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# Project Summary



# Level 1 Environmental Assessment of Electric Submerged-Arc Furnaces Producing Ferroalloys

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**An EPA/IERL-RTP Level 1 multimedia environmental assessment of the ferroalloy industry was conducted. The report contains general industry statistics and the results of sampling and analysis at three plants (six furnaces total).**

**The industry is facing severe pressure from imported products and its continued viability is uncertain. In addition, this report indicates that the potential for serious environmental problems exists within some segments of the industry but does not prove that the pollution problems are occurring. Specifically, the pollution potential of covered (mix-sealed and sealed) furnaces is substantially higher than for open type furnaces, primarily due to the high concentration of organics in gases generated by covered furnaces. The covered furnaces are estimated to generate polycyclic organic material (POM) at the rate of about 1,230 to 11,080 kg/yr (2,710 to 24,430 lb/yr) per megawatt of furnace capacity or 208,800 to 1,878,800 kg/yr (460,300 to 4,120,000 lb/yr) for all U.S. furnaces of this type. Open furnace POM generation rate is estimated to be 100 to 900 kg/yr (220 to 1,980 lb/yr) per megawatt of furnace capacity or 134,500 to 1,210,500 kg/yr (296,500 to 2,668,700 lb/yr) for all U.S. furnaces of this type. Covered furnaces comprise only 14 percent of the industry's production capacity and no growth in their use is expected. These estimated nationwide POM generation rates (estimated rates before the emission control devices) are in the same order of magnitude as estimated POM generation rates (before control devices) of slot type coke ovens, which EPA considers to be a major emitter. However, the control devices, which are in use on all U.S. ferroalloy furnaces, remove most of this material from the gas stream. Samples from one mix-sealed furnace were analyzed by GC/MS which gave positive identification of known organic carcinogens in both the clean gas discharged by the scrubber *(but before passing through the flare which is expected to destroy some organics)* and in the water discharged by the scrubber (which is treated before discharge from the plant). Low resolution mass spectrographic (LRMS) analysis indicates the presence of carcinogens in the cleaned scrubber discharged gas (before flaring) or four of the five scrubber equipped furnaces tested, and the water discharged from all scrubbers tested (before wastewater treatment), and in the gases generated by one open furnace served by a baghouse (emissions from the baghouse were not determined). LRMS indicated the presence of carcinogens in the wastewater discharged by only one (no longer operating) of the three plants tested.**

**The report indicates areas in which further study and/or emissions quantification is needed.**

***This Project Summary was developed by EPA's Industrial Environmental Research Laboratory, Research Triangle Park, NC, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).***

## Introduction

Ferroalloys are alloying elements which when added to molten iron or steel impart specific characteristics, such as hardness, ductility, and corrosion resistance, to the finished product. The United States is one of the world's largest producers and consumers of ferroalloys. Annual U.S. production is about 1.45 million tonnes and consumption is about 2.1 million tonnes.

Ferroalloys are manufactured primarily in submerged arc electric furnaces. Other production and refining methods are vacuum and induction furnaces, exothermic (alumino-silico-thermic) processes and electrolytic manufacture of high purity metals.

The submerged arc furnace, Figure 1, consists of a refractory lined crucible with a tap hole near the hearth level to withdraw the molten product. Power is supplied to the furnace through carbon electrodes which extend downward through the charge material to a point slightly above the hearth. Charge materials, which include ores, scrap iron, gravel, coal, coke, and sometimes woodchips, are fed to the furnace as required to keep the crucible filled. The electric current passing into the furnace raises the temperature of the charge into the range that the reduction reactions (basically removal of oxygen from the metals) can occur. Large volumes of carbon monoxide gas are produced in the reduction reactions. Furnace power consumption rates range from about 7 megawatts to over 50 megawatts depending on furnace size and product being made.

Furnaces are categorized by the type of furnace top cover used. There are two basic categories (open and covered) and two subtypes for each basic category. The open category is composed of totally open furnaces in which there is an open gap of one meter or more between the crucible top and the fume collecting hood, and close hooded in which this gap is significantly reduced by removable doors or panels that reduce the amount of air drawn into the hood system. The covered category includes the mix-sealed furnaces in which a tight-fitting cover is installed on the crucible and is partially sealed by raw materials mounded over the openings in the cover through which the electrodes pass, and sealed furnaces which are similar to the mix-sealed furnace except mechanical seals are used around the electrodes. Two emission control systems are used with covered furnaces, one system to withdraw gases from beneath the cover (primary control system) and a hood system above the cover to collect fumes escaping the cover (secondary control system).

