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EPA

Characterization of Air Pollution Control Equipment Operation and Maintenance Problems

CHARACTERIZATION OF AIR POLLUTION CONTROL EQUIPMENT OPERATION AND MAINTENANCE PROBLEMS

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EXECUTIVE SUMMARY

The Environmental Protection Agency (EPA) and the Council on Environmental Quality (CEQ) sponsored five separate studies and EPA conducted an additional four studies for a total of nine to determine the extent to which industrial sources emit pollutants in excess of their applicable regulatory limit. These studies were directed at better understanding the degree to which a source maintains continuous compliance over time. The frequency, duration, and magnitude of individual "excess emissions" episodes were quantified as was the primary cause of each emissions incident. These reports have been submitted to the EPA by the participating contractors.

This report presents the results of classifying, synthesizing and analyzing the data compiled in these initial reports. A total of 169 individual source surveys were investigated and quantified, from which 119 data points on excess emissions incidents were extracted. GCA/Technology Division correlated this excess emissions data with four causal factors and four major source and control equipment parameters in order to answer three distinct questions:

- What is the extent of the excess emissions problem?
- Why is this problem occurring?
- Who is experiencing this problem?

A presentation of the data averages which were statistically adjusted to eliminate the bias of unusally large values serves to define the extent of the problem and the "typical" source investigated in this report.

Source Data

• Annual uncontrolled emissions (tons)	13,341.5
• Annualized allowable emissions (tons)	179.2
• Annual excess emissions (tons)	22.0
• Normalized excess (percent of allowed)	24.7
• Annual emissions credits (tons)	100.1
• Normalized credits (percent of allowed)	50.0

Excess Emissions Incidents Data

• Frequency (incidents/year)	12.3
• Duration (hours/incident)	23.7
• Magnitude (percent in excess of allowable/incident)	828.0
• Magnitude (tons/incident)	1.8

Control Equipment Data

• Capital cost (10^3\$)	1,623.3
• Annual operating and maintenance cost (10^3\$)	180.9
• Size of control device (10^3acfm)	105.4
• Age of control device (years)	5.1

Figure 1 graphically displays this data for the "average" source. With reference to the figure, the average source experiences twelve excess emissions incidents per year each lasting 23.7 hours with an emissions release of 1.8 tons which is equal to 8.3 times that allowed. On a yearly basis, the source operates at a normal emission level equal to 50 percent of that allowed, and emits excess emission resulting from the twelve incidents which is equivalent to 24.7 percent of that allowed.

The data for the "average" control device is graphically presented in Figure 2. Referring to the figure, the control device has an inlet loading of 13,341.5 tons per year and a controlled outlet emission rate of 79.1 tons. This "average" device, which is required to maintain a pollutant collection efficiency of at least 98.7 percent in order to meet the regulatory limit, has an actual collection efficiency of 99.4 percent. The device was installed in mid 1972 at a 1977 cost equivalent of $1,623,300. and has a flow of 105,400 acfm. Annual operation and maintenance costs are $180,900.

To determine why an excess emissions problem occurs, we investigate its causes. All factors leading to an excess emissions incident were defined by one of the following four causal codes:

- Causal Code 1 - Design Related
- Causal Code 2 - Process Disruption Related
- Causal Code 3 - Control Equipment O&M Related
- Causal Code 4 - Unforeseen Event

The frequency duration and absolute magnitude of each incident was first quantified and each incident was tabulated by its causal code. The proportion of all frequencies, durations and absolute magnitude attributable to each of the four causal codes was then calculated. A graphical representation of these calculations is presented in Figure 3.

These charts display the relative contribution of each causal factor to the primary excess emissions indicators of frequency, duration, and absolute magnitude. They were derived by separately dividing the frequency, duration and absolute magnitude of incidents with similar causal codes by the total number of incident frequencies, the total hours of excess mode operation and the absolute tonnage of all incidents in the excess mode, respectively.

