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A Method for Characterization and Quantification of Fugitive Lead Emissions from Secondary Lead Smelters, Ferroalloy Plants and Gray Iron Foundries (Revised)

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by

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1.0 INTRODUCTION

Currently, there is insufficient information to determine if fugitive lead emissions from secondary lead smelters, ferroalloy plants, and gray iron foundries are significant enough to cause violations of a proposed national ambient air quality standard for lead. Limited data do show, however, that such a possibility exists.

The purpose of this task is to summarize current information relative to fugitive lead emissions from these sources, investigate the application of fugitive lead emission factors developed for other source categories, and report the applicability of fugitive lead factors developed from a field study. Current state of the art techniques are developed for source measurements of fugitive emissions (i.e. inplant) and ambient measurements of fugitive emissions (i.e. upwind/downwind). A comparison of both methods is presented. This report will aid in determining if field studies are worthwhile and, if so, recommend the types of studies to be followed.

2.0 STATUS OF CURRENTLY AVAILABLE INFORMATION

There are only limited data currently available regarding quantitative estimates of fugitive lead emissions from secondary lead smelters, ferroalloy plants, and gray iron foundries. Also, little information is available concerning the impact on ambient air quality and possible violations of an ambient lead standard due to these three source categories. The extent of this information is summarized for each source category in the following sections.

2.1 SECONDARY LEAD SMELTERS

Data indicate that particulate emissions from secondary lead blast furnaces contain approximately 23 percent lead.[1,2,3,4,5,6] It is unknown if this composition is also characteristic of fugitive emissions that occur during charging or slag and lead tapping. Only total particulate fugitive emission factors are available for secondary lead reverberatory, blast, or pot furnaces; and, these factors are based on an engineering estimate that fugitive emissions equal 5 percent of the uncontrolled stack emissions.[7] The casting emission factor was based on limited tests of the roof monitor over casting operations of a primary smelter.

Using the total particulate fugitive emission estimates in conjunction with the assumption that the emissions have the same characteristics as the furnace emissions (i.e., approximately 23 percent lead), would result in fugitive emission factors that are based entirely on estimates. These would be at the very best, "order of magnitude" estimates and are as follows:

Source	Fugitive emission estimates: Total particulate[7]	Fugitive emission estimates: Lead only
Lead and iron scrap burning	0.5-1.0 g/kg scrap (1.0-2.0 lb/ton)	0.1-0.2 g/kg scrap (0.2-0.5 lb/ton)
Sweating furnace	0.8-1.75 g/kg charge (1.6-3.5 lb/ton)	0.2-0.4 g/kg charge (0.4-0.8 lb/ton)
Reverberatory or blast furnace	1.4-7.85 g/kg charge (2.8-15.7 lb/ton)	0.3-1.8 g/kg charge (0.6-3.6 lb/ton)
Pot furnace	0.02 g/kg charge (0.04 lb/ton)	0.005 g/kg charge (0.009 lb/ton)
Casting	0.44 g/kg lead cast (0.88 lb/ton)	0.1 g/kg lead cast (0.2 lb/ton)

Estimates of the air quality impact of fugitive lead emissions from this industry, based on such highly subjective factors, would certainly be subject to criticism if utilized for proposed standards or for health effects analyses. Collection of sampling data is necessary to support development of emission factors.

Limited data were found on ambient air lead concentrations around secondary lead smelters.[8] Measurements by the Texas Air Control Board show 24-hour lead concentrations at 76 meters (250 ft) from one secondary lead smelter to be in the range of 3.3 to 13.7 $\mu g/m^3$, and at 91 meters (300 ft) from another secondary lead smelter to be in the range of 24.8 to 111.6 $\mu g/m^3$.[8,9] These concentrations were measured relatively close to the plant, indicating that fugitive emissions could very well be the major contributing emission source. However, there was a lack of detailed information about the emission sources.[8] It was not reported whether fugitive sources, or poorly controlled or uncontrolled nonfugitive sources were believed to be causing the lead impact.

These limited data show in Table 2-1 that it is likely that 100 percent of the monthly average lead concentrations near secondary lead smelters will exceed 5.0 $\mu g/m^3$.[8] As a result, it appears that the ambient lead concentrations surrounding secondary lead smelters can be expected to exceed 1.5 $\mu g/m^3$, 90-day average, on a regular basis.

In another study using samplers at various distances from two secondary lead smelters, 24-hour lead concentrations were 0.5 to 26.5 $\mu g/m^3$ when measured 60 meters (197 ft) from one smelter, and 0.2 to 74.0 $\mu g/m^3$ when measured 90 meters (295 ft) from the other smelter.[8,11] The range of

Table 2-1. PROBABILITY OF EXCEEDING LEAD CONCENTRATION LEVELS NEAR SELECTED INDUSTRIES (8,9,10)

Industry and plant	Percentage of monthly averages exceeding given levels, μg/m³ 0.5	1.5	2.0	3.0	5.0	Number of monthly averages	Total number of samples	Average lead concentration of all samples, μg/m³
Secondary Lead Smelter								
Dixie Lead, Dallas, TX	100	100	100	100	100	1	4	8.2
NL Industries, Dallas, TX	100	100	100	100	100	1	4	70.0
Ferroalloy Producer								
Tenn-Tex Alloy, Houston, TX	100	100	100	100	0	1	2	3.4
Gray Iron Foundry								
Oil City Iron Works, Corsicana, TX	0	0	0	0	0	1	2	ND
Lufkin Industries, Lufkin, TX	100	100	100	100	100	1	2	36.9
Tyler Pipe, Tyler, TX	100	0	0	0	0	1	4	1.4
Trinity Valley Iron and Steel, Fort Worth, TX	100	100	100	0	0	1	2	2.4
Green's Bayou Founrdy, Houston, TX	100	100	100	100	100	1	2	9.3
McKinley Iron Works, Fort Worth, TX	100	100	100	100	100	1	2	9.2
American Darling Foundry, Beaumont, TX	100	100	100	100	100	1	2	12.6

ND = Not detectable.

Sources: Texas Air Control Board. April 1974a. A Report of Typical Element Emissions from Texas Smelters; (Reference 9, as reported in Reference 8).
Texas Air Control Board. April 1974b. A Report of Typical Element Emissions from Texas Foundries; (Reference 10, as reported in Reference 8).

concentrations at each receptor are shown in Table 2-2. The samplers showing the highest lead impact were located nearest the two plants. Other samplers, located farther from the sources, showed a decrease in lead concentrations with distance from the smelters. This again indicated that fugitive sources (characteristically with low emission release heights) were the primary contributor to the nearby measured concentrations.[8,11] The geometric mean ambient lead concentration near the two smelters was 3.0 $\mu g/m^3$ while in an urban control area away from the smelters the mean was 0.8 $\mu g/m^3$.[8,11] This is another indication that an assumed ambient lead standard of 1.5 $\mu g/m^3$, 90-day average, may be exceeded around secondary lead smelters.

2.2 FERROALLOY PLANTS

Information on fugitive lead emissions from the ferroalloy industry is also lacking. Electric submerged arc furnaces are the type most widely used for the production of ferroalloys. The little information that is available on lead emissions from ferroalloy plants pertains to this furnace type.

Open electric arc ferroalloy furnaces are considered a fugitive emission source since the emissions emanate from a nonconfined area. Emissions from this source are captured

Table 2-2. LEAD CONCENTRATION STUDY NEAR TWO SECONDARY LEAD SMELTERS (8,11)

Source and receptor	Lead emissions, tons/day (Mg/day)	Distance from source, meters	Number of samples	24-hour concentration range $\mu g/m^3$
Smelter A	0.045 (0.041)	-	-	-
Receptor 1		60	96	0.5-26.5
Receptor 2		100	57	0.5-9.7
Receptor 3		220	94	0.2-13.7
Smelter B	0.09 (0.082)	-	-	-
Receptor 4		90	101	0.2-74.0
Receptor 5		120	64	0.4-6.0
Receptor 6		130	73	0.3-27.5
Receptor 7		195	101	0.3-5.0

Source: Roberts, T.M., T.C. Hutchinson, J. Paciga, A. Chattopadhyay, R.E. Jervis, and J. Van Loom. December 20, 1974. "Lead Contamination Around Secondary Smelters: Estimation of Dispersal and Accumulation by Humans," Science, Volume 186 (4169), pp. 1,120-1,123. (Reference 11, as reported in Reference 8.)

by hooding or enclosing the furnace, then removed from the gas stream by fabric filters, venturi scrubbers, or (less common) electrostatic precipitators.

The uncontrolled lead emission factor for electric arc furnaces producing manganese alloys (FeMn and SiMn) was developed knowing that the lead content of manganese ore ranges from 0.002 to 0.01 percent by weight, with an average lead content of 0.005 percent.[1,12] Manganese ore is imported because there is no domestic production of this ore. Since about 75 percent of the lead in the ore is released in the furnace fume,[12] this results in an uncontrolled lead emission factor of 0.038 g/kg product (0.075 lb/ton) for manganese alloys.[1] However, note that there may be wide variations in the lead emission rates, depending on the ore used.[13]

The lead emission factor for silicon alloy production (FeSi, silicon metal, and CaSi) is calculated using the reported lead content of particulate from a furnace producing silicon alloy (0.02% lead)[12,13] and the total particulate emission factor for silicon alloy furnaces (weighted by product mix) of 275 g/kg product (550 lb/ton).[12,13] This results in an uncontrolled lead emission factor of 0.05 g/kg product (0.1 lb/ton).[1,12]

The lead emission factor for production of chromium alloys is estimated using a reported lead content of 0.001 percent[12,13] in the fume from a furnace producing FeCrSi, and an uncontrolled total particulate emission factor for chromium alloy furnaces (weighted by product mix) of 260 g/kg product (520 lb/ton).[12,13] This results in an uncontrolled lead emission factor of 0.0025 g/kg product (0.005 lb/ton).[12]

These emission rates represent uncontrolled emissions. In practice, the ferroalloy furnaces are hooded or enclosed and emissions ducted to control devices. However, there are likely to be some fugitive emissions from the furnace that escape capture. Quantitative estimates of emission rates for leaks due to ineffective capture have not been made, possibly due to the very site-specific nature of these emission levels. Emission factors for tapping and casting emissions also have not been developed. Therefore lead emission rates from these operations are unknown.

Ferroalloy ore handling is a minor source of fugitive lead emissions. Total fugitive emissions from ore and raw materials handling and preparation have been estimated at 5 g/kg alloy produced (10 lb/ton).[1,14] However, lead content of FeMn, SiMn, and FeCrSi ores have been reported at 0.01 percent and less.[12,13] If the percent lead in the emissions is assumed to be the same as the percent lead in the raw materials, the lead emission factor for material handling would be 0.0005 g/kg alloy produced (0.001 lb/ton). Assuming this factor valid for the entire 1975 industry production of 2.0 x 10^6 Mg[1] (2.2 x 10^6 tons), the industry-wide fugitive lead emissions from materials handling would be 1 Mg/yr (1.1 tons/yr).

Two ambient air samples at a ferroalloy plant show 24-hour lead concentrations at 61 meters (200 ft) from the source to be 2.5 and 4.5 $\mu g/m^3$.[8,9] These are the only data found in the literature and are very little information on which to estimate the industry-wide fugitive lead impact from ferroalloy production. However, from these data as shown in Table 2-1, it appears that there may be an ambient lead concentration problem surrounding ferroalloy plants.

2.3 GRAY IRON FOUNDRIES

Cupolas are the most widely used furnace for the production of gray iron. Other furnace types include electric arc, electric induction, and reverberatory. Fugitive emissions from the cupola and reverberatory furnaces occur during charging and tapping. The furnace emissions from cupolas and reverberatories are not considered fugitive since they always emanate from a stack. The electric arc and induction furnace emissions are considered fugitive for the charging, tapping, and furnace operations.

The only fugitive emission factors for gray iron foundry cupola/reverberatory furnaces are for total particulate fugitive emissions; and, these factors are based on an engineering estimate that fugitive emissions equal 5 percent of the uncontrolled stack emissions reported in AP-42.[7,15]

Tests on several cupolas indicate that emissions of lead and particulate vary considerably, depending on the quality of the scrap charged, cupola blast velocity, temperature of the melt zone, and lead content. One study reported a range of 0.5 to 2.0 percent lead in cupola particulate emissions, with an average of 1.2 percent.[17] Another study reported a concentration of 2.6 to 3.4 percent lead in the emissions.[18] One investigator indicated a lead content of 1.2 to 5.7 percent, with an average of 4.3 percent.[19] Tests on a Los Angeles cupola operation showed that 17 percent of the particulate emissions was lead,[20] probably attributable to a high percentage of scrap metal in the charge. Thus the average lead content of emissions from foundry cupola furnaces is approximately 3 percent.[1] [Note that increased use of scrap could raise the lead content of the emissions.] Applying the 3 percent lead to the total particulate fugitive emission estimates would result in the following estimates:

Furnace type	Fugitive emission estimates per unit weight of metal charged	
	Total particulate(7)	Lead only
Cupola	0.05-1 g/kg (0.1-2 lb/ton)	0.0015-0.03 g/kg (0.003-0.06 lb/ton)
Reverberatory	0.05 g/kg (0.1 lb/ton)	0.0015 g/kg (0.003 lb/ton)

The emission factor for electric induction furnaces published in AP-42[15] for total particulate emissions is 0.75 g/kg of metal charged (1.5 lb/ton). Total particulate emission rates for electric arc furnaces have been estimated at 7.75 g/kg of iron produced (15.5 lb/ton).[16] Of this total, 0.75 g/kg of iron produced (1.5 lb/ton) are for charging and tapping emissions.[16] Charging represents the bulk (90 to 95%) of the combined charging and tapping emissions.

Since there are no data on the percent lead in particulate emissions from electric or reverberatory furnaces, these emissions may also be assumed to contain 3 percent lead. Applying the 3 percent lead to the electric induction and electric arc furnace total particulate emission factors would result as follows:

Furnace type	Fugitive emission estimates, per unit weight of metal	
	Total particulate[15,16]	Lead only
Electric induction	0.75 g/kg charged (1.5 lb/ton)	0.02 g/kg charged (0.04 lb/ton)
Electric arc	7.75 g/kg produced (15.5 lb/ton)	0.23 g/kg produced (0.46 lb/ton)

Again, these estimates would be at very best "order of magnitude estimates." Factors developed in such a manner are inadequate to assess the air quality impact of fugitive lead emissions from these furnace types in the gray iron industry; at least for the purposes of proposed standards. Sampling data are necessary in order to develop the needed emission factors.

Ambient air lead concentrations were measured around seven gray iron foundries in Texas and are summarized in Table 2-1.[8,10] The measurements were taken 76 to 168 meters (250 to 550 ft) from the source. The reported 24-hour lead concentrations ranged from "not detectable" to 50.9 $\mu g/m^3$.

Based on these limited tests (a total of only 16 samples), it can be seen (Table 2-1) that the ambient lead concentrations surrounding gray iron foundries will generally exceed 1.5 $\mu g/m^3$.[8]

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3.0 APPLICATION OF FUGITIVE LEAD EMISSION FACTORS DEVELOPED FOR OTHER SOURCE CATEGORIES

Because of the lack of information on fugitive lead emissions from secondary lead smelters, ferroalloy plants, and gray iron foundries, the application of fugitive lead emission factors from other source categories was investigated. The major difficulty in applying fugitive lead emission factors developed for one source to another source is the variation in emissions caused by differences in raw materials. While the same general type of equipment may be used, the difference in raw materials causes different emission rates and characteristics. The lead emission rates will likely differ significantly due to differences in lead contents of the raw materials. Therefore when applying fugitive lead emission factors developed for one source to another source category, the total particulate emission rates and lead contents of the raw materials must be compared.