New Source Performance Standards (NSPS) for emission to the atmosphere from ferroalloy manufacture were based on best available control technology for the open type furnaces. EPA data collected in support of these standards showed that a particulate emission standard based on sealed furnace technology would have resulted in even lower particulate emissions. This standard was not adopted because of an objection that such a standard could seriously affect the industry's ability to respond to rapidly changing market conditions by restricting their ability to manufacture different products in the same furnace.

EPA did, however, decide to further investigate the subject of product flexibility recognizing that solution of this problem could ultimately lead to standards of performance based on sealed furnace technology. This task was assigned to EPA's Industrial Environmental Research Laboratory (IERL) in Research Triangle Park, N. C. As a first step, IERL analyzed some of the samples previously obtained and found indications that sealed furnaces generated substantially more organics, including polynuclear aromatics (PNA), than did open furnaces. To verify this finding, gases generated by one sealed furnace, which was alternatively producing silicomanganese and ferromanganese, were sampled and analyzed. That study, which experienced some sampling difficulties, did indicate that a significant concentration of PNAs exist in the gases generated by the furnace and that high energy venturi scrubbers might be effective in their capture.

Since these test results suggested that a standard of performance based on sealed furnaces might result in decreased environmental protection, a decision was made to more fully characterize

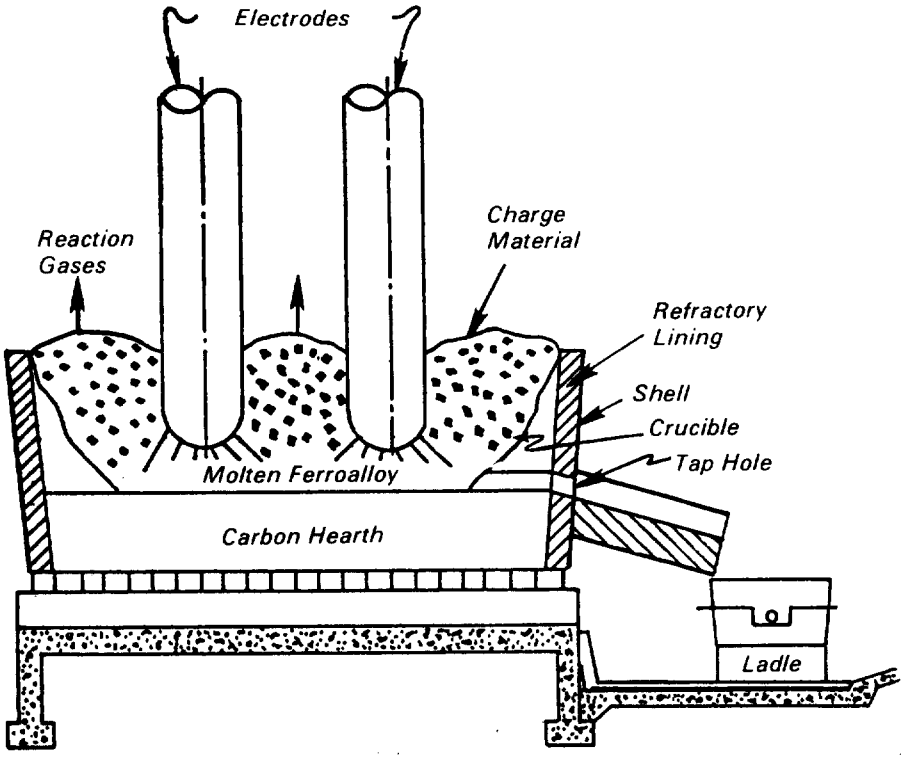


*Figure 1. Submerged-arc furnace for ferroalloy production.*

pollutants generated by and emitted from ferroalloy furnaces. The present study is the first phase of this effort. A complete multimedia environmental assessment of the industry was desired; however, funding limitations prevented such a comprehensive study. The study design which resulted from consideration of funding limitations, and the need to explore the pollutant generation potential of several ferroalloy furnaces, particularly the mix-sealed type, do not include furnace types and mode of pollution control (i.e., baghouse or scrubber) in the same proportions as they exist in the industry. The design is believed, however, to accomplish the next logical step in the assessment and to represent the best approach for the available funds.

