlitic ductile, or ferritic ductile cast iron is formed, depending on the cooling rate. The outstanding characteristic of the "ordinary" gray cast iron is the presence of graphite, in the form of carbon flakes, that causes the metal to exhibit brittleness. Graphite is also present in the malleable and ductile cast irons but in the form of spherical nodules rather than flakes. In addition to the types of cast irons previously discussed, hybrid forms are often created for special purposes by varying the cooling rates involved, sometimes by oil quenching.<sup>2</sup>

Figures 4-1 and 4-2 present a flow sheet and a graphic presentation of the major operations and equipment involved in the foundry industry.

### 3.0 INTRODUCTION

The foundry industry is basic to an industrial society. Sand casting is the most primitive method of fabricating metals and yet the most economic and most practical method for various items. Since the 19th century it has been an important producer of farm implements, water pipe, and valves. In this century, all energy producing machines, electric motors, internal combustion engines, and turbines, both steam and jet engines, are made in part from cast metal. Most of these castings are made in sand molds bound by clay and containing organic additives. Pouring the molten metal into these molds produces smoke and organic vapors.

The majority of metal is melted in cupolas with the remainder melted in induction or electric arc furnaces. Cupolas are generally considered the most practical furnace for melting 9 Mg (10 tons) per hour or more. The particulate emissions from cupolas has been a notable contributor to excessive smoke in communities. In virtually all cases particulate emissions are now controlled by baghouses or wet scrubbers. Emissions from electric arc furnaces are also controlled, usually with a baghouse.

Emissions of particulate have been studied but no environmental assessment has been made of the organic emissions from pouring, cupolas or electric arc furnaces. The primary objective of this study was to determine if potentially hazardous organic materials are generated by these processes and pass through common air pollution control systems.

Emissions from the inoculation of iron with magnesium to make ductile iron was also sampled. Some of the rare earth elements used as additives were found in the shakeout emissions<sup>1</sup> and an examination of the inoculation process was considered worthwhile.

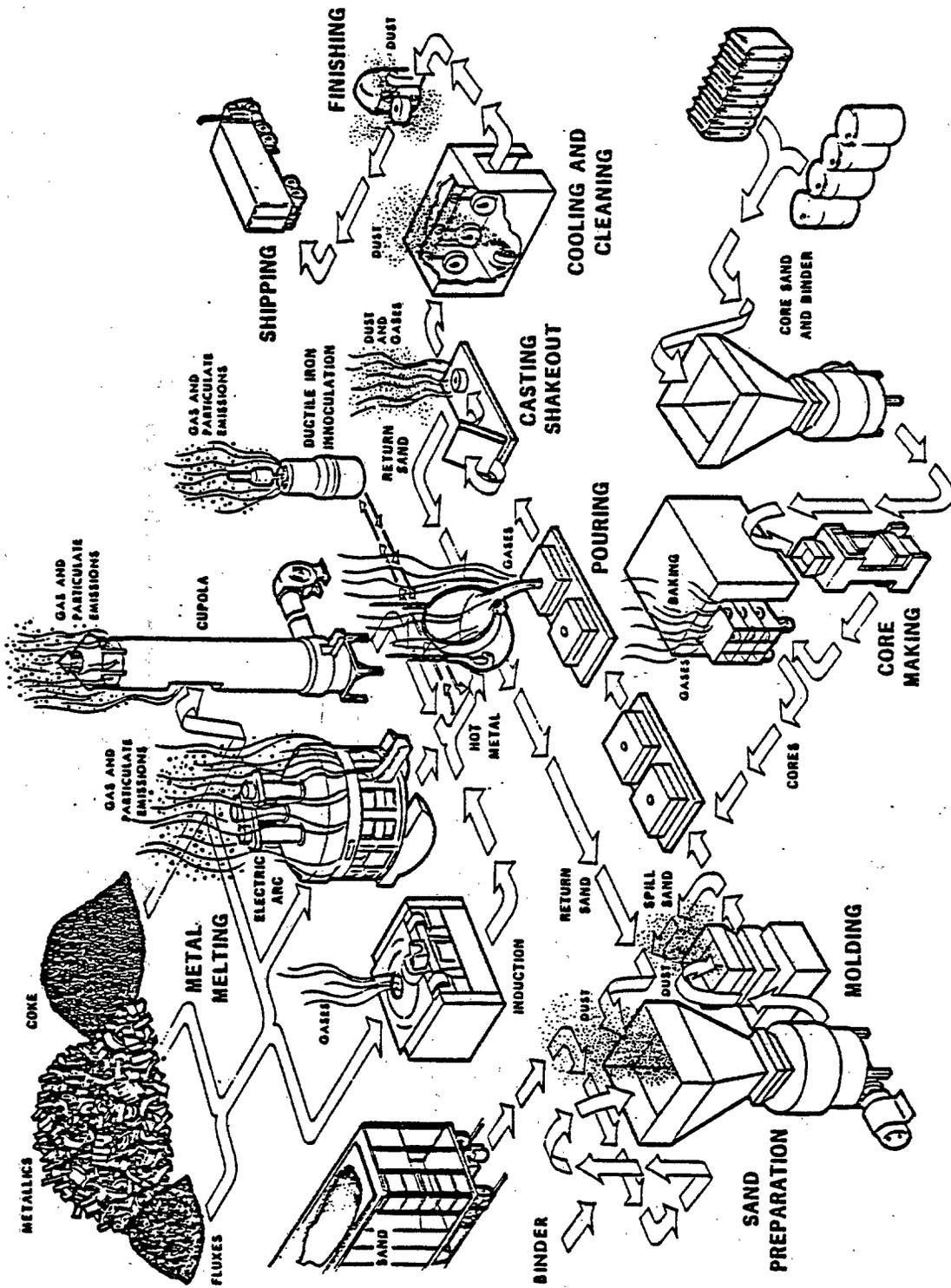


Figure 4-2. Iron Foundry process flowsheet, emission sources.<sup>1</sup>



Virtually all the remaining foundry iron is electric furnace melted. Electric furnaces are a unique category in which the energy of a fuel is used in the secondary form of electrical energy. During the early stages of transition into environmentally nonpolluting operation of industry, it was popular for small foundries to convert to induction furnaces and transfer the pollution problems to the power companies. This also meant paying the power companies, through higher rates, to solve the pollution problems, an approach most feasible for a small company.

There are two types of electric furnaces suitable for melting iron, the induction furnace and the electric arc furnace. The induction furnace uses magnetic induction to cause the iron to self heat, and produces little pollution during melting if charged with clean pre-heated metal. Induction furnaces generate smoke during charging and tapping. The arc furnace, in which most electric furnace melting occurs, uses the radiant and conducted heat from an electric arc between carbon rods and the metal. Electric arc furnaces generate smoke which must be captured by an emission system, usually a baghouse.

#### 4.1.1 The Induction Furnace

The induction furnace is a well proven device for melting most metals under a wide variety of conditions. Induction furnaces are made as small as 30 g (one ounce) capacities for laboratory work, up to the world's largest of 110 Mg (121 tons). The normal range of furnace sizes in foundry use is from 0.023 to 64 Mg (0.025 to 70 tons), but usually not over 14 Mg (15 tons) for melting purposes. Induction furnaces can be made to operate in ultra-high vacuum chambers or under the demanding environment of a production shop. The majority of induction furnaces for melting are under one Mg in capacity. The electric arc furnace takes over usually at the one Mg level. The most common foundry use of larger furnaces is not for melting, but as holding furnaces to receive hot metal from cupolas and maintain it at a desired temperature.

There are two basic types of induction furnaces. The channel furnace has a refractory lined channel in the bottom to enable the liquid metal to form a complete electrical circuit around a transformer core. This induces a current in the metal which heats it; the interaction of the magnetic fields causes the liquid metal to circulate into the main vessel, heating

#### 4.1 MELTING METHODS

There are three fundamental types of metal melting furnaces:

- 1) Gaseous or liquid fuel-fired furnaces,
- 2) Solid fuel furnace (cupola), and
- 3) Electric furnaces.

The first category can be subdivided into indirect flame furnaces and direct flame furnaces. The indirect flame furnaces are used for lower melting point, nonferrous metals. The direct flame furnace as exemplified by the "air furnace" or reverberatory furnace in which oil or gas and air are blown into the furnace over the iron charge is more practical for iron melting. When the direct flame furnace is adjusted to eliminate smoke, the iron melts under strong oxidizing conditions, resulting in a significant loss of metal to the flux. Air furnaces are usually found in the older and smaller foundries. They are simple and reliable and their lower efficiency in metallic yield is balanced against the lack of need for air scrubbers. They can operate smoke free with a very short chimney. In recent years the increased cost of energy places the air furnace under some economic pressure and some foundries are replacing them with induction furnaces. The use of heat exchangers to recover some energy for heating the plant would help in some situations. However, the small number of these furnaces and the economic structure of the companies using them precludes this form of energy recovery from being significant in the industry.

A category of gas-fired furnace that stands alone is the gas-fired cupola. While a successful technical experiment, the uncertainty of the price and supply of natural gas makes its future uncertain. See Section 4.1.3.3.

The cupola, a solid-fuel fired furnace, is the most common melting device in the industry, especially in the foundries pouring over 9 Mg (10 tons) per hour, and melts about 70 percent of the iron poured. There are many types of cupolas and ways of operating them. All cupolas generate copious amounts of smoke, and must be equipped with a pollution control device, typically a baghouse or wet scrubber. The economics of cupola operation have varied with not only fuel and scrap costs but also with improvements in design and operating techniques. At the present time the economics, under reasonable circumstances, seem to favor the cupola.

Usually the fluxing materials such as limestone, silica and fluorspar are added to the furnace first. This may be done either by hand, shoveling them through a side charging door, or by placing them in the bottom of a drop bottom bucket that is then filled with scrap. In addition to fluxes, a carbon raiser (coke) may be added according to the metal desired and the scrap composition.

Since the fundamental raw material is scrap metal, careful attention is given to scrap handling. Different grades of metal scrap will be stored in segregated piles, preferably covered. In the case of an alloy steel foundry, there might be 5 or 10 segregated scrap bins, and even more in some cases.<sup>3</sup> The reason for this segregation is to allow the furnace operator to conserve the expensive alloys in the scrap and produce a melt close to the desired composition. Even in the production of "plain" gray cast iron, a recipe is followed, mixing various types of scrap to obtain consistent metal chemistry.

The scrap is usually transferred with a crane and electromagnet, putting the low density scrap into the drop bottom bucket first, so as to cushion the fall of the high density scrap when the charge is dumped.

The charging of most EAFs is done from the top. The roof, with electrodes, is lifted and swung aside. In addition to fluxing agents previously mentioned, iron ore and coke and/or some alloying metals may be charged before meltdown.

The furnace itself is a squat cylindrical steel shell lined with refractory. The lid is called a roof, and is also refractory lined. There are three holes in the roof for graphite electrodes. Power is supplied through the electrodes using three phase alternating current.

The refractory lining is usual "acidic" if the furnace is primarily for melting gray iron or steel and "basic" if it is used for refining steel. Basic furnaces are most common and flexible in use, but acidic furnaces require less heat and time, due to the thermal characteristics of the different refractories, and are thereby less costly. "Acidic" and "basic" as used in this context means that the acidic refractories will chemically react with bases to form salts and the basic refractories will react with acids to form salts. Acidic furnaces have silica bricks as walls and supporting brickwork, while the hearth is covered with quartzite ( $\text{SiO}_2$ ). Alumina ( $\text{Al}_2\text{O}_3$ ) is also an acidic refractory. In basic furnaces,

the charge. Because of this mechanism of operation it is necessary to start the furnace with a small amount of liquid metal, or else leave a "heel" of metal always remaining in the furnace.

The crucible or "coreless" furnace is much simpler, consisting of a cylindrical crucible which is wound with water-cooled electrical conductors, thereby placing the metallic charge within a solenoid coil. A magnetic field and current is induced in the charge, melting and stirring it. The lack of an iron core puts this furnace at a disadvantage, for nonferrous metals especially. To obtain efficient heating, the smaller furnaces are operated at higher frequencies, ranging from kilocycles to megacycles for 30 g sized furnaces. Most induction furnaces in iron foundries operate at 60 Hertz (60 cycles). The largest coreless induction furnace ever made was a 110 Mg (131 tons) capacity unit for melting bronze for ship propellers.

The induction furnace is one of the cleanest operating device there is for melting metal. The emissions that occur during melting are primarily the result of boiling off organic contaminants on the scrap. Since totally clean scrap is seldom obtained and since fumes are generated during charging and tapping, it is usual to have a canopy hood and exhaust system to control emissions. When nontoxic alloys are melted, it is not unusual to control the furnace with general ventilation. The energy efficiency of an induction furnace is not as high as that of an electric arc furnace.

#### 4.1.2 The Electric Arc Furnace

The electric arc furnace (EAF) is a relatively low cost, flexible device that can be used for either melting iron or refining of steel. In 1978, 1,074 EAFs were in use in 440 foundries. In foundry practice, the size of these furnaces range from 27 kg (60 lbs) to 27 Mg (30 tons). Most are 1 Mg or more and the average is about 9 Mg (10 tons) with a few exceeding 14 Mg (15 tons). The EAF is more flexible in the type of materials it can accept and the type of metal it can produce. An EAF can be used alternately to produce both cast iron and steel.

The production of iron, or steel in the case of a steel foundry, in an EAF is a batch operation consisting of several sequential actions. The production cycle usually takes 1½ to 5 hours depending on the furnace, operating techniques and type of metal alloy being made.

### 4.1.3 Cupola Furnaces

The cupola furnace has long been considered one of the most economical devices for melting iron. In recent years many foundries have converted to induction furnaces for environmental reasons. However the rise in the cost of electricity has caused some reevaluation of melting. Many hold the view that with state-of-the-art design and operating methods, plus suitable air pollution control devices, the cupola is still the most economical melting device.

There are metallurgical reasons for preferring cupola melting. Properties of metals are dependent on the chemical composition and the time temperature history. Often trace quantities of components will affect properties such as surface tension and nucleation rate in manners that are yet incompletely understood, thus sustaining the "art" nature of the industry. Iron melted in a cupola has natural characteristics favored by foundrymen: a low tendency to chill (an undesirable freezing structure), good fluidity, machinability, and low shrinkage characteristics. All these properties result from nucleation promoted by various impurities. Iron melted in electric furnaces does not have the same characteristics.<sup>4</sup>

About 70 percent of cast iron is cupola melted. The move away from the cupola has been reversed not only because of fuel and electricity cost but also because of the technical advances in cupola design and operation. With better air pollution control equipment, water cooled cupolas and components, preheated blast, oxygen enrichment, divided blast, recuperative hot blast, gas analyzing equipment and computer control, the advances in cupola technology match that of electric furnaces, but cost less.

The cupola is a vertical tube furnace, usually a steel shell lined with refractory bricks. The bottom is a removable steel door, which is covered with sand to protect it from the molten iron. Less than one furnace diameter above the bottom, a set of tuyeres encircle the furnace and blow air into the charge. Coke, iron, and limestone or other fluxing agents are dropped into the top of the furnace. The coke added may be from 8 to 16 percent of the weight of the iron, depending on the type of furnace and method of operation. The charge is usually in the form of alternating layers of iron and coke. These mix together as the charge descends in the

the bottom is covered with magnesite brick ( $\text{MgCO}_3$ ) and then a layer of magnesite or dolomite ( $\text{MgCO}_3 \cdot \text{CaCO}_3$ ) 150 to 200 mm thick is rammed. Steel produced in basic furnaces is more ductile than that from acidic furnaces. The basic refractories will react with the oxides of silicon and phosphorous and thus change the metal composition.

The electrodes can be raised and lowered into the furnace independently. They are driven by an automatic mechanism that adjusts the arc length according to the power consumption. The power is set low when the arc is struck with the new charge. About 200 volts is applied through a ballast which causes it to drop to 100 volts when the arc is operating. Upon striking the arc, a great deal of noise is emitted in the form of popping or exploding sounds. As the electrodes bore down through the charge, this quiets to a hum and the power is increased.

As the electrodes melt the scrap, a pool of molten metal forms which melts more scrap by thermal conduction. Radiant heat from the arc also melts the metal surrounding the arc, and therefore, a long arc is desirable at first. As the scrap is melted and the arc is no longer surrounded by scrap, the arc length is decreased to reduce excessive heating of the refractory walls by the radiant heat from the arc.

An electric arc furnace consumes graphite electrodes at a rate of about 5 kg/Mg (10 lbs/ton) of metal produced. This can be increased if the air pollution control system is poorly designed and draws an unnecessary amount of air past the hot portions of the electrodes increasing their rate of combustion. The electrodes burn to carbon monoxide which is usually oxidized further to carbon dioxide when ambient air is added to the gas drawn from the furnace.

The quantity of electricity consumed is relatively constant at  $1,764 \times 10^6$  joules/Mg (445 kwh/ton). The quantity required is higher for the first heat of the day and declines thereafter. The power consumed per ton melted will also increase if the furnace is operated at less than full capacity. The power consumption can be reduced 5 to 15 percent by the use of state-of-the-art electronic and computer controlled power supplies.

When the melt is complete and all adjustments of the chemistry are right, the melt is poured into a transfer ladle. Then the slag is poured into a slag pot and removed. The furnace is then ready to be charged again.

this technique however, and forced the utilization of the recuperative heat exchanger.

In the recuperative heat exchange method, some of the heat output is used to preheat the blast air to about 510° C (950° F). There is no standard way of doing this and it may involve particulate removal before or after the recuperator (heat exchanger) but usually involves combustion of the CO in the top gas to recover the latent heat.

Since the advent of sharply increased fuel prices, heat recovery for purposes other than hot blast is being implemented. At one plant the cupola off gas is ignited, passed through a heat exchanger to provide a hot blast, then passed through an oil heat exchanger to provide heat for other uses in the plant. A 43.5 Mg/hr (48 tons/hr) cupola can supply \$100,000/yr of energy, in addition to the value of the hot blast, to a foundry.<sup>6</sup>

4.1.3.2 The Divided Blast Cupola. The divided blast cupola has two sets of tuyeres, the second set being about 36 inches above the first. This results in the iron melting above the top set of tuyeres and then trickling down through hot coke before reaching the bottom. This provision for additional solid-liquid heat exchange after the melt zone increases the iron temperature and fluidity, and also causes the iron to pick up more carbon from the coke. The net result is better control of iron chemistry, hotter molten iron which will remain above the minimum casting temperature longer, and fewer bad castings due to the increased fluidity. A significant operating difference is an increase in combustion efficiency, allowing coke consumption to be reduced to as low as 8 percent of charge weight. A 20 to 30 percent cost savings of coke is possible. This system allows an increase in metal temperature and melting rate, or a decrease in coke consumption, or intermediate values, according to the needs of the foundry.<sup>7</sup>

The characteristics of the divided blast cupola have even greater implications than a mere reduction of coke consumption. With coke at 8 or 9 percent of charge weight, top gas volume is about two thirds that obtained for commonly used coke ratios. In addition, for reasons not fully understood, the top gas from twin blast operation carries a smaller load of particulates. The consequence of these characteristics is that the cost of top gas cleaning equipment can be decreased by 30 to 40 percent by operating the cupola at low percentages of coke.

furnace. The charge may be introduced vertically from the top, or more commonly, through a door in the side of the furnace near the top. The air blast from the tuyeres provides oxygen to burn the coke. The high efficiency of the cupola results from the efficient heat transfer from the hot gases to the iron as the gases rise through the charge.