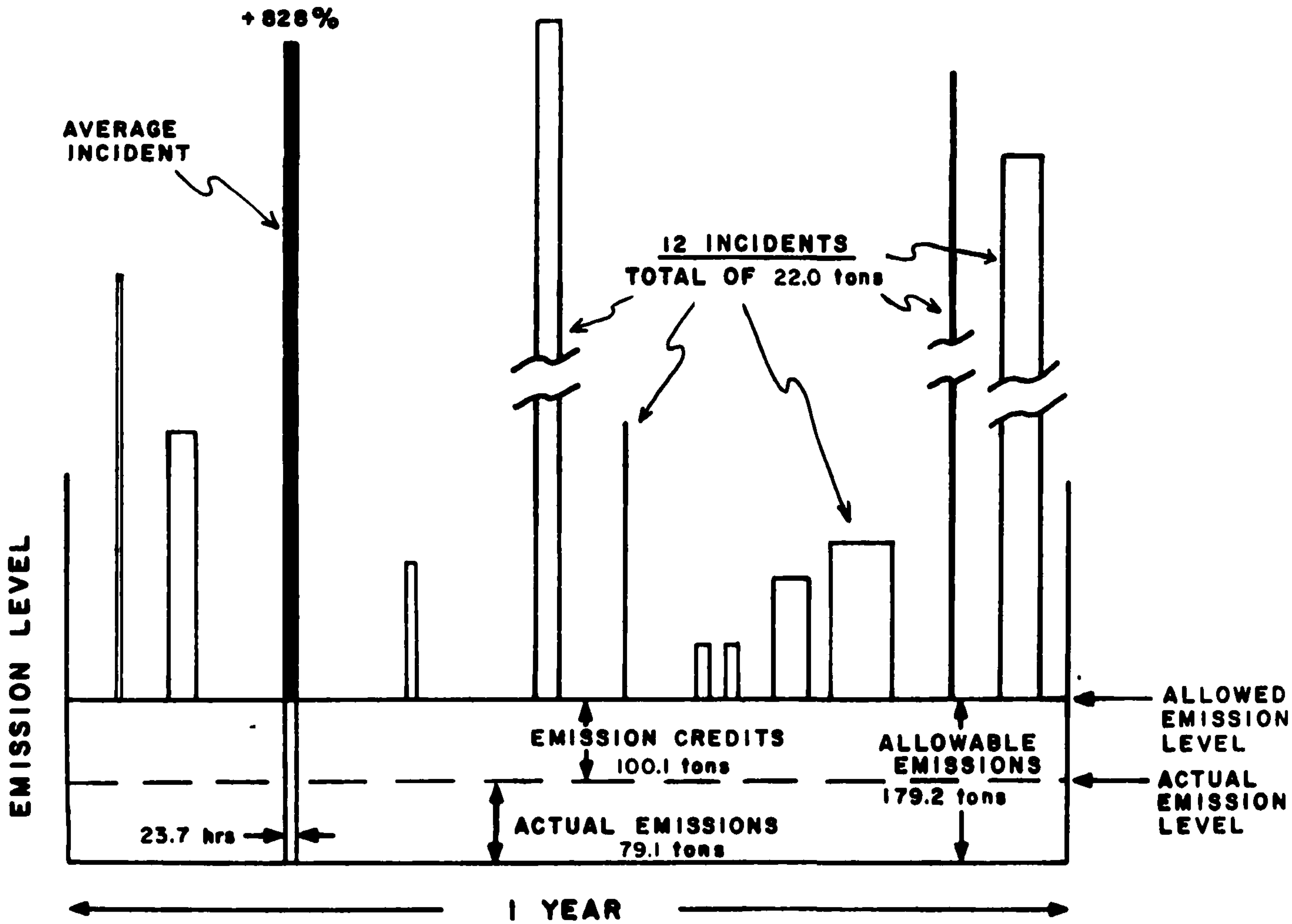
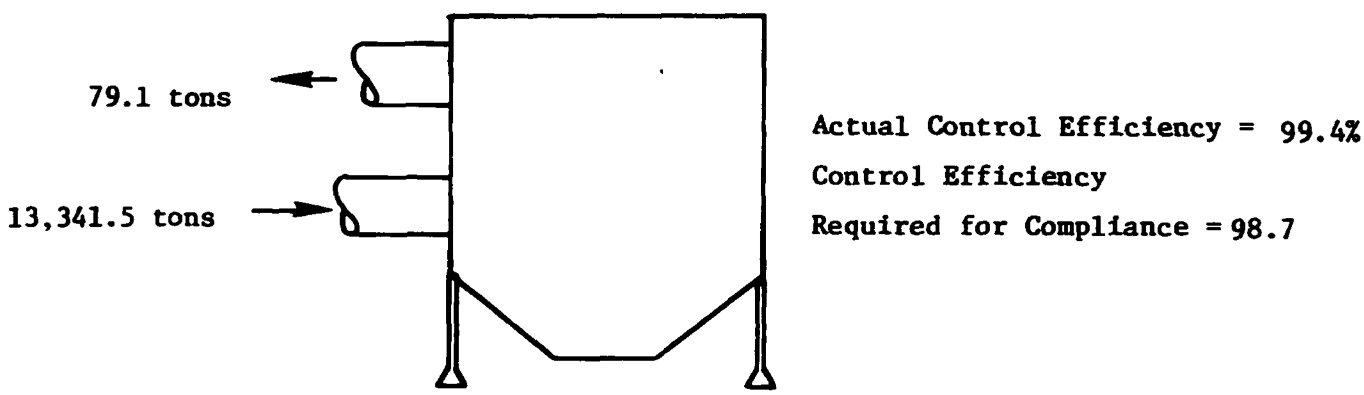