The primary objective of this study is to determine if there is a significant difference in the types and amounts of organic pollutants generated by open and mix-sealed furnaces. To accomplish this objective detailed testing, by EPA/IERL-RTP Level 1 procedures, was done at three plants. Level 1 is designed to determine a wide variety of inorganic and organic species each to within at least 1/3 to 3 times the actual concentration in the stream sampled. Some of the information obtained, however, is better than the overall accuracy. Particulate concentrations in the gas streams, which are sampled at a single point, should be within 1/2 to 2 times actual values. Accuracy for gaseous components is not affected by the velocity profile. Thus, total organics, which are determined by extracting the samples and weighing the residue in the extract, should be within 1/2 to 2 times actual stream concentrations. The final steps, fractionation of the extracts by liquid chromatography and quantitation by infrared and mass spectrographic analysis, reduce the accuracy for determining an individual compound category to within 1/3 to 3 times the actual concentration in the stream sampled.

Both open and mix-sealed furnaces were tested and products included ferromanganese, 50 percent ferrosilicon, and 75 percent ferrosilicon. The study design does not allow a complete elucidation of the separate effects of furnace type and product manufactured. Also, since the gas from mix-sealed furnaces is flared, the actual organic emission to the atmosphere generally cannot be determined.

Two furnaces at each of three plants were tested. Scrubbers were used on five of the furnaces and samples were taken of scrubber waters and of the scrubbed gas before it was flared. The one furnace tested which was served by a baghouse was sampled before the pollution control devices. Samples were also taken of the plant discharge wastewaters.

## Results and Conclusions

Summarized in Table 1 are the particulate generation rates by the furnaces (before emission control). The data are only for particulate going to the primary emission control systems. Thus, tapping and product handling are not included.

With the exception of furnace A-1, there does not seem to be a significant difference in particulate generation rates from variations in product type or type of furnace used when compared on a kg/MW-hr basis. Furnace A-1 seemed to be generating more secondary fume (based on visual estimates) than typical mix-sealed furnaces which may account for the low value obtained. When compared on a kg/Mg of alloy produced basis, it appears that particulate generation rates increase in the order of FeMn, 50 percent FeSi, and 75 percent FeSi. The data are not conclusive for different types of furnaces since particulate generation rates of furnaces B-1 and B-2 are comparable but less than for furnace C-2, all 50 percent FeSi product. The difference may be due to lower efficiency (kW-hr/kg product) in furnace C-2.

Summarized in Table 2 are the organic generation rate data (equivalent to Table 1 for particulates). In this case, significant differences are noted when the generation rates are compared on either a kg/MW-hr or kg/Mg basis. The open furnaces obviously have lower overall organic generation rates than the mix-sealed furnaces in which limited combustion was occurring. It is interesting to note the variation in organic generation rates by the different mix-sealed furnaces. Although the same product was being made in furnaces B-2 and C-2, the organic generation rates differ by almost a factor of 3 (a wider variation than expected for determination of total organics by Level 1 procedures). This is probably due to more combustion under the cover of furnace C-2 (indicated by the Orsat analyses of the furnace gases).

Most interesting are the results for furnace A-1 which had almost complete undercover combustion. The trend observed for the mix-sealed and open furnaces strongly indicates that more complete destruction of organics would occur in sealed or mix-sealed furnaces in which complete undercover combustion was occurring.

The efficiencies of the scrubbers for removal of particulate and organic matter from the gases generated by the furnaces are given in Table 3. Although all scrubbers have particulate capture efficiencies of over 90 percent, a significant difference in capture efficiency for organics is observed. As expected, the capture efficiency increased with an increase in either pollutant inlet concentration or scrubber pressure drop.

**Table 1.** *Summary of Furnace Particulate Generation Data*

| Furnace | Type | Product | Operating Power, MW | kg/hr | kg/MW-hr | kg/Mg alloy |
|---|---|---|---|---|---|---|
| A-1 | Mix-sealed | FeMn | 11.4 | 47.3 | 4.1 | 10.1 |
| A-2 | Open | FeMn | 15.8 | 174.9 | 11.1 | 26.0 |
| B-1 | Open | 50% FeSi | 48.4 | 470.6 | 9.7 | 49.2 |
| B-2 | Mix-sealed | 50% FeSi | 48.0 | 447.7 | 9.3 | 46.0 |
| C-1 | Mix-sealed | 75% FeSi | 15.5 | 196.7 | 12.7 | 103.0 |
| C-2 | Mix-sealed | 50% FeSi | 16.8 | 187.9 | 11.2 | 68.9 |