Good cupola operation requires scheduling of molds to be poured to consume the full output of the cupola. This allows the cupola to be operated at a uniform rate which gives uniform iron chemistry. Some smaller foundries turn the air blast off and on to obtain iron at a rate less than the cupola optimally operates. This cycling operation not only adversely affects iron chemistry but also affects the temperature of the afterburner and sometimes results in failure of the afterburner to remove oily smoke generated when charging dirty scrap.

The lining of the cupola is eroded away rather quickly and must be checked and repaired each day.

4.1.3.1 The Hot Blast Cupola. The hot blast cupola is one of the modifications effected since 1950. The idea is a century old but was slow to be put into practice. By using a blast of hot air, there is a decrease in coke consumption, and melting losses.<sup>5</sup> The melting rate and temperature of the molten metal is increased. Since hotter metal will pick up more carbon from the coke, more low carbon content scrap (e.g., steel) can be used. There is also a lower sulfur pickup in a hot blast furnace.

The furnace can be operated so that the use of preheated air either allows a reduction of coke consumption or an increase in hot metal temperature, or an increase in melt rate. A 100° F increase in the blast air allows a 0.40 percent decrease in the charge rate of coke, or alternatively, an 8° C (15° F) increase in metal temperature. This means that for a 27 Mg (30 tons) per hour furnace operating 15 hours per day, 250 days per year using 137.5 kg coke per Mg iron (275 lbs coke per ton of iron), the coke saved amounts to \$533,400 per year at \$124/Mg (\$112/ton). The use of hot blast also reduces emissions because of the reduced coke rate or blast volume. Emissions have been reduced in excess of 50 percent in some trials.<sup>4</sup>

The blast air can be heated with another fuel or from the cupola's own heat output. In the first case direct gas assisted firing can be used but it is not favored. The most popular way is the direct fired heat exchanger, which is an off the shelf item. The increase in oil prices has discouraged

The major results obtainable by using oxygen enrichment are:<sup>19</sup>

- 1) A 20 percent reduction in coke rate, or
- 2) a 20 percent increase in melting rate.
- 3) An increase in iron temperature, if desired. The air/coke ratio will affect this.
- 4) Greater carbon pickup can be achieved by allowing the increase of iron temperature.
- 5) Reduces silicon loss and results in the consumption of 50 percent less ferrosilicon.
- 6) Allows an increase of up to 50 percent in the amount of steel scrap used, due to the greater carbon pickup possible.
- 7) Increases combustion efficiency to the point that afterburners are not necessary.
- 8) Reduces scrap loss because the first heat is hot enough to be cast and therefore does not need to be poured into pigs.
- 9) Reduces casting rejects caused by low temperature metal. Metal temperature is 10 to 50° F hotter.
- 10) Reduces overtime cost. The ability to pour the first heat, heat the cupola faster, and reduce casting rejects has reduced overtime pay in many plants to the extent of ten times the oxygen cost.
- 11) Slag fluidity is greater, therefore a savings in slag fluidizers such as fluorspar is effected.

#### 4.2 THE NODULARIZING PROCESS

One of the more notable phenomena in the field of metallurgy this century has been the rapid acceptance of ductile cast iron. Since its commercial appearance after World War II ductile iron has replaced pearlitic and ferritic malleable cast irons, steel castings, forgings, and weldments. It has become an established material in automotive, agricultural equipment, machine tool, construction equipment, steel mill service castings, and diesel engines. The increased emphasis of high strength to weight ratio in the automotive industry is a major factor in the growth of ductile iron.

Ductile iron is an entirely new material consisting of a steel matrix contain spheroidal particles (or "nodules") of graphite. Ordinary cast iron, that is, gray cast iron, contains flakes of graphite. Each flake acts as a crack, with the result that cast iron is well known for its brittleness. Ductile irons are notably more silvery in appearance than

It should be noted that operation at minimum coke levels requires better supervision of the cupola and more attention to the coordination of melting and molding. This requires additional training of supervision personnel.

4.1.3.3 The Gas Cupola. Another innovation in cupola design is the gas cupola.<sup>8</sup> This cupola, as its name implies, uses gas as the sole source of fuel. It is charged with metal and flux only. The charge is held above the molten metal and slag by a water cooled refractory coated grate. The lack of coke requires the addition of graphite, blown in with an air stream, to add carbon to the iron. The results of experiments with this type cupola were technically appealing. The iron was far more consistent, lower in sulfur and cleaner than that from a coke cupola. The most important consequence to foundrymen is that iron from the gas fired cupola is definitely more fluid at a given temperature than that from the coke cupola. Thin sections were perfectly cast at temperatures known to give misrunning with coke cupola iron. Ductile iron was also perfectly cast at temperatures of 1300-1320° C, 80° C lower than required for gray iron. The gas cupola does cost slightly more (\$0.60/ton in 1972) than the coke cupola to operate.

The emissions from the gas cupola were "negligible." There was no visible emission or smoke and a person could "stand on the top of the cupola with no ill effects."<sup>8</sup> Some particulate of iron oxide and carbon was measured by B.C.I.R.A. but the amount of emissions would have met Los Angeles regulations. No capital outlay for emission control is anticipated. If this were figured into the operating cost, the result would probably be more economical operation than a coke cupola.<sup>8</sup>

Obviously, in the past decade the fuel situation has changed, making the future of the gas cupola uncertain.

4.1.3.4 The Oxygen Enriched Blast Cupola. Oxygen enrichment of the cupola's blast air is a relatively simple way of obtaining many of the advantages of hot blast or divided blast.

Oxygen enrichment results in a higher flame temperature, a shorter coke combustion zone, and allows a reduced gas velocity, which in combination with the higher temperature increases the preheat efficiency and effectively shortens the cupola. This is an ideal way to improve cupolas that are too short.

graphite rod is plunged deep into a ladle of molten iron. A turbulent reaction ensues because the magnesium boils under the heat of the molten iron. One purpose of using ferrosilicon containing magnesium, or other "nodularizing alloys", is to reduce the violence of this reaction and incorporate a larger percentage of magnesium into the iron. As much as 65 percent of the magnesium may be lost in the inoculation process, and the magnesium vapor that issues from the iron ignites in air, creating large quantities of smoke.

In the pour over method the nodularizing alloy is placed on the bottom of a vessel and the iron is poured on top of it. This method gives the lowest efficiency of utilization of the magnesium but requires no capital equipment other than air control. High efficiencies of magnesium recovery, in the range of 80 to 90 percent, can be obtained with Incomag Alloy 3, which is 5 percent magnesium and 95 percent nickel.

The formation of spheroidal graphite in cast iron by inoculation with a nodularizing substance involves many factors, and the process has been improved by the addition of elements other than magnesium. The high vapor pressure of magnesium causes a rapid loss of this additive, giving rise to "fading". The effectiveness of inoculation with magnesium alone fades 50 percent every five minutes after introduction.<sup>9</sup> The addition of cerium will lengthen the pouring time available. Cerium, although expensive, is the most effective spheroidizing element. Its boiling point is so high that it does not vaporize out of the melt as magnesium does. Cerium also controls the influence of subversive elements such as titanium, lead, antimony, and arsenic. Cerium and calcium additionally reinforce the carbide stabilizing influence of magnesium. Lanthanum is sometimes added because lanthanum ductile irons have a higher level of ductility and impact resistance. Calcium reduces the violence of the reaction of the inoculating alloy with the iron. Calcium, apparently as a nucleating agent, also increases the nodule count thus increasing the effectiveness of inoculants. If calcium is present in excess of 0.03 percent it acts in combination with magnesium to intensify the carbide stabilizing influence of magnesium. Barium is also added to promote a high nodule count, and minimize the formation of centerline carbides in thin section castings.

gray irons and have an amazing range of properties which cannot be matched by any other single metal. They can be cast as thin as 1/16 inch or as thick as 30 inches and have much of the strength and ductility of steel. The tensile strength can be controlled from 60,000 psi to 150,000 psi with ductilities of 25 to 4 percent, respectively.

Ductile iron made with magnesium was an accidental discovery during World War II when an attempt was made to substitute magnesium for chromium. The process was developed further and introduced in March 1947. The mechanism and factors causing the formation of spheroidal graphite and ductile iron have still not been elucidated. It is known that the phenomena involves the nucleation and growth of graphite and that the graphite grows in the direction of the "C" or vertical axis, whereas in ordinary gray iron it grows in the "A" or horizontal direction, forming a flake. This must be caused by surface phenomena, such as the preferential adsorption of foreign atoms on the graphite and/or the variation of the graphite-iron interfacial energy due to added elements.

Spheroidal graphite formation (ductile iron) is promoted by magnesium, cerium, lanthanum, calcium, potassium, lithium, sodium, beryllium and yttrium. Its formation is retarded by sulfur, oxygen, hydrogen, nitrogen, lead, titanium and arsenic. The activity of these elements in affecting the type of graphite structure formed is observed to vary from batch to batch of metal and even at different locations in the same iron. This is probably due to the effect of trace quantities of various impurity elements, the effects of which have not been determined or controlled. Surface activity is a two dimensional phenomena and thus very small quantities of substances can have large effects. Thus, for cubic centimeter or larger pieces of matter, replacing the matter in three dimensions requires 100 percent replacement substance, but total replacement of the surface of the cube with an impurity requires only about two millionths of a percent of impurity. A similar earlier example given of the imponderable factors in the metallurgical art was the fact that cupola melted iron behaves differently from electric furnace melted iron.

The practice of inoculation of the iron with magnesium has not stabilized to a universal procedure. Two more common methods are plunging and pour over. In plunging, the magnesium or magnesium containing alloy is loaded into a graphite "bell" containing holes. The bell on the end of a

In foundries that do limited ductile iron casting, inoculants may be added to the pouring ladle just prior to tapping the furnace.

The pouring process itself is deceptively simple. The object is to pour the metal directly into the sprue hole in a continuous smooth action until the mold is full. In practice the pourers "aim" can be off, causing the metal to miss the hole initially. Usually the miss is close enough that after sloshing around the top of the mold the metal finally goes "down the drain," and by the time it does the pourer has usually corrected his aim and the proper stream of hot metal is pouring into the mold. The initial metal however has been given the opportunity to cool, which changes its viscosity. Thus if it enters the mold as a "slug" of cooler metal, it may not behave as desired, especially in thin sections and sections with fine detail.

When thin sections of metal are to be cast, the temperature is critical, as the metal will not fill narrow crevices if the temperature is too low. Thus, the pourer must pour the hot metal as expeditiously as possible.

Sometimes bubbles of air get entrained with the metal, causing a "porous casting." This may or may not be tolerable, depending on the product.

Although seldom mentioned in the literature, gases emitted during pouring will accumulate under the mold and then explode after a few seconds. This makes a loud report but does not otherwise disturb operations.

Emissions from pouring can be successfully captured by two methods. The most convenient method for a large foundry is the hooded pouring station. In this type of hood, air is blown down from vents placed either behind the pourer or directly above the mold. A lower grill mounted at an angle close beside the molds draws in the smokey air, thus completing a "push-pull" action to remove emissions. This is also called a horizontal draft, cantilevered hood. This push-pull system is also obtained in some places by introducing the incoming air through floor mounted grates.

Another method of capturing pouring emissions is with a hood mounted on the pouring ladle carrier and connected by a flexible hose to the evacuation system.

Pouring and cooling are areas of major concern from an emissions standpoint. During the pouring operation, the mold and core are usually

A complete coverage of the details of nodularizing and the alloys used would be beyond the scope of this work. Suffice it to say, more than magnesium is involved and there is a good probability that the additive elements also get into the air when adequate air pollution control systems are not employed. The level of environmental concern involved has not been established.

#### 4.3 POURING

Pouring hot metal into a sand mold is not a totally predictable situation. The gate in the mold may be blocked, or any of several other problems caused by the limited dependability of a sand mold. The iron pouring process defies satisfactory automation because of the need for intelligent reaction and quick adaptability that are more easily obtained with humans. Automated systems have been made, but are seldom used in ironcasting, even in the large automotive foundries. The melting point of iron is so high that serious damage can occur from spillage and refractories must be repaired, literally by the hour. This makes automating ironcasting more difficult than automating the casting of lower melting point metals.

Commonly, iron is tapped from the cupola or electric arc furnace into a holding ladle or induction holding furnace. From that it is tapped into small pouring ladles of 1/3 to 1/2 ton capacity. The pouring ladle usually hangs from an overhead track or conveyer. In the case of a track, the pourer must provide the energy required to move it around. If a conveyer system is used, there is a switch, convenient to the ladle, that causes the ladle carrier to lock onto or disconnect from a conveyer mechanism that is in synchronization with the mold line. The pouring man moves the ladle beside the moving mold line until it is positioned with respect to a given mold. A switch is then closed, causing the ladle carrier to lock onto the conveyer system, holding the ladle alongside the mold. The pourer then manually pours the metal into the sprue hole.

In foundries that do extensive ductile iron casting, the metal is sometimes tapped to an inoculation ladle. After inoculation the ladle, typically 3.6 Mg (4 tons), is transported to a point adjacent to the pouring station and used to refill the pouring ladles, several of which will be in simultaneous use.

## 5.0 WASTE STREAM CHARACTERISTICS

Visible emissions and, sometimes, obnoxious odors, were the most noticeable environmental effect of a foundry upon a community of earlier decades. The major sources of solid wastes are the melting furnaces (slag and particulates) and the molding lines (used sand). Water pollution is generally a lesser problem than particulates control. Water used in scrubbers picks up inorganic and some organic contaminants, most of which can be removed in settling tanks. The remaining soluble organics are reduced by digestion in holding ponds.

### 5.1 SOLID WASTES

The solid wastes generated consist of used core and molding sand, sweepings, core butts, melting wastes such as slag, refractories, flux, and the solids from the scrubbers and the dust collection devices, including abrasives and shot. Generally, these wastes are landfilled.

Over 75 percent of foundry generated solid waste is from the core making and molding operations, with the remainder coming from the melting operations and emission control processes.<sup>11 12 13 14 15</sup>

Material balances for these wastes have been determined. Values for three typical types of foundries were presented in a previous report.<sup>1</sup>

### 5.2 WATER EFFLUENTS

The only effluents from foundries are indirect, i.e., resulting from the air pollution control systems. Larger foundries remove the sand and dust from the scrubber discharge in a clarifier tank and landfill it. The partially clarified water goes to a settling pond for final solids removal before being, typically, discharged to a river. Sometimes part of the pond water is recirculated to the scrubbers. Foundries using phenolic bound cores or molds occasionally have a problem with higher than normal levels of phenol in the scrubber water. The problem has been solved by providing sufficient retention time in a series of ponds for biological action to remove the phenol.

enclosed in a flask. Within seconds of pouring, emissions are evolved. A controlled laboratory test with an uncured, greensand mold containing 5 percent seacoal in which a 30 pound 4 inch cube was cast was performed by Bates and Scott.<sup>10</sup> The carbon monoxide concentrations peaked at about 1,900 ppm after 6 minutes. The sand to metal ratio was 3:1.

The same study used greensand molds with various formulations of core sand. Maximum values were reached after 1 to 5 minutes for carbon monoxide, 1 minute for carbon dioxide, 1 to 5 minutes for methane, 1 to 6 minutes for total hydrocarbons. Particulate emissions were 142 mg/m<sup>3</sup> (0.6625 grain/scf) during solidification. Peak particle counts ( $3 \times 10^4$ ) of 0.35 to 1.0 micron particles occurred approximately 11 minutes after pouring.<sup>10</sup>

The experiments of Bates and Scott that most closely approximate the pouring conditions were the sealed flask experiments. The effluent from flasks after pouring was analyzed by GC-MS and several carcinogenic compounds were identified. Unfortunately, no quantification was performed. It should be noted that these were sealed flask experiments, in which all the emissions were collected. In practice a large quantity of H<sub>2</sub>, CO, and CH<sub>4</sub> is formed and are ignited. Burning of these gases will probably oxidize the high molecular weight compounds, and destroy most of the carcinogens, but the fate of the carcinogens in an actual foundry situation has not been established. Some emissions escape unignited and, as previously explained in "Environmental Assessment of Iron Casting"<sup>1</sup> are the most likely source of polynuclear aromatic emissions in the casting process.

## 6.0 ENVIRONMENTAL DATA ACQUISITION

Although a great deal of work has been done in studying the particulate emissions of various foundry processes, including some covered in this study, there have been no Level 1 assessments or other assessments that have focused on or revealed the level of organic chemical emissions from electric arc furnaces, cupolas, magnesium inoculation or pouring. The most extensive work on potential toxic chemical emissions was done by Bates and Scott.<sup>10</sup> In their laboratory study of pouring and shakeout emissions, BaP was identified but not quantified. Determining the actual amount of toxic emissions requires sampling under practical industrial conditions, and that is the purpose of this work.

### 6.1 SAMPLING AND ANALYTICAL STRATEGY

The decision to sample the melting, pouring, and magnesium inoculation processes was based on the results and recommendations of a previous study.<sup>1</sup> Inoculation was the only one of these processes in which the inorganic emissions were of primary interest. Since magnesium used in the inoculation will react with nitrogen, the presence of  $Mg_3N_2$  in the emissions is a distinct possibility. This could be environmentally undesirable because of the possible interactions with moist plant or animal tissue. Alternatively, normal humidity could react with any magnesium nitride formed, or, the quantities formed may be insignificant. Arrangements were made for the expeditious analysis of the dust by x-ray diffraction, which was thought to be the best way to identify the compounds present.

The examination of the pouring emissions follows from the work of Bates and Scott,<sup>10</sup> in which laboratory simulations of the foundry processes exhibited BaP in the emissions and greater emissions of BaP from shakeout than from pouring. The study of the shakeout<sup>1</sup> however, failed to find significant quantities of PNA's present. Thus pouring was the remaining operation to examine for the possible presence of BaP or other PNA's.

One foundry that was sampled<sup>20</sup> to develop effluent limitations and standards for the foundry industry used a scrubber on the cupola. The water was entirely recirculated after settling out the solids and only makeup water was added. No effluent was released. An analysis of the recycle water for 130 critical chemicals revealed 38 compounds at an average concentration of 12.7 µg/l, ranging from 5 to 50 µg/l with a standard deviation of 11.8.

The major source of industry water pollution is in the form of leachate from discarded sand. An extensive study undertaken by the American Foundrymen's Society showed that the major emission occurs within a 1- to 2-year period.<sup>16</sup> These results were summarized in a previous report.<sup>1</sup>

a common duct which carried the fumes out of the building to the baghouse. Samples were taken in the duct prior to the baghouse. Foundry "I" was selected because it had efficient emission control and accounting systems, thereby enabling a more accurate sampling effort.