3.1 SECONDARY LEAD SMELTERS

Although there is more emission information available for primary lead smelters than secondary lead smelters, the emission factors for these two source categories are not comparable. The total particulate emission rate from a secondary lead smelter blast furnace is approximately half the emission rate from a primary lead smelter blast furnace.(1) This may be because ore is used at primary smelters while scrap is used at secondary smelters. The differences in raw materials cause a significant difference in emission rates and characteristics (i.e., percent lead). In addition, the fugitive emissions from primary lead smelter dross reverberatory furnaces can not be expected to approximate the fugitive emissions from a secondary smelter reverberatory furnace. Total particulate emissions from the secondary lead smelter reverberatory furnace are more than seven times the primary smelter dross reverberatory furnace.(1) Lead casting emissions for primary and secondary lead smelters may be comparable; however, some measured data or at least a materials-balance analysis would be required to determine if a valid comparison exists.

3.2 FERROALLOY PLANTS

Although many industries use electric arc furnaces, emissions generated by electric arc furnaces for the production of ferroalloys are unique for the following reason. For the production of ferroalloys, total particulate emissions from open electric arc furnaces range from 97.5 to 312.5 g/kg produced (195 to 625 lb/ton) depending on the type of product.[1] By comparison, particulate emission factors for electric arc furnaces used in steel foundries range from 2 to 20 g/kg metal charged (4 to 40 lb/ton).[1] This large disparity in emission rates occurs because of the difference in raw materials. Raw materials used in steel foundries include scrap steel, pig iron, ferroalloy, and limestone; while alloy ore (e.g., chrome ore for production of FeCr), limestone, quartz, coal and wood chips, and scrap iron are used for the production of ferroalloys. Lead emissions from tapping and casting ferroalloys cannot be compared to other industries (such as foundries), primarily because of the anticipated differences in lead content of the products and differences in total emission rates. It seems apparent that emissions, especially lead emissions, generated by the ferroalloy furnaces are unique to that industry.

3.3 GRAY IRON FOUNDRIES

It is difficult to apply fugitive lead emission factors developed for other source categories to the gray iron foundry industry. This difficulty is largely due to the wide variation that is found in lead content of the scrap and other raw materials. This variation occurs within the gray iron foundry industry as well as between that industry and other related industries. For example, the lead content of metals charged in a gray iron electric arc furnace may be less than or greater than the lead content of metals charged to a steel foundry electric arc furnace. The specifications of the finished product influence the quality control of the scrap metals and the lead content of the charge. There are also wide variations in total particulate emission rates between the gray iron foundry industry and other related industries.

Cupolas are used in foundries primarily for the production of gray iron, but may also be used for brass and bronze production. The total particulate emission factor for a brass/bronze production cupola is 36.5 g/kg metal charged (73 lb/ton) while the gray iron cupola total particulate emission factor is 8.5 g/kg metal charged (17 lb/ton).[1] This difference in emission rates plus an anticipated difference in lead content of the raw materials, make unlikely a good agreement of fugitive lead emission factors between these two sources.

The total particulate emission factor for an electric induction furnace producing gray iron is 0.75 g/kg metal charged (1.5 lb/ton).[1] This is 15 times the particulate emission factor for an induction furnace in a steel foundry, but similar to the brass/bronze induction furnace emission factor of 1 g/kg metal charges (2 lb/ton).[1] However, it is not anticipated that the lead emissions for the gray iron and brass/bronze induction furnaces would be as close as their respective total particulate emission rates because of differences in the lead content of the metals usually charged.

The total particulate emission rate from a gray iron electric arc furnace, 7.75 g/kg iron produced[2] (15.5 lb/ton), is similar to the particulate emission rate from a steel foundry, 6.5 g/kg metal charged[1] (13 lb/ton). As was pointed out, however, the lead contents of the charge materials may not be the same; in fact, they are often quite different. Therefore while an operational relationship may be found between these two source categories, data developed specifically for gray iron electric arc furnaces would be much more accurate for that source category.

Reverberatory furnaces producing gray iron have a particulate emission factor of 1 g/kg metal charged (2 lb/ton) while steel foundry open hearth furnaces have a particulate emission factor of 5.5 g/kg metal charged (11 lb/ton) and brass/bronze reverberatory furnaces have a particulate emission factor of 35 g/kg metal charged (70 lb/ton).[1] Again, because of the large disparity among these particulate emission factors plus an anticipated variation of the percent lead in the charge, it is unlikely that fugitive lead emission factors for the steel and brass/ bronze furnaces would approximate fugitive lead emission factors for the gray iron reverberatory furnace.

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4.0 APPLICABILITY OF FUGITIVE LEAD FACTORS DEVELOPED FROM A FIELD STUDY

Before conducting a field study to measure fugitive lead emissions and develop emission factors, it must be determined if such a study at one or several representative plants would be reasonably applicable for estimation of emissions from other individual plants in the same source category.

4.1 SECONDARY LEAD SMELTERS

In 1975, over 548,500 Mg of lead(1) (604,600 tons) was produced at approximately 90 secondary lead smelters(2) in the United States. Two-thirds of the production from the secondary lead industry is processed in blast furnaces (or cupolas), with the remaining done in reverberatory furnaces and pot furnaces.(1)

The three most common grades of lead are soft, semi-soft, and hard. Soft lead is approximately 99.9 percent lead and is produced by the pot furnace. Semisoft lead is approximately 99.6 percent lead and is produced by the reverberatory furnace. Hard lead is typically between 88 and 95 percent lead and is produced by the blast furnace.(3)

Figure 4-1 shows secondary lead smelter processes and emission points. Blast furnaces generally produce 18 to 73 Mg per day of lead (20 to 80 ton/day).[4] The furnace is a vertical production unit which is charged through a door near the top while blast air is blown in through tuyeres near the bottom. The process is semicontinuous in that the charge is added over a period of 1 or 2 days and product is withdrawn nearly continuously during that period. The charge stock consists of oxidized lead and lead scrap to be reduced, plus coke for combustion, limestone, scrap iron, and rerun slag.[5] Approximately 70 percent of the molten charge material is tapped off as hard lead.[3,6]

A reverberatory furnace is merely a device for heating the charge stock by direct contact with the products of combustion of oil and/or gas burners and by radiation from the hot walls of the furnace. The charges may be a mixture of lead scrap, battery plates, oxides, drosses, and lead residues. These are put into the furnace at regular intervals as the mass of the charge becomes fluid. Molten metal is tapped off as the level of metal rises.[6]

A typical reverberatory furnace produces 45 Mg/day of lead ingot (50 ton/day).[4] About 47 percent of the charge stock is recovered as metal, 46 percent is recovered as slag, and 7 percent leaves as smoke and fumes.[6,7]

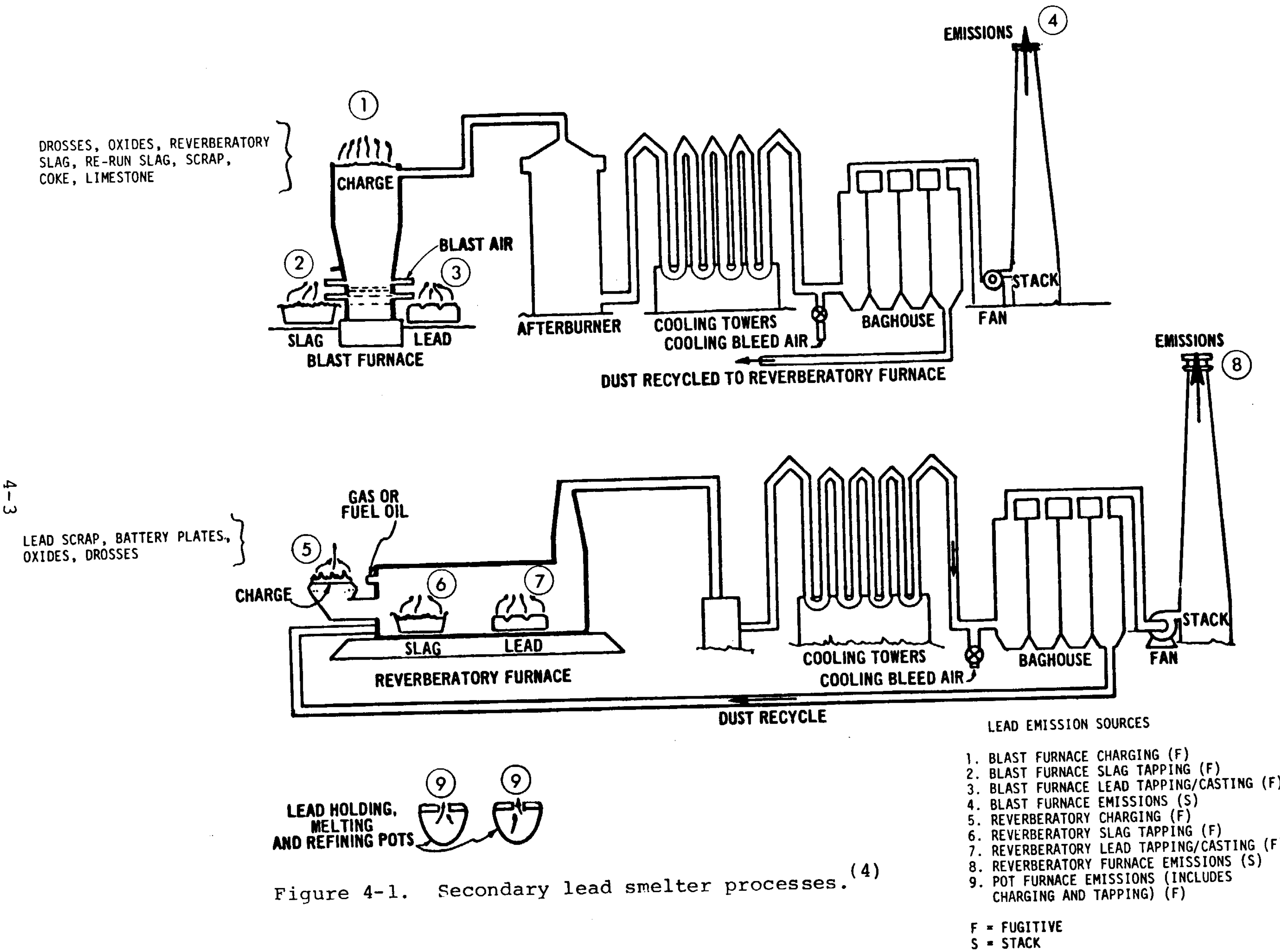


Figure 4-1. Secondary lead smelter processes.[4]

Pot furnaces generally produce from 0.9 to 45 Mg of lead per day (1 to 50 ton/day) and are used primarily for remelting, alloying, and refining processes. In general, since pot furnaces are indirectly fired, their pollution potential is much lower than that of blast or reverberatory furnaces. During melting and holding operations, uncontrolled emissions are low because the vapor pressure of lead is low at the melting temperature. During dross skimming and refining, however, emissions increase substantially.[4,6]

Since approximately two-thirds of the production from secondary lead smelters is from blast furnaces, testing of this furnace type would cover the majority of the industry. Also, plant to plant variations in the operation of blast furnaces, reverberatory furnaces, and pot furnaces could not be identified from literature sources. The major difference that may occur between plants is the variation in quality of scrap materials used. The effect this variation may have on fugitive lead emissions is not known but is something that could be determined as a result of a test program. The fugitive lead emission rates may be found to relate to the lead content of the materials charged to the furnace.

Testing of blast/reverberatory furnaces for fugitive lead will cover the large sources in the secondary lead industry. Since blast furnaces produce the majority of secondary lead, this furnace type warrants emphasis in the test program. Additional testing of pot furnaces will complete the sources of fugitive lead emissions in this industry. All of these sources may possibly be found at one smelter, but testing of several representative plants is suggested so that results will be more representative of industry-wide emission rates. This will also minimize bias of the results by a single plant and will permit an analysis relating emission levels to lead content of the raw materials.

4.2 FERROALLOY PLANTS

The United States produced 2,009,000 Mg (2,215,000 tons) of ferroalloys in 1975[8] at 50 plants[2] utilizing one of six types of operations: electric furnace, vacuum furnace, induction furnace, blast furnace, electrolytic process, and exothermic (aluminothermic) process.[6,9,10,11] Of these, over 90 percent are electric submerged-arc furnaces.[6,9] There are only six electrolytic processes, six aluminothermic processes, fewer than five vacuum and induction furnaces, and two blast furnaces producing ferroalloys in the United States.[6,10] Since the submerged-arc electric furnace is by far the most common furnace type, it is recommended that any sampling program of the ferroalloy industry should concentrate on this furnace.

The basic design and operation of all ferroalloy producing submerged-arc electric furnaces are essentially the same. Figure 4-2 shows a process flow diagram for submerged-arc electric furnace ferroalloy production. The charge consists of raw ore with a reducing agent, such as alumina, coal and/or coke, and slagging materials such as silica or gravel. Lead is a naturally occurring trace element of variable concentrations in the raw materials. The zone of intense heat (2200 to 2800°C, or 4000 to 5000°F) around the carbon electrodes is responsible for carbon reduction of the metallic oxides present. The various impurities are trapped in the slag, and the molten ferroalloy is tapped from the bottom of the furnace and cast.[6,9]

Although there is uniform industry-wide operation of electric arc ferroalloy furnaces, there are major variations in particulate emission rates depending on the type of ferroalloy produced.[12] Also, the lead emission rates vary depending on the product because the different ores used have various lead contents. Table 4-1 shows typical lead analyses that have been reported.

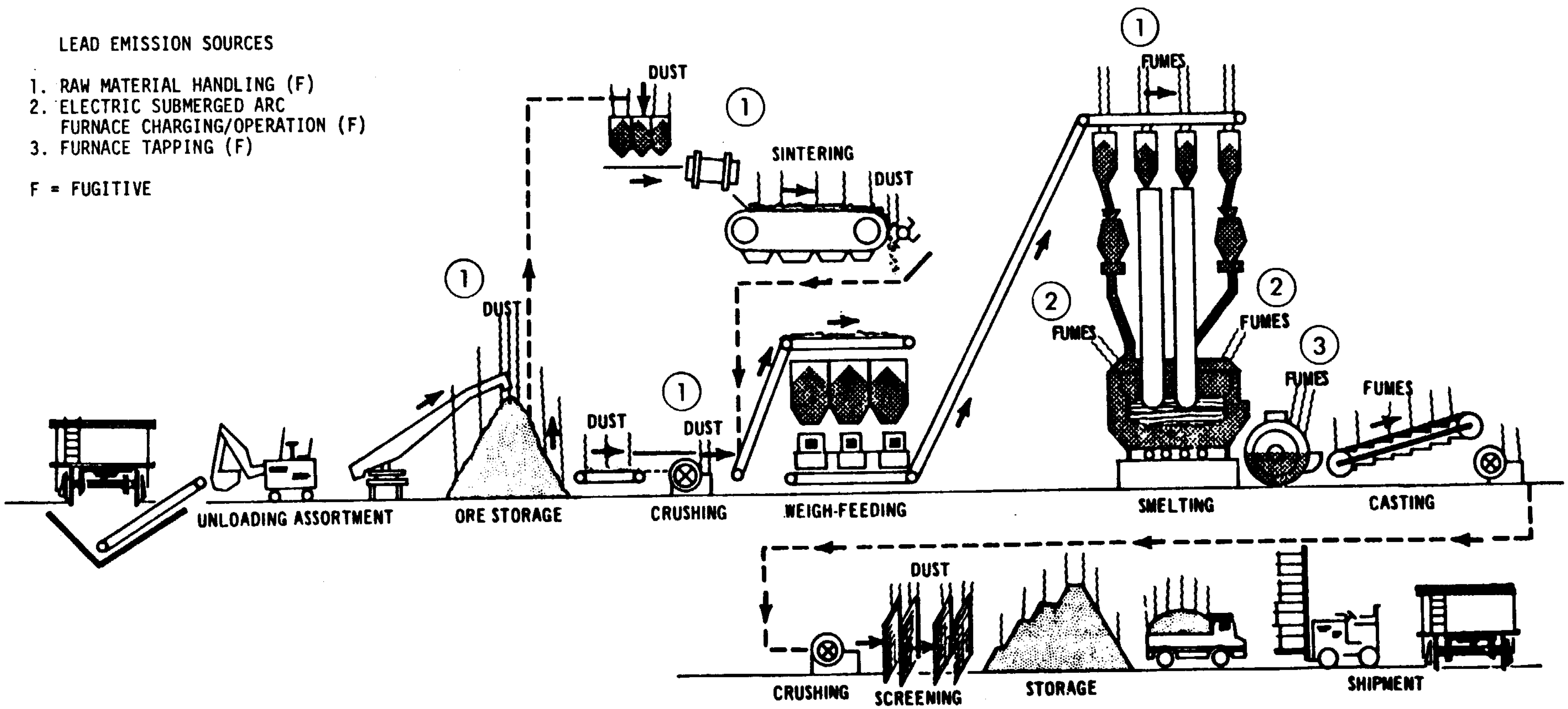


Figure 4-2. Submerged-arc ferroalloy production process.[10]

Table 4-1. LEAD CONTENT OF VARIOUS FERROALLOY ORES

Ore	Percent lead
FeMn	0.002 - 0.01[a]
FeCrSi	<0.01[b]
SiMn	<0.01[b]

[a] Reference 13.
[b] Reference 11.