**Table 2.** *Summary of Furnace Organic Generation Data*

| Furnace | Type | Product | Operating Power, MW | kg/hr | kg/MW-hr | kg/Mg alloy |
|---|---|---|---|---|---|---|
| A-1 | Mix-sealed | FeMn | 11.4 | 0.72 | 0.06 | 0.15 |
| A-2 | Open | FeMn | 15.8 | 5.5 | 0.35 | 0.82 |
| B-1 | Open | 50% FeSi | 48.4 | 12.0 | 0.25 | 1.25 |
| B-2 | Mix-sealed | 50% FeSi | 48.0 | 76.7 | 1.60 | 7.89 |
| C-1 | Mix-sealed | 75% FeSi | 15.5 | 19.6 | 1.27 | 10.27 |
| C-2 | Mix-sealed | 50% FeSi | 16.8 | 9.9 | 0.59 | 3.65 |

The concentrations of particulates and organics in the plant discharge wastewaters are given in Table 4. These effluents do not contain cooling or sanitary water.

All samples collected during the test were extracted with methylene chloride and analyzed by infrared (IR) and low resolution mass spectograph (LRMS). The analyses are not adequate for individual compound identification but do indicate compound categories and potential compounds present. Both the cleaned gas and the water discharged by the scrubber used for control of fumes generated by furnace C-2 were analyzed by gas chromatograph-mass spectrograph (GC-MS) for exact compound identification.

The IR and LRMS analyses of furnaces A-1, A-2, and B-1, all of which were achieving nearly complete combustion of the furnace gas, indicate a low concentration of most organic categories. Potentially low concentrations of the carcinogens, indeno(1,2,3-cd)pyrene and dibenzochrysene isomer, in emissions to the air from furnace A-2 are indicated by LRMS responses at masses 276 and 302, respectively. Similarly, low concentrations of the carcinogens, benzanthracene and benzo(a)pyrene, in gases generated by furnace B-1 (before emission control equipment) are indicated by LRMS responses at masses 228 and 252, respectively. No evidence of potential carcinogens was found in emissions to the air (primary emission control system) from furnace A-1. The scrubber discharge water from furnace A-1 contained organic compounds with masses (LRMS analysis) of 228, 252, 256, and 302 which could be the carcinogens, benzanthracene, benzo(a) pryene, dimethylbenzoanthracene, and dibenzochrysene isomer, respectively. The scrubber discharge water from furnace A-2 contained, in addition to the cited organic for furnace A-1, masses at 266 and 276 (dibenzofluorene and indeno(1,2,3-cd)pyrene, respectively).

The scrubbed gases from the covered furnaces B-2, C-1, and C-2 (measured before the flares) all contain similar types of organic compounds although the concentration from the B-2 furnace is lower than that of the other two, presumably due to the higher scrubber efficiency for furnace B-2. For these furnaces, the LRMS analysis indicates significant concentrations of fused aromatic organics at masses 252, 266, 276, and 302 which could be carcinogens, benzo(a) pyrene, dibenzofluorene, indeno(1,2,3-cd)pyrene, and dibenzochrysene isomer, respectively. All scrubber discharge waters from these furnaces contain relatively high concentrations of organics with masses 228, 252, 256, 266, 276, and 302 which could be the carcinogens cited previously. Evidence for potential carcinogens (at masses 228 and 252) was found only in the treated process discharge water from plants C. No evidence of organic carcinogens was found for the treated water discharged from plants A and B.

The GC-MS analysis of the scrubbed gases from furnace C-2 (before flaring which should destroy some organics) gave positive identification of 13 polycyclic aromatic hydrocarbons (PAH) including the known carcinogens, benz(a)-anthracene, chrysene, benzo(a)pryene, and indeno(1,2,3-cd)pyrene. Another 10 PAHs were tentatively identified and include the known carcinogen, benz(j) fluoranthene. Because of difficulties in the sample analysis, accurate quantitation was not possible. However, an estimate of the maximum concentration of these identified compounds in the scrubbed, but not flared, gas was made after some assumptions were included. This estimate is shown in Table 5.

Given in Table 6 is a typical presentation of the Level 1 organic compound category summary data. This table is for the back half (organic collection module) of the sampling train and indicates the types of compounds and approximate concentrations in the scrubbed but not flared gas from mix-sealed furnace C-2. Similar types of compound categories were found for most samples. The concentrations of the various categories were significantly lower for samples form open furnaces than from mix-sealed furnaces.

Using the Level 1 data obtained, estimates were made of the polycyclic organic matter (POM) generated by the furnaces (except for A-1 which was considered to be atypical). The results of these estimates are given in Table 7.

Because of inaccuracies inherent in the Level 1 approach, the data given in Table 7 should be considered to be within 1/3 to 3 times the correct values.