The sample of pouring emissions was obtained at foundry "P", a large foundry making gray iron castings of automotive parts. The iron was cupola melted and stored in an induction holding furnace. The pouring was entirely manual. The pourer added a scoop of silicon to his pouring ladle, pushed the ladle into position to be filled from the induction furnace, then pulled the ladle around to the start of the pouring line. The pouring lasted a little over two minutes per ladle. The iron was poured into greensand molds with sea coal as the organic additive, typical of the industry. The particular time of testing involved production without phenolic cores. Foundry "P" was selected because the emission control system design and the pouring rate indicated the possibility of obtaining a relatively undiluted sample. Samples were taken of the uncontrolled emissions.

The sample of cupola emissions was obtained at Foundry "C", a 9 Mg (10 ton) per hour iron foundry within a large manufacturing plant that poured other metals also. Emissions from the two cupolas were controlled by a baghouse system. A water quench was used to cool the gases. The baghouse was designed with sampling ports and platforms for testing of the exhaust to the atmosphere, thereby facilitating the sampling effort. Although the total plant was significant in size, the operating methods were more representative of a very well operated small foundry with capital assets sufficient to employ the best available pollution control system. Foundry "C" is surrounded by residential areas and appears to make a "best effort" to be a good neighbor. It was selected for sampling because of the high quality of the emission system and the ease of obtaining a sample that would indicate the level of organics in the gas after baghouse cleaning.

The sample of electric arc furnace emissions was obtained at Foundry "E". This is a small, relatively clean, innovative steel foundry located in a "business" section of town. All furnaces and other metal processing devices were well controlled but some of the pouring and cooling areas had visible smoke emissions. Plain carbon steel was being melted at the time of testing but much of the foundry output is corrosion resistant alloy

The testing of an electric arc furnace and a cupola was required to obtain Level I type information concerning the organic emissions. Much has been done to establish the particulate emissions, even as a function of operating conditions, but a comprehensive examination such as the Level I assessment had not been performed.

The philosophy of the phased approach developed by the Process Measurements Branch of EPA's Industrial Environmental Research Laboratory at Research Triangle Park, North Carolina was employed as a guide in the sampling and analysis. The Level I Procedure Manual<sup>21</sup> outlines this approach and describes the Level I sampling and analytical techniques. The goal of Level I sampling and analysis is to identify the pollution potential of a source in a quantitative manner within a factor of  $\pm 3$ . A statistically representative sample is not required. The sample is acquired with the Source Assessment Sampling System, usually called "the SASS train," which collects particulates by size range and traps organic and inorganic compounds in the gas for later analysis.

## 6.2 TEST SITE SELECTION

The selection of sampling sites was based on a) the processes to be sampled, b) the representativeness of the site to the industry in general, c) general quality of operation and construction, and d) plant permission to sample.

The greatest difficulty was locating a suitable sample site that was still in business. Over 50 percent of the industry was shut down during of this project. The remainder of the industry was involved in business worries of such magnitude that they declined to participate in this study.

The sample of inoculation smoke was obtained at Foundry "I", a large modern installation producing ductile iron castings. At this plant, the iron is desulfurized in the molten state, and stored in an induction holding furnace. The iron is transferred to a two ton bull ladle for inoculation which is done by plunging a graphite bell containing magnesium ferrosilicon into the molten iron.

The bull ladle was weighed within 5 pounds at the metal transfer station. Thus quite accurate metal weights could be obtained. At the plunging station the ladle was covered with a movable hood, which captured virtually all the fumes. Several plunging station ducts were connected to

### 6.3.2 Sampling at Foundry "I"

At Foundry "I", the inoculation stations or "plunging stations" are designed to lower a hood over the ladle during inoculation, giving very efficient capture of the smoke. The ducts from the inoculation stations joined into a single 0.61 meter (24 inch) diameter duct that passed through the building to the baghouse. The company installed the necessary equipment platform and a sampling port 6.1 meters (20 feet) downstream from the last junction into the ducts and 12.2 meters (40 feet) upstream from a bend in the duct. A twelve point traverse was made prior to sampling at a single point, 85 percent of the duct diameter into the duct, at a rate of 0.108 m<sup>3</sup>/min (3.81 cfm). The exhaust gas was sampled until 26.41 dsm<sup>3</sup> (932.58 dscf) were collected. The sample was 95.9 percent of isokinetic. After the test, a tear in the filter was found which possibly could have allowed some particulate to escape into the XAD resin. The frit, filter back half and organic module, however, appeared clean and it is therefore felt that the tear had no effect during the run.

### 6.3.3' Sampling at Foundry "C"

Foundry "C" had a baghouse that was constructed with an exhaust stack, sampling ports, and equipment platform to facilitate sampling. At the time of design and construction the company projected their future needs would include periodic sampling.

The gas volume collected for the SASS run was 24.66 dsm<sup>3</sup> (870.912 dscf). Testing was performed at a sampling rate of 0.099 m<sup>3</sup>/min (3.5 cfm) and was 93.2 percent isokinetic. A twelve point traverse was made before the run. Sampling was performed at a single point, 85 percent of the stack diameter into the baghouse exhaust stack.

### 6.3.4 Sampling at Foundry "E"

Foundry "E" had well hooded electric arc furnaces with long ducts that extended from the building to a baghouse. After the baghouse another duct ran about 15 meters (50 feet) to the blower room and the blower exhaust stack extended 4.9 meters (16 feet) up from the blower. The company reinforced the roof of the blower house to enable setting up an equipment platform for the SASS train. The sample was obtained from a port in the stack.

steels. The sample was obtained after the baghouse, thereby giving the truest representation of what enters the environment. Foundry "E" was selected because it was well controlled and easy to sample. The design of the emission control system also facilitated the objective of determining the organic level after baghouse cleaning.

### 6.3 SOURCE ASSESSMENT SAMPLING SYSTEM ACQUISITION OF SAMPLES

The samples were acquired with the Source Assessment Sampling System,<sup>21</sup> commonly called the SASS train. This unit draws in gas through a button hook nozzle at a constant velocity approximately equal to that of the stream being sampled and conveys it, via a heated tube, to a series of three cyclones in an oven. The cyclones separate the particulate into three size ranges;  $> 10 \mu\text{m}$ ,  $10\text{-}3 \mu\text{m}$ , and  $3\text{-}1 \mu\text{m}$ . The sample is then passed through a fiberglass filter to remove the  $< 1 \mu\text{m}$  particulates, cooled, and passed through a cartridge of XAD-2 resin to adsorb organic materials. After the organics are removed, the collected gas passes through a series of reagent bubblers to remove volatile inorganics.

All reagents and procedures were according to the recommended Level 1 practices.<sup>21</sup> The field sampling data and drawings are in the Appendix.

#### 6.3.1 Sampling at Foundry "P"

Foundry "P" had pre-existing ports on the roof stack for the SASS probe. Two wood platforms, each 1.2 x 3 meters (4 x 10 feet), at right angles, provided adequate working space on the 1 in 3 sloped roof, which was reached with a "cherry picker" crane. The air control system for pouring consisted of a hooded pouring station with a fresh air vent mounted behind the pourers, creating a cross draft that efficiently removed the pouring emissions. The pouring station hood was exhausted through a single duct, 1.2 meters (48 inches) in diameter with an axial fan. This duct extended through the roof and was 12.8 meters (42 feet) in total length. The sampling ports were 9 meters (30 feet) above the hood and 3.7 meters (12 feet) below the top of the stack. After a twelve point velocity traverse of the duct, sampling was performed at a single point, 85 percent of the stack diameter into the stack, at the rate of  $0.111 \text{ m}^3/\text{min}$  (3.93 cfm). The exhaust gas was sampled until  $27.84 \text{ dsm}^3$  (983.283 dscf) was collected. The sampling was 77.9 percent isokinetic. The sample was collected in two time periods--before and after the lunch break, during which there is no pouring.

## 7.0 ENVIRONMENTAL DATA ANALYSIS

Following Level 1 procedures, one sample was obtained at each site as previously discussed. The sample collected by the SASS train was analyzed according to the IERL-RTP Procedures Manual: Level I Environmental Assessment.<sup>21</sup>

### 7.1 COMPARISON SUMMARY OF RESULTS

To obtain a better perspective of the pollution potential of the processes studied it is useful to have a side by side presentation of the overall testing results from this and the previous study of the shakeout.<sup>1</sup> Table 7-1 presents the uncontrolled particulate emissions from pouring (P), inoculation (I), shakeout (SO), and the controlled (scrubbed) shakeout emissions, cupola (C), and electric arc furnace (E).

TABLE 7-1. SUMMARY OF PARTICULATE DATA<sup>a</sup>

Sample site	Uncontrolled			Controlled		E
	P	I	SO	SSO	C	
Air flow rate, m <sup>3</sup> /min	1,337	262	635	867	630	860
Particulate concentration, mg/m <sup>3</sup>	15.2	99.7	1,996	8.9	ND <sup>b</sup>	ND
Particulate generated, g/Mg processed	66.6	55.7	7,010	43.4	-	-

<sup>a</sup>Sampled at 204° C (400° F). Thus some organic matter may have distilled off of the particulate.

<sup>b</sup>None detected.

Table 7-1 shows that in terms of particulate generated per Mg processed, the shakeout exceeds the pouring and inoculation by two orders of magnitude. The fumes from pouring and inoculation are roughly equal to the wet scrubbed (controlled) shakeout emissions. No detectable particulate matter was found in the baghouse emissions from the cupola and EAF. An extended sampling period (>6 hours) would be required to obtain an accurate measurement.

A gas sample of 29.27 dsm<sup>3</sup> (1033.555 dscf) was drawn through the sampling system. The sampling was performed at a rate of 0.122 m<sup>3</sup>/min (4.31 cfm) at 100 percent of the isokinetic rate. A nine point traverse was made prior to sampling. Sampling was performed at a single point, 83 percent of the stack depth into the rectangular stack.

Table 7-3 compares the organics extracted from the particulate of the processes previously described with each other and with the organic matter captured in the XAD-2 resin. This implies that most of the organic matter is low boiling point material. Particulate matter was collected at 204° C (400° F).

### 7-3. ORGANIC EXTRACTABLES

Type of sample	Process sampled				
	S0	Uncontrolled P	I	Controlled C	E
<u>Emission concentrations, mg/m<sup>3</sup></u>					
Filter (< 1µm) <sup>a</sup>	0	composite particulate	composite particulate	NA <sup>b</sup>	NA
1-3µm <sup>a</sup>	0			NA	NA
3-10µm <sup>a</sup>	0.12			NA	NA
> 10µm <sup>a</sup>	0.82			NA	NA
Probe		1.22	0.299	NA	NA
XAD-2	173.67	14.29	4.355	26.54	9.19
Total	174.61	15.51	4.65	26.54	9.19
<u>Emission concentrations, g/Mg processed</u>					
Filter (< 1µm) <sup>a</sup>	0			NA	NA
1-3µm <sup>a</sup>	0			NA	NA
3-10µm <sup>a</sup>	0.42			NA	NA
> 10µm <sup>a</sup>	2.88			NA	NA
Probe		5.36	0.1671	NA	NA
XAD-2	614	62.76	2.433	90.422	173.7
Total	614	68.12	2.600	90.422	173.7

<sup>a</sup>Organics remaining on particulate. Particulate collected at 204° C (400° F).

<sup>b</sup>Not analyzed - insufficient sample collected.

Table 7-4 is a summary and comparison of sampling data for the four processes examined in this study.

Table 7-5 lists the pertinent production data during sampling.

Table 7-2 presents the total organic emissions from the same sources.

TABLE 7-2. SUMMARY OF ORGANIC DATA

Sampling site	Uncontrolled			Controlled		
	P	I	SO	C	E	SO
Air flow, m <sup>3</sup> /min	1,337	262	635	630	860	857
Total organic concentration, mg/m <sup>3</sup>	15.5	4.3	174.6	26.6	9.2	105.3
Total organic generated, g/Mg processed	68.1	2.6	614	90.4	173.7	512

Table 7-2 shows that the organics generated, on a g/Mg basis, during shakeout is also greater than those generated during pouring and inoculation by factors of 10 and 200, respectively. The shakeout also had higher levels of controlled organic emissions, g/Mg basis, than the cupola or EAF. Uncontrolled pouring emissions were of the same magnitude as controlled cupola emissions. For the four processes tested in this study, i.e., excluding shakeout, the cupola produced the highest concentration of organic matter. It should be noted, however, that concentrations depend on system air flows.

On a production basis, the electric arc furnace emitted the most organics per Mg of metal processed. The quality of scrap used will have some effect. If the electric arc furnace (EAF) is clean and is loaded with completely clean scrap, then no emission of organic compounds would be expected, except for those synthesized in the electric arc and "boil off" of the residual coal tars in the graphite. Thus the major portion of organic emissions from the EAF can be attributed to dirty scrap. The scrap used appeared to contain engine oil, lubricants, and dirt.

Inoculation is a completely inorganic process and thus would be expected not to produce any organic compounds. As Table 7-2 shows, a low level of organic matter was measured. While the production of methane and simple organics is possible from carbon in iron under reducing conditions, the synthesis of larger organic compounds that would be adsorbed onto XAD-2 resin is not easily conceivable under the oxidizing conditions of magnesium inoculation.

## 7.2 ANALYSIS OF SASS TRAIN SAMPLE OF POURING EMISSIONS

Sample "P" is the raw emission from a pouring line in which gray iron was poured into green sand molds without cores. The organic additives consisted of sea coal and used core sand from oil cores with cereal. The sand was 55-60 AFS silica and was replenished with about 10 percent used core sand, about 18 Mg (20 tons) per day. A constant disposal of some sand is required. When cores are not being used, the make up sand is naturally bonded red sand. This sample represents the uncontrolled fume (before any air pollution control device) from a typical casting operation.

Production and material data pertinent to the pour sample are as follows:

Normal casting rate: 18.27 Mg (20 tons) per hour

Capacity casting rate: 41 Mg (45 tons) per hour

Weight of iron per mold: 62.1 kg (137 lbs)

Weight of individual pieces: 8.9-15.6 kg (20-34 lbs)

Molds per hour: 295

Weight of green sand per mold: 350 kg (775 lbs)

Sand to metal ratio: 5.7:1

Carbon content of return sand: 3.5-4 percent

Moisture in molding sand: 3.8-4.2 percent

Clay content: 10-11 percent

Total active clay: 8 percent (methylene blue method)

Volatiles: 2.5 percent (482° C)

Organic components: Sea coal  
Cereal and oil from core sand

### 7.2.1 Total Particulate Loading

The total mass of uncontrolled particulates from the pouring process is given in Table 7-6. Included in this table are the values of particulates per Mg of metal cast. Since the sand to metal ratio was 5.7:1, a common value, these values could be extrapolated to obtain an order of magnitude estimate for similar plants. The less than one micrometer ( $\mu\text{m}$ ) particulates generated were about one third that from a shakeout and the 1 to 3 micrometers range particulates were one-half percent that of a shakeout, on a g/Mg metal processed basis. Table 7-7 summarizes the sampling conditions.

TABLE 7-4. SUMMARY OF SAMPLING DATA

Sample	P	I	C	E
Date of test	3/11/81	2/11/81	3/25/81	2/25/81
Volume of gas sampled, m <sup>3</sup>	27.84	26.41	24.66	29.27
Duct gas temperature, °C	33	40	178	31
Duct gas pressure, cm Hg	74.60	73.81	75.74	73.58
Duct gas molecular wt., dry	28.84	28.84	29.60	28.84
Duct gas moisture, %	3	3	15	3
Duct gas velocity, m/sec	20.94	16.95	16.34	17.98
Duct gas flow rate, m <sup>3</sup> /sec	22.29	4.360	10.50	14.34
Total sampling time, min	250	245	250	240
SASS train flow rate, m <sup>3</sup> /sec	0.001856	0.001797	0.001644	0.002033
Metal processed during sampling, Mg	76.12	114.7	46.21	11.83

TABLE 7-5. PRODUCTION DURING SAMPLING

	P	I	C	E	SO	SO <sup>a</sup>
Total metal, Mg	76.124	114.71	46.21	11.83	27.84	59.81
Metal/hr, Mg/hr	18.270	28.09	11.09	2.73	10.79	10.56
Total sand, Mg	430.63				114.52	279.68
Sand/metal ratio	5.7:1				4.47	4.99
Coke, Mg			5.78			
Coke/metal			1/8			
Sample volume, m <sup>3</sup>	27.843	26.408	24.661	29.267	15.23	26.15
Air flow, m <sup>3</sup> /Mg processed	4,392	558.7	3,407	18,900	3,516	4,865
Sampling time, min	250	245.0	250.0	240.0	155	377
Air flow rate, m <sup>3</sup> /min	1,337.3	261.6	629.7	860.4	631.8	562.5
Flask/hr	294	17.6			250	250
Metal/flask, lb	137	3,510			140-160	140-160
Sand/flask, lb	775				750-800	750-800
Heats/hr				0.632		

<sup>a</sup>During test of shake out scrubber emissions.

### 7.2.2 Level 1 Organic Analysis

The organic extractables have been listed previously in Table 7-3. Table 7-8 summarizes the liquid chromatography (LC) and infrared (IR) spectrophotometry analysis of the organic compounds extracted from the dust and the XAD-2 resin. This summary comes from Tables 7-9 and 7-10, the "Organic Extract Summary Table" (OEST). The seven fractions the sample is divided into by LC are listed in the OEST. For each fraction there is a list of compound classes that may occur in that fraction. If the IR shows the functional groups for a chemical family are present, an intensity of 100 is assigned. If a functional group for a chemical family that could be present is not found in the IR spectra, an intensity of 10 is assigned. Within a given LC fraction these intensities were summed and each chemical class assigned its proportion of the total weight of extracted organics in that LC fraction. The low resolution mass spectrometer (LRMS) data for fractions analyzed by this technique were examined for the presence of compound categories and molecular weights of specific compounds of concern. The intensities of the compounds or classes found were used to make quantitative estimates.

Table 7-8 lists the MEG<sup>17</sup> trigger values, where they have been established, for each chemical category. These trigger values are used as engineering tools for selecting waste streams and pollutants for further analyses.

The values listed in this report are the lowest MEG (air, health) values in each category of compounds. Thus, unless the specific compound having this MEG value is actually in the sample, the MEG value shown would be too low and the severity (concentration found/MEG) too high.

Table 7-8 shows that the minimum MEG value was exceeded in six categories, halogenated hydrocarbons, aromatic hydrocarbons, halogenated aromatics, heterocyclic N compounds, amines, and carboxylic acids. These have been listed in Table 7-11 together with range of MEG values for each category, the severity if the midpoint of the MEG range is used, and comments on the origin of the data.

The compounds and categories found by LRMS were quantified and listed in Tables A4 and A8, found in the appendix. The LRMS results do not indicate BaP is present. Low concentration of other polycyclic aromatics, none of significant environmental concern, were also found.