The production distribution by ferroalloy type is shown in Table 4-2.

Table 4-2. U.S. FERROALLOY PRODUCTION IN 1975[a]

Product	Production	
	Mg	Tons
Ferro-manganese (FeMn)	551,300	607,697
Silico-manganese (SiMn)	202,100	222,772
Ferro-silicon (FeSi, silvery iron, silicon metal)	907,200	1,000,000
Ferro-Chromiums (FeCr)	222,200	244,938
Other ferroalloys (FeP, FeCo, FeTi, etc.)	127,000	140,000
Total estimated production	2,009,800	2,215,000

[a] Obtained from Mr. Thomas Jones, U.S. Bureau of Mines, Ferroalloys Division, Washington, D.C. July 20, 1976.(6)

This product distribution indicates that representative results will not be obtained by testing only one plant which produces just one type of ferroalloy. Tests must include the major ferroalloy products; ferro-silicon and ferro-manganese, followed in importance by ferro-chromiums and silicomanganese. Tests possibly could be completed at one facility, but would likely require several plants to complete a full test program.

The test program should also include analysis of the raw materials (ores) for lead content. This will provide the necessary data to determine if the fugitive lead emission factors are related to type of product, lead content of the ore, or both.

4.3 GRAY IRON FOUNDRIES

Gray iron is produced from cupola, electric, or reverberatory furnaces in approximately 1500 foundries in the United States.[2,14] The estimated throughputs of raw materials in 1975 are shown in Table 4-3.

Table 4-3. ESTIMATED AMOUNT OF MATERIAL CHARGED IN THE VARIOUS TYPES OF FOUNDRY MELTING FURNACES IN 1975[a]

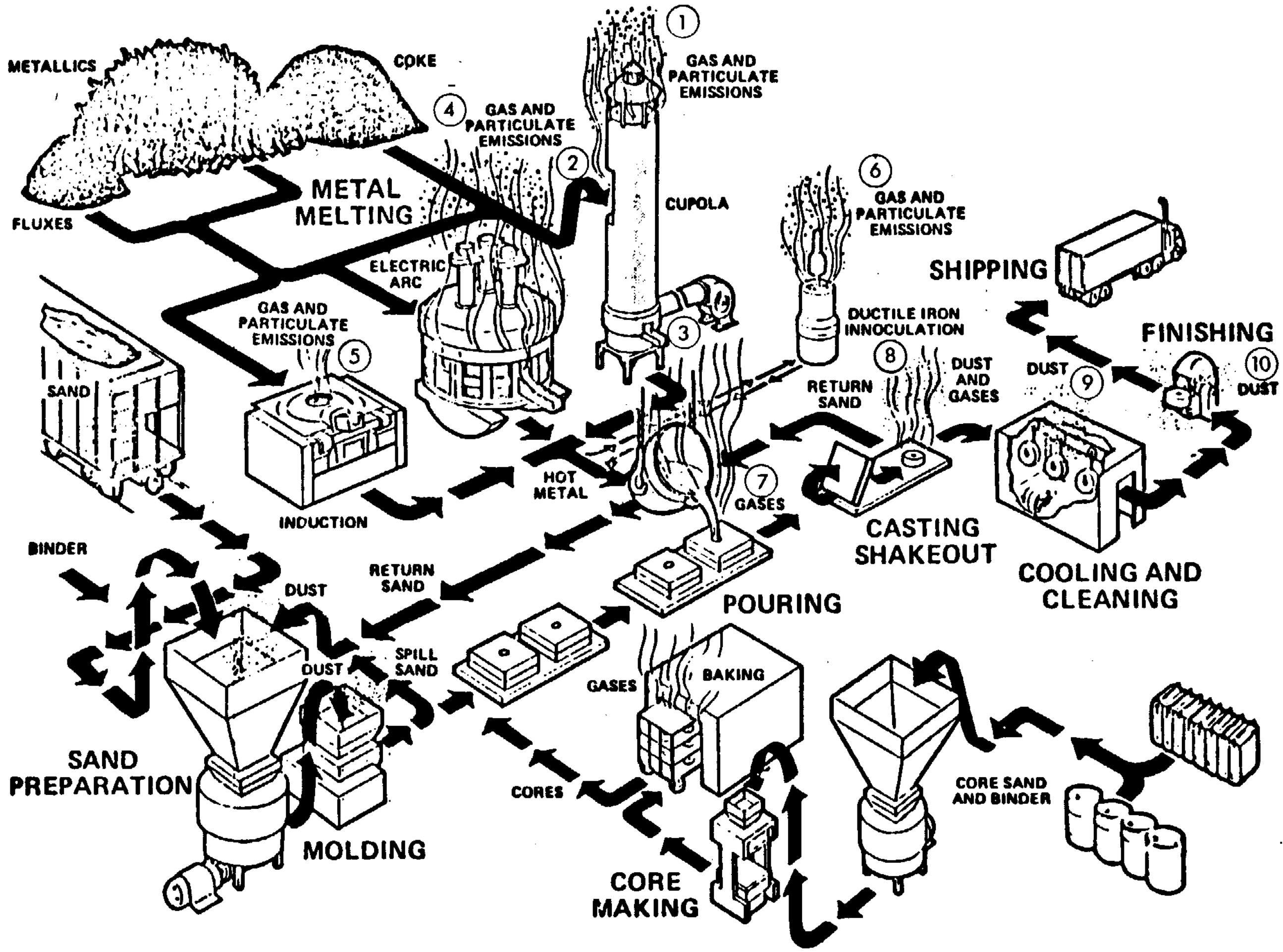
Type of melting furnace	Material charged to furnace		Percent of total
	Mg	tons	
Cupola	12,400,000	13,700,000	70
Electric	4,260,000	4,700,000	24
Reverberatory	1,090,000	1,200,000	6

[a] Source: Communication with Mr. Don Dussy. U.S. Bureau of Mines. Washington, D.C. July 12, 1976.[6]

Approximately 85 percent of the charge is metal;[12] therefore a total of 15,100,000 Mg of gray iron (16,700,000 tons) was produced in 1975.[6] Approximately 70 percent of the electric furnace production is from electric arc furnaces. The remainder is from electric induction furnaces.[14] The iron foundry processes are shown in Figure 4-3. [Note: not shown in this figure is the reverberatory furnace, since it is a minor part of the gray iron industry.]

The cupola utilized is similar to the blast furnace used in the iron and steel industry. The furnace is a firebrick-lined vertical cylindrical steel shell, approximately 0.7 to 2.9 meters in diameter (27 to 108 in), supported on structural steel legs. Air is supplied near the base of the cupola through a windbox and tuyeres.

The cupola is prepared for melting by securing the bottom drop door, placing a layer of sand over the door to prevent heat damage, closing the tap and slag holes, and charging coke for the bed. The bed is ignited and allowed to burn through. The charges of coke, flux (limestone, fluorspar and soda ash), and metal (pig iron, scrap and steel) are placed in alternate layers up to the charge door which is 4.9 to 6.7 meters above the bottom (16 to 22 ft). The blast air is then turned on, and melting begins. Charg-



LEAD EMISSION SOURCES

1. CUPOLA FURNACE (S)
2. CUPOLA CHARGING (F)
3. CUPOLA TAPPING (F)
4. ELECTRIC ARC FURNACE (INCLUDING CHARGING AND TAPPING) (F)
5. ELECTRIC INDUCTION FURNACE (INCLUDING CHARGING AND TAPPING) (F)
6. DUCTILE IRON INNOCULATION (F)
7. POURING (F)
8. CASTING SHAKEOUT (F)
9. COOLING AND CLEANING (F)
10. FINISHING (F)

F = FUGITIVE
S = STACK

Figure 4-3. Gray Iron foundry process.(14)

ing continues until the desired quantity has been melted, after which the blast is shut off and the furnace bottom is dropped, allowing the remaining excess charge to fall to the foundry floor or into a charging box. This material is recharged during the next operating cycle.[6,15]

Operating factors are broken down into two distinct groups: 1) methods of operations, such as blast rate and temperature, type of lining, operating variables of the afterburners; and 2) the quality of charge materials, including metal to coke ratios, use of oxygen or natural gas, and the use of coke briquettes.[3,6]

Electric arc furnaces are commonly used in the secondary melting of iron where special alloys are to be made. These furnaces may be either the direct or indirect arc type. Pig iron and scrap iron are charged to the furnace and melted, and alloying elements and fluxes are added at specified intervals. These furnaces have the advantage of rapid and accurate heat control.[3,6]

Since no gases are used in the heating process, some undesirable effects on the metal are eliminated. Since arc furnaces in the iron industry are virtually always used to prepare special alloy irons, the quality of the material charged is closely controlled. The charging of greasy scrap, which would emit combustible air contaminants, would only needlessly complicate the alloying procedure.[3,6]

Channel and coreless types of electric induction furnaces are used for melting cast iron. In this type of furnace, alternating current is passed through a primary coil with a solid iron core or hollow barcoil. The molten iron contained within a loop that surrounds the primary coil acts as the secondary coil. The alternating current (from 60 to 1000 hz) that flows through the primary coil induces a current in the loop. The electrical resistance of the molten metal creates the heat for melting. The heated metal in the channel type circulates to the main furnace chamber and is replaced by cooler metal. This circulation results in uniform metal temperature and alloy composition.[3,6]

Use of induction melting has grown during the last decade, principally because of its potential for air pollution control. No fossil fuels are used, no significant metal oxidation takes place during melting, and contamination of the charge is minimal.[6]

A reverberatory furnace operates by radiating heat from the burner flame, roof, and walls onto the charged material. The reverberatory furnace usually consists of a shallow rectangular refractory hearth for holding the metal charge.

The furnace is enclosed by vertical side walls and covered with a low, arched, refractory-lined roof. Combustion of fuel occurs directly above the molten bath; the walls and roof receive radiant heat from the hot combustion products and reradiate this heat to the surface of the bath. These furnaces are being phased out of production due to curtailments of natural gas and oil supplies.[3,6]

In addition to expected plant-to-plant differences in the types of furnaces used, different types of scraps and other raw materials are used in various foundries depending on end product specifications. Tests have shown that foundry furnace emissions range from 0.5 to 17 percent lead.[6] Foundries using high quality scrap and/or ingots would likely have lower fugitive lead emissions than foundries using lead contaminated scrap. The operations of iron innoculation (where done), pouring into molds, casting, shakeout, cleaning and finishing are relatively independent of the furnace type used to melt the metal. These operations are conducted in a consistent manner throughout the industry.

The melting furnaces are the major sources of fugitive lead emission found in the gray iron foundry. To obtain representative test results, the cupola must be given the highest priority for sampling since it produces 70 percent of all gray iron. Electric arc furnaces should have the next highest priority in the sampling program. These two furnace types account for over 85 percent of all gray iron production. Since electric induction and reverberatory furnaces are a minor part of the gray iron industry, these furnaces would have low priority in a sampling program.

The quantities of lead emissions expected from iron innoculation, pouring into molds, casting, shakeout, cleaning and finishing are unknown. However these lead emissions are expected to be small since it is likely that the majority of lead contained in the furnace charge material is emitted from the furnace as fume or removed in the slag. Tests are needed to determine the actual lead emission levels from these sources.

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5.0 STATE OF THE ART FOR DETERMINATION OF INPLANT FUGITIVE LEAD EMISSIONS

The three industries, namely secondary lead smelting, ferroalloy production and gray iron foundries, have similar fugitive emission sources. The fugitive lead emission sources include: secondary lead smelting - blast furnace charging/tapping, reverberatory furnace charging/tapping, and pot furnace charging/melting/tapping; ferroalloy production - materials handling, and electric arc furnace charging/smelting/tapping; and gray iron foundry - cupola charging/tapping, and electric arc or induction furnace charging/melting/tapping.

These operations normally occur inside of buildings with the fugitive emissions escaping to the atmosphere through power vents (wall or roof mounted) or natural draft vents (common in the roofs of large buildings). Open sources, such as materials handling, also occur. Since the three industries have these common types of fugitive emission points, the sampling approaches would be similar. The remainder of this section discusses the sampling techniques for power vents, natural draft vents, and materials handling operations. Also included is the quasi-stack method, which requires the temporary enclosure or hooding of the source. The quasi-stack technique may be used for open sources or sources within a building, the limiting factor being the ability to enclose or hood the emission source. Estimates pertaining to man power requirements for the performance of these tests are also presented.

5.1 GENERAL APPROACHES FOR MONITORING AND ANALYSES

5.1.1 Determination of Sources for Test

The initial task in a test program would be to conduct a presurvey. A two man team, consisting of an engineer and the senior field monitoring technician, would visit the plant and obtain the following information:[1]

- Source Isolability. Can the emissions be measured separately from emissions from other sources? Can the source be enclosed?
- Source Location. Is the source indoors or out? Does location permit access of measuring equipment?
- Meteorological Conditions. Will wind conditions or precipitation interfere with measurements? Will rain or snow on ground effect dust levels?
- Number and Size of Sources. Are emissions from a single, well defined location or many scattered locations? Is source small enough to hood?
- Homogeneity of Emissions. Are emissions the same type everywhere at the site? Are reactive effects between different emissions involved?

- Continuity of Process. Will emissions be produced long enough to obtain meaningful samples?

- Effects of Measurements. Will installation of measuring equipment alter the process or the emissions? Will measurements interfere with production?

- Nature of Emissions. Are measurements of particles, gases, liquids required? Are emissions hazardous?

- Emission Generation Rate. Are enough emissions produced to provide measurable sampling time?

- Emission Dilution. Will transport air reduce emission concentration below measurable levels?

- Physical Plant Parameters

  The following list of physical parameters should be obtained:

  Building layout and plan view of potential study areas
  Building site elevations to identify obstructions and structure available to support test setup
  Work flow diagrams
  Locations of suitable sampling sites
  Physical layout measurements to supplement drawings
  Work space required at potential sampling sites

- Process Description

  The following information pertaining to the process should be obtained:

  Process flow diagram with fugitive emission points identified
  General description of process chemistry
  General description of process operations including initial estimate of fugitive emissions
  Drawings of equipment or segments of processes where fugitive emissions are to be measured
  Photographs (if permitted) of process area where fugitive emissions are to be measured.