Although it is recognized that the furnaces sampled do not constitute a statistically representative sample of the industry and that repeat measurements were not taken to determine individual furnace variability, the data were extrapolated to provide an estimate of the total POM generated annually by ferroalloy manufacturing.

These extrapolations of the data indicate that polycyclic organic matter (POM) is generated by covered furnaces at the rate of about 1,230 to 11,080 kg/yr (2,710 to 24,430 lb/yr) per megawatt of furnace capacity or 208,800 to 1,878,800 kg/yr (460,300 to 4,120,000 lb/yr) for all U.S. furnaces of this type. POM generation by open furnaces is estimated to be about 100 to 900 kg/yr (220 to 1,980 lb/yr) per megawatt of furnace capacity or 134,500 to 1,210,500 kg/yr (296,500 to 2,068,700 lb/yr) for all U.S. furnaces of this type. Calculations for both furnace types are based on generation rates and are before collection and treatment by emission control equipment.

About 363,000 tonnes (400,000 tons) of solid waste is generated annually by

*Table 3. Scrubber Efficiencies, Percent*[a]

| Furnace | Efficiency for particulates | Efficiency for organics |
|---|---|---|
| A-1 | 98.4 | 57.2 |
| A-2 | 97.0 | 16.2 |
| B-2 | 99.5 | 96.7 |
| C-1 | 96.1 | 76.7 |
| C-2 | 93.1 | 79.5 |

[a]*Furnace B-1 does not have a scrubber.*

*Table 4. Plant Wastewater Discharge*

| Plant | Suspended Solids mg/l | Suspended Solids kg/day | Organics mg/l | Organics kg/day |
|---|---|---|---|---|
| A | 9.4 | 230 | 6.7 | 163 |
| B | 2.3 | 25 | 12.0 | 131 |
| C | 17.8 | 145 | 8.0 | 65 |

**Table 5.** *Estimated Concentrations of Identified PAHs*

| Compound | Mass | Carcinogen Rating [a] | Normalized Relative Sample Concentration | Estimated Concentrations in Unflared Gas | |
|---|---|---|---|---|---|
| | | | | mg/Nm³ | DMEG Air Health Limit, mg/Nm³ |
| Phenanthrene | 178 | — | 6.8 | 18.3 | 1.6 |
| Anthracene | 178 | — | 6.8 | 18.3 | 56 |
| Fluoranthene | 202 | — | 10.2 | 27.4 | 90 |
| Pyrene | 202 | — | 10.6 | 28.5 | 230 |
| Benz(a)anthracene | 228 | + | 3.9 | 10.5 | 0.045 |
| Chrysene | 228 | ± | 3.0 | 8.1 | 2.2 |
| Benzo(e)pyrene | 252 | — | 0.30 | 0.81 | 3.0 |
| Benzo(k)fluoranthene | 252 | — | 0.06 | 0.16 | 1.6 |
| Perylene | 252 | — | 0.16 | 0.43 | — |
| Benzo(a)pyrene | 252 | +++ | 0.61 | 1.64 | $2 \times 10^{-5}$ |
| Indeno(1,2,3-cd)pyrene | 276 | + | 0.41 | 1.10 | 1.6 |
| Benzo(ghi)perylene | 276 | — | 1.20 | 3.2 | — |
| Coronene | 300 | — | 0.38 | 1.0 | — |
| Fluorene* | 166 | — | 27.9 | 75.0 | — |
| 9-Methylphenanthrene* | 192 | — | 0.56 | 1.5 | — |
| Cyclopenta(def) phenanthrene* | 190 | — | 4.0 | 10.7 | — |
| Benzo(a)fluorene* | 216 | — | 0.20 | 0.54 | — |
| Methyl Pyrene* | 216 | — | 0.025 | 0.07 | — |
| Benzo(b)fluorene* | 216 | — | 0.025 | 0.07 | — |
| Benzo(ghi)fluoranthene* | 226 | — | 3.3 | 8.9 | — |
| Benzo(j)fluroanthene* | 252 | ++ | 1.3 | 3.5 | 6.5 |
| Benzo(e)acephenanthrylene* | 252 | ? | 1.3 | 3.5 | — |
| Anthanthrene* | 276 | — | 0.31 | 0.83 | — |

[a] ±Weakly carcinogenic, + carcinogenic, ++ and +++ strongly carcinogenic, — not carcinogenic.
*Tentative identification.