TABLE 7-6. UNCONTROLLED PARTICULATE FROM POURING<sup>a</sup>

Category	Wt, mg	Load mg/m <sup>3</sup>	Percent of total	Emission g/Mg
< 1µm dust	42.6	1.530	10.1	6.72
1-3µm dust	6.8	0.244	1.6	1.07
3-10µm dust	47.2	1.695	11.2	7.44
> 10µm dust	200	7.183	47.3	31.55
Probe rinse	125.8	4.518	29.8	19.84
Total	422.4	15.171	100	66.63

Sample volume (std): 27.843 m<sup>3</sup>

Total load: 0.006630 grains/ft<sup>3</sup>

Metal processed during sample period: 76.124 Mg

Air flow/Mg processed: 4,392 m<sup>3</sup>

<sup>a</sup>Particulate mass may be understated since some organics may have distilled off during sampling. Particulate samples were collect at 204° C (400° F).

TABLE 7-7. SUMMARY OF SAMPLING DATA FOR POURING

Date of test: 3/11/81  
 Volume of gas sampled: 27.843 m<sup>3</sup> (983 ft<sup>3</sup>)  
 Stack gas temperature: 32.8° C (91° F)  
 Stack gas pressure: 74.60 cm Hg  
 Stack gas molecular weight: 28.84  
 Stack gas moisture: 3 percent  
 Stack gas velocity: 20.94 m/sec (68.7 ft/sec)  
 Stack gas flow rate: 22.29 m<sup>3</sup>/sec (47,230 cfm)  
 Total sampling time: 15,000 sec  
 SASS train flow rate: 0.001856 m<sup>3</sup>/sec (3.93 cfm)  
 Percent isokinetic: 77.9  
 Iron cast during sampling: 76.124 Mg (83.9 tons)

TABLE 7-9. ORGANIC EXTRACT SUMMARY TABLE, SAMPLE NO. P-XR (XAD-2 RESIN)  
POURING EMISSIONS, VOLUME SAMPLED 27.843 dsm<sup>3</sup>

	LC1	LC2	LC3	LC4	LC5	LC6	LC7	Σ
Total organics, mg/m <sup>3</sup>	3.706	1.08	3.886	1.39	1.19	3.04		14.287
TCO, mg/m <sup>3</sup> (40.5%)	3.13		2.23	0.090	0.11	0.23		5.793
GRAV, mg/m <sup>3</sup> (59.5%)	0.575	1.081	1.656	1.297	1.081	2.805	*	8.494
Category	Assigned Intensity - mg/m <sup>3</sup>							
Aliphatic hydrocarbons	100/1.853	100/.263						2.116
Halogenated aliphatics	100/1.853	100/.263						2.116
Aromatic hydrocarbons		100/.263	100/1.253					1.517
Halogenated aromatics		100/.263	100/1.253					1.517
Silicones		10/.026	10/.125	10/.025				0.177
Heterocyclic O compounds			100/1.253	10/.025				1.278
Nitroaromatics				10/.025	10/.027			0.052
Ethers				100/.248	100/.270			0.519
Aldehydes				10/.025	10/.027			0.052
Phosphates				10/.025	10/.027			0.114
Nitriles				10/.025	10/.027		10/.062	0.052
Heterocyclic N compounds				100/.248	10/.027			0.337
Heterocyclic S compounds				100/.248	10/.027			0.337
Alcohols					10/.027	100/.620	10/	0.647
Phenols					10/.027	10/.062	10/	0.089
Ketones				50/.124**	100/.270	100/.620	100/	1.015
Amines				50/.124**	10/.027	100/.620	10/	0.772
Alkyl S compounds					10/.027	10/.062	10/	0.089
Sulfonic acids					10/.027	10/.062	10/	0.089
Sulfoxides					10/.027	10/.062	10/	0.089
Amides				50/.124**	10/.027	10/.062	10/	0.213
Carboxylic acids					10/.027	100/.620	100/	0.647
Esters				50/.124**	100/.270	10/.062	10/	0.457

\* Quantity not sufficient.

\*\* Possible contaminant.

\*\*\* The value of 10 indicates functional groups for this category were not present in IR spectra.

TABLE 7-8. SUMMARY OF ORGANICS FROM POURING

Category	Remaining <sup>a</sup> on particulate mg/m <sup>3</sup>	Captured by XAD-2 resin mg/m <sup>3</sup>	Total mg/m <sup>3</sup>	Min MEG value in category mg/m <sup>3</sup>	Severity ( $\frac{\text{conc.}}{\text{MEG}}$ )
Aliphatic hydrocarbons	0.018	2.116	2.13	20	(b)
Halogenated hydrocarbons	0.002	2.116	2.12	0.1	21.2
Aromatic hydrocarbons	0.000	1.517	1.52	1.0	1.5
Halogenated aromatics	0.000	1.517	1.52	0.7	2.2
Silicones	0.014	0.177	0.19	0.7	
Heterocyclic O compounds	0.014	1.278	1.29	300	
Nitroaromatics	0.015	0.052	0.07	1.3	
Ethers	0.015	0.519	0.53	16	
Aldehydes	0.015	0.052	0.07	0.25	
Phosphates	0.046	0.114	0.16	400	
Nitriles	0.015	0.052	0.07	1.8	
Heterocyclic N compounds	0.046	0.337	0.38	0.1	3.8
Heterocyclic S compounds	0.046	0.337	0.38	2	
Alcohols	0.078	0.647	0.73	10	
Phenols	0.032	0.089	0.12	2	
Ketones	0.146	1.015	1.16	12	
Amines	0.078	0.772	0.85	0.1	8.5
Alkyl S compounds	0.032	0.089	0.21	1	
Sulfonic acids	0.078	0.089	0.17	0.8	
Sulfoxides	0.032	0.089	0.12	0.8	
Amides	0.032	0.213	0.25	1.0	
Carboxylic acids	0.078	0.647	0.73	0.3	2.4
Esters	0.146	0.457	0.60	5.0	

(a) Some organics adsorbed on the particulate at source conditions may have been distilled into the XAD-2 resin. Particulate samples are collected at 204° C (400° F).

(b) Blanks indicate severity <1.

TABLE 7-11. COMPARISON OF ORGANIC CONCENTRATIONS WITH MEG RANGES - POURING EMISSIONS

Category	Ratio conc. min. MEG	MEG range mg/m <sup>3</sup>	Conc. - Severity		Comments
			midpoint MEG	Severity	
Halogenated hydrocarbons	21.2	0.11 to 5,600	0.000	Finding based on weak IR peak	
Aromatic hydrocarbons	1.5	1 to 440	.007	Finding based on weak IR peak	
Halogenated aromatics	3	.5 to 450	.007	Weak IR peak for aromatic	
Heterocyclic N compounds	3.8	.22 to 90	.008	Weak amide peaks, medium amide peaks. Mostly strong ketone, ester peaks in this fraction	
Amines	8.5	.1 to 130	.01	Weak, broad IR peak that could also be -O-H	
Carboxylic acids	2.4	.32 to 140	.01	Strong IR peak	

TABLE 7-10. ORGANIC EXTRACT SUMMARY TABLE, SAMPLE NO. P-PART.  
POURING EMISSIONS, PARTICULATE - VOLUME SAMPLED 27.843 dsm<sup>3</sup>

	LC1	LC2	LC3	LC4	LC5	LC6	LC7	Σ
Total organics, mg/m <sup>3</sup>	0.02	0.13	0.13	0.26	0.02	0.34	0.33	1.218
TCO, mg/m <sup>3</sup> (40.5%)		0.072	0.054	0.03		0.11	0.083	0.345
GRAV, mg/m <sup>3</sup> (59.5%)	0.018	0.054	0.072	0.226	0.018	0.233	0.251	0.873
Category	Assigned Intensity - mg/m <sup>3</sup>							
Aliphatic hydrocarbons	100/.018 *							0.018
Halogenated aliphatics	10/.002***							0.002
Aromatic hydrocarbons								0
Halogenated aromatics								0
Silicones				10/.014				.014
Heterocyclic O compounds				10/.014				.014
Nitroaromatics				10/.014	10/.001			.015
Ethers				10/.014	10/.001			.015
Aldehydes				10/.014	10/.001			.015
Phosphates				10/.014	10/.001			.015
Nitriles				10/.014	10/.001	10/.005	10/.026	.046
Heterocyclic N compounds				10/.014	10/.001			.015
Heterocyclic S compounds				10/.014	10/.001	10/.005	10/.026	.046
Alcohols				10/.014	10/.001	10/.005	10/.026	.078
Phenols				50/.068**	10/.001	10/.005	10/.026	.032
Ketones					10/.001	100/.051	10/.026	.146
Amines					10/.001	100/.051	10/.026	.078
Alkyl S compounds					10/.001	10/.005	10/.026	.032
Sulfonic acids					10/.001	100/.051	10/.026	.078
Sulfoxides					10/.001	10/.005	10/.026	.032
Amides					10/.001	10/.005	10/.026	.032
Carboxylic acids					10/.001	100/.051	10/.026	.078
Esters				50/.068**	10/.001	100/.051	10/.026	.146

\*Quantity not sufficient. \*\*Possible contaminant. \*\*\*The value of 10 indicates functional groups for this category was not present in IR spectra.

TABLE 7-12. METAL CONTENT OF COMPOSITE POURING DUST

Element	Observed $\mu\text{g}/\text{m}^3$	MEG trigger value $\mu\text{g}/\text{m}^3$	Severity (Conc.) (MEG)
Li	0.77	$2.5 \times 10^1$	a
Be	0.01	$2.6 \times 10^0$	
B	13.05	$1.0 \times 10^4$	
F	MC <sup>b</sup>	$2.5 \times 10^3$	
Na	MC	$2.0 \times 10^3$	
Mg	MC	$3.2 \times 10^4$	
Al	MC	$2.0 \times 10^3$	
Si	MC	$7.5 \times 10^3$	
P	MC	$1.0 \times 10^2$	
S	MC	$2.0 \times 10^4$	
K	MC	$2.0 \times 10^3$	
Ca	MC	$5.4 \times 10^2$	
Sc	0.03	$5.4 \times 10^3$	
Ti	MC	$1.0 \times 10^4$	
V	0.18	$5.0 \times 10^1$	
Cr	MC	$1.0 \times 10^0$	>15
Mn	MC	$5.0 \times 10^3$	
Fe	MC	$1.0 \times 10^3$	
Co	0.18	$4.2 \times 10^1$	
Ni	5.76	$1.4 \times 10^1$	
Cu	3.34	$2.0 \times 10^2$	
Zn	MC	$5.0 \times 10^3$	
Ga	0.18	$8.3 \times 10^4$	
As	0.29	$2.0 \times 10^0$	
Se	0.17	$2.0 \times 10^2$	
Rb	0.05	$3.8 \times 10^4$	
Sr	0.90	$5.6 \times 10^4$	
Y	0.18	$1.0 \times 10^3$	
Zr	0.90	$5.0 \times 10^0$	
Nb	0.12	$2.2 \times 10^4$	

(CONTINUED)

The level of carboxylic acid only slightly exceeds the MEG for a few members of the "Acids with Other Functional Groups" category, and does not exceed the lowest MEG for carboxylic acids alone.

The findings in summary form are thus:

- Halogenated hydrocarbons - present, low priority
- Aromatic hydrocarbons - present, low priority
- Halogenated aromatics - present, low priority
- Heterocyclic N compounds - possibly present, low priority
- Amines - possibly present, low priority
- Carboxylic acids - present, low priority
- Fused aromatics - present, low priority

### 7.2.3 Level 1 Inorganic Analysis

The particulate collected from pouring was analyzed by spark source mass spectrometry (SSMS). Table 7-12 lists the elements found and their concentration along with the MEG (Air, Health) trigger values. Only chromium definitely exceeded the trigger value. This was one of fourteen elements that overloaded the readout, which goes to 1,000 parts per million or 0.1 percent. In terms of this sample, this means a major component (MC) is greater than 15  $\mu\text{g}/\text{m}^3$ . It is unlikely any other of these elements exceeded their respective trigger value. Since this foundry was casting plain gray iron with no intentional addition of chromium, it is unlikely that the emission of chromium can be reduced by selection of process or materials. Chromium is one of the well known problems in the metallurgical industry and the only conclusion that can be drawn here is that it is a problem in pouring emissions also.

The value for mercury listed in Table 7-12 is not from SSMS but from standard level one wet analysis and atomic absorption. It was included in the table for the purpose of simplifying presentation. The arsenic and antimony levels by atomic absorption (AA) analysis were below the detection limit.

### 7.3 ANALYSIS OF SASS TRAIN SAMPLE OF INOCULATION FUMES

Sample "I" is the uncontrolled emission from a set of magnesium inoculation stations at a ductile iron foundry. The bull ladle was filled from an induction holding furnace with an average of 1.593 Mg (3,512 lbs) of iron (weighed within 5 lbs) then transferred to the inoculation station.

Nonferrous metallic elemental additives, except CaC:

Magnesium: 88.68 kg (195.5 lbs)  
 Nickel: 8.66 kg (19.1 lbs)  
 Cerium: 17.66 kg (38.93 lbs)  
 Zirconium: 2.864 kg (6.315 lbs)  
 Calcium: 7.59 kg (16.74 lbs)  
 Copper: 34.9 kg (77 lbs)

These were in seven substances added. (The company's recipe for inoculation is considered proprietary.)

7.3.1 Total Particulate Loading

The total mass of particulates from an uncontrolled inoculation process is given in Table 7-13 which also includes the percentage of each size range and the emission per Mg of production.

Table 7-14 gives the sampling data for this test.

TABLE 7-13. PARTICULATES FROM INOCULATION

Category	Wt., mg	Load, mg/m <sup>3</sup>	Percent of total	Uncontrolled emission g/Mg of inoculant
< 1µm (filter)	726.3	27.50	27.6	15.36
1-3µm	1,006.4	38.11	38.2	21.29
3-10µm	376.6	14.26	14.3	7.97
> 10µm	523.0	19.805	19.9	11.07
Total	2,632.3	99.68	100.0	55.69

Sample volume (std): 26.408 m<sup>3</sup>  
 Total load: 0.04356 grains/ft<sup>3</sup>  
 Metal processed during sampling: 114.7 Mg  
 Air flow/tonne processed: 558.7 m<sup>3</sup>

*0.055 kg/Mg = 1000  
14/11*

TABLE 7-12. (CONTINUED)

Element	Observed $\mu\text{g}/\text{m}^3$	MEG trigger value $\mu\text{g}/\text{m}^3$	Severity (Conc.) (MEG)
Mo	1.52	$5.0 \times 10^3$	
Ag	0.23	$1.0 \times 10^1$	
Cd	0.18	$4.0 \times 10^1$	
Sn	0.23	$1.0 \times 10^2$	
Sb	0.17	$5.0 \times 10^2$	
Te	0.05	$2.2 \times 10^2$	
Cs	0.00	$2.0 \times 10^3$	
Ba	14.87	$5.0 \times 10^2$	
La	0.58	$1.1 \times 10^5$	
Ce	0.71	$1.3 \times 10^5$	
Pr	0.03	$1.2 \times 10^5$	
Nd	0.03	$9.6 \times 10^4$	
Sm	0.05	$1.1 \times 10^5$	
Eu	0.01	$1.3 \times 10^5$	
W	0.03	$1.0 \times 10^3$	
Hg	2.53	$5.0 \times 10^1$	
Pb	2.58	$1.0 \times 10^2$	
Bi	0.02	NOT DETERMINED	
Th	.24	$5.3 \times 10^4$	
U	0.08	$1.5 \times 10^1$	

(a) Blanks indicate severity <1.

(b) MC = Major component, i.e.,  $> 15\mu\text{g}/\text{m}^3$ . Severity cannot be calculated.

At the inoculation station a graphite bell was loaded with a sheet iron can containing the inoculant and plunged to the bottom of the ladle. At the same time a hood was lowered over the ladle and essentially all fumes were captured. Sampling was done in the duct leading the collected smoke to a baghouse.

The production and material data pertinent to the inoculation sample are as follows:

Number of plunges during sampling: 72

Iron inoculated during test: 114.7 Mg (252,785 lbs) (Plus 45 kg - 100 lbs - of cans and support rods)

TABLE 7-15. SUMMARY OF ORGANIC ANALYSIS FROM UNCONTROLLED INOCULATION  
Emission Rate: 2.60 g/Mg processed

Category	Remaining <sup>a</sup> on particulate mg/m <sup>3</sup>	Captured by XAD-2 resin mg/m <sup>3</sup>	Total mg/m <sup>3</sup>	Min MEG value in category mg/m <sup>3</sup>	Severity ( $\frac{\text{conc.}}{\text{MEG}}$ )
Aliphatic hydrocarbons	QNS <sup>b</sup>	0.362	0.362	20	(c)
Halogenated hydrocarbons	QNS	0.362	0.362	0.1	3.6
Aromatic hydrocarbons	QNS	0.814	0.814	1.0	
Halogenated aromatics	QNS	0.814	0.814	0.7	1.2
Silicones	QNS	0.205	0.205	0.7	
Heterocyclic O compounds	QNS	0.796	0.796	300	
Nitroaromatics	0.001	0.015	0.016	1.3	
Ethers	0.001	0.235	0.236	16	
Aldehydes	0.001	0.028	0.029	0.25	
Phosphates	0.005	0.028	0.033	400	
Nitriles	0.001	0.015	0.016	1.8	
Heterocyclic N compounds	0.005	0.028	0.033	0.1	
Heterocyclic S compounds	0.005	0.028	0.033	2	
Alcohols	0.005	0.019	0.024	10	
Phenols	0.005	0.019	0.024	2	
Ketones	0.059	0.186	0.245	0.12	
Amines	0.005	0.019	0.024	0.1	
Alkyl S compounds	0.005	0.019	0.024	1	
Sulfonic acids	0.005	0.019	0.024	0.8	
Sulfoxides	0.005	0.019	0.024	0.8	
Amides	0.005	0.019	0.024	1.0	
Carboxylic acids	0.005	0.019	0.024	0.3	
Esters	0.048	0.019	0.067	5.0	

<sup>a</sup>Some organics adsorbed on the particulate at source conditions may have distilled into the XAD-2 resin. Particulate samples are collected at 204°C (400° F).

<sup>b</sup>QNS = Quantity not sufficient for analysis.

<sup>c</sup>Blanks indicate Severity <1.

TABLE 7-14. SUMMARY OF SAMPLING DATA FOR INOCULATION

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Date of test:	2/11/81	
Volume of gas sampled:	26.408 m <sup>3</sup> (933 ft <sup>3</sup> )	
Duct gas temperature:	40° C (104° F)	
Duct gas pressure:	73.81 cm Hg	
Duct gas molecular weight:	28.84	
Duct gas moisture:	3 percent	
Duct gas velocity:	16.95 m/sec (55.6 ft/sec)	
Duct gas flow rate:	4.36 m <sup>3</sup> /sec (9,238 cfm)	9,238 cfm x
Total sampling time:	14,700 sec	
SASS train flow rate:	0.001796 m <sup>3</sup> /sec (3.81 cfm)	
Percent isokinetic:	95.9	
Iron cast during sampling:	114.7 Mg (126.4 tons)	28.09 Mg/hr

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### 7.3.2 Level 1 Organic Analysis

Table 7-15 summarizes the liquid chromatography and infrared spectrophotometry analysis of the organic compounds extracted from the air and the dust. This summary comes from Table 7-16 and 7-17, the Organic Extract Summary Table. The treatment of these tables has been discussed in Section 7.2.2. Table 7-15 shows that the severity was >1 in two categories, halogenated hydrocarbons and halogenated aromatics.