- Inplant Support and Assistance

  Items listed below are of extreme value since they will enable the test team to perform these functions more efficiently.

  Location of available services (power outlets, maintenance and plant engineering personnel, laboratories, etc.)
  Local vendors who can fabricate and supply test system components
  Shift schedules
  Location of Operations Records (combine with process operation information)
  Health and safety considerations
  Names, extensions, locations of process foremen and supervisors where tests are to be conducted
  Access routes to the areas where test equipment/instrumentation will be located
  Names, extensions, locations of plant security and safety supervisors
  Regional meteorological summaries

5.1.2 Selection of Monitoring Equipment

In general, three basic types of fugitive emission sources are normally encountered, they are: power vents which can be roof or wall mounted, natural ventilators such as doors, windows, and large open roof vents, and open sources such as material storage and transfer operations and furnace charging operations which are not controlled.

Particulate sampling equipment best suited for these sampling operations are high volume filtration devices which can be employed with a various sampling media. For gross particulate emission measurements, glass fiber filter media is preferred. The use of size fractionation devices such as the virtual impactor on Dichotomas sampler has gained wide usage for the determination of respirable particulates. Other filtration devices, employing sampling rates in the 1 to 10 l/min range and membrane filter substrates can be used for particle size distribution data employing microscopic techniques.

Beyond the physical collection of the sample other equipment to measure volumetric gaseous emission rates, emission gas temperature and barometric pressure are required.

In addition to the collection and measurement devices, in many cases, it will be necessary to have duct flanges, extentions etc. fabricated and in some instances custom fabricated traverse systems to which the sampling equipment may be attached such that traverse sampling can be conducted.

In summary, the minimum equipment required for conducting fugitive emission sampling is presented in Table 5-1. Additional discussion of meteorological instrumentation is contained in Sections 6.1 and 6.2.

Table 5-1. REQUIRED FUGITIVE EMISSION SAMPLING EQUIPMENT

Equipment	Number required	Estimated cost
Directional high volume air samplers	4	$ 2,400
Custom fabricated high volume traversing air samplers	7	2,100
Recording meteorological system	1	3,000
Respirable dust* samplers	2	6,000
Rotating vane anemometers	3	450
Hot-film wedge sensors and data system	7	5,000
Thermocouples and records	2	2,400
Barometers	1	180
Expendable support equipment and filter media	-	8,000

* Optional

5.1.3 The Field Test Plan

The U.S. EPA "Technical Manual for the Measurement of Fugitive Emissions: Roof Monitor Sampling Method for Industrial Fugitive Emissions"(1) presents an indepth discussion pertaining to this topic. The plan as presented, and extracted from this document is presented below:

"Measurement programs are very demanding in terms of the scheduling and completion of many preparatory tasks, observations at sometimes widely separated locations, instrument checks to verify measurement validity, etc. It is therefore essential that all of the experiment design and planning be done prior to the start of the measurement program in the form of a detailed test plan. The preparation of such a plan enables the investigator to "pre-think" effectively and cross-check all of the details of the design and operation of a measurement program prior to the commitment of manpower and resources. The plan then also serves as the guide for the actual performance of the work. The test plan provides a formal specification of the equipment and procedures required to satisfy the objectives of the measurement program. It is based on the information collected in the informal pretest survey report and describes the most effective sampling equipment, procedures, and timetables consistent with the program objectives and site characteristics."

5.1.3.1 Outline of Field Test Plan - The following outline was abstracted from the EPA document "Technical Manual for the Measurement of Fugitive Emissions: Roof Monitor Sampling Method for Industrial Fugitive Emissions."[1]

- Background

The introductory paragraph containing the pertinent information leading to the need to conduct the measurement program and a short description of the information required to answer that need.

- Objective

A concise statement of the problem addressed by the test program and a brief description of the program's planned method for its solution.

- Approach

A description of the measurement scheme and data reduction methodology employed in the program with a discussion of how each will answer the needs identified in the background statement.

- Instrumentation/Equipment/Facilities

A description of the instrumentation arrays to be used to collect the samples and meteorological data identified in the approach description. The number and frequency of samples to be taken and the sampling array resolution should be described.

A detailed description of the equipment to be employed and its purpose.

A description of the facilities required to operate the measurement program, including work space, electrical power, support from plant personnel, special construction, etc.

- Schedule

A detailed chronology of a typical set of measurements, or a test, and the overall schedule of events from the planning stage through the completion of the test program report.

- Limitations

A definition of the conditions under which the measurement project is to be conducted. If, for example, successful tests can be conducted only during occurrences of certain source operations, those favorable limits should be stated.

- Analysis Method

A description of the methods which will be used to analyze the samples collected and the resultant data, e.g., statistical or case analysis, and critical aspects of that method.

- Report Requirements

A draft outline of the report on the analysis of the data to be collected along with definitions indicating the purpose of the report and the audience it is to be directed to.

- Quality Assurance

The test plan should address itself to the development of a quality assurance program. This QA program should be an integral part of the measurement program and be incorporated as a portion of the test plan either directly or by reference.

- Responsibilities

A list of persons who are responsible for each phase of the measurement program, as defined in the schedule, both for the testing organization and for the plant site.

5.1.4 Production Rate Determination

To determine fugitive lead emission rates from each fugitive emission source, the production rate pertaining to the specific operation must be measured during the sampling period. The method for determination of the production rate will vary with each operation. For example, the tapping operation of a blast furnace may be based on the quantity of molten lead processed per cast, if a "Quasi-stack" sampling method[2] is used for the determination of the fugitive emissions. Should the fugitive measurement be based on a roof or wall mounted power vent, then measurements of the total production rate, which is represented by the emissions through the power vent(s), would be required. In most cases measurements of this production rate will not be a function of the emission test team. The plant production engineer will have this data available. Therefore a strong line of communication must be established between both parties such that exact production rates can be obtained during the test period.

5.1.5 Common Analytical Requirements

Several common analytical requirements exist with respect to the determination of fugitive lead emission rates from the three processes. They can be summarized as follows:

- Filter media for use with the various sample collection systems. This media must be preweighed following the published U.S. EPA QA guidelines.
- Calibration equipment for field sampling equipment.
- Analytical services for gravimetric analyses.
- Analytical services for lead analyses.
- Analytical services for particle size distribution employing microscopic techniques.

- Quality Control Audit functions for both field and laboratory operations.

The EPA tentative reference method for lead analysis is presented in Reference 3. This method can be employed with minor alterations, as the sample type may dictate, for the determinants of lead content of samples collected from fugitive lead emission studies.

5.2 SAMPLING APPROACHES

As previously stated, several approaches are available for sampling particulate emissions from fugitive dust sources. The selection of which approach to use will depend on the physical configuration of the emission source. The sampling approaches which are presented in this section cover the majority of the types of emission sources most commonly encountered.

5.2.1 Power Vents

Power ventilators are wall or roof mounted. The sampling techniques employed for this type of source are identical. In order to sample this type of source, the following data must be obtained:

- Area of power vent
- Average air velocity through the power vent
- Barometric pressure and temperature at the time of sampling

- Sampling rate of the collection device
- Total particulate loading and lead content during sampling
- Process production rate for the sampling time period

5.2.1.1 Example Test for Power Vents - A typical example for sampling power vents is presented below.

As a result of the presurvey, a power ventilator was identifyed as a fugitive emission source. The vent is located approximately three stories above ground level within the plant building and is wall mounted. The total height of the building is approximately six stories. Scaffolding was erected into place to serve as a working platform. The diameter of the vent was measured to be 1.8 m (6 ft). A circular sheet metal flange, 0.3 m x 1.8 m (1 ft x 6 ft) was fabricated and installed around the vent to eliminate velocity contour effects on the velocity measurements. The velocity of the fan was then measured employing a rotating vane anemometer. The following procedure is recommended for this measurement, it is based on measuring the velocity at several points which properly represent equal areas based on aerodynamic fan characteristics.

- Procedure for Fan Velocity Measurements

Since fan characteristics are such that the maximum velocity is observed at the tips of the blades, and as a result velocity contour effects are present in the areas around the vent opening. To eliminate these effects, which would result in negative biased velocity error, a circular sheet metal flange should be installed in front of the power vent. Measurements of the fan velocity are then made several equal areas which are representative of the fan characteristics. At each point a one minute rotating vane velometer measurement is made. The location of the points at which the measurements should be made are presented in Figure 5-1.

The 13 one minute velocity measurements are averaged to obtain the average fan velocity.

The volumetric air flow of the fan was then determined by multiplying the fan velocity by the area of the flange around the power vent. This volumetric air flow rate was then corrected to standard conditions of 760 mm Hg and 25°C. A calibrated high volume air sampler was then located approximately 1.8 m (6 ft) from the power vent. Sampling of the fugitive emissions entering the power vent was conducted for three one-hour periods during one eight-hour work shift. The collection media employed was a 20 cm x 25 cm (8 in. x 10 in.) glass fiber filter. The total fugitive emissions and the lead content was determined employing gravimetric

POINT I.D.	% OF DIAMETER FROM INSIDE WALL
A1,C1	10%
B1,D1	25%
A2,C2	33%
A3	50%
A4,C3	67%
B2,D2	75%
A5,C4	90%

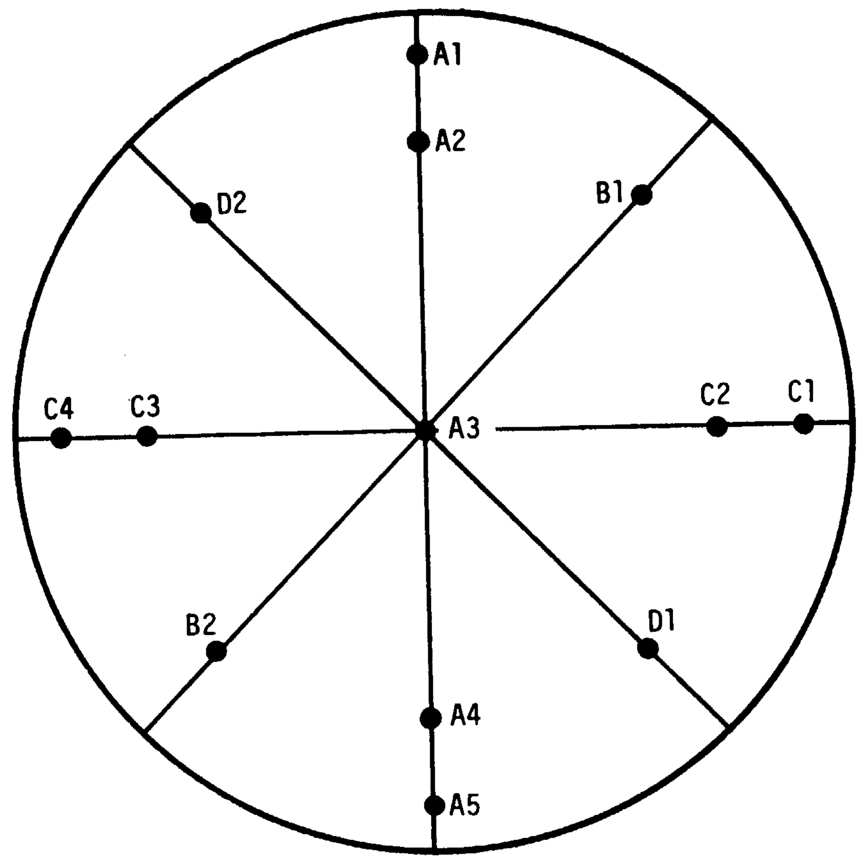

Figure 5-1. Locations of velometer measurement points to achieve representative velocity from a vane axel fan.

and atomic absorption spectroscopy. The concentration of the total suspended particulates and the lead content were expressed in $\mu g/m^3$ at standard conditions, 760 mm Hg and 25°C. During the three test periods the process production rate data was obtained from the plant process engineer.

From the above data the emission rates for each test period was calculated by multiplying the concentrations from the sampler by the average volumetric flow rate of the power vent. With this data and the process production rate, an emission factor was calculated.

5.2.2 Natural Draft Vents

Natural draft ventilators are most commonly installed on the roof of large buildings which house many batch type process operations. These vents are often referred to as the cupola on the roof of the building. This term should not be confused with the cupola furnace. The same data must be obtained as described for power ventilators, the major difference is that the air velocity through the cupola is very low and the opening is normally quite large. It is not uncommon for a cupola to be 90 m (300 ft) long by 8 m (25 ft) wide which results in an area of 720 m^2 (7500 ft^2). Emissions rise as a result of the operations below which produce hot gases. The major sampling problems associated with sampling this type of vent are centered around the low gaseous flow rate. The determination of the velocity can become a problem since it is low, normally less than 60 m/min (200 ft/min), and can vary with meteorological conditions while sampling. In addition to the problem of measuring a low velocity, it is not homogenous throughout the area of the ventilator. Hot wire anemometers and hot-film wedge sensors are the instrument of choice since they have good accuracy and precision and provide the capability for remote read out of the velocity.(4)

5.2.2.1 Example Test for Natural Draft Vents - A typical example for sampling natural draft ventilators is presented below.

As a result of the presurvey a "cupola" was identified as a source of fugitive emissions. The cupola was above a lead casting operation where twelve casting pots and molds were operating on a batch basis. Cupola emissions varied in intensity as well as physical location as a result of the batch type operation. The inside dimensions of the cupola were 30 m by 8 m or 240 m^2 (100 ft by 25 ft or 2500 ft^2). As a result of the above information, sampling was performed in the following manner:

- Seven constant speed traversing lines were fabricated, each system was designed to traverse at a rate of 4.2 cm/min (1.66 in./min) to provide a three hour sampling period over the 8 m (25 ft) vent width.

- The traversing systems were installed at the base of the cupola. Figure 5-2 illustrates this configuration.

- To each traversing system an inverted high volume air sampler and a hot film wedge sensor was installed.

- The traversing systems were spaced across the cupola such that two systems were 1.5 m (5 ft) from each end and the other five were 4.6 m (15 ft) apart, see Figure 5-3.

- The electrical outputs from each hot film wedge were connected to a multichannel read out system where the velocity was recorded.

- Each of the high volume samplers were calculated at standard conditions, 760 mm Hg and 25°C, and glass fiber filter media was used as the collector substrate.

- The seven systems were activated simultaneously and sampled for three hours, which comprised one test.

- The process production rate was obtained from the plant production engineer for the period during the test. In addition to the production rate, the number of batch pours were also obtained.

- The average velocity for each sensor, each minute was determined and from these measurements and the area of the vent on average volumetric flow rate was determined.

- The total suspended particulate and lead content was determined from each sample and expressed in terms of $\mu g/m^3$. From the seven samples an average concentrate for both total suspended particles and lead was determined.

- The total emissions for TSP and lead were then calculated using the average volumetric flow rate (m^3/min) and the average concentrations ($\mu g/m^3$).