**Table 6.** *Organic Extract Summary Table, Sample No. CI-X*

| | LC1 | LC2 | LC3 | LC4 | LC5 | LC6 | LC7 | Σ |
|---|---|---|---|---|---|---|---|---|
| Total Organics, mg/m³ | 264.0 | 81.0 | 31.0 | 30.4 | 17.7 | 62.0 | 5.1 | 491.2 |
| TCO, mg/m³ | 262.7 | 59.5 | 5.70 | 19.0 | 8.9 | 19.0 | 0 | 374.7 |
| GRAV, mg/m³ | 1.3 | 21.5 | 25.3 | 11.4 | 8.8 | 43 | 5.1 | 116.5 |
| Category | Assigned Intensity - mg/(m³) | | | | | | | |
| Aliphatic Hydrocarbons | 100/66.0[†] | — | | — | QNS* | — | QNS* | 66.0 |
| Halogenated Aliphatics | 100/66.0 | 100/16.2 | | — | | — | | 82.2 |
| Aromatic Hydrocarbons | 100/66.0** | 100/16.2 | 100/28.0 | — | | — | | 110.2 |
| Halogenated Aromatics | 100/66.0** | 100/16.2 | | — | | — | | 82.2 |
| Silicones | — | 100/16.2 | | 10/0.80 | | — | | 17.0 |
| Heterocyclic O Compounds | — | — | | 10/0.80 | | — | | 0.8 |
| Nitroaromatics | — | — | | 10/0.80 | | — | | 0.8 |
| Ethers | — | — | | 100/8.0 | | — | | 8.0 |
| Aldehydes | — | — | | 10/0.80 | | — | | 0.8 |
| Phosphates | — | — | | 10/0.80 | | 10/0.94 | | 1.74 |
| Nitriles | — | — | | 10/0.80 | | — | | 0.8 |
| Heterocyclic N Compounds | — | — | | 10/0.80 | | 100/9.4 | | 10.2 |
| Heterocyclic S Compounds | — | — | | 10/0.80 | | — | | 0.8 |
| Alcohols | — | — | | — | | 100/9.4 | | 9.4 |
| Phenols | — | — | | — | | 100/9.4 | | 9.4 |
| Ketones | — | — | | 100/8.0** | | 10/0.94 | | 8.94 |
| Amines | — | — | QNS* | | QNS* | 100/9.4 | QNS* | 9.4 |
| Alkyl S Compounds | — | — | | | | 10/0.94 | | 0.94 |
| Sulfuric Acids | — | — | | | | 10/0.94 | | 0.94 |
| Sulfoxides | — | — | | | | 10/0.94 | | 0.94 |
| Amides | — | — | | | | 100/9.4 | | 9.4 |
| Carboxylic Acids | — | — | | | | 100/9.4 | | 9.4 |
| Esters | — | 100/16.2** | 10/3.0 | 100/8.0** | | 10/0.94 | | 28.14 |

*Quantity Not Sufficient. **Possible Contamination.
[†] The data are presented as assigned intensity (from IR and/or LRMS)/concentration.

*Table 7.* *Estimates of Furnace Generated POM*[a]

| Furnace | Captured by Control Device kg/yr/MW of Capacity | Total Generated by Furnace kg/yr/MW of Capacity |
|---|---|---|
| A-2 | 280 | 690 |
| B-1 | ND[+] | 280 |
| B-2 | 3,600 | 4,400 |
| C-1 | 2,800 | 3,900 |
| C-2 | 1,200 | 2,800 |

[a]*Furnace A-1 is atypical.*
[+]*ND = Not Determined.*

the ferroalloy industry or about 9,100 tonnes (10,000 tons), on the average, for each plant. About 30 percent of this material may contain wastes specifically listed as hazardous by proposed section 3001 of the Resources Conservation and Recovery Act (RCRA). About 85 percent of the waste is disposed of in landfills or lagoons which are unlined. The dusts and sludges from open furnaces may contain about 0.1 percent organic matter. Sludges from covered furnaces may contain up to 8 percent organic matter. Sludges, from covered furnaces in particular, may contain high concentrations of polynuclear aromatic hydrocarbons including known carcinogens. Information is presented which indicates that the POM concentration in the clarified scrubber water should be less than its solubility in pure water (POMs are preferentially absorbed on suspended solids). Since suspended solids are generally removed from the scrubber water before chemical wastewater treatment and since previous research has shown that POMs degrade at a slow rate, it is likely that most POMs collected by the scrubber accumulate in solid waste disposal sites and disposal lagoons. Industry tests indicate that the dusts from a hard, fairly impermeable mass (permeability K values of $10^{-4}$ to $10^{-6}$ cm/sec) when wetted and allowed to dry. Industry data from monitor wells show virtually no contamination of groundwater based on analysis for five metals (Ba, Cd, Cr, Pb, and Hg). No data are available on organic leaching from these sludges. To the best of our knowledge, there is no evidence available to prove or disprove that sealing occurs.