Figure 1. Source Profile



Control: Age: 5.1 years

Size: 105,400 ACFM

Capital cost: $1,623,300 (1977) = $15.40/ACFM

O&M cost: $180,900 (1977) = $1.72/ACFM

Figure 2. Control Equipment Profile

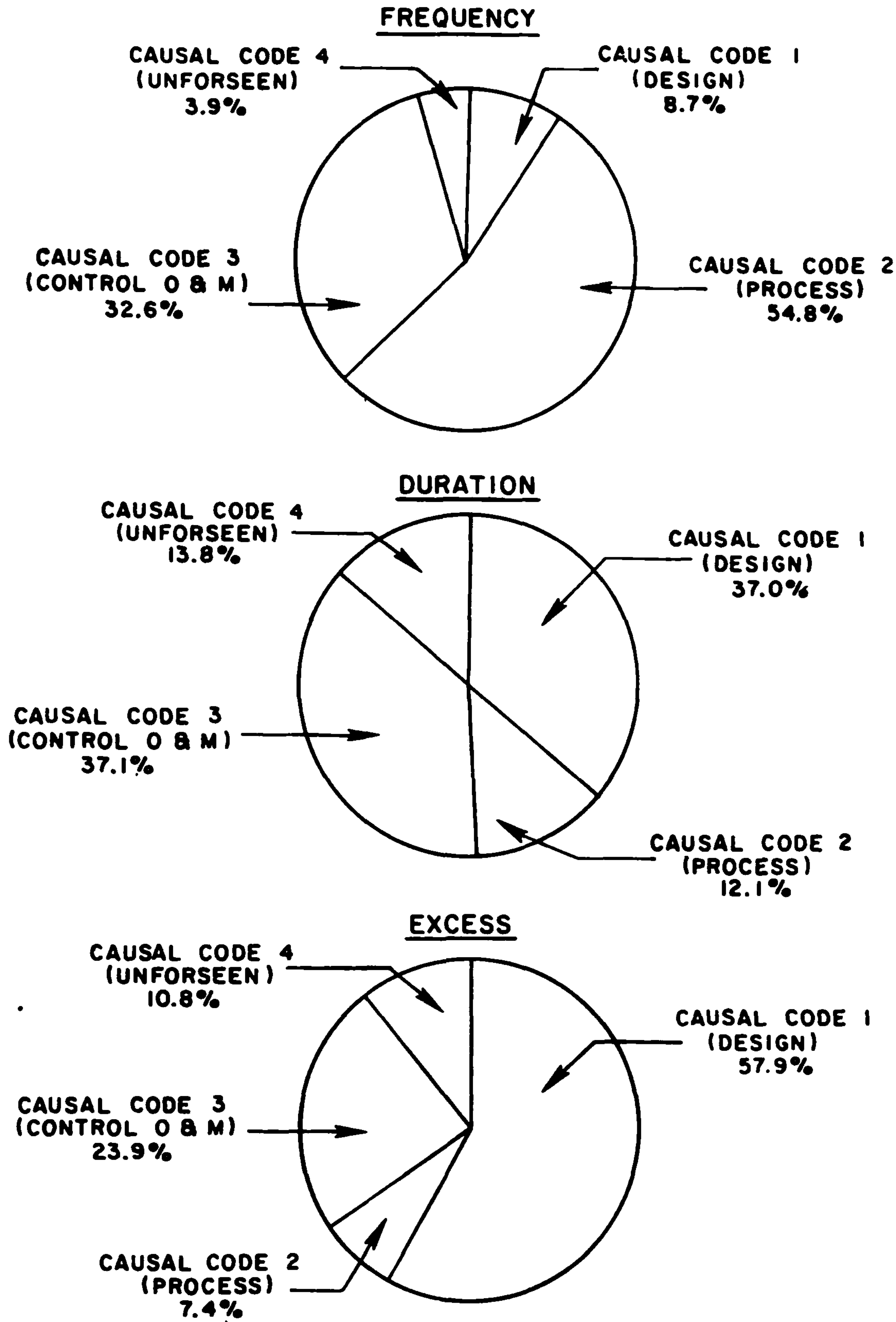


Figure 3. Percent contribution of each causal code by incident indicator.

With respect to "who" is experiencing the problems, the data from the 119 sources were analyzed by four major process and control related parameters. These were:

- Source type - industrial classification
- Source size - uncontrolled emission potential
- Control device type
- Control device size

Each parameter was broken down into specific categories to facilitate data analysis. Excess emissions indicator data (frequency, duration, magnitude) were then entered into each category according to the characteristics of the source surveyed. Once tabulated, the data for each parameter was ranked by category according to the average frequency, duration, and magnitude of occurrence. These individual indicator standings were then integrated into one overall ranking which displayed the seriousness of the excess emissions problems by category. The results of this integrated ranking technique are presented in Table 1. According to our established convention, the lower the rank number, the greater the excess emissions problem for that category.