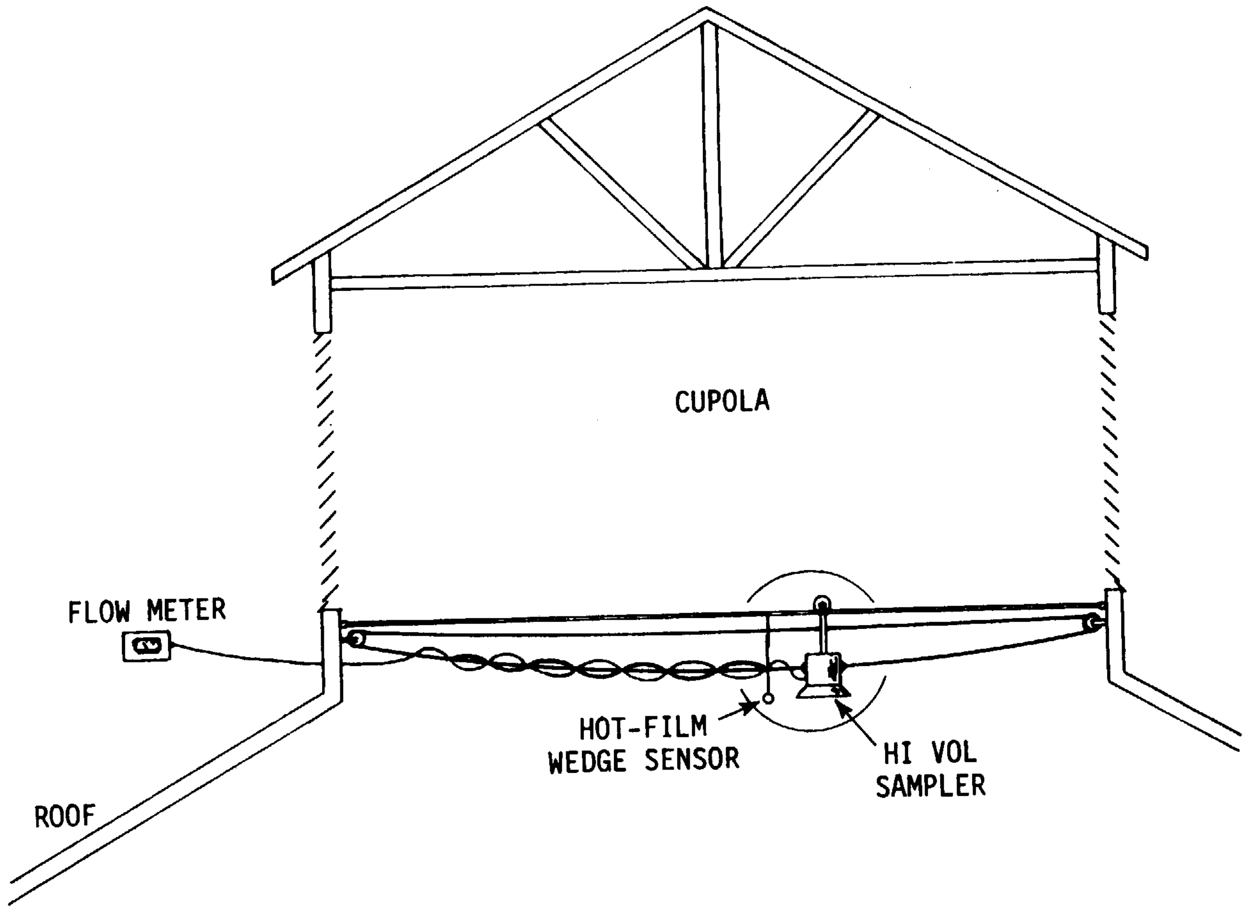

Figure 5-2. Diagram of traversing system.

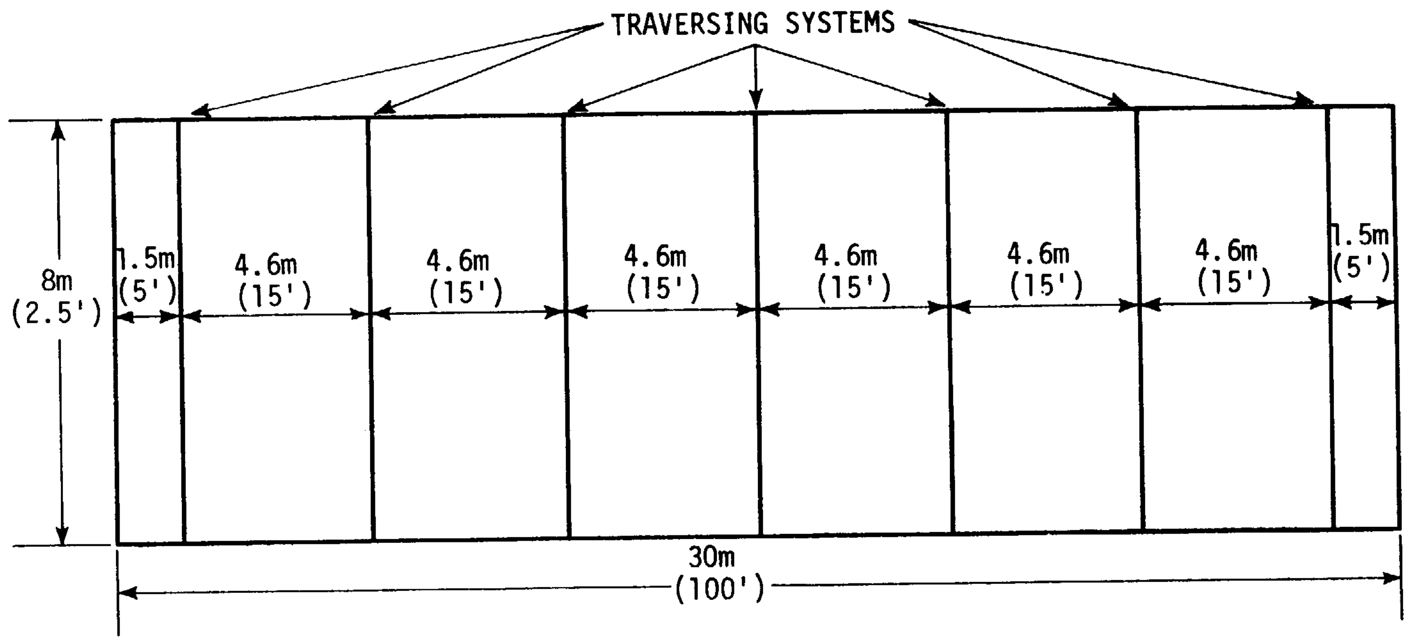

Figure 5-3. Spacial diagram of traversing systems.

From the emission data and the process data, a fugitive lead emission factor was calculated for the production rate and for each batch casting.

5.2.3 Material Handling Operations

Emissions of fugitive particulate material are often a result of open conveyor belt, dumping and storage operations of materials and products. The magnitude of the emission depends on the prevailing meteorological conditions and the type of material handled. One approach for the determination of emission factors from these sources requires an extended sampling program employing directional operated high volume sampling and meteorological equipment.

5.2.3.1 Example Test for Sampling Materials Handling Operations - The fugitive particulate emission source was identified as a dross transfer operation. This material was being transferred back to an electric arc furnace for additional recovery of product. The sampling of this source consisted of the placement of four directional operated high volume air samplers and a meteorological system in the near proximity of the material transfer operation. Three of the samplers were placed 3 m (10 ft) apart at a location which was determined to be in the predominate down wind director approximately 3 m (10 ft) from the operation. The other sampler was placed approximately 8 m (25 ft) up wind of the operation to serve as a background site. All directional samplers were set to operate over a 180° sector such that they would sample when the wind direction was perpendicular to the transfer belt. Each sampling period consisted of 24 hours, at the end of each period the glass fiber filters were changed and the average wind speed for the period that the samplers were operational was calculated. This sampling program was continued until three sets of samples were collected for each of the following average wind speed conditions; less than 2.2 m/sec (5 mph), 2.2 to 4.5 m/sec (5 to 10 mph), and greater than 4.5 m/sec (10 mph). The total suspended particulate and lead concentrations, less the background levels, were determined for each set of wind speed conditions. From the emission data, and an estimate of the emission area, an emission rate was determined for each of the three average wind speed conditions. These emission rates were then employed with the average process rate to obtain emission factors for the operation under varying wind speed conditions.

5.2.4 <u>Quasi-Stack Method</u>[1,2]

This method requires that the source of emissions be isolable and that an enclosure can be installed capable of capturing emissions without interference with plant operations. These types of sources are normally single operations with emissions which are not confined within a building and as a result other techniques as described above cannot be applied. The techniques consist of constructing a temporary hood or enclosure over the source. The enclosure is then vented to an exhaust duct or stack of regular cross-sectional area. Emissions are then measured in the exhaust duct using standard stack sampling or similar well recognized methods. This approach is necessarily restricted to those sources of emissions that are isolable and physically arranged so as to permit the installation of a temporary hood or enclosure that will not interfere with plant operations or alter the character of the process of the emissions.

5.2.4.1 Example Test for Quasi-Stack Sampling - As a result of a presurvey a major fugitive particulate emission source was identified at a ferroalloy production process. The source was a result of emissions from an electric arc furnace. A large hood with a measurement duct and blower was constructed over the source. The volumetric air flow within the duct was adjusted such that no visible particulate emissions were observed escaping the hood. At this point the particulate emissions were sampled employing the EPA source sampling method 5.[5] Three sampling periods of 60 minutes each were conducted during a normal work shift. The total suspended particulate and lead emissions were determined from these samples. From this data and the production rate data an emission factor was determined.

5.3 MANPOWER ESTIMATES

Table 5-2 presents estimates of manpower requirements for each of the example test programs as presented in the above sections. The total manhour requirements for conducting four test programs as outlined above is estimated at 2770 hours. This level of effort does not include the fabrication of sheet metal ducts, hoods, etc. which would require the services of a subcontractor. The cost of this element is estimated at $5000 to $7000. Therefore, assuming no extraordinary services/resources are required, the cost of a series of power vent, natural draft vent, materials handling, and quasi-stack tests can be estimated as follows:

Table 5-2. ESTIMATED MANPOWER REQUIREMENTS WITH RESPECT TO TASKS AND MANPOWER CATEGORIES (MANHOURS)

Tasks	Project Director	Senior Professional	Professional	Junior Professional/ Technician
Plant presurvey and report	20	40	40	0
Power vent test				
Field set-up*	20	20	20	20
Field study	10	30	30	30
Sample analyses	10	10	20	60
Data analyses	10	40	20	20
Report preparation	20	20	20	-
Natural draft vent test				
Field set-up*	20	30	30	30
Field study	10	40	40	40
Sample analyses	10	10	20	120
Data analyses	10	60	20	20
Report preparation	20	20	20	-
Material handling test				
Field set-up	10	10	10	10
Field study	10	10	120	120
Sample analyses	10	10	20	120
Data analyses	10	40	60	40
Report preparation	20	40	40	20
Quasi-stack test				
Field set-up*	10	40	40	120
Field study	10	10	20	40
Sample analyses	10	10	20	60
Data analyses	10	40	20	20
Report preparation	20	20	20	-
Total Professional Manhours	280	550	650	890
Clerical Manhours - 400				
Total Manhours** - 2700				

* Does not include fabrication requirements for sheet metal work which requires the services of an outside contractor.

** This estimate is based on the measurement and determination of emission factors from the four emission sources above at one plant.

Item	Estimated cost*
° Burdened labor, 2700 hours @ $22/hr	$ 59,400
° Transportation and Per Diem	
(1) Pre-survey, 2 men for 2 days @ $150/ day (including transportation)	600
(2) Field test, 6 men for 20 days @ $70/ day (including transportation)	8,400
° Sampling Site Preparation	
(1) Four sites @ $100 ea	400
(2) Fabrication of sheet metal ducts, hoods, etc.	6,000
° Expendable supplies; estimated @ $40/ day for 20 days	800
Total Estimated Cost	$ 75,600

* This estimate is based on the measurement and determination of emission factors from the four emission sources (power vent, natural draft vent, materials handling, and quasi-stack) at one plant.

REFERENCES FOR SECTION 5.0

1. Technical Manual for the Measurement of Fugitive Emissions: Roof Monitor Sampling Method for Industrial Fugitive Emissions. U.S. EPA - 600/2-76-089b. May 1976.

2. Technical Manual for the Measurement of Fugitive Emissions: Quasi-Stack Sampling Method for Industrial Fugitive Emissions. U.S. EPA - 600/2-76-089c. May 1976.

3. Tentative Reference Method for the Determination of Lead in Suspended Particulate Matter Collected from Ambient Air. U.S. EPA, Environmental Monitoring and Support Laboratory. July 1977.

4. Vollaro, R.F. A Survey of Commercially Available Instrumentation for the Measurement of Low-Range Gas Velocities. U.S. EPA, Emission Measurement Branch, January 3, 1977.

5. Federal Register, Vol. 36, No. 247, December 23, 1971.

6.0 STATE OF THE ART FOR DETERMINATION OF A PLANT EMISSION FACTOR FROM AMBIENT SAMPLING

As noted in Section 5.0, the three industries under consideration, namely secondary lead smelting, ferroalloy production and grey iron foundries, have similar fugitive emission sources. For example, the major sources of fugitive lead emissions from a secondary lead smelter (typically producing 45 Mg/day or 50 ton/day) all result from blast furnace operations - charging, slag tapping, and lead tapping/casting (≃ 33 g/sec or 4.3 lbs/hr). For a similarly-sized ferroalloy facility, again the principle sources of fugitive lead particulates are furnace charging and tapping operations (≃ 76 g/sec or 10.0 lbs/hr). And, for a gray iron foundry with a cupola and electric arc furnace each producing 9 Mg/hr (10 ton/hr) with an induction unit operating at 1.8 Mg/hr (2 ton/hr), the combined charging and tapping operations will produce the bulk of the fugitive lead particulates (≃ 38 g/sec or 5.0 lbs/hr).

Due to their inherent commonalities relative to fugitive lead sources, the elements of a generalized sampling approach which is applicable to each industry has been developed. The plant emission factor then may be developed from the sampling data.

6.1 GENERAL APPROACH - MONITORING AND ANALYSIS

In the case of the three industrial source-types under consideration, it appears that the best currently-available technique for measuring their ambient impact is by judiciously measuring the ambient particulate concentrations upwind and downwind of "typical" facilities with high volume samplers.[1] The contribution of emissions from nonfugitive sources can be estimated by dispersion modeling. This contribution can then be subtracted from the estimated impact for the entire plant. The remainder is then inferred to be the impact of the fugitives.

This technique is not without sources of error. Precautions should be taken in the interpretation of all measured and inferred concentrations. However, the approach is nevertheless a reasonable one for estimating the magnitude of a suspected fugitive emission problem and for identifying possible corrective actions.

The short-term, "worst case" impact of fugitive emissions at points near a plant is generally of chief concern. Accordingly, the downwind sampler(s) should be located so as to be sensitive to this impact. The number of samplers to be used to determine downwind concentrations should reflect the number, strength, and size of suspected fugitive lead sources at the facility. The field sampling program should be conducted over a sufficiently long period to assure that conditions reasonably approximating the worst case are observed.

The upwind sampler(s) should be located so as to be representative of the same air mass as that being sampled by the downwind sampler(s). It is important to ensure that no extraneous sources are affecting the sampler(s). Generally, the downwind sampler(s) should be located as near as possible to the emission sources in question. Because many of these sources are near ground level, their air quality impact is highest near the source and decreases rather quickly with downwind distance. However, for some elevated sources, such as roof monitors, the maximum air quality impact may be at an appreciable distance from the plant boundary. The selection of locations for samplers must be made with this in mind.

In order to document the relationship between measured air quality and suspected fugitive lead particulate sources, simultaneous meteorological measurements must also be made. Meteorological parameters to be measured include, at a minimum, wind speed and wind direction. The availability of on-site meteorological data is also important in situations where dispersion modeling is applied to determine the impact of nonfugitive stack emissions. For this purpose, hourly observations of temperature and cloud cover are also needed. Cloud cover may be best obtained from a nearby National Weather Service station.