### 7.3.3 Level 1 Inorganic Analysis

This particular sample was given an extra analysis beyond the usual scope of Level 1 assessments. Since magnesium reacts with nitrogen and can form Mg<sub>3</sub>N<sub>2</sub>, it was desired to determine whether or not this occurs during the inoculation process. Magnesium nitride would be an undesirable byproduct because of hydrolysis to form alkaline magnesium hydroxide and ammonium hydroxide. Soon after collection and weighing particulates, a portion of the particulate was analyzed by x-ray, using the CuK $\alpha$  emission in a 57.3 mm diameter powder camera. The resulting spectra was checked against file data on MgO, Mg<sub>3</sub>N<sub>2</sub>, Mg(NO<sub>3</sub>)<sub>2</sub>, MgO<sub>2</sub>, Mg<sub>2</sub>P<sub>27</sub>, MgCO<sub>3</sub>·5H<sub>2</sub>O. The sample is predominantly MgO with traces of iron, (magnetically separable). Four lines (d = 4.23, 3.86, 3.02, 1.70) do not fit this explanation. No fit could be obtained for Mg<sub>3</sub>N<sub>2</sub>. The strongest Mg<sub>3</sub>N<sub>2</sub> line is 1.76 which is too far removed from the observed 1.70. The other strong lines (except 4.23), coincide with the MgO lines. The most likely explanation for the extra lines is magnesium carbonate pentahydrate, MgCO<sub>3</sub> · 5H<sub>2</sub>O. This could result from reaction of MgO with water and carbon dioxide in the air or it could result from reaction of Mg<sub>3</sub>N<sub>2</sub> with water and carbon dioxide. The latter reaction is fast, whereas

TABLE 7-17. ORGANIC EXTRACT SUMMARY TABLE, SAMPLE NO. I-PARTICULATES.  
 INOCULATION EMISSIONS, PARTICULATE EXTRACT - VOLUME SAMPLED 26.408 dsm<sup>3</sup>

	LC1	LC2	LC3	LC4	LC5	LC6	LC7	Σ	
Total organics, mg/m <sup>3</sup>			0.023	0.004	0.030	0.121	0.121	0.299	
TCO, mg/m <sup>3</sup> (6.4%)			0.023	0.004	0.030	0.011	0.121	0.011	
GRAV, mg/m <sup>3</sup> , (93.6%)						0.110		0.288	
Category			Assigned Intensity - mg/m <sup>3</sup>						
Aliphatic hydrocarbons	QNS	QNS		QNS			QNS	QNS	
Halogenated aliphatics								QNS	
Aromatic hydrocarbons								QNS	
Halogenated aromatics								QNS	
Silicones								QNS	
Heterocyclic O compounds								QNS	
Nitroaromatics					10/.001			0.001	
Ethers					10/.001			0.001	
Aldehydes					10/.001			0.001	
Phosphates					10/.004			0.005	
Nitriles					10/.001			0.001	
Heterocyclic N compounds					10/.001	10/.004		0.005	
Heterocyclic S compounds					10/.001	10/.004		0.005	
Alcohols					10/.001	10/.004		0.005	
Phenols					10/.001	100/.039		0.059	
Ketones			50/.011**		10/.001	100/.004		0.005	
Amines					10/.001	10/.004		0.005	
Alkyl S compounds					10/.001	10/.004		0.005	
Sulfonic acids					10/.001	10/.004		0.005	
Sulfoxides					10/.001	10/.004		0.005	
Amides					10/.001	10/.004		0.005	
Carboxylic acids					10/.001	10/.004		0.005	
Esters					100/.009	100/.039		0.048	

TABLE 7-16. ORGANIC EXTRACT SUMMARY TABLE, SAMPLE NO. I-XR (XAD-2 RESIN)  
 INOCULATION EMISSIONS, VOLUME SAMPLED: 26.408 dsm<sup>3</sup>.

	LC1	LC2	LC3	LC4	LC5	LC6	LC7	Σ
Total organics, mg/m <sup>3</sup>	0.16	0.644	2.44	0.27	0.142	0.432	0.28	4.359
TCO, mg/m <sup>3</sup> , (56.3%)		0.443	1.68	0.19	0.04	0.102		2.455
GRAV, mg/m <sup>3</sup> , (43.7%)	0.163	0.201	0.757	0.076	0.102	0.329	0.276	1.904
Category	Assigned Intensity - mg/m <sup>3</sup>							
Aliphatic hydrocarbons	100/.082	100/.280						0.362
Halogenated aliphatics	100/.082	100/.280						0.362
Aromatic hydrocarbons		10/.028	100/.786					0.814
Halogenated aromatics		10/.028	100/.786					0.814
Silicones		10/.028	10/.079	100/.099				0.205
Heterocyclic O compounds			100/.786	10/.010				0.796
Nitroaromatics				10/.010	10/.005			0.015
Ethers				100/.099	10/.005	100/.131		0.235
Aldehydes				10/.010	10/.005	10/.013		0.028
Phosphates				10/.010	10/.005	10/.013		0.028
Nitriles				10/.010	10/.005			0.015
Heterocyclic N compounds				10/.010	10/.005	10/.013		0.028
Heterocyclic S compounds				10/.010	10/.005	10/.013		0.028
Alcohols					10/.005	10/.013		0.019
Phenols					10/.005	10/.013		0.019
Ketones					100/.055	100/.131		0.186
Amines					10/.005	10/.013		0.019
Alkyl S compounds					10/.005	10/.013		0.019
Sulfonic acids					10/.005	10/.013		0.019
Sulfoxides					10/.005	10/.013		0.019
Amides					10/.005	10/.013		0.019
Carboxylic acids					10/.005	10/.013		0.019
Esters					10/.005	10/.013		0.019

QNS = Quantity not sufficient.

TABLE 7-18. METAL CONTENT OF INOCULATION SMOKE

Element	Observed $\mu\text{g}/\text{m}^3$	MEG trigger values $\mu\text{g}/\text{m}^3$	Severity (Conc.) (MEG)
Li	8.7	$2.5 \times 10^1$	a
Be	0.03	$2.6 \times 10^0$	
B	> 100	$1.0 \times 10^4$	
Na	> 100	$2.0 \times 10^3$	
Mg	> 100	$3.2 \times 10^4$	
Al	> 100	$2.0 \times 10^3$	
Si	> 100	$7.5 \times 10^2$	
P	27	$1.0 \times 10^2$	
S	> 100	$2.0 \times 10^4$	
K	> 100	$2.0 \times 10^3$	
Ca	> 100	$5.4 \times 10^2$	
Sc	0.07	$5.4 \times 10^3$	
Ti	> 100	$1.0 \times 10^4$	
V	> 100	$5.0 \times 10^1$	>2 7
Cr	7.1	$1.0 \times 10^0$	
Mn	62.8	$5.0 \times 10^3$	
Fe	> 100	$1.0 \times 10^3$	
Co	0.09	$4.2 \times 10^1$	
Ni	0.60	$1.4 \times 10^1$	
Cu	20.9	$2.0 \times 10^2$	
Zn	> 100	$5.0 \times 10^3$	
Ga	2.09	$8.3 \times 10^4$	
Ge	0.10	$1.5 \times 10^4$	
As	13.0	$2.0 \times 10^0$	6.5
Se	0.8	$2.0 \times 10^2$	
Rb	1.3	$3.8 \times 10^4$	
Sr	10.	$5.6 \times 10^4$	
Y	0.09	$1.0 \times 10^3$	
Zr	4.0	$5.1 \times 10^0$	
Mo	0.7	$5.0 \times 10^3$	
Ag	1.2	$1.0 \times 10^1$	
Cd	0.2	$4.0 \times 10^1$	
Sn	2.5	$1.0 \times 10^2$	
Sb	21.9	$5.0 \times 10^2$	
Te	0.2	$2.2 \times 10^2$	
Cs	0.09	$2.0 \times 10^3$	
Ba	> 100	$5.0 \times 10^2$	
La	1.3	$1.1 \times 10^5$	
Ce	9.1	$1.3 \times 10^5$	
Pb	> 100	$1.0 \times 10^2$	>1
Bi	0.5	NOT DETERMINED	

<sup>a</sup> Blanks indicate severity <1.

the reaction of MgO which is formed at high temperatures is known to be slow. Since a more sophisticated analytical procedure could not be effected onsite at the time of collection there is no way of selecting between these two possibilities. However the important finding is that there is no measurable amount of magnesium nitride in the emitted smoke.

Table 7-18 gives the metal content of the dust collected. This was determined by spark source mass spectrometry. Chromium, vanadium, lead, and arsenic exceed their trigger values. The source of these could not be determined. The company provided a complete analysis, to the 0.01 percent level, of the metal cans used to contain the plunging additives. Evidently these elements may be entering the system through the scrap.

Level 1 procedure provides for the wet chemical and atomic absorption analysis of As, Sb, and Hg in the impinger solutions the sample gas passes through after the SASS train cyclones, filter, and XAD-2 resin cartridge, thereby giving the concentrations of these volatile elements in the gaseous state. These results are as follows:

<u>Element</u>	<u>Observed <math>\mu\text{g}/\text{m}^3</math></u>	<u>MEG trigger value <math>\mu\text{g}/\text{m}^3</math></u>	<u>Severity</u>
As	3.69	2	1.8
Sb	0.24	500	<1
Hg	3.07	50	<1

Arsenic exceeds the MEG by a factor of 1.8. The most significant source of arsenic is the dust, which is baghouse collected, thus the problem with chromium and arsenic emissions to the atmosphere would appear to be essentially under control at the plant tested. Tests of the baghouse emission would be required to prove this. Uncontrolled emissions, however, could present an environmental problem.

#### 7.4 ANALYSIS OF SASS TRAIN SAMPLE OF CUPOLA EMISSIONS

Sample "C" is the baghouse filtered emission from a 21.3 cm (54 inch) cupola rated at 9 Mg (10 tons) per hour; output can be increased to 10.9 Mg (12 tons) per hour with oxygen enrichment. Oxygen enrichment is also used in this plant for chemistry adjustment. The cupola has three afterburners followed by multiple quenching water sprays. The stack gas temperature into the quench is maintained above 732° C (1,350° F) to insure that all carbon monoxide is converted to carbon dioxide. The quench sprays are sequentially activated by baghouse inlet gas temperature to keep the temperature into the baghouse at an acceptable level below 300° C. After the quench towers the

TABLE 7-19. SUMMARY OF SAMPLING DATA FOR THE CUPOLA EMISSION TEST

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Date of Test:	3/25/81
Volume of gas sampled:	24.66 m <sup>3</sup> (871 ft <sup>3</sup> )
Stack gas temperature:	178° C (352° F)
Stack gas pressure:	75.74 cm Hg
Stack gas molecular weight:	29.60
Percent CO <sub>2</sub> by volume, dry:	6.1
Percent O <sub>2</sub> by volume, dry:	12.9
Percent N <sub>2</sub> by volume, dry:	80.1
Percent A by volume, dry:	0.9
Stack gas moisture:	15 percent
Stack gas velocity:	16.34 m/sec (53.6 ft/sec)
Stack gas flow rate:	10.50 m <sup>3</sup> /sec (22,248 cfm)
Total sampling time:	15,000 sec
SASS train flow rate:	0.001644 m <sup>3</sup> /sec (3.43 cfm)
Percent isokinetic:	93.2
Iron melted during sampling:	42.0 Mg (46.2 tons)

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#### 7.4.2 Level 1 Organic Analysis

Table 7-20 summarizes the liquid chromatography and infrared (IR) spectrophotometry analysis of the organic compounds extracted from the air. This summary comes from Table 7-21, the Organic Extract Summary Table. The treatment of these tables has been discussed in Section 7.2.2.

Table 7-20 shows that the severities were >1 for six categories; halogenated hydrocarbons, aromatic hydrocarbons, halogenated aromatics, heterocyclic N compounds, amines, and silicones.

The IR data on aromatic hydrocarbons is based on two weak peaks and one medium peak. The LRMS also shows only a weak presence. Halogenated hydrocarbons are also indicated by two medium peaks which, combined with the concern ratio of 36, indicates a possible problem. The halogenated aromatics are confirmed by medium and strong IR peaks.

The presence of silicones at slightly more than the trigger value is probably an overestimate. There is no IR confirmation of silicones in fractions LC2 or LC3. Fraction LC4 does have a strong peak which can be either ketones or silicones. This fraction alone would assign a quantity of 0.488 mg/m<sup>3</sup> silicones, which is half the trigger value. Considering the high level of ketones in Fractions LC4, LC5, and LC6, it is more likely that the observed peak is due to ketones than silicones.

off-gas goes to a baghouse. The exhaust of the baghouse was designed as a single stack with a sampling platform and ports to allow easy sampling.

The production and material data pertinent to the cupola sample are as follows:

Charge:

Scrap	544 kg (1,200 lbs)
Pig iron	204 kg (450 lbs)
Steel	159 kg (350 lbs)
Limestone	18 kg (40 lbs)
Flourspar	1.8 kg (4 lbs)
Coke	113 kg (250 lbs)

Iron to Coke Ratio:

8:1

Coke Analysis:

Carbon	94.1%
Ash	5.1%
Sulfur	0.58%
Volatiles	0.8%

Blast Air:

227 m<sup>3</sup>/min (8,000 cfm) at 232° to 260° C (450° to 500° F)

Oxygen Enrichment:

1.5%

Production Rate:

10.1 Mg/hr (11.1 tons/hr)

7.4.1 Total Particulate Loading

This sample was collected from the baghouse exhaust. No measurable particulates were obtained.

Table 7-19 gives the sampling data for this test.

The findings in summary form are:

Halogenated hydrocarbons - present, moderate priority  
Aromatic hydrocarbons - present, low priority  
Halogenated aromatics - present, low priority  
Heterocyclic N compounds - possibly present, low priority  
Amines - possibly present, low priority  
Silicones - possibly present, low priority

TABLE 7-20. SUMMARY OF ORGANIC VAPOR ANALYSIS FROM CUPOLA EMISSIONS  
Emission Rate: 90.4 g/Mg processed

Category	Remaining on particulate mg/m <sup>3</sup>	Captured by XAD-2 resin mg/m <sup>3</sup>	Total mg/m <sup>3</sup>	Min MEG value in category mg/m <sup>3</sup>	Severity (conc./MEG)
Aliphatic hydrocarbons	N.A. <sup>a</sup>	3.618	3.618	20	(b)
Halogenated hydrocarbons	N.A.	3.618	3.618	0.1	36
Aromatic hydrocarbons	N.A.	3.207	3.207	1.0	3.2
Halogenated aromatics	N.A.	3.207	3.207	0.7	4.6
Silicones	N.A.	0.809	0.809	0.7	1.2
Heterocyclic O compounds	N.A.	1.906	1.907	300	
Nitroaromatics	N.A.	0.206	0.206	1.3	
Ethers	N.A.	2.065	2.065	16	
Aldehydes	N.A.	0.206	0.206	0.25	
Phosphates	N.A.	0.308	0.308	400	
Nitriles	N.A.	0.206	0.206	1.8	
Heterocyclic N compounds	N.A.	0.308	0.308	0.1	3.1
Heterocyclic S compounds	N.A.	0.308	0.308	2	
Alcohols	N.A.	0.259	0.259	10	
Phenols	N.A.	0.259	0.259	2	
Ketones	N.A.	2.838	2.838	12	
Amines	N.A.	0.259	0.259	0.1	2.6
Alkyl S compounds	N.A.	0.259	0.259	1	
Sulfonic acids	N.A.	0.259	0.259	0.8	
Sulfoxides	N.A.	0.259	0.259	0.8	
Amides	N.A.	0.259	0.259	1.0	
Carboxylic acids	N.A.	0.259	0.259	0.3	
Esters	N.A.	1.679	1.679	5.0	

<sup>a</sup>Not analyzed. Insufficient particulate matter collected.

<sup>b</sup>Blanks indicate Severity <1

The halogenated organics likely originate from one source, fluorspar, which is calcium fluoride,  $\text{CaF}_2$ . Organic compounds will react with molten halides to form halogenated organic compounds. The level of halogenated organics produced will probably vary with the amount of oxygen enrichment (due to temperature effects), as well as the amount of fluorspar used. Reduction of either oxygen enrichment or fluorspar results in a reduction in production level and an increase in energy consumption.

Although the low resolution mass spectrometer data does indicate polynuclear aromatic compounds, no BaP or other fused aromatics of particular environmental concern were detected. A worse case assignment of mass 268 as methyl cholathene was made. However, this compound has only been definitively identified in emissions originating from biological materials.<sup>17</sup>

#### 7.4.3 Level 1 Inorganic Analysis

The sampled gas passing through the SASS train is bubbled through three "impingers" designed to collect arsenic, mercury and antimony, the volatile metallic elements. These solutions are subjected to atomic absorption spectrophotometry for these elements. Only arsenic was found. The first 750 mL impinger contained 0.204  $\mu\text{g/mL}$  and the second and third impingers contained 0.024  $\mu\text{g/mL}$  of arsenic, indicating good capture efficiency. This calculates out to 7.66  $\mu\text{g/m}^3$  in the sampled offgas. The MEG for arsenic is 2  $\mu\text{g/m}^3$ , giving a severity of 3.8. The flux contains fluorspar. Arsenic fluorides are very volatile. Arsenic was probably leached out the raw material containing it by the fluoride from the flux. The source of the arsenic is unknown but could be the coke or lime.

#### 7.5 ANALYSIS OF SASS TRAIN SAMPLE OF ELECTRIC ARC FURNACE

Sample "E" is the baghouse filtered emission from a 4.5 Mg (5 ton) electric arc furnace in a steel foundry. The furnace used 493 to 584 kilowatt hours of electricity per Mg melted (447 to 584 Kwh/ton) and consumed 6 kg of graphite electrodes per Mg charged (12 to 13 lb/ton). At the time of the test, plain carbon steel was being made, therefore the process is comparable to the melting of cast iron with the exception that more energy is required to raise the temperature of the steel.