The conclusions of this report are based, in part, on sampling and analysis data obtained using EPA/IERL-RTP Level 1 assessment procedures which yield final results accurate to within at least 1/3 to 3 times the actual value of the stream sampled. This approach is used to identify potential environmental problems and is not in itself sufficient proof that a problem exists. Appropriately, therefore, the data are interpreted using the worst case approximation unless data exist to prove this approximation invalid. The major conclusions of this report are as follows.

1. There are basically two types of furnaces: open, 86 percent of installed capacity, in which combustion of the furnace gas occurs before the emission control equipment; and covered, 14 percent of installed capacity, in which the gas is combusted after passing through the emission control equipment.
2. The pollution potential of covered (mix-sealed) furnaces is substantially higher than for open furnaces, primarily due to much higher organic generation rates by the covered furnaces. However, mix-sealed furnaces appear to vary in the rate of organic production (kg/MW-hr basis) probably due to varying rates of combustion under the furnace cover. Open furnaces are estimated to generate POM at the rate of about 100 to 900 kg/yr (220 to 1,980 lb/yr) per megawatt of furnace capacity or 134,500 to 1,210,500 kg/yr (296,500 to 2,668,700 lb/yr) for all U.S. furnaces of this type. The covered furnaces are estimated to generate POM at the rate of about 1,230 to 11,080 kg/yr (2,710 to 24,430 lb/yr) per megawatt of furnace capacity or 208,800 to 1,878,800 kg/yr (460,300 to 4,120,000 lb/yr) for all U.S. furnaces of this type. Control devices, which are in use on all U.S. furnaces, remove most of this material from the furnace gas. Thus, the estimated nationwide POM generation rates (estimated rates before the emission control devices) are in the same order of magnitude as POM generation rates (before control devices) of slot type coke ovens, a major POM emitter, which are estimated to be 317,000 to 3,200,000 kg/yr (700,000 to 7,000,000 lb/yr) for all U.S. coke ovens.
3. The industry generates about 363,000 tonnes (400,000 tons) of solid waste annually, about 85 percent of which is disposed of in unlined lagoons and landfills. Although the wastes contain known and/or suspected hazardous inorganic and organic materials, there is some evidence that the wastes are self-sealing and that heavy metals do not leach into the groundwater.
4. The industry consumes about 9 million megawatt hours of electricity annually, 6 percent of which is used for pollution control. Open and mix-sealed furnaces use up to 5 times as much energy for pollution control as does a typical totally sealed furnace.
5. For the six furnaces tested, there appears to be no significant difference in the kg of particulate generated/megawatt hour of furnace power (before emission control) as a function of furnace size, type, or product being manufactured. There does appear to be a difference in the kg of particulate (per megawatt hour of furnace power) in the gas discharged from the scrubber, which appears to be related to scrubber design and pressure drop, but may also be a function of furnace type and/or product being manufactured.
6. Scrubbers appear to be less efficient for capturing organics than for particulate capture.
7. Low resolution mass spectrographic analysis indicates the potential presence of carcinogens in the cleaned gas from the scrubbers, before it was flared, from four of five furnaces tested (the exception being one mix-sealed furnace in which complete undercover combustion was apparently occurring), and in the gas from one open furnace which was tested before emission control.
8. Low resolution mass spectrographic analysis indicates the presence of potential carcinogens

in all scrubber discharge waters and in the plant discharge water from only one plant (no longer operating) of the three tested.

9. Analysis of samples of one mix-sealed furnace by GC-MS techniques gave positive identification of known carcinogens in the cleaned gas discharged by the scrubber *(but before passing through the flare which may destroy some of the organics)* and in the scrubber discharge water *(before wastewater treatment)*. Two of these carcinogens could exceed DMEG[1] values by factors of up to 200 and 80,000 respectively, if significant destruction does not occur in the flare. These data provide strong evidence that the preliminary identifications listed above in 7 and 8 are probably correct.
10. U.S. production of ferroalloys has declined during the last decade to about 1945 levels. Imports have risen from about 2.4 percent of domestic consumption in 1945 to over 40 percent in the years since 1975.
11. Unless action is taken soon to stem the tide of imports, the continued viability of the U.S. industry is questionable.
12. There are no plans to expand U.S. production capacity. Rather, some furnaces are idle, some plants are being closed, and some older furnaces are being replaced by larger, more efficient furnaces.
13. Based on information obtained in these tests, we must conclude that a potential for a significant multimedia environmental problem exists with ferroalloy manufacture and that this potential is significantly greater for plants using mix-sealed and sealed furnaces than for those using open furnaces. It has not been established that a real environmental problem exists in any of the three media—air, water, or solid waste.