Prior to conducting field sampling, three important functions must be completed:

- Field pre-survey and report.
- Sampling system design.
- Test plan and field protocol development.

These are discussed in the following sections.

6.1.1 Pretest Survey

In order to design an effective test plan, a pretest survey of the facility and its surroundings is required. A good general knowledge is required of the plant layout, process chemistry and flow, surrounding environment, and prevailing meteorological conditions. Specific operational characteristics relative to the products involved, the space and manpower skills available, emission control equipment installed, and the safety and health procedures observed, will also influence the sampling plan. Work flow patterns and production schedules that may result in periodic changes in the nature or quantity of emissions or that indicate periods for the most effective and least disruptive sampling must also be considered. Most of this information can only be obtained by a site survey and follow-on discussions with plant management. Table 6-1 notes some of the most useful data to be obtained. Additional information will be suggested by considerations of the particular on-site situation.

6.1.2 Sampling System Design

The number and location of the samples is extremely important to the successful conduct of an upwind-downwind sampling program. The design of the sampling system is influenced by factors such as source complexity and size, available sampling locations, topography, and prevailing meteorological conditions which govern the distribution of the pollutant plume in the ambient atmosphere. Most situations will in general fit into some combination of the following parameters:[1]

- Source - Sources may be either homogeneous, emitting a single type of mixture of pollutants from each and every emission location, or heterogeneous, emitting different types or mixtures of pollutants from different locations. The physical size of a source will determine the extent of the pollutant plume and may influence its homogeneity, the proximity of different emissions to each other largely influencing the degree of mixing in the plume for a given downwind distance.

Table 6-1. PRE-TEST SURVEY INFORMATION TO BE OBTAINED FOR APPLICATION OF FUGITIVE EMISSION SAMPLING METHODS [1]

Plant Layout	Drawings: Building Layout and Plan View of Potential Study Areas Building Side Elevations to Identify Obstructions and Structure Available to Support Test Setup Work Flow Diagrams Locations of Suitable Sampling Sites Physical Layout Measurements to Supplement Drawings Work Space Required at Potential Sampling Sites
Process	Process Flow Diagram with Fugitive Emission Points Identified General Description of Process Chemistry General Description of Process Operations Including Initial Estimate of Fugitive Emissions Drawings of Equipment or Segments of Processes Where Fugitive Emissions are to be Measured Photographs (if permitted) of Process Area Where Fugitive Emissions are to be Measured Names, Extensions, Locations of Process Foremen and Supervisors Where Tests are to be Conducted
Operations	Location of Available Services (Power Outlets, Maintenance and Plant Engineering Personnel, Laboratories, etc.) Local Vendors Who Can Fabricate and Supply Test System Components Shift Schedules Location of Operations Records (combine with process operation information) Health and Safety Considerations
Other	Access routes to the areas Where Test Equipment/Instrumentation Will Be Located Names, Extensions, Locations of Plant Security and Safety Supervisors

- Site - Sites should be located on level terrain with free access of ambient air from all sides, not obstructed by hills or buildings that interfere with or influence the ambient air flow either up- or downwind, or located in a valley between hills or large buildings that influence the air flow both up- and downwind. Each type of topography will influence the extent and homogeneity of the pollutant plume depending on the direction of the wind flow relative to the obstructions.

- Wind Direction - The direction of the prevailing wind determines the basic location of upwind and downwind samplers. It will influence the pollutant plume in every instance except that of a homogeneous cloud at an open level site. In other instances, the wind may be directed generally across or parallel to obstructing hills or valleys which may result in channeling, lofting, or swirling of the air flow across the site that will distort the pollutant plume.

- Localized - The homogeneity of the ambient air approaching the measurement site may affect the composition and distribution of different pollutants within the pollutant plume. Contributions from sources upwind of the site may result in variations in the pollutant concentrations in the ambient air passing over the site and thus in the pollutant plume as well.

- Wind Speed - Wind speed, which can affect the plume's size and distribution, need not be considered as a governing design factor since it is controllable by scheduling to avoid sampling during periods of either excessive wind velocity or calm conditions. Wind speeds within normal limits are taken into consideration in data reduction calculations.

The location of the samplers, especially those downwind, is critical in order to ensure that samples are taken at points known to be within the pollutant plume at measurable concentrations. An estimate of acceptable downwind sampler locations may be made utilizing the equation[2] for the diffusion of gases and particulates in the atmosphere along the plume centerline from a ground level source: $\chi = Q/\pi K u$, where

χ = pollutant concentrations representative of sampling times up to one hour at receptor point, gm/m^3

Q = source emission rate, gm/sec

K = product of standard deviations of vertical and horizontal pollutant distribution, m^2

u = wind speed, m/sec

This equation assumes a Gaussian distribution of pollutants in both the vertical and horizontal directions and no deposition or reaction of pollutants at the earth's surface. By rearranging terms, the product of the standard deviations (K), which are functions of the downwind distance (x) of the receptor from the source, may be determined as a function of easily estimated or measured parameters in:

$K = Q/\pi\chi u$, where[1]

Q is estimated from published emission factors,

χ is set equal to a selected hourly value related to the sampling method detection limit, and

u is measured at the site.

The maximum downwind sampler distance from the source along the axis of the wind direction (x) may then be determined from the curves of Figure 6-1,[1] which relate K and x for various atmospheric stability categories. For distances

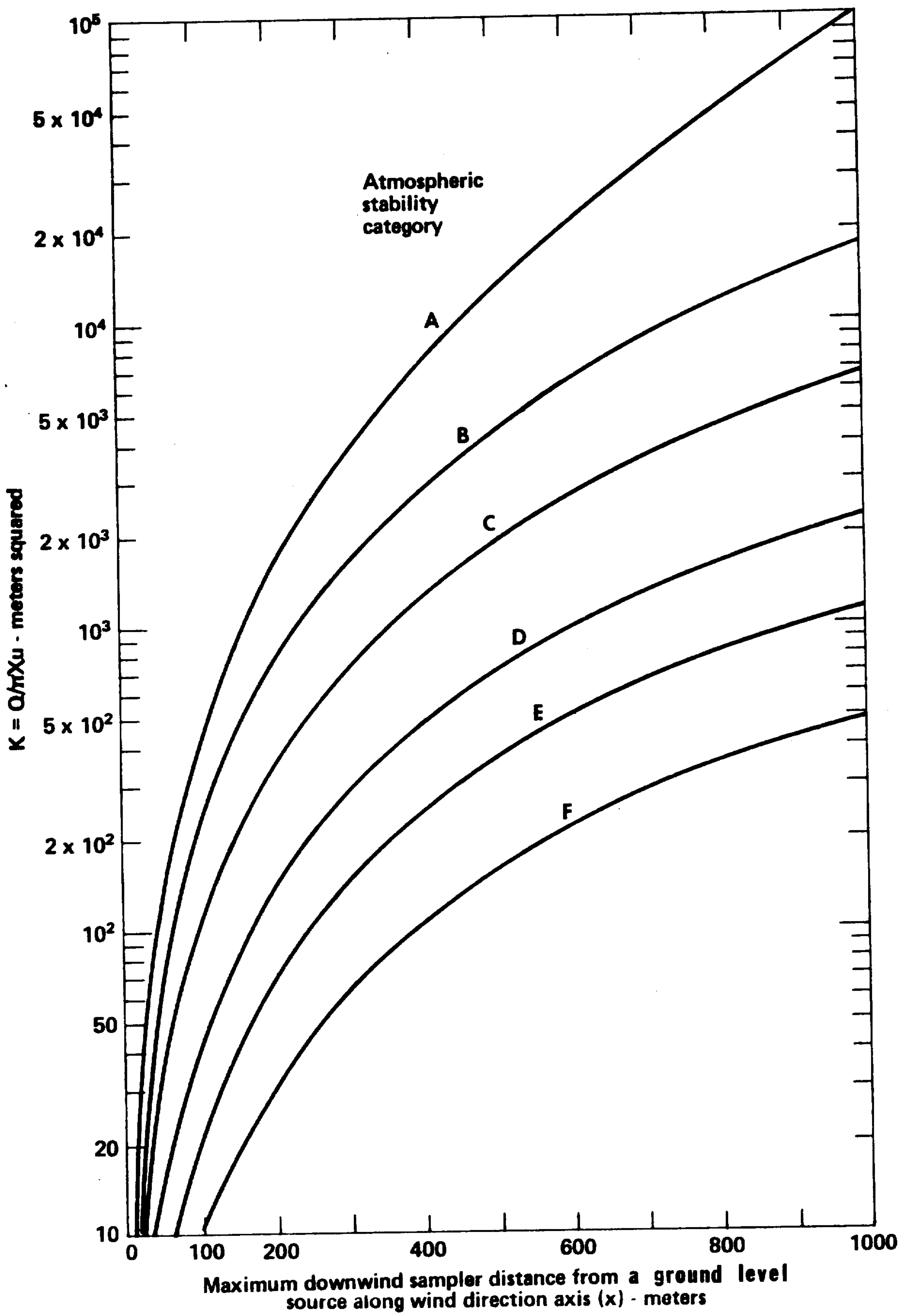

Figure 6-1. Maximum downwind sampler distances.(1)

less than 100 meters the curves have been extrapolated from original data[2] and should be used with caution espcially when comparing measured and estimated concentrations. The stability categories are listed and explained in Table 6-2.[1]

Table 6-2. ATMOSPHERIC STABILITY CATEGORIES[1]

Wind speed m/sec	Day* Solar altitude† > 60°	35°-60°	15°-35°	Night Thin Overcast or > 50% Clouds	< 50% Clouds
< 2	A	A-B	B	-	-
2-3	A-B	B	C	E	F
3-5	B	B-C	C	D	E
5-6	C	C-D	D	D	D
> 6	C	D	D	D	D

* Day is one hour after sunrise to one hour before sunset.
† Solar altitude may be determined from Table 170, Solar Altitude and Azimuth, Smithsonian Meteorological Tables. Use neutral class D for overcast conditions at any time. Partial cloud cover (60 percent to 85 percent) will reduce effective solar altitude one division (e.g., from > 60° to 35°-60°) for middle clouds and two divisions (e.g., from > 60° to 15°-35°) for low clouds.

When suitable x-distances have been selected, which may be any distance less than the maximum determined from Figure 6-1, cross-wind distances (y) perpendicular to the x-axis must be determined that will ensure that samples are taken within the limits of the plume. Maximum cross-wind distances are plotted as a function of x in the curves of Figure 6-2 for the same atmospheric stability categories used in determining x.[1]

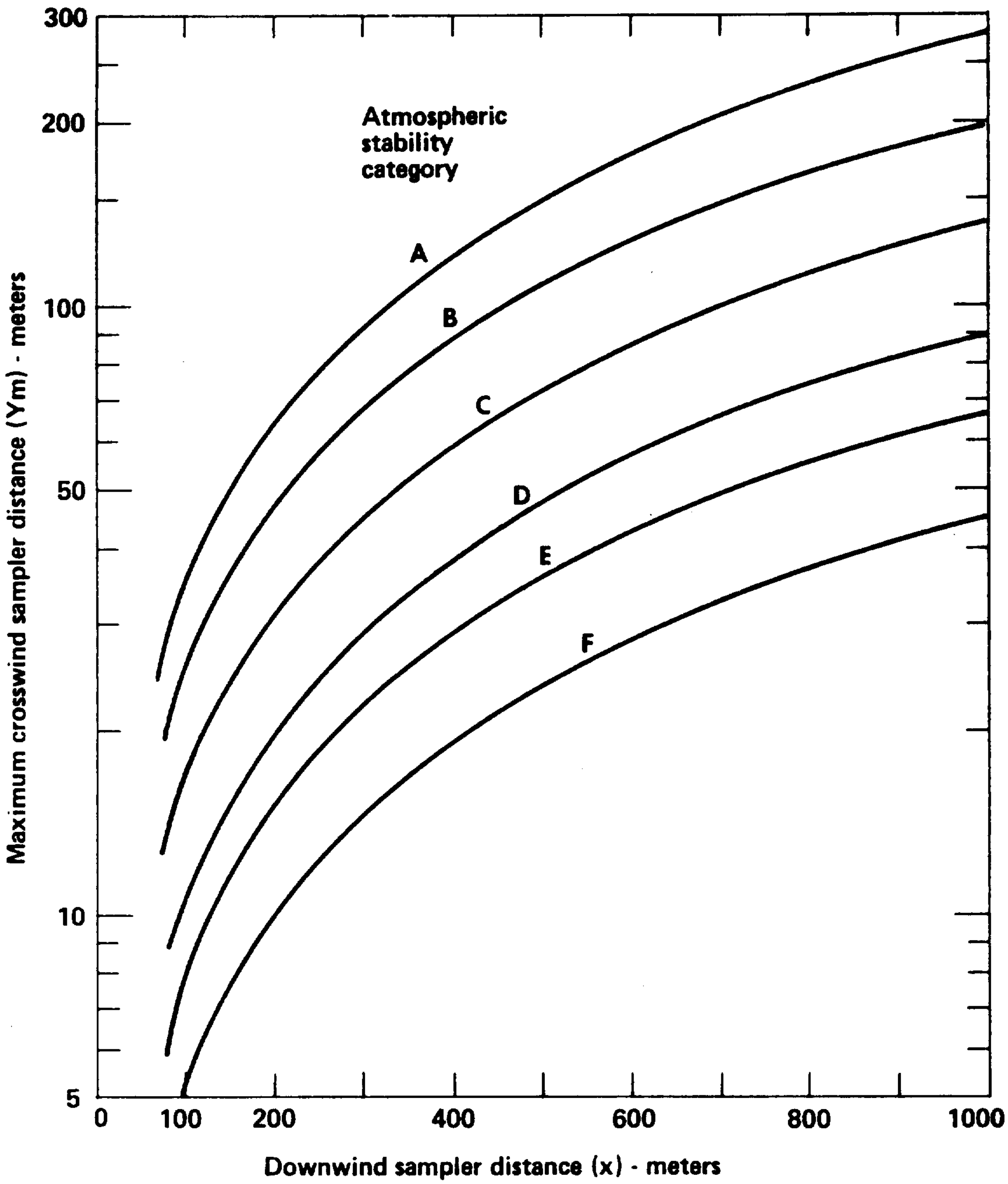

Figure 6-2. Maximum crosswind sampler distances.(1)

To illustrate the application of the equations and curves presented in this section, assume a source emitting particulates into a four m/sec wind, u (expected at site), at an estimated emission rate, Q, 30 g/sec (from emission factors and plant production rate) and a sampler with a lower detection limit, M, of 0.001 g and flow rate, F, 1.4 m^3/min (50 cfm). For an expected sampling time, T, of 60 minutes, the required pollutant concentration, χ, at the sampler is $\chi = M/FT$, where [1]

$M = 0.001$ g,

$F = 1.4\ m^3/min \times 1.5$ adjustment factor (to compensate for likely inaccuracies in estimates of concentra tion) = 2.1 m^3/min, and

$T = 60$ minutes,

thus $\chi = 8 \times 10^{-6}\ g/m^3$

The product of the pollutant plume's standard deviations, K, is found in the equation $K = Q/\pi\chi u$, where

$Q = 30$ g/sec

$\chi = 8 \times 10^{-6}\ g/m^3$, and

$u = 4$ m/sec,

thus $K = 3 \times 10^5\ m^2$

As you can see from this K and Figure 6-1, our maximum downwind distances for sampler locations for any atmospheric stability category will exceed 1000 meters.

Now as an additional example, to measure the plant emissions under a worse case condition let us assume this occurs during very early morning with clear skies and a 2 m/sec wind speed resulting in a stability category F. We are able to locate a sampler 600 meters downwind from the plant and obtain a one hour sample. Our resulting (measured) χ, after we have adjusted for background, is 4×10^{-3} g/m^3. From Figure 6-1, K is 200 m^2. Therefore, our empirical plant emission rate is 5 grams per second.