The furnace was well hooded and all fumes were collected during smooth operation but some "puffing" fume during the initial meltdown occasionally escaped. The company is in the planning process of installing a doughnut hood to capture the puffing fumes as well. The fumes collected by the fur-

TABLE 7-21. ORGANIC EXTRACT SUMMARY TABLE, SAMPLE NO. C-XR (XAD-2 RESIN)  
 CUPOLA EMISSIONS, AIR - STANDARD VOLUME SAMPLED 24.661 ds<sup>3</sup>

	LC1	LC2	LC3	LC4	LC5	LC6	LC7	Σ
Total organics, mg/m <sup>3</sup>	4.54	5.54	5.76	1.56	6.94	2.24		26.54
TCO, mg/m <sup>3</sup> , (64.1%)	2.65	4.31	3.82	1.05	4.90	0.30		17.00
GRAV, mg/m <sup>3</sup> , (35.9%)	1.886	1.225	1.938	0.511	2.04	1.938		9.537
Category	Assigned Intensity - mg/m <sup>3</sup>							
Aliphatic hydrocarbons	100/2.268	100/1.350						3.618
Halogenated aliphatics	100/2.268	100/1.350						3.618
Aromatic hydrocarbons		100/1.350	100/1.857					3.207
Halogenated aromatics		100/1.350	100/1.857					3.207
Silicones		10/0.135	10/0.186	100/.488				0.809
Heterocyclic O compounds			100/1.857	10/.049				1.906
Nitroaromatics				10/.049	10/.158			0.206
Ethers				100/.488	100/1.577			2.065
Aldehydes				10/.049	10/.158			0.206
Phosphates				10/.049	10/.158	10/.102		0.308
Nitriles				10/.049	10/.158			0.206
Heterocyclic N compounds				10/.049	10/.158	10/.102		0.308
Heterocyclic S compounds				10/.049	10/.158	10/.102		0.308
Alcohols					10/.158	10/.102		0.259
Phenols					10/.158	10/.102		0.259
Ketones				50/.244**	100/1.577	100/1.017		2.838
Amines					10/.158	10/.102		0.259
Alkyl S compounds					10/.158	10/.102		0.259
Sulfonic acids					10/.158	10/.102		0.259
Sulfoxides					10/.158	10/.102		0.259
Amides					10/.158	10/.102		0.259
Carboxylic acids					10/.158	10/.102		0.259
Esters					100/1.577	10/.102		1.679

\* Quantity not sufficient.  
 \*\* Possible impurity.

TABLE 7-22. SUMMARY OF SAMPLING DATA FOR ELECTRIC ARC FURNACE EMISSIONS

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Date of test: 2/25/81  
Volume of gas sampled: 29.27 m<sup>3</sup> (1,034 ft<sup>3</sup>)  
Stack gas temperature: 31° C (88° F)  
Stack gas pressure: 73.58 cm Hg  
Stack gas molecular weight: 28.84  
Stack gas moisture: 3 percent  
Stack gas velocity: 17.98 m/sec (59 ft/sec)  
Stack gas flow rate: 14.34 m<sup>3</sup>/sec (30,384 cfm)  
Total sampling time: 14,400 sec  
SASS train flow rate: 0.002033 m<sup>3</sup>/sec (4.31 cfm)  
Percent isokinetic: 100.0  
Metal melted during sampling: 11.83 Mg (13.0 tons)

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### 7.5.2 Level 1 Organic Analysis

The organic analysis of the extracted XAD-2 resin cartridge in the SASS train was pursued as with the previous samples. Table 7-23 is the summary of the organic analysis of the EAF emissions. The summary comes from Table 7-24, the Organic Extract Summary Table. The treatment of these tables has been discussed in Section 7.2.2.

Table 7-23 shows that the trigger values were exceeded in four categories: halogenated hydrocarbons, aromatic hydrocarbons, halogenated hydrocarbons, and amines.

Halogenated aromatics are indicated at a severity of 2 value but only alkyl chloride peaks were identified.

The presence of halogenated hydrocarbons is very significant with a severity of 20. Strong alkyl chloride peaks are present in fraction two which accounts for 0.7 mg/m<sup>3</sup> of the assigned quantity but only a weak peak is found in fraction one, which accounts for 1.3 mg/m<sup>3</sup> of the assigned quantity. The source of the halogen was not elucidated. No fluorspar was used in the flux, but some might have been in the furnace from previous runs. Chloride can come into the system through the limestone used as flux.

Although fused aromatics are present, no BaP was detected by LRMS.

Again, as for the cupola emissions the mass at 268 was assigned, as a worst case, as methyl cholanthene. However, we do not anticipate this assignment will prove to be correct.

### 7.5.3 Level 1 Inorganic Analysis

The Level 1 procedure for the atomic absorption analysis of As, Sb, and Hg was followed. The XAD-2 resin was ashed and subjected to spark source

nace hood were drawn through the baghouse with a 100 horsepower blower. Gas flow rate through the blower exhaust stack was  $860.4 \text{ m}^3/\text{min}$  (30,384 DSCFM). Draft at the furnace hood may have been lower if leaks existed in the system. No attempt was made to determine if the system had leaks. The SASS sample of the baghouse exhaust gas was taken through a port in the blower exhaust stack (see appendix for exact location).

#### 7.5.1 Total Particulate Loading

This sample was obtained after the baghouse. No bags were leaking. No measurable particulates were obtained.

The production and material data pertinent to this sample are as follows:

Melting rate:

2.73 Mg/hr. (3.00 tons/hr)

Charge:

Returns:	1,814 kg (4,000 lbs)
Plate:	2,722 kg (6,000 lbs)
Pig iron:	45 kg (100 lbs)
FeSi 50%:	34-39 kg (75-85 lbs)
Mn:	2.3-9 kg (5-20 lbs)
Carbon:	32 kg (70 lbs)
Al:	4.5 kg (10 lbs)
SiZr:	5.4 kg (12 lbs)
Lime:	227 kg (500 lbs)

Tap temperature:

1,782° C (3,240° F)

Average kilowatt hours per melt:

2,333

Table 7-22 gives the summary of the sampling data for this test. The sampling occurred continuously throughout three taps and three charges, starting during a melt and ending during a melt.

TABLE 7-24. ORGANIC EXTRACT SUMMARY TABLE, SAMPLE NO. E-XR (XAD-2 RESIN)  
ELECTRIC ARC FURNACE - VOLUME SAMPLED 29.267 dsm<sup>3</sup>

	LC1	LC2	LC3	LC4	LC5	LC6	LC7	Σ
Total organics, mg/m <sup>3</sup>	2.55	2.96	2.05	0.034	0.103	0.991	0.513	9.191
TCO, mg/m <sup>3</sup> (53.5%)	1.49	2.00	1.20			0.24		4.920
GRAV, mg/m <sup>3</sup> (46.5%)	1.059	0.957	0.854	0.034	0.103	0.752	0.513	4.271
Category	Assigned Intensity - mg/m <sup>3</sup>							
Aliphatic hydrocarbons	100/1.275	100/.721			QNS*			1.996
Halogenated aliphatics	100/1.275	100/.721						1.996
Aromatic hydrocarbons		100/.721	100/.663					1.384
Halogenated aromatics		100/.721	100/.663					1.384
Silicones		10/.072	10/.066	100/.011				0.149
Heterocyclic O compounds			100/.663	10/.001				0.664
Nitroaromatics				10/.001				0.001
Ethers				100/.011				0.011
Aldehydes				10/.001				0.001
Phosphates				10/.001		100/.320	10/.013	0.334
Nitriles				10/.001				0.001
Heterocyclic N compounds				10/.001		10/.032	10/.013	0.046
Heterocyclic S compounds				10/.001		10/.032	100/.128	0.046
Alcohols						10/.032	10/.013	0.160
Phenols						100/.320	10/.013	0.045
Ketones						100/.320	100/.128	0.338
Amines				50/.005**		10/.032	100/.128	0.160
Alkyl S compounds						10/.032	10/.013	0.045
Sulfonic acids						10/.032	10/.013	0.045
Sulfoxides						10/.032	10/.013	0.045
Amides						10/.032	10/.013	0.045
Carboxylic acids						10/.032	100/.128	0.045
Esters						10/.032	100/.128	0.160

\* Quantity not sufficient.  
\*\* Possible impurity.

TABLE 7-23. SUMMARY OF ORGANIC VAPOR ANALYSIS FROM THE ELECTRIC ARC FURNACE  
Emission rate: 173.7 g/Mg processed

Category	Remaining on particulate mg/m <sup>3</sup>	Captured by XAD-2 resin mg/m <sup>3</sup>	Total mg/m <sup>3</sup>	Min DMEG value in category mg/m <sup>3</sup>	Ratio (conc./DMEG)
Aliphatic hydrocarbons	N.A. <sup>a</sup>	1.996	1.996	20	
Halogenated hydrocarbons	N.A.	1.996	1.996	0.1	20
Aromatic hydrocarbons	N.A.	1.384	1.384	1.0	1.4
Halogenated aromatics	N.A.	1.384	1.384	0.7	2
Silicones	N.A.	0.149	0.149	0.7	
Heterocyclic O compounds	N.A.	0.664	0.664	300	
Nitroaromatics	N.A.	0.001	0.001	1.3	
Ethers	N.A.	0.011	0.011	16	
Aldehydes	N.A.	0.001	0.001	0.25	
Phosphates	N.A.	0.334	0.334	400	
Nitriles	N.A.	0.001	0.001	1.8	
Heterocyclic N compounds	N.A.	0.046	0.046	0.1	
Heterocyclic S compounds	N.A.	0.046	0.046	2	
Alcohols	N.A.	0.160	0.160	10	
Phenols	N.A.	0.045	0.045	2	
Ketones	N.A.	0.338	0.338	12	
Amines	N.A.	0.160	0.160	0.1	1.6
Alkyl S compounds	N.A.	0.045	0.045	1	
Sulfonic acids	N.A.	0.045	0.045	0.8	
Sulfoxides	N.A.	0.045	0.045	0.8	
Amides	N.A.	0.045	0.045	1.0	
Carboxylic acids	N.A.	0.160	0.160	0.3	
Esters	N.A.	0.045	0.045	5.0	

<sup>a</sup>Not analyzed, insufficient particulate collected.

## 8.0 DISCUSSION OF RESULTS

The results of this study show that there are some areas which may need further analysis. The most significant finding is the consistent presence of halogenated compounds. In terms of similarity of processes, only the cupola and electric arc furnace can be directly compared. However, some interesting observations can be made by comparing the percentage of each organic component present in the emissions from the four processes. These are presented in Table 8-1.

Organics in the pouring emissions are not unexpected considering the presence of sea coal in the sand.

There was some concern that the inoculation organic emissions might contain fume from an adjacent pouring line. This concern is not supported by a comparison of the pouring and inoculation emissions. This is seen by comparing the first two categories, aliphatic hydrocarbons and halogenated hydrocarbons with the third and fourth categories, aromatic hydrocarbons and halogenated aromatics. The percentages for these two sets are almost completely inverted, and the proportions of other categories likewise do not match well. Thus, the inoculation process itself is indeed a source of organic emissions. This may arise from impurities in the calcium carbide used for desulfurization or the ferrosilicon or the ferrosilicon magnesium inoculant.

Normally it is assumed that organic substances are not present in ferrosilicons because of the high temperature of their manufacture. While neither chemists nor metallurgists concern themselves with the thought of organic compound impurities in iron, such a possibility is worth considering. Indeed it may correlate with some of the "mysteries" of cupola iron versus induction furnace iron. Another data point that suggests the presence of unrecognized factors is the unusual fluidity of cast iron from the experimental gas fired cupolas. The use of gas for heat and graphite for carbon would certainly reduce the exposure of the metal to organic compounds that can be present in

mass spectrometry. The values obtained were corrected with a blank analysis of unused XAD-2 resin. The composite findings of these two techniques are presented in Table 7-25, Metal Content of Filtered EAF Emissions.

TABLE 7-25. METAL CONTENT OF FILTERED EAF EMISSIONS

Element	Observed $\mu\text{g}/\text{m}^3$	MEG trigger value $\mu\text{g}/\text{m}^3$	Severity (Conc.) (MEG)
B	4.27	$1.0 \times 10^4$	(b)
Cr	5.12	$1.0 \times 10^0$	5
Mn	3.42	$5.0 \times 10^3$	
Pb	17.1	$1.0 \times 10^2$	
As	N.D. <sup>a</sup>	$2.0 \times 10^0$	
Hg	1.90	$5.0 \times 10^1$	
Sb	0.16	$5.0 \times 10^2$	

<sup>a</sup>None detected.

<sup>b</sup>Blanks indicate severity >1.

From Table 7-25 it is seen that chromium is the only element exceeding the DMEG. There was no deliberate additions of chromium in the melt, however the steel melted averaged 0.25 percent Cr and this could account for the emissions.

coke, not to mention the trace inorganics. If organic compounds are present in the iron, they certainly would segregate at the grain boundaries, which is metallurgically significant. If any organic molecules were trapped in the iron grains (crystals), their interaction with dislocations would certainly be different from that of carbon atoms, and thus some difference in mechanical properties would be obtained. The indicated presence of organics in the inoculation process thus signals an area of research that could have metallurgical as well as environmental consequences. The analysis of the basic and secondary raw materials would be a good starting point to pursue this, if the presence of organic compounds in the metal is verified.

The presence of organic compounds in the cupola offgas is not surprising. The intent of the afterburners is to eliminate carbon monoxide and many would hope the organic compounds, too.

The most significant finding is the consistent presence of halogenated hydrocarbons. These probably originate by a reaction between the organics present and halogen salts in the flux or furnace lining materials. This is of greater concern if these halogens are fluorocarbons, as could be the case when fluorspar is used as a fluxing agent. It would not be unusual for the limestone to contain salt, which would produce chlorinated hydrocarbons. Clarification of the situation will require more specific analyses combined with a close examination of the raw materials. Reducing the emission of these compounds could require a large increase in energy consumption as well as capital investment. The better approach would be an examination of raw material sources and their effect on emissions.

The inorganic emissions needing further analysis and evaluation consisted primarily of arsenic and chromium. Arsenic as a volatile compound was present at  $7.7 \mu\text{g}/\text{m}^3$  in gas from the cupola, and at  $3.7 \mu\text{g}/\text{m}^3$  from inoculation. Arsenic could be originating from ferrosilicon, calcium carbide or some other source. Arsenic was also present in the inoculation smoke at a level of  $13.0 \mu\text{g}/\text{m}^3$ . In the case of inoculation both calcium carbide and ferrosilicon are very probable arsenic sources. A correlation of data and a raw materials analysis approach might show that arsenic emissions in the foundry are related to the source of coal used to make ferrosilicon, calcium carbide and coke.

Chromium levels should also be further evaluated. It was present in the inoculation particulate at  $7.1 \mu\text{g}/\text{m}^3$ , and in the pouring particulates at  $> 15$

TABLE 8-1. PERCENTAGE OF EACH COMPONENT IN SAMPLES

Category	P	I	<u>Samples</u> C	E
Aliphatic hydrocarbons	13.9	8.5	13.6	21.9
Halogenated hydrocarbons	13.8*	8.5*	13.6*	21.9*
Aromatic hydrocarbons	9.9*	19.1	12.1*	15.2*
Halogenated aromatics	9.9*	19.1*	12.1*	15.2*
Silicones	1.2	4.8	3.0*	1.6
Heterocyclic O compounds	8.4	18.7	7.2	7.3
Nitroaromatics	0.5	0.4	0.8	0.01
Ethers	3.5	5.5	7.8	0.1
Aldehydes	0.5	0.7	0.8	0.01
Phosphates	1.0	0.8	1.2	3.7
Nitriles	0.5	0.4	0.8	0.01
Heterocyclic N compounds	2.5*	0.8	1.2*	0.5
Heterocyclic S compounds	2.5	0.8	1.2	0.5
Alcohols	4.7	0.6	1.0	1.8
Phenols	0.8	0.6	1.0	0.5
Ketones	7.5	5.8	10.7	3.7
Amines	5.5*	0.6	1.0*	1.8*
Alkyl S compounds	1.4	0.6	1.0	0.5
Sulfonic acids	1.1	0.6	1.0	0.5
Sulfoxides	0.8	0.6	1.0	0.5
Amides	1.6	0.6	1.0	0.5
Carboxylic acids	4.7*	0.6	1.0	1.8
Esters	3.9	1.6	6.3	0.5
Total mg/m <sup>3</sup>	15.37	4.25	26.55	9.10

\*Severity >1, i.e. MEG was exceeded

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$\mu\text{g}/\text{m}^3$ . Chromium is a proverbial problem in metallurgical processes. The presence of halogen salts in the process may leach out small quantities of chromium as volatile halides. Here again an examination of the purity of the raw materials could lead to a partial solution of the problem.

A significant finding is the small amount of fused aromatics from the pouring line. In a previous study the shakeout was selected because the work of Bates and Scott<sup>10</sup> showed it produced the greatest quantity of emissions. Their work was a laboratory study which collected emissions from a small sealed flask. The pouring emissions were only slightly less than the shakeout emissions in their laboratory work. The actual plant emissions collected from the shakeout<sup>1</sup> showed a lack of significant or even measurable Polynuclear aromatic organics (PNA) of health concern. It was hypothesized<sup>1</sup> that by the shakeout stage the high boiling PNA's (496-510° C for BaP) were condensed onto the sand or adsorbed onto the clay and were not significantly released on shakeout. Most of the high molecular weight shakeout emissions were naphthalene derivatives. This led to the selection of pouring as the most likely place to find PNA's in the casting process because the temperatures obtained are certainly high enough to boil off these compounds. There remains the speculation that some of the emissions from pouring would be oxidized by the burning of methane, hydrogen, and carbon monoxide, the major pouring emissions. The finding of very little fused aromatics from the pouring process seems to confirm that most of the high molecular weight emissions are destroyed rather than emitted to the atmosphere during pouring. Since health statistics show a slightly higher rate of cancer only among workers in the pouring-cooling area, this leaves cooling as the remaining process where a problem might be found.<sup>18</sup> After the casting enters the cooling area the emissions of combustible vapors declines to the level that continued combustion of the gases released is not possible. At this stage, the iron is still molten and some smoke is released. Often there is no significant visible smoke from the flasks shortly after entering the cooling room.