## Recommendations

More accurate testing should be done to quantify the pollutants produced by the furnaces and determine how much is ultimately discharged to the environment through any and all three media. If these tests should prove that unacceptable amounts of pollutants are emitted, or are disposed of in an environmentally unsound manner, work should be initiated to determine if the public is being, or is likely to be, endangered. If these studies indicate public endangerment, studies should be undertaken to reduce pollutant releases from the industry.

Specifically, the following additional work is recommended. More accurate sampling (i.e., isokinetic, duct traverse, integrated composite water sampling) and analysis (GC-MS, for example) need to be used to quantify discharges from the plants to all media. For plants using only open furnaces and capturing and disposing of only dry dust (baghouse control system), sampling will be required for emissions from the baghouse and for surface water runoff and groundwater intrusions from the dust disposal site. A few locations control emissions from open furnaces with scrubbers or slurry the dust captured by the baghouse. The number and size of these facilities are probably not large enough to warrant detailed testing. Sampling in the gas stream before the control device (baghouse) and of the collected baghouse dust is also recommended since these tests will allow a measure of control efficiency for the contaminants, a measure of contaminants entering the disposal sites, and an indication of possible emissions in the event of control device failure (bag rupture, etc.).

Quantifying emissions to the air from covered (mix-sealed and sealed) furnaces is extremely difficult since the gas is flared on discharge to the atmosphere. At present, there are no established techniques for measuring emission rates from flares. It is recommended, therefore, that the gas be sampled in the duct after the scrubber and before the flare. This should provide a reasonable estimate of particulate emissions, although some change in mass is to be expected since flaring may change the form of some of the particulate components and is expected to burn off some of the organics on the particulate matter. Determining the actual organic emission rate is complicated by the fact that the flare will destroy some of the organic matter and the percentage destruction (for total organics or for individual compounds) cannot be accurately measured. As a first approximation, it can be assumed that the flare is 100 percent effective and the emission rate calculated based on the percent of time that the flares are not operating. Other assumptions about flare efficiency could be made. If adequate methods are developed, an actual assessment of flare effectiveness should be made.

The wastewater discharged by the plant should be analyzed for priority pollutants including polynuclear aromatics. The possibility of leaching inorganics and organics into the groundwater at disposal sites and lagoons should be examined.

It is recommended that, in conjunction with the above tests, the water discharged by the scrubbers on the furnace be tested since this provides information as to the control efficiency of both the scrubber and the wastewater treatment system.

If the above test should prove that unacceptable amounts of pollutants are emitted or are disposed of in an environmentally unsound manner, work should be initiated to determine if the public is, or is likely to be, endangered. To accomplish this, modeling studies for the pollutants of concern should be done to determine the potential impact on the population surrounding a plant.

If the weight of evidence gathered indicates public endangerment, work should be initiated to reduce pollutants emitted by the industry. While we cannot predict with certainty which pollutants would be involved or which media would have the most impact, we can suggest some areas in which additional work might be fruitful. Included in the suggested efforts below are some already being instituted by the industry.

1. Improve flare design and operability.
2. Improve scrubber efficiency, particularly for organics.
3. Reduce gas volume from open furnaces, possibly by the use of close hooding.
4. Investigate the possibility of controlled undercover combustion in mix-sealed and sealed type furnaces for organic matter destruction.
5. Investigate improved water treatment methods, including clarification and filtration for improved suspended solid removal and an investigation of the applicability of reuse and/or recycle of wastewater since this has the potential for significantly reducing mass emissions of suspended solids (on

[1]Kingsbury, G.L., et al. "Multimedia Environmental Goals for Environmental Assessment - MEG Charts and Background Information Summaries," Vol. III-Categories 1-12, EPA-600/7-79-176a (NTIS PB80-115108), and Vol. IV-Categories 13-26, EPA-600/7-79-176b (NTIS PB80-115116), August 1979.

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which polycyclic aromatic hydrocarbons can be absorbed) and dissolved materials.

6. Investigate alternate methods for treatment or disposal of solid wastes generated.

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*The complete report, entitled "Level 1 Environmental Assessment of Electric Submerged-Arc Furnaces Producing Ferroalloys," (Order No. PB 81-210 106; Cost: $24.50, subject to change) will be available only from:*
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