Upwind samplers should ideally be located on the wind direction axis just far enough upwind to prevent sampling the backwash of the pollutant plume. A minimum upwind distance of roughly twice the height of the building housing the source will usually be sufficient.

6.1.3 Field Test Plan

The field test plan provides a formal specification of the equipment and procedures required to meet the objectives of the measurement program. It is based on the information collected in the pretest survey and defines the required sampling equipment, procedures, and schedules consistent with the program objectives in light of the constraints imposed by the specific source being evaluated. A suggested[3] outline for the field test plan is abstracted as follows:

- Background - The introductory paragraph containing the pertinent information leading to the need to conduct the measurement program and a short description of the information required to answer that need.

- *Objective* - A concise statement of the problem addressed by the test program and a brief description of the program's planned method for its solution.

- *Approach* - A description of the measurement scheme and data reduction methodology employed in the program with a discussion of how each will answer the needs identified in the background statement.

- *Instrumentation/Equipment/Facilities* - A description of the instrumentation arrays to be used to collect the samples and meteorological data identified in the approach description. The number and frequency of samples to be taken and the sampling array resolution should be described.

  A detailed description of the equipment to be employed and its purpose.

  A description of the facilities required to operate the measurement program, including work space, electrical power, support from plant personnel, special construction, etc.

- *Schedule* - A detailed chronology of a typical set of measurements, or a test, and the overall schedule of events from the planning stage through the completion of the test program report.

- *Limitations* - A definition of the conditions under which the measurement project is to be conducted. If, for example, successful tests can be conducted only during occurrences of certain source operations, those favorable limits should be stated.

- *Analysis Method* - A description of the methods which will be used to analyze the samples collected and the resultant data, e.g., statistical or case analysis, and critical aspects of that method.

- *Report Requirements* - A draft outline of the report on the analysis of the data to be collected along with definitions indicating the purpose of the report and the audience it is to be directed to.

- Quality Assurance - The test plan should address itself to the development of a quality assurance program. This QA program should be an integral part of the measurement program and be incorporated as a portion of the test plan either directly or by reference.
- Responsibilities - A list of persons who are responsible for each phase of the measurement program, as defined in the schedule, both for the testing organization and for the plant site.

6.2 SPECIFIC APPROACH FOR FUGITIVE LEAD SAMPLING

As previously noted, fugitive lead emissions from all three industries under consideration eminate from furnace charging, tapping, and affiliate process operations as well as reentrainment of settled dust by wind and vehicles. Therefore, recognizing that for a specific industrial facility there may well be a series of constraining factors (operational, topographical, physical, etc.) which will influence the actual sampling program required, an approach has been developed which presents a reasonable plan for a typical source evaluation. The approach presented is somewhat idealized in that only minor constraints have been placed on the resources and time allocated. In actual application, practical considerations may well dictate or permit reductions in both resources (personnel and equipment) and sampling period.

Based on the plant configuration and the frequency distribution of wind directions in the area, a single high-volume sampler should be positioned upwind of the plant fence line and four samplers along the downwind fence line. For illustrative purposes, Figure 6-3 depicts the proximate location of these samplers, as well as the physical plant layout, location of paved roads, and local topographic features as they would be alligned for upwind/downwind sampling at a typical cement plant assuming prevailing wind direction is westerly.[4]

Sampling periods should be selected so as to be representative of both routine and maximum operating conditions if at all possible. Plant management should agree to keep a record of in-plant operating activity during the periods selected for sampling. By correlating the measured particulate lead levels with source-related activities, the agency will be able to determine if it is possible to develop meaningful emission or air quality impact factors by the upwind/downwind technique.

6.2.1 Sampling Protocol

The upwind/downwind monitor configuration should consist of a monitoring site at the upwind plant fence line, including one high-volume air sampler and a recording meteorological system. On the downwind side of the source, near the property line, four high-volume air samplers will be located parallel to the fence line at intervals of ap-

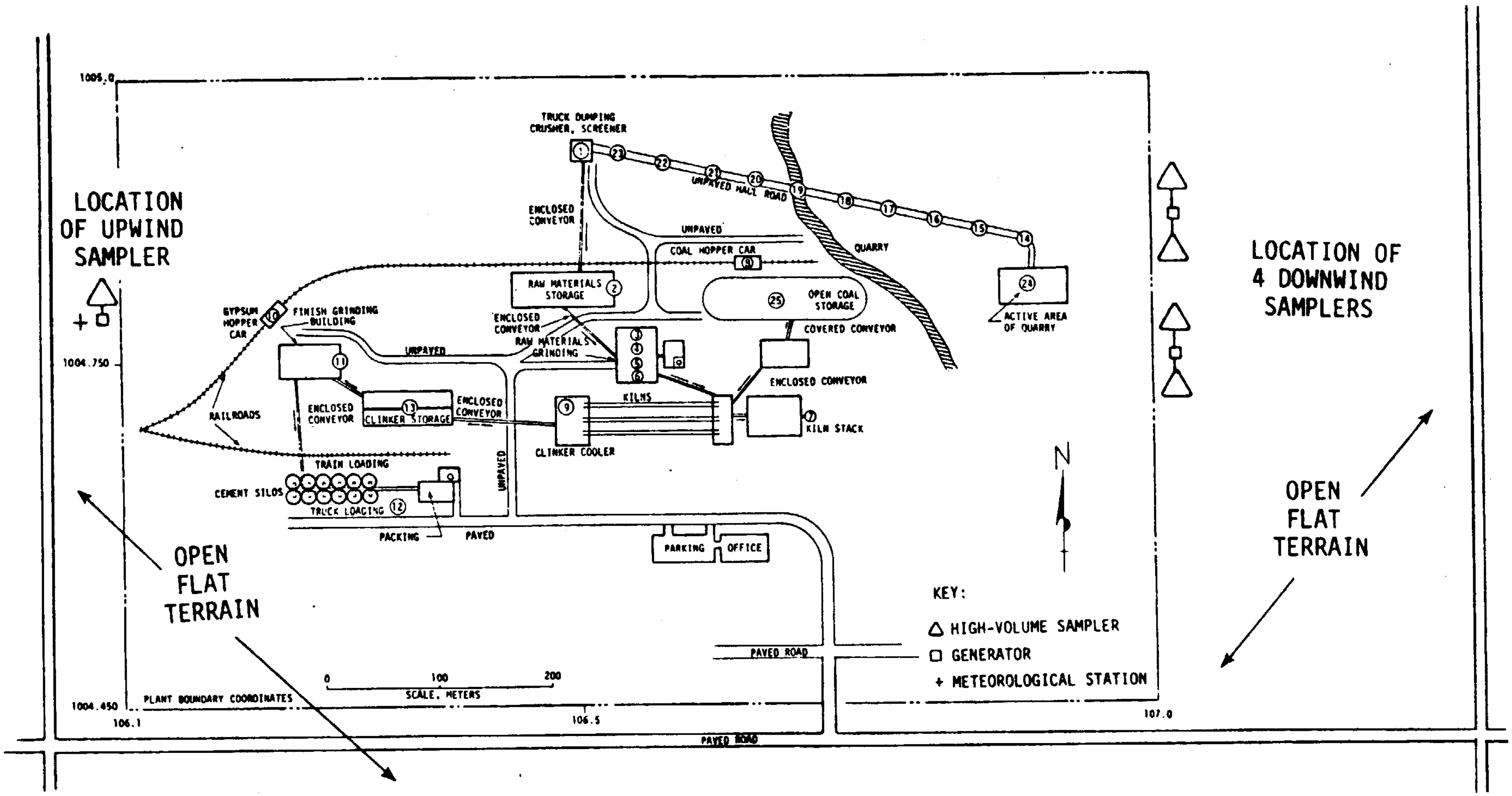

Figure 6-3. Upwind/downwind sampler locations for cement plant.[4]

proximately 60 meters (200 ft). The upwind site will employ a small generator to power the single sampler and the meteorological station; the other sites will require two larger motor generators for electrical power. One generator is necessary for each pair of downwind samplers. The generator is placed between the pair of samplers with 30 meter (100 ft) power lines to each sampler. Three field technicians will perform the tests, one at each generator location. Whenever the wind direction is verified to be from the upwind direction (± about 20 degrees), the technician at the meteorological control site will contact the other technicians via radio and initiate sampling. Each sampling period will be as long as practicable, during which the wind direction will be monitored to determine whether it persists from the desired directional sector. A decrease in flow rates of more than 10 percent on the downwind samplers indicates that sufficient sample has been collected, and the test period will be terminated. The above program will be repeated several times (approximately three to six) with the objective of observing optimum conditions of speed and directional persistence of the wind. Also, it is imperative that various source operational conditions be observed.

6.2.2 Monitoring Instrumentation

The two basic measurements required for this task are the measurement of wind speed/direction and the total suspended particulates in the ambient air.

Meteorological Monitoring - Wind speed and direction should be monitored using instrumentation meeting the specifications in EPA's Ambient Monitoring Guidelines for Prevention of Significant Deterioration (PSD), as follows:(5)

- Systems should exhibit a starting threshold of less than 0.5 m/sec wind speed (at 10 degrees deflection for direction vanes). Wind speed systems should be accurate above the starting threshold to within 0.25 m/sec at speeds equal to or less than 5 m/sec. At higher speeds, the error should not exceed 5 percent of the observed speed (maximum error not to exceed 2.5 m/sec).
- The damping ratio of the wind vane should be between 0.4 and 0.65.
- Wind direction system errors should not exceed 3 degrees from true 10-minute or greater averages, including sensor orientation errors.
- The standard exposure of wind instruments is 10 meters above level, open ground. Where this is not possible, the anemometer should be installed such that its indications are reasonably unaffected by local obstructions.

Total Suspended Particulate Monitoring - Total suspended particulates will be collected with a high-volume air sampler, as described in the Code of Federal Regulation 40, Part 50.11, Appendix B, July 1, 1975, Pages 12 through 16.

Specifically, five samplers are required, which will be equipped with the following ancillary equipment:

- Dixon flow recorders
- Running time meters
- Quick-change filter cartridges

Monitoring Support Equipment

Support equipment to be used is listed below:

- High-volume air sampler calibration kit
- Three motor generators:

  1) Two 3-KVA, 5-hp gasoline
  2) One 1.5-KVA, 3-hp gasoline

- Sampling van with covered bed
- Power extension cords; five 30 m (100 ft) cords of No. 12 wire with ground and exterior duplex receptacles, two 15 m (50 ft) cords of No. 14 wire with ground, and exterior extension cords
- Preweighed fiberglass filter media consisting of 100 filters, folders, envelopes, and data sheets
- Three portable citizen-band radios

6.2.3 Analytical Requirements

Various analytical requirements exist with respect to the determination of fugitive lead emissions on ambient air quality. They can be summarized as follows:

- Filter media for use with the various sample collection systems. This media must be preweighed following the published U.S. EPA QA guidelines.
- Calibration equipment for field sampling equipment.
- Analytical services for gravimetric analyses.
- Analytical services for lead analyses.
- Quality control audit functions for both field and laboratory operations.

The EPA tentative reference method for lead analysis was discussed in Section 5 and is presented in Reference 6.

This method can be employed, with minor alterations as the sample type may dictate, for the determination of lead content of samples collected.

6.2.4 Scheduling

The test program schedule is presented in Figure 6-4. Ten specific tasks are defined and programmed over an anticipated period of performance of 25 days. This schedule allows ten working days for field monitoring. This period may turn out to be much shorter if the desired meteorological conditions are observed relatively early in the program. However, the desired conditions may not be observed at all and therefore the time period may have to be extended. Additionally, Figure 6-5 presents a test activity schedule to be used by the supervisory field technician in conducting each field test in the series. Eight specific activities are defined over a projected 9-hour test period.

6.2.5 Laboratory Procedures and Data Reporting

The suspended particulate loading will be determined according to the method described in the Code of Federal Regulations 40, part 50.11, Appendix B, July 1, 1975, pages 12 through 16. The lead fraction will be determined by the methodology referenced in 6.2.3. The particulate material on the exposed filter will be equilibrated under the same temperature and humidity conditions as experienced in weigh-

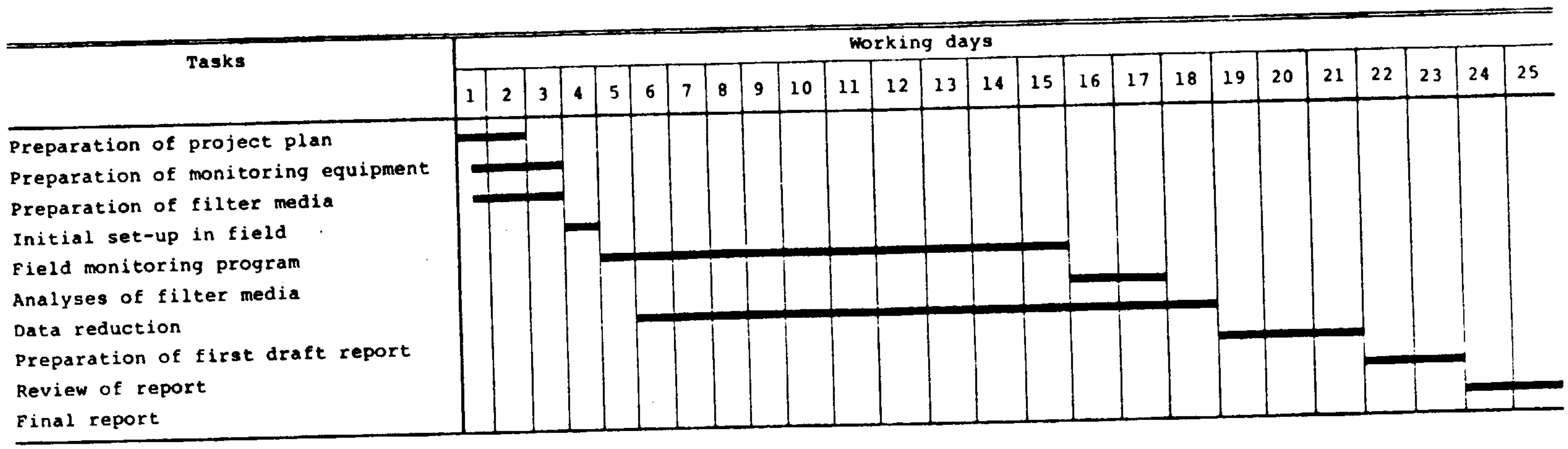

Figure 6-4. Test program schedule.