APPENDIX

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TABLE A-2. IR REPORT - POURING EMISSIONS, AIR

Wave Number (cm <sup>-1</sup> )	Intensity	Assignment	Comments
<u>Fraction 1</u>			
2858, 2921, 2952	S	Sat'd C-H	
1456	M	Sat'd C-H	
1378	W	Sat'd C-H	
697, 752	W	Alkyl, C-Cl	
<u>Fraction 2</u>			
3023, 3062	W	Unsat'd C-H	
2929, 2960	S	Sat'd C-H	
2874	M	Sat'd C-H	
1495, 1605	W	Aromatic C=C	
1456	M	Sat'd C-H	
1378	W	Sat'd C-H	
767-885	W	Subst. Aromatic	Multiplet
728	M	Alkyl, C-Cl	
697	S	Alkyl	
<u>Fraction 3</u>			
3062	W	Unsat'd C-H	
3023	M	Unsat'd C-H	
2929, 2968	S	Sat'd C-H	
2850, 2874	M	Sat'd C-H	
1496, 1605	M	Aromatic C=C	
1449	M	Sat'd C-H	
1370	W	Sat'd C-H	
752-963	W	Subst. Aromatic	Multiplet
697	S	Alkyl, C-Cl	
<u>Fraction 4</u>			
2854, 2964	M	Sat'd C-H	
2924	S	Sat'd C-H	
1732	S	Ester, Ketone	
1716	S	Ketone	
1638	W	Amide (3°)	
1449	W	Sat'd C-H	
1269	S	Ketone, Ester	
1175	W	Ester, Amine (3°)	
1120	M	Amine (3°), Ether	
712	S	Alkyl, C-Cl	

(CONTINUED)

TABLE A-1 LC ANALYSIS REPORT, SAMPLE NO. P-XR

Sample Site "P" \_\_\_\_\_ Sample Acquisition Date 3/11/81  
 Type of Source Pouring emissions, Air  
 Test Number \_\_\_\_\_ Sample ID Number 2885-120-18  
 Sample Description XAD-2, Module Rinse  
 Original Sample Volume or Mass \_\_\_\_\_  
 Analyst Responsible J. J. Kearney  
 Calculations and Report Reviewed by R. W. Handy

	TCO mg	GRAV mg	TCO + GRAV Total mg	Concentration mg/ (m <sup>3</sup> , L, or kg) <sup>6</sup>
Total Sample, Calc. <sup>1</sup>				
Total Sample <sup>2</sup>	338	263	601	
Taken for LC <sup>3</sup>	67.5	52.5	120	
Recovered <sup>4</sup>	32.2	47.2	79.4	

Fraction	TCO in mg				GRAV in mg				TCO + GRAV Total mg	Concentration mg/ (m <sup>3</sup> , L, or kg) <sup>6</sup>
	Found in Fraction	Blank	Corrected	Total <sup>5</sup>	Found in Fraction	Blank	Corrected	Total <sup>5</sup>		
1	17.4		17.4	87.2	3.2		3.2	16.0	103.2	3.71
2					6.0		6.0	30.1	30.1	1.08
3	12.4		12.4	62.1	9.2		9.2	46.1	108.2	3.89
4	0.5		0.5	2.5	7.2		7.2	36.1	38.6	1.39
5	0.6		0.6	3.0	6.0		6.0	30.1	33.1	1.19
6	1.3		1.3	6.5	15.6		15.6	78.1	84.6	3.04
7										
Sum	32.2		32.2	161.3	47.2		47.2	236.4	397.8	14.29

- Calculated total quantity in original sample correcting for amounts withdrawn for TCO, GRAV and error in water sample analysis, where appropriate
- Quantity in entire sample, determined before LC
- Portion of whole sample used for LC, actual mg
- Quantity recovered from LC column, actual mg
- Total mg computed back to total sample
- Supply values for both sample size and concentrations

TABLE A-3. LRMS REPORT: POURING EMISSIONS, AIR

Intensity	Category	MW Range	M/e	Composition
<u>Fraction No. 1</u>				
<u>Major Categories</u>				
100	Aliphatics	to 500		
<u>Sub-categories, Specific Compounds</u>				
100	Possibly oxygenated hydrocarbon		368	C <sub>25</sub> H <sub>52</sub> O, C <sub>24</sub> H <sub>48</sub> O <sub>2</sub> , or C <sub>23</sub> H <sub>44</sub> O <sub>3</sub>
<u>Fraction No. 2</u>				
<u>Major Categories</u>				
10	Fused Aromatic	MW > 216:240		
<u>Sub-categories, Specific Compounds</u>				
10	Methyl benzofuloroanthracene		240	C <sub>19</sub> H <sub>12</sub>
100	Possibly oxygenated hydrocarbon		308	C <sub>25</sub> H <sub>52</sub> O, C <sub>24</sub> H <sub>48</sub> O <sub>2</sub> , or C <sub>23</sub> H <sub>44</sub> O <sub>3</sub>
<u>Other</u>				
IR shows no evidence of aromatic structures				
<u>Fraction No. 3</u>				
<u>Major Categories</u>				
10	Fused Aromatics	MW < 216:128,178		
10	Fused Aromatics	MW > 216:	302	
100	Aliphatics	to 550		
<u>Sub-categories, Specific Compounds</u>				
10	Naphthalene		128	C <sub>10</sub> H <sub>8</sub>
10	Phenanthracene, Anthracene		178	C <sub>14</sub> H <sub>10</sub>
10	Dibenzochrysene isomer		302	C <sub>24</sub> H <sub>14</sub>
<u>Other</u>				
Alkyl fragments at m/e <sup>+</sup> 251, 223, 195, 167				

TABLE A-2. (CONTINUED)

Wave Number (cm <sup>-1</sup> )	Intensity	Assignment	Comments
<u>Fraction 5</u>			
2925, 2964	M	Sat'd C-H	
2854	W	Sat'd C-H	
1724	S	Ketone, Ester	
1450	W	Sat'd C-H	
1269	S	Ketone, Ester	
1112	W	Ether	
712	S	Alkyl, C-Cl	
<u>Fraction 6</u>			
3200-3450	W	O-H/N-H	Broad
2858, 2960	M	Sat'd C-H	
2929	S	Sat'd C-H	
1723	S	Acid, Ketone	
1456	M	Sat'd C-H	
1370	W	Sat'd C-H	
1276	S	Acid, Alcohol, Ketone	
1112	S	Alcohol	Broad
712	M	Alkyl, C-Cl	
<u>Fraction 7</u>			
2858, 2968	M	Sat'd C-H	
2929	S	Sat'd C-H	
1731	S	Acid, Ketone	
1456	M	Sat'd C-H	
1276	M	Acid, Ketone	
1112	S	Ether	Broad
712	W	Alkyl, C-Cl	

TABLE A-5 LC ANALYSIS REPORT, SAMPLE NO. P-PARTICULATE

Sample Site "P" Sample Acquisition Date 3/11/81  
 Type of Source Pouring Emission, Particulate Extract  
 Test Number \_\_\_\_\_ Sample ID Number 2885-120-CY  
 Sample Description Composite Cyclone Dust  
 Original Sample Volume or Mass \_\_\_\_\_  
 Analyst Responsible J. J. Kearney  
 Calculations and Report Reviewed by R. W. Handy

	TCO mg	GRAV mg	TCO + GRAV Total mg	Concentration mg/ (m <sup>3</sup> , L, or kg) <sup>6</sup>
Total Sample, Calc. <sup>1</sup>				
Total Sample <sup>2</sup>	8.3	38.0	46.3	
Taken for LC <sup>3</sup>	3.3	15.2	18.5	
Recovered <sup>4</sup>	3.8	9.7	13.5	

Fraction	TCO in mg			GRAV in mg			TCO + GRAV Total mg	Concentration mg/ (m <sup>3</sup> , L, or kg) <sup>6</sup>
	Found in Fraction	Blank	Corrected Total <sub>5</sub>	Found in Fraction	Blank	Corrected Total <sub>5</sub>		
1				0.2		0.2	0.5	0.02
2	0.8		0.8	2.0		0.6	1.5	3.5
3	0.6		0.6	1.5		0.8	2.0	3.5
4	0.3		0.3	0.8		2.5	6.3	7.1
5				0.2		0.2	0.5	0.02
6	1.2		1.2	3.0		2.6	6.5	9.5
7	0.9		0.9	2.3		2.8	7.0	9.3
Sum	3.8		3.8	9.6		9.7	24.3	33.9

1. Calculated total quantity in original sample correcting for amounts withdrawn for TCO, GRAV and error in water sample analysis, where appropriate
2. Quantity in entire sample, determined before LC
3. Portion of whole sample used for LC, actual mg
4. Quantity recovered from LC column, actual mg
5. Total mg computed back to total sample
6. Supply values for both sample size and concentrations

TABLE A-4. CALCULATED ESTIMATES FROM LRMS DATA - POURING EMISSIONS, AIR

Category	Intensity	Quantity mg/m <sup>3</sup>
<u>LC Fraction 1; Total Organics = 3.71 mg/m<sup>3</sup></u>		
Aliphatics < 500 MW	100	1.8
Possible oxygenated hydrocarbon, 368 MW	100	1.8
<u>LC Fraction 2; Total Organics 1.08 mg/m<sup>3</sup></u>		
Fused aromatics > 216 MW; 240 MW	10	0.09
Methyl benzofluoroanthracene, 240 MW	10	0.09
Possibly oxygenated hydrocarbon, 308 MW	100	0.9
<u>LC Fraction 3; Total Organics 3.89 mg/m<sup>3</sup></u>		
Fused aromatics < 216 MW; 128, 178 MW	10	0.26
Fused aromatics > 216 MW; 302 MW	10	0.26
Aliphatics to 550 MW	100	2.59
Naphthalene, 128 MW (MATE = 50 mg)	10	0.26
Phenanthracene, anthracene, 178 MW (MATE = 56 mg)	10	0.26
Dibenzochrysene isomer, 302 MW	10	0.26

TABLE A-7. LRMS REPORT - POURING EMISSION, PARTICULATES

Intensity	Category	MW Range	M/e	Composition
<u>Fraction No. 1</u>				
<u>Major Categories</u>				
100	Aliphatics	to 500		
<u>Sub-categories, Specific Compounds</u>				
100	Possibly oxygenated hydrocarbon		368	C <sub>25</sub> H <sub>52</sub> O, C <sub>24</sub> H <sub>48</sub> O <sub>2</sub> , or C <sub>23</sub> H <sub>44</sub> O <sub>3</sub>
<u>Other</u>				
IR shows no evidence of aromatic structures				
<u>Fraction No. 2</u>				
<u>Major Categories</u>				
10	Aliphatics	to 500		
<u>Sub-categories, Specific Compounds</u>				
100	Possibly oxygenated hydrocarbon		368	C <sub>25</sub> H <sub>52</sub> O <sub>7</sub> , C <sub>24</sub> H <sub>48</sub> O <sub>2</sub> , or C <sub>23</sub> H <sub>44</sub> O <sub>3</sub>
<u>Other</u>				
Quantity not sufficient for IR.				
<u>Fraction No. 3</u>				
<u>Major Categories</u>				
10	Aliphatics	to 550		
<u>Sub-categories, Specific Compounds</u>				
100	Possibly oxygenated hydrocarbon		368	C <sub>25</sub> H <sub>52</sub> O, C <sub>24</sub> H <sub>48</sub> O <sub>2</sub> , or C <sub>23</sub> H <sub>44</sub> O <sub>3</sub>
<u>Other</u>				
Quantity not sufficient for IR.				

TABLE A-6. IR REPORT - POURING EMISSIONS, PARTICULATE EXTRACT

Wave Number (cm <sup>-1</sup> )	Intensity	Assignment	Comments
<u>Fraction 1</u>			
2855, 2995	M	Sat'd C-H	
2922	S	Sat'd C-H	
1480	W	Sat'd C-H	
<u>Fraction 2</u>			
QUANTITY NOT SUFFICIENT			
<u>Fraction 3</u>			
QUANTITY NOT SUFFICIENT			
<u>Fraction 4</u>			
2855	M	Sat'd C-H	
2929	S	Sat'd C-H	
1744	M	Ester, Ketone	
1458	W	Sat'd C-H	
<u>Fraction 5</u>			
2858, 2960	W	Sat'd C-H	
2911	M	Sat'd C-H	
<u>Fraction 6</u>			
3200-3450	W	O-H, N-H	Broad
2850, 2952	M	Sat'd C-H	
2921	S	Sat'd C-H	
1723	M	Ketone, Ester	Shoulder
1715	S	Acid, Ketone	
1464	M	Sat'd C-H	
1362	W	Sat'd C-H	
1284	W	Alcohol, Ketone	
1190	W	Acid, Ester, Sulfonic Acid	
1120	W	Alcohol, Ether	
1073	W	Sulfonic Acid, Ether, Alcohol	
720	W	Alkyl, C-Cl	
<u>Fraction 7</u>			
2855, 2955	W	Sat'd C-H	
2922	M	Sat'd C-H	

TABLE A-9 LC ANALYSIS REPORT, SAMPLE NO. I-XR

Sample Site "I" Sample Acquisition Date 2/11/81  
 Type of Source Inoculation Emmisions, Air  
 Test Number \_\_\_\_\_ Sample ID Number 2885-106-4  
 Sample Description XAD-2, Module Rinse  
 Original Sample Volume or Mass \_\_\_\_\_  
 Analyst Responsible J. J. Kearney  
 Calculations and Report Reviewed by R. W. Handy

	TCO mg	GRAV mg	TCO + GRAV Total mg	Concentration mg/ (m <sup>3</sup> , L, or kg) <sup>6</sup>
Total Sample, Calc. <sup>1</sup>				
Total Sample <sup>2</sup>	378	87.0	465	
Taken for LC <sup>3</sup>	113	26.1	139.1	
Recovered <sup>4</sup>	19.4	15.1	34.5	

Fraction	TCO in mg				GRAV in mg				TCO + GRAV Total mg	Concentration mg/ (m <sup>3</sup> , L, or kg) <sup>6</sup>
	Found in Fraction	Blank	Corrected	Total <sub>J</sub>	Found in Fraction	Blank	Corrected	Total <sub>J</sub>		
1				1.3			1.3	4.3	4.3	0.16
2	3.5		3.5	11.7	1.6		1.6	5.3	17.0	0.64
3	13.3		13.3	44.3	6.0		6.0	20.0	64.3	2.44
4	1.5		1.5	5.0	0.6		0.6	2.0	7.0	0.27
5	0.3		0.3	1.0	0.8		0.8	2.7	3.7	0.14
6	0.8		0.8	2.7	2.6		2.6	8.7	11.4	0.432
7				2.2			2.2	7.3	7.3	0.28
Sum	19.4		19.4	64.7	15.1		15.1	50.3	115.0	4.36

1. Calculated total quantity in original sample correcting for amounts withdrawn for TCO, GRAV and error in water sample analysis, where appropriate
2. Quantity in entire sample, determined before LC
3. Portion of whole sample used for LC, actual mg
4. Quantity recovered from LC column, actual mg
5. Total mg computed back to total sample
6. Supply values for both sample size and concentrations

TABLE A-8. CALCULATED ESTIMATES FROM LRMS DATA  
 - POURING EMISSIONS, PARTICULATES

Category	Intensity	Quantity mg/m <sup>3</sup>
<u>LC Fraction 1; Total Organics = 0.02 mg/m<sup>3</sup></u>		
Aliphatics to 500 MW	100	0.01
Possible oxygenated hydrocarbon, 368 MW (No aromatic structures)	100	0.01
<u>LC Fraction 2; Total Organics 0.13 mg/m<sup>3</sup></u>		
Aliphatics to 500 MW	10	0.01
Possibly oxygenated hydrocarbon, 368 MW (Quantity not sufficient for IR)	100	0.11
<u>LC Fraction 3; Total Organics 0.13 mg/m<sup>3</sup></u>		
Aliphatics to 500 MW	10	0.01
Possibly oxygenated hydrocarbon, 368 MW (Quantity not sufficient for IR)	100	0.11

TABLE A-10. (CONTINUED)

Wave Number (cm <sup>-1</sup> )	Intensity	Assignment	Comments
<u>Fraction 6</u>			
2855, 2960	S	Sat'd C-H	
1724	S	Ketone	
1451	M	Sat'd C-H	
1378	W	Sat'd C-H	
1271	S	Ketone	
1112	S	Ether	
712	M	Alkyl, C-Cl	
<u>Fraction 7</u>			
(Quantity not sufficient)			

TABLE A-10. IR REPORT - INOCULATION EMISSIONS, AIR - I-XR

Wave Number (cm <sup>-1</sup> )	Intensity	Assignment	Comments
<u>Fraction 1</u>			
2855, 2955	S	Sat'd C-H	
1460	M	Sat'd C-H	
1380	W	Sat'd C-H	
700	W	Alkyl, C-Cl	
<u>Fraction 2</u>			
2960	M	Sat'd C-H	
2850	S	Sat'd C-H	
1450	M	Sat'd C-H	
1375	W	Sat'd C-H	
757	W	Alkyl	
1378	W	Sat'd C-H	
700	M	Alkyl, C-Cl	
<u>Fraction 3</u>			
3060	W	Unsat'd C-H	
3022	M	Unsat'd C-H	
2962	M	Sat'd C-H	
2875	S	Sat'd C-H	
1600	M	Aromatic	
1495	S	Aromatic	
1455	S	Sat'd C-H	
1378	W	Sat'd C-H	
800, 835, 890, 1025	W	Subst. Aromatic	
757	M	Alkyl	
700	S	Alkyl, C-Cl	
<u>Fraction 4</u>			
2855, 2960	M	Sat'd C-H	
1265	M	Silicone	
1115	W	Silicone, Ether	
705	M	Alkyl, C-Cl	
<u>Fraction 5</u>			
2850, 2960	W	Sat'd C-H	
1720	W	Ketone	
1275	W	Ketone	
710	W	Alkyl, C-Cl	

(CONTINUED)

TABLE A-12 LC ANALYSIS REPORT, SAMPLE NO. I-PARTICULATE

Sample Site "I" Sample Acquisition Date 2/11/81  
 Type of Source Inoculation Emissions, Particulate Extract  
 Test Number \_\_\_\_\_ Sample ID Number 2885-108-34  
 Sample Description Filtered Particulates and Cyclone/Probe Rinses  
 Original Sample Volume or Mass \_\_\_\_\_  
 Analyst Responsible J. J. Kearney  
 Calculations and Report Reviewed by R. W. Handy

	TCO mg	GRAV mg	TCO + GRAV Total mg	Concentration mg/ (m <sup>3</sup> , L, or kg) <sup>6</sup>
Total Sample, Calc. <sup>1</sup>				
Total Sample <sup>2</sup>		16.0		
Taken for LC <sup>3</sup>		15.8		
Recovered <sup>4</sup>	0.3	7.3	7.6	

Fraction	TCO in mg			GRAV in mg			TCO + GRAV Total mg	Concentration mg/ (m <sup>3</sup> , L, or kg) <sup>6</sup>
	Found in Fraction	Blank	Corrected	Total <sup>5</sup>	Found in Fraction	Blank		
1								
2								
3					0.6	0.6	0.6	.02
4					0.1	0.1	0.1	.004
5					0.8	0.8	0.8	.03
6	0.3		0.3	0.3	2.6	2.6	2.6	.12
7					3.2	3.2	3.2	.12
Sum	0.3		0.3	0.3	7.3	7.3	7.6	.30

1. Calculated total quantity in original sample correcting for amounts withdrawn for TCO, GRAV and error in water sample analysis, where appropriate
2. Quantity in entire sample, determined before LC
3. Portion of whole sample used for LC, actual mg
4. Quantity recovered from LC column, actual mg
5. Total mg computed back to total sample
6. Supply values for both sample size and concentrations

TABLE A-11. LRMS REPORT: INOCULATION EMISSIONS, AIR

Intensity	Category	MW Range	M/e	Composition
<u>Fraction No. 1</u>				
<u>Major Categories</u>				
100	Aliphatics	270-368		
<u>Sub-categories, Specific Compounds</u>				
100	Possibly oxygenated hydrocarbon		368	C <sub>25</sub> H <sub>52</sub> O, C <sub>24</sub> H <sub>48</sub> O <sub>2</sub> , or C <sub>23</sub> H <sub>44</sub> O <sub>3</sub>
10	Possibly oxygenated hydrocarbon		326	C <sub>22</sub> H <sub>46</sub> O, etc.
10	Possibly oxygenated hydrocarbon		270	C <sub>18</sub> H <sub>38</sub> O, etc.
<u>Other</u>				
IR shows no evidence of aromatic structures				
<u>Fraction No. 2</u>				
<u>Major Categories</u>				
100	Aliphatics	242-368		
<u>Sub-categories, Specific Compounds</u>				
100	Possibly oxygenated hydrocarbon		368	C <sub>25</sub> H <sub>52</sub> O, C <sub>24</sub> H <sub>48</sub> O <sub>2</sub> , or C <sub>23</sub> H <sub>44</sub> O <sub>3</sub>
10	Possibly oxygenated hydrocarbon		242	C <sub>16</sub> H <sub>34</sub> O, etc.
<u>Other</u>				
IR shows no evidence of aromatic structures				
<u>Fraction No. 3</u>				
<u>Major Categories</u>				
10	Aliphatics	to 660		
100	Fused Aromatics	MW > 216		
<u>Sub-categories, Specific Compounds</u>				
100	Possibly oxygenated hydrocarbon		368	C <sub>25</sub> H <sub>52</sub> O, C <sub>24</sub> H <sub>48</sub> O <sub>2</sub> , or C <sub>23</sub> H <sub>44</sub> O <sub>3</sub>
10	Methyl Cholanthrene		268	C <sub>21</sub> H <sub>16</sub>
10	Methyl Dibenzanthracene		292	C <sub>23</sub> H <sub>16</sub>
10	Pyrenefluorene		340	C <sub>27</sub> H <sub>16</sub>
<u>Other</u>				
IR showed no evidence of other functional groups.				

TABLE A-14. LRMS REPORT: INOCULATION EMISSIONS, PARTICULATES

Intensity	Category	MW Range	M/e	Composition
<u>Fraction No. 1</u>				
<u>Major Categories</u>				
100	Aliphatics	to 500		
<u>Sub-categories, Specific Compounds</u>				
100	Possibly oxygenated hydrocarbon		368	C <sub>25</sub> H <sub>52</sub> O, C <sub>24</sub> H <sub>48</sub> O <sub>2</sub> , or C <sub>23</sub> H <sub>44</sub> O <sub>3</sub>
<u>Other</u>				
Quantity not sufficient for IR				
<u>Fraction No. 2</u>				
<u>Major Categories</u>				
100	Aliphatics	236-410		
<u>Sub-categories, Specific Compounds</u>				
100	Possibly oxygenated hydrocarbon		368	C <sub>25</sub> H <sub>52</sub> O, C <sub>24</sub> H <sub>48</sub> O <sub>2</sub> , or C <sub>23</sub> H <sub>44</sub> O <sub>3</sub>
<u>Other</u>				
Quantity not sufficient for IR.				
<u>Fraction No. 3</u>				
<u>Major Categories</u>				
10	Aliphatics	236-410		
100	Aliphatics	to 676		
<u>Sub-categories, Specific Compounds</u>				
100	Possibly oxygenated hydrocarbon		368	C <sub>25</sub> H <sub>52</sub> O, C <sub>24</sub> H <sub>48</sub> O <sub>2</sub> , or C <sub>23</sub> H <sub>44</sub> O <sub>3</sub>
<u>Other</u>				
IR showed no evidence of aromatic structures.				

TABLE A-13. IR REPORT - INOCULATION EMISSIONS, PARTICULATE EXTRACT

Wave Number (cm <sup>-1</sup> )	Intensity	Assignment	Comments
<u>Fraction 1</u>			
Quantity not sufficient.			
<u>Fraction 2</u>			
Quantity not sufficient.			
<u>Fraction 3</u>			
2855-2922	S	Sat'd C-H	Possible contaminant
1738	M	Ester, Ketone	
1458	M	Sat'd C-H	
<u>Fraction 4</u>			
Quantity not sufficient.			
<u>Fraction 5</u>			
2855, 2958	M	Sat'd C-H	Broad
2921	S	Sat'd C-H	
1747	M	Ester, Ketone	
1460	W	Sat'd C-H	
1294	W	Ketone	
1154	M	Ester	
<u>Fraction 6</u>			
2922	S	Sat'd C-H	
2855	M	Sat'd C-H	
1744	M	Ketone, Ester	
<u>Fraction 7</u>			
Quantity not sufficient.			

TABLE A-16. IR REPORT - CUPOLA EMISSIONS

Wave Number (cm <sup>-1</sup> )	Intensity	Assignment	Comments
<u>Fraction 1</u>			
2858-2952	S	Sat'd C-H	
1456	S	Sat'd C-H	
1378	M	Sat'd C-H	
759	W	Alky1	
697	M	Alky1, C-Cl	
<u>Fraction 2</u>			
3023, 3062	W	Unsat'd C-H	
2929, 2968	S	Sat'd C-H	
2874	M	Sat'd C-H	
1495, 1605	W	Aromatic C=C	
1456	M	Sat'd C-H	
1378	W	Sat'd C-H	
697, 759	M	Alky1, C-Cl	
<u>Fraction 3</u>			
3030, 3062	M	Unsat'd C-H	
2929, 2968	S	Sat'd C-H	
2874	M	Sat'd C-H	
1495, 1605	M	Aromatic C=C	
1456	M	Sat'd C-H	
1378	W	Sat'd C-H	
800, 835, 893, 1026	W	Subst. Aromatic	
759	M	Alky1	
697	S	Alky1, C-Cl	
<u>Fraction 4</u>			
2854, 2957	M	Sat'd C-H	
2925	S	Sat'd C-H	
1724	S	Ketone	
1457	M	Sat'd C-H	
1269	S	Ketone, Silicone	
1112	M	Ether, Silicone	Broad
711	M	Alky1, C-Cl	

(CONTINUED)

TABLE A-15 LC ANALYSIS REPORT, SAMPLE NO. C-XR

Sample Site "C" Sample Acquisition Date 3/25/81  
 Type of Source Cupola Offgas after Baghouse  
 Test Number Sample ID Number 2885-120-1  
 Sample Description XAD-2  
 Original Sample Volume or Mass 24.66 m<sup>3</sup>  
 Analyst Responsible J. J. Kearney  
 Calculations and Report Reviewed by R. W. Handy

	TCO mg	GRAV mg	TCO + GRAV Total mg	Concentration mg/ (m <sup>3</sup> , L, or kg) <sup>6</sup>
Total Sample, Calc. <sup>1</sup>				
Total Sample <sup>2</sup>	283	254	537	
Taken for LC <sup>3</sup>	45.0	40.4	85.4	
Recovered <sup>4</sup>	66.7	37.4	104.1	

Fraction	TCO in mg			GRAV in mg			TCO + GRAV Total mg	Concentration mg/ (m <sup>3</sup> , L, or kg) <sup>6</sup>	
	Found in Fraction	Blank	Corrected <sup>5</sup>	Total <sup>5</sup>	Found in Fraction	Blank			Corrected <sup>5</sup>
1	10.4		10.4	65.4	7.4	7.4	46.5	111.9	4.54
2	16.9		16.9	106.3	4.8	4.8	30.2	136.5	5.53
3	15.0		15.0	94.3	7.6	7.6	47.8	142.1	5.76
4	4.1		4.1	25.8	2.0	2.0	12.6	38.4	1.56
5	19.1		19.1	120.8	8.0	8.0	50.3	171.1	6.94
6	1.2		1.2	7.5	7.6	7.6	47.8	55.3	2.24
7									
Sum	66.7		66.7	419.4	37.4	37.4	235.1	654.5	26.543

1. Calculated total quantity in original sample correcting for amounts withdrawn for TCO, GRAV and error in water sample analysis, where appropriate
2. Quantity in entire sample, determined before LC
3. Portion of whole sample used for LC, actual mg
4. Quantity recovered from LC column, actual mg
5. Total mg computed back to total sample
6. Supply values for both sample size and concentrations

TABLE A-17. LRMS REPORT: CUPOLA EMISSIONS

Intensity	Category	MW Range	M/e	Composition
<u>Fraction No. 1</u>				
<u>Major Categories</u>				
100	Aliphatics	242-368		
<u>Sub-categories, Specific Compounds</u>				
100	Possibly oxygenated hydrocarbon		368	C <sub>25</sub> H <sub>52</sub> O, C <sub>24</sub> H <sub>48</sub> O <sub>2</sub> , or C <sub>23</sub> H <sub>44</sub> O <sub>3</sub>
10	Possibly oxygenated hydrocarbon		298	C <sub>20</sub> H <sub>42</sub> O, etc.
100	Possibly oxygenated hydrocarbon		270	C <sub>18</sub> H <sub>38</sub> O, etc.
10	Possibly oxygenated hydrocarbon		242	C <sub>16</sub> H <sub>34</sub> O, etc.
<u>Other</u>				
IR shows no evidence of aromatic structures				
<u>Fraction No. 2</u>				
<u>Major Categories</u>				
10	Fused Aromatic	MW > 216:128-178		
10	Fused Aromatic	MW > 216:242-268		
100	Aliphatics	270-410		
<u>Sub-categories, Specific Compounds</u>				
10	Naphthalene		128	C <sub>10</sub> H <sub>8</sub>
10	Phenanthracene		178	C <sub>14</sub> H <sub>10</sub>
10	Methyl Chrysene		242	C <sub>19</sub> H <sub>14</sub>
10	Methyl Cholanthrene		268	C <sub>21</sub> H <sub>16</sub>
100	Possibly oxygenated hydrocarbon		368	C <sub>25</sub> H <sub>52</sub> O, C <sub>24</sub> H <sub>48</sub> O <sub>2</sub> , or C <sub>23</sub> H <sub>44</sub> O <sub>3</sub>
10	Possibly oxygenated hydrocarbon		396	C <sub>27</sub> H <sub>56</sub> O, etc.
<u>Other</u>				
IR showed no evidence of other functional groups.				
<u>Fraction No. 3</u>				
<u>Major Categories</u>				
10	Fused Aromatics	MW < 216:178		
10	Fused Aromatics	MW > 216:242		
10	Aliphatics	to 600		
100	Aliphatics	312-410		
<u>Sub-categories, Specific Compounds</u>				
10	Phenanthracene, Anthracene		178	C <sub>14</sub> H <sub>10</sub>
10	Methyl Chrysene		242	C <sub>19</sub> H <sub>14</sub>
100	Possibly oxygenated hydrocarbon		368	C <sub>25</sub> H <sub>52</sub> O, C <sub>24</sub> H <sub>48</sub> O <sub>2</sub> , or C <sub>23</sub> H <sub>44</sub> O <sub>3</sub>
<u>Other</u>				
IR showed no evidence of other functional groups.				

TABLE A-16. (CONTINUED)

Wave Number (cm <sup>-1</sup> )	Intensity	Assignment	Comments
<u>Fraction 5</u>			
2855, 2949	M	Sat'd C-H	
2925	S	Sat'd C-H	
1741	S	Ester, Ketone	
1458	M	Sat'd C-H	
1278	M	Ketone	
1176	W	Ester	Broad
1105	W	Ether	Broad
712	M	Alkyl, C-Cl	
<u>Fraction 6</u>			
2858, 2960	M	Sat'd C-H	
2929	S	Sat'd C-H	
1723	S	Ketone	
1456	M	Sat'd C-H	
1370	W	Sat'd C-H	
1276	M	Ketone	
1104	S	Ether	Broad
712	W	Alkyl, C-Cl	
<u>Fraction 7</u>			
Quantity not sufficient.			

TABLE A-19. IR REPORT - ELECTRIC ARC FURNACE EMISSIONS

Wave Number (cm <sup>-1</sup> )	Intensity	Assignment	Comments
<u>Fraction 1</u>			
2860-2960	S	Sat'd C-H	
1380, 1460	M	Sat'd C-H	
700	W	Alkyl, C-Cl	
<u>Fraction 2</u>			
3022, 3060	M	Unsat'd C-H	
2865-2960	S	Sat'd C-H	
1600	M	Aromatic C=C	
1497	M	Aromatic C=C	
1450	S	Sat'd C-H	
1377	M	Sat'd C-H	
758, 780	M	Subst. Aromatic	
700	S	Alkyl, C-Cl	
<u>Fraction 3</u>			
3250	W	Unsat'd C-H	
3061, 3082	M	Unsat'd C-H	
2937, 2966	M	Sat'd C-H	
2878	W	Sat'd C-H	
1495, 1600	M	Aromatic C=C	
1452	M	Sat'd C-H	
1378	W	Sat'd C-H	
760, 838, 892	W	Subst. Aromatic	
700	S	Alkyl, C-Cl	
<u>Fraction 4</u>			
2960	M	Sat'd C-H	
2860	S	Sat'd C-H	
1740	S	Ketone	
1458	M	Sat'd C-H	
1260	S	Silicone, Ketone	
1110		Silicone, Ether	
703	M	Alkyl, C-Cl	

Fraction 5

Quantity not sufficient

(CONTINUED)

TABLE A-18 LC ANALYSIS REPORT, SAMPLE NO. E-XR

Sample Site "E" Sample Acquisition Date 2/25/81  
 Type of Source Electric Arc Furnace Emissions, Baghouse Filtered  
 Test Number \_\_\_\_\_ Sample ID Number 2885-108-5  
 Sample Description XAD-2, Module Rinse  
 Original Sample Volume or Mass 29.267 m<sup>3</sup>  
 Analyst Responsible J. J. Kearney  
 Calculations and Report Reviewed by R. W. Handy

	TCO mg	GRAV mg	TCO + GRAV Total mg	Concentration mg/ (m <sup>3</sup> , L, or kg) <sup>6</sup>
Total Sample, Calc. <sup>1</sup>				
Total Sample <sup>2</sup>	210	133	343	
Taken for LC <sup>3</sup>	42.0	26.6	68.6	
Recovered <sup>4</sup>	28.8	25.0	53.8	

Fraction	TCO in mg			GRAV in mg			TCO + GRAV Total mg	Concentration mg/ (m <sup>3</sup> , L, or kg) <sup>6</sup>	
	Found in Fraction	Blank	Corrected Total <sub>5</sub>	Found in Fraction	Blank	Corrected Total <sub>5</sub>			
1	8.7		8.7	43.5	6.2	6.2	31.0	74.5	2.55
2	11.7		11.7	58.5	5.6	5.6	28.0	86.5	2.96
3	7.0		7.0	35.0	5.0	5.0	25.0	60.0	2.05
4					0.2	0.2	1.0	1.0	0.03
5					0.6	0.6	3.0	3.0	0.10
6	1.4		1.4	7.0	4.4	4.4	22.0	29.0	0.99
7					3.0	3.0	15.0	15.0	0.51
Sum	28.8		28.8	144.0	25.0	25.0	125.0	269.0	9.19

1. Calculated total quantity in original sample correcting for amounts withdrawn for TCO, GRAV and error in water sample analysis, where appropriate
2. Quantity in entire sample, determined before LC
3. Portion of whole sample used for LC, actual mg
4. Quantity recovered from LC column, actual mg
5. Total mg computed back to total sample
6. Supply values for both sample size and concentrations

TABLE A-20. LRMS REPORT: ELECTRIC ARC FURNACE EMISSIONS

Intensity	Category	MW Range	M/e	Composition
<u>Fraction No. 1</u>				
<u>Major Categories</u>				
100	Aliphatics	242-298		
<u>Sub-categories, Specific Compounds</u>				
100	Possibly oxygenated hydrocarbon		242	C <sub>25</sub> H <sub>52</sub> O, C <sub>24</sub> H <sub>48</sub> O <sub>2</sub> , or C <sub>23</sub> H <sub>44</sub> O <sub>3</sub>
10	Possibly oxygenated hydrocarbon		270	C <sub>18</sub> H <sub>38</sub> O <sub>3</sub> , etc.
10	Possibly oxygenated hydrocarbon		298	C <sub>20</sub> H <sub>42</sub> O, etc.
<u>Other</u>				
IR shows no evidence of aromatic structures				
<u>Fraction No. 2</u>				
<u>Major Categories</u>				
10	Fused Aromatics	MW < 216:128, 178		
10	Fused Aromatics	MW > 216:240-268		
100	Aliphatics	238-396		
<u>Sub-categories, Specific Compounds</u>				
10	Naphthalene		128	C <sub>10</sub> H <sub>8</sub>
10	Phenanthracene, Anthracene		178	C <sub>14</sub> H <sub>10</sub>
10	Methyl Chrysene		242	C <sub>19</sub> H <sub>14</sub>
10	Methyl Cholanthrene		268	C <sub>21</sub> H <sub>16</sub>
100	Possibly oxygenated hydrocarbon		270	C <sub>18</sub> H <sub>38</sub> O, C <sub>17</sub> H <sub>34</sub> O <sub>2</sub> , C <sub>16</sub> H <sub>30</sub> O <sub>3</sub>
100	Possibly oxygenated hydrocarbon		368	C <sub>25</sub> H <sub>52</sub> O, C <sub>24</sub> H <sub>48</sub> O <sub>2</sub> , or C <sub>23</sub> H <sub>44</sub> O <sub>3</sub>
<u>Other</u>				
IR shows no evidence of other functional groups				
<u>Fraction No. 3</u>				
<u>Major Categories</u>				
10	Fused Aromatics	MW < 216:242-340		
100	Aliphatics	238-410		
100	Aliphatics	to 660		
<u>Sub-categories, Specific Compounds</u>				
10	Methyl Chrysene		242	C <sub>19</sub> H <sub>14</sub>
10	Methyl Cholanthrene		268	C <sub>21</sub> H <sub>16</sub>
10	Pyrenefluorene		340	C <sub>27</sub> H <sub>16</sub>
100	Possibly oxygenated hydrocarbon		368	C <sub>25</sub> H <sub>52</sub> O, C <sub>24</sub> H <sub>48</sub> O <sub>2</sub> , or C <sub>23</sub> H <sub>44</sub> O <sub>3</sub>
10	Possibly oxygenated hydrocarbon		396	C <sub>27</sub> H <sub>56</sub> O, etc.
<u>Other</u>				
IR showed no evidence of other functional groups				

TABLE A-19. (CONTINUED)

Wave Number (cm <sup>-1</sup> )	Intensity	Assignment	Comments
<u>Fraction 6</u>			
2960	M	Sat'd C-H	
2848	S	Sat'd C-H	
1720	S	Ketone	
1450	M	Sat'd C-H	
1380	W	Sat'd C-H	
1278	S	Ketone, Phosphate	
1110	S	Ether	
1010	W	Phosphate	
710	S	Alkyl, C-Cl	
<u>Fraction 7</u>			
3200-3400	W	N-H, O-H	Broad
2850, 2960	M	Sat'd C-H	
1725	W	Acid	
1557	M	Amine	
1458	M	Alcohol	
1260	M	Acid	
1065	M	Alcohol, Amine	