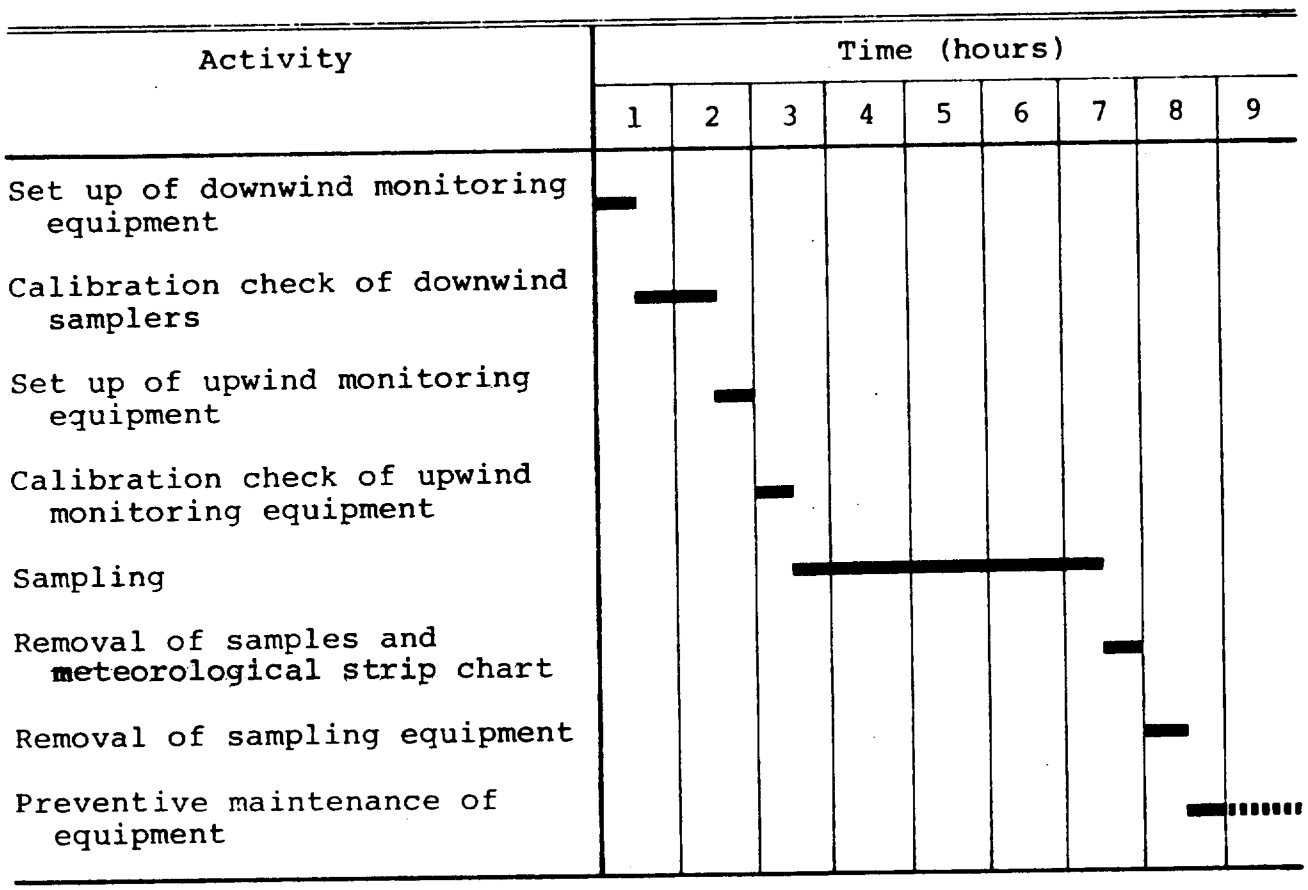

Figure 6-5. Field test schedule.

ing the unexposed filters. The weight of the particulate material collected on exposed filters will be determined gravimetrically. The calculated TSP and lead concentrations are based on the net weight of collected material and the sample air volume corrected to standard conditions (760 mm Hg and 25°C). These data will be reported on a separate data sheet for each test in the series. This data sheet will include the following information:

- Date/time of sampling
- Test series identification
- Identification of the specific location of each sampler
- TSP concentration expressed in $\mu g/m^3$
- Lead concentration expressed in $\mu g/m^3$

In addition, the meteorological data for the specific study period should be reduced and reported in SAROAD format.

Quality control procedures to be followed throughout this test series will be consistent with those defined in "Quality Control Practices in Processing Air Pollution Samples," U.S. Environmental Protection Agency Publication No. APTD-1132. After all data have been reduced to SAROAD format, an independent audit will be performed on 7 percent of all values reported.

6.3 MANPOWER ESTIMATES

Table 6-3 presents an estimate of manpower requirements for a typical 10-day test program as described in the above

Table 6-3. ESTIMATED MANPOWER REQUIREMENTS WITH RESPECT TO TASKS AND MANPOWER CATEGORIES (MANHOURS)

Tasks	Personnel - Man-hours			
	Project Manager	Chemist	Sr. Tech.	Tech.
Preparation of project plan	16			
Preparation of monitoring equipment			20	20
Preparation of filter media		2		6
Initial field set up and checkout			8	16
Field monitoring program			80	160
Data reduction and analyses	4	8	20	80
Quality assurance program		4	8	
Preparation of first draft reports	20	10	10	20
Preparation of final reports	8	4		4
Total man-hours	48	28	146	306

sections. A total of approximately 528 man-hours/plant evaluation is projected. This level of effort does not include any specialized site preparation, such as grading, which would require the services of a subcontractor. Therefore, assuming no extraordinary services/resources are required, the cost per upwind/downwind test series can be estimated as follows:

Item	Estimated Cost
° Burdened Labor; 528 hours @ $22/hr	$ 11,600
° Transportation and Per Diem	
(1) Pre-survey, 2 men for 2 days @ $150/day (including transportation)	600
(2) Field test, 3 men for 10 days @ $70/day (including transportation)	2,100
° Sampling Site Preparation; 5 sites @ $100 ea.	500
° Expendable Supplies; estimated @ $40/day for 10 days	400
Total Estimated Cost	$ 15,200

6.4 CALCULATION OF PLANT EMISSION FACTOR

The upwind/downwind sampling program provides an indication of the total plant impact - conventional point sources as well as fugitive emission sources. In order to determine the impact of only the fugitive emission sources, it is necessary to subtract the impact of the conventional point sources. Subtracting the upwind concentrations and predicted pollutant concentrations contributed by conventional point sources at the downwind measuring site from the actual downwind measured values yields the fugitive impact.

For monitoring to be reliable, the data collection program must be comprehensive in scope and subject to strict quality control. Also, the interpretation of monitoring results is not always straightforward. Neighboring sources and/or high background concentrations often present complications. This is especially true for urban or industrialized areas. High background concentrations or severe influence from other sources can make it very difficult, if not impossible, to isolate and separate the actual plant contribution to measured air quality. Even when it is possible to isolate the impact of the plant of concern, it is often difficult to relate the total impact to the individual contributing sources in the plant complex. It is even difficult in some cases to adequately distinguish the impact of fugitive sources from that of the stack emissions.

An estimate of the contribution of the conventional point sources under the meteorological conditions that occurred during a given sampling interval may be determined by the application of a dispersion model. The major disadvantage is the uncertainty associated with model estimates. The major sources of error in dispersion modeling are as follows:

- Inadequacies in the simulation of physical phenomena by models
- Inadequacies in the input data to models
- Lack of expertise in applying models and in interpreting the results.

To the extent practicable, emissions from nonfugitive sources should be quantified and characterized for the specific days of interest. For example, it is entirely likely that a source whose controls normally operate at a specified collection efficiency may, on a particular day, actually be emitting at a rate much higher than normal. If such were the case, the point source modeling results based upon the normal emission rate would greatly underestimate the contribution of nonfugitive sources and thereby exaggerate the inferred impact of the fugitive sources.

Once the ambient fugitive emission impact has been determined a dispersion model can again be applied to back-calculate the estimated fugitive emission source strength or emission rate. The fugitive emission rate divided by the plant production rate will result in the plant fugitive emission factor. The results from several plants are necessary if an industry-wide plant fugitive emission factor is to be developed. This factor may also include such parameters as plant capacity and lead content of the raw materials.

REFERENCES FOR SECTION 6.0

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7.0 CONCLUSIONS AND FACTOR DEVELOPMENT CONSIDERATIONS

In Sections 2.0 through 6.0 of this report, the current status of information relative to fugitive lead emissions from the three source categories in question, plus both inplant emissions and ambient impact quantification techniques, has been summarized.

In this section we present our evaluation of these factors, resulting in conclusions and formulation of recommendations dealing with the development of fugitive lead emission factors from data gathered by a field measurement program.

7.1 CONCLUSIONS

Based on our evaluation of information available in existing literature, the following conclusions are apparent:

- There are insufficient data from which to develop reliable industry-wide fugitive lead emission factors for all three categorical sources.
- Evaluation of very limited ambient lead sampling data, in light of proportional estimated impact from identified fugitive lead sources, indicates that all three process sources examined have a realistic potential for emitting fugitive lead-bearing materials which will cause local ambient lead measurements to exceed 1.5 $\mu g/m^3$ on a regular basis.

- It is not possible to apply fugitive lead emission data/factors developed for several other similar process sources to the three categories under investigation, basically due to significant differences in raw materials being processed and techniques used.

- It is not feasible to develop an industry wide fugitive lead emission factor based on plant production using the upwind-downwind ambient monitoring technique due to the following reasons:

  1. The use of this ambient monitoring technique coupled with dispersion model estimates of the nonfugitive impact is open to significant and variable sources of error.

  2. There is a variation in lead content in the raw materials used in these industries. In addition, each process within a facility may undergo variations in throughput.

  3. The number and type of individual processes per plant vary within the industry. Also, the levels of control at each plant are not the same.

- It is possible to develop a short-term, "worst case" plant wide lead emission factor using the upwind-downwind technique. This would be especially applicable for enforcement or compliance purposes.

- In-plant sampling of fugitive lead emission points such as draft and fan vents, roof monitors, materials handling operations, hood exhausts, and furnace/cupola charging and tapping, can be accomplished using available sample collectors and state-of-the-art techniques such as "quasi-stack." While the measurement methods are not universally accepted or standardized, they are capable of providing relative and reproducible results applicable to the development of reliable fugitive lead emission factors.

Finally, as pointed out previously, the three industries (secondary lead smelting, ferroalloy production and gray iron foundries) have similar fugitive emission sources such as: blast furnace charging/tapping, pot furnace charging/melting/tapping, materials handling, electric arc furnace charging/smelting/tapping, and cupola charging/tapping. Most of these operations normally occur inside plant buildings with the fugitive emissions escaping to the atmosphere through vents, monitors, leakage, or due to poor housekeeping. Open sources, such as materials handling, also occur. Since the three industries have these common types of fugitive emission points, their sampling approaches would be similar.

All of the above leads to a final conclusion that it is technically feasible (within state-of-the-art limitations) to conduct an inplant fugitive lead emissions measurement program leading to the development of reliable lead emission factors applicable to sources common to the industry operations evaluated in this report. Further, considering the real or potential impact these emissions have on atmospheric lead levels, it would appear there is a need to have these factors available for future use by agencies as an aid in determining the possible compliance status of those categorical sources within their jurisdiction.

7.2 FACTOR DEVELOPMENT CONSIDERATIONS

If U.S. EPA wishes to develop fugitive lead emission factors for the three industrial categories in question, several items must be considered. Following, in general terms, are these major considerations.

7.2.1 Number of Plants and Operations to be Tested

- Secondary Lead Smelters - Since approximately two-thirds of the production from secondary lead smelters is from blast furnaces, testing of this furnace type would cover the majority of the industry. However, plant-to-plant variations in the operation of furnaces could not be identified from literature sources. The effect this variation may have on fugitive lead emissions is not known but is something that could be determined as a result of the test program. Testing of blast/reverberatory furnace operations will cover the large sources in the industry. Additional testing of pot furnaces will complete the sources of fugitive lead emissions in this industry. All of these sources may possibly be found at one smelter, but testing at more than one plant is suggested so that results will be more representative of industry-wide emission rates. This will also minimize bias of the results by a single plant and will permit an analysis relating emission levels to lead content of the raw materials.

- Ferroalloy Plants - Based on product distribution, representative results will not be obtained by testing only one plant which produces just one type of ferroalloy. Tests must include the major ferroalloy products; ferro-silicon and ferro-manganese, followed in importance by ferro-chromiums and silicomanganese. Tests possibly could be completed at one facility, but would likely require several plants to complete a full test program. The test program should also include analysis of the raw materials (ores) for lead content. This will provide the necessary data to determine how the fugitive lead emission factors are related to type of product, lead content of the ore, or both.

- Gray Iron Foundries - The melting furnaces are the major source of fugitive lead emission found in the gray iron foundry. To obtain representative test results, the cupola must be given the highest priority for sampling since it produces 70 percent of all gray iron. Electric arc furnaces should have the next highest priority in the sampling program since together, they account for over 85 percent of all gray iron production. Since electric induction and reverberatory furnaces are a minor part of the gray iron industry, these furnaces could reasonably be omitted from the sampling program. Additionally, while the quantities of lead emissions expected from iron innoculation, pouring into molds, casting, shakeout, cleaning and finishing are unknown, emissions are expected to be small since it is likely that the majority of lead contained in the furnace charge material is emitted from the furnace as fume or removed in the slag.

In summary, a minimal, but reasonable, inplant sampling program for the three industry types is tabulated as follows:

Plant Type and Number Tested	Source	Operations
Secondary Lead Smelters - 2	Blast Furnace	Charging/ tapping
	Pot Furnace	Charging/ melting/ tapping
Ferroalloy Plants - 2	Electric-arc Furnace	Charging/ smelting/ tapping
Gray Iron Foundries - 2	Cupola	Charging/ tapping
	Electric-arc Furnace	Charging/ melting/ tapping

In addition, at all plants the handling and transfer operations should be sampled. Also, raw material samples should certainly be taken for comparative analysis with fugitive samples.

7.2.2 General Cost Estimate/Schedule

A cost estimate was presented in Section 5.0 for emission factor development for individual processes within one facility. Since there are process variations between facilities within the three categories studied, a suggested test program with cost estimate (±15%) is developed herein for a six-plant, two per category, test series. There are considerable savings of resources due to efficiencies gained in a multiple plant test program. The following assumptions have been made:

- Each field test/plant will require an average of 12 days (10 test days plus 2 travel days) instead of 20. This reduction in the number of sampling days will occur as a result of a multiple test series. Repeated tests will increase the familiarity with the process and sampling techniques which will result in greater efficiency.
- Pre-survey travel and man-hour requirements can be reduced by 40 percent through planning and dual-purpose trips.
- Fabrication costs for specialized field sampling ducts, temporary hoods, etc., can be reduced by 50 percent through multiple use in various plants.

Therefore the estimated cost/test series/plant presented on Page 5-25 is modified as follows:

Item	Estimated cost*
° Burdened labor, 1640 hours @ $22/hr	$36,080
° Transportation and Per Diem	
(1) Pre-survey, 2 men for 1.2 days @ $150/day (including transportation)	360
(2) Field test, 6 men for 12 days @ $70/day (including transportation)	5,040
° Sampling Site Preparation	
(1) Four sites @ $100 ea	400
(2) Fabrication of sheet metal ducts, hoods, etc.	3,000
° Expendable supplies; estimated @ $40/day for 12 days	480
° Analysis of raw materials	400
Total Estimated Cost	$45,360

* This estimate is based on the measurement and determination of emission factors from the four emission sources (vents, common sources, materials handling, and quasi-stack) at one plant.

Therefore, if the six-plant series were to be implemented, U.S. EPA should anticipate an expenditure in the range of $230,000 to $310,000. Additionally, the entire test series, plus data analysis and reporting, should be able to be accomplished over an eight to nine month period.

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15. SUPPLEMENTARY NOTES

EPA Task Officer - Charles C. Masser

16. ABSTRACT

This report summarizes current information relative to fugitive lead emissions from secondary lead smelters, ferroalloy plants, and gray iron foundries. Also included are an investigation of the application of fugitive lead emission factors from other source categories to the three subject industries, and a report on the applicability of fugitive lead factors that could be developed from a field study. Current state of the art techniques for source measurements of fugitive emissions (i.e. inplant) and ambient measurements of fugitive emissions (i.e. upwind/downwind) are presented and compared. This report aids in determining if field studies are worthwhile and recommends the types of studies to be followed.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Air Pollution	Emission Factors	13B
Dust	Fugitive Dust	11G
Metallurgy	Secondary Lead Smelters, Ferroalloy Plants, Foundries	11F, 13H
Lead		

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