The majority of this report concerns itself with the tabulation of incident data along parameter and category lines, in an effort to profile the problem sources. A total of nearly 3000 excess emissions incidents were documented and synthesized to form the basis of our findings. We feel that the true extent of excess emissions may be greater than our study has shown. We also feel that a more thorough study aimed at specific industrial categories will serve to more clearly delineate the problem.

TABLE 1. OVERALL RANKING OF PARAMETERS A THROUGH D.

	Parameter A Industrial category		Parameter B Source size		Parameter C Control device type		Parameter D Control device size	
Rank	Category	Number of samples	Category (10^3 ton/yr)	Number of samples	Category	Number of samples	Category (10^3 acfm)	Number of samples
1	Cement plants	9	100 - 500	6	ESP	22	500 - 1000	6
2	Surface coating operations	13	0.1 - 0.5	31	Scrubber	36	100 - 500	23
3	Grain handling operations	5	10 - 100	11	Other	26	10 - 50	49
4	Petroleum products and handling	13	<0.1	24	Baghouse	35	<10	31
5	Incinerators	6	1 - 10	30			>1000	1
6	Stone, clay and glass plants	10	0.5 - 1	17			50 - 100	9
7	Steam generating plants	10						
8	Pulp and paper mills	6						
9	Petrochemical plants	6						
10	Lumber and wood plants	3						
11	Asphalt plants	10						
12	Iron and steel plants	10						
13	Other	6						
14	Brass and bronze plants	5						
15	Food and drug plants	3						
16	Aluminum plants	4						
	Total =	119	Total =	119	Total =	119	Total =	119

CONTENTS

FIGURES

TABLES

TABLES (continued)

TABLES (continued)

TABLES (continued)

TABLES (continued)

SECTION 1

INTRODUCTION

BACKGROUND

The Clean Air Act of 1970 and subsequent amendments passed by Congress in the summer of 1977 provided for the establishment of national ambient air quality standards specifying the maximum levels of certain "criteria" pollutants to be permitted in the ambient air. States were charged to develop and implement approved state implementation plans (SIPs) designed to limit the amount of air pollutants emitted from stationary and mobile sources in accordance with the established standards. These SIPs defined specific emission limitations which, when achieved by all pollutant sources, should lead to the attainment of the national ambient air quality standards. With certain noted exceptions, much of the United States has, as of this date, achieved the air quality standards established by EPA. Further refinements and revisions to the SIPs are currently underway, however, in an attempt to resolve those still outstanding "nonattainment" situations.

The vast majority of all major stationary sources (those with an uncontrolled emission potential in excess of 100 tons of pollutant per year) are currently considered in compliance with their applicable emission limitation. This compliance determination, however, is often based on estimated uncontrolled pollutant emission rates and control equipment design efficiencies, or on specific one-time stack tests of the pollutant in question. The extent to which a source maintains the process and control equipment parameters upon which the compliance determination was made has never been fully investigated. Perturbations to steady state operation due to changes in these parameters can cause emissions incidents which are in excess of the applicable regulatory standard. To fill the informational gaps that currently exist concerning "continued" compliance of stationary sources, the EPA, in conjunction with the Council on Environmental Quality (CEQ) sponsored nine separate studies, involving six state and three local air pollution control agencies. While these individual studies varied in their overall scope and purpose, all were involved in the collection and processing of specific pollutant information from stationary sources within the jurisdiction of each air pollution control agency studied. This data gathering involved comprehensive onsite inspections of the sources surveyed, collection of operating and maintenance data on selected processes at each source, and the reduction of the emission data obtained into frequency, duration and magnitude values associated with each "excess emission" incident. In addition, data concerning uncontrolled and allowable emission rates, emission credits and excesses, age, type, size and cost of control equipment were gathered during the site visits.

The contractors involved in these initial source inspections, their geographic areas of concern, and the number of facilities evaluated and reported, were as follows:

- GCA/Technology Division - New York State and Iowa - 29 sources
- The Research Corporation of New England (TRC) - Connecticut, New Jersey and Oregon - 52 sources
- PEDCo/Booz-Allen and Hamilton - North Carolina and Houston - 40 sources
- Pacific Environmental Services (PES) - San Diego and Chicago - 48 sources

The results of these source evaluations have been previously reported to the EPA and CEQ in fulfillment of the initial contract requirements.

The purpose of this study is to review the individual source data from all these earlier studies, eliminate those sources that have unusable data or that do not meet the minimum criteria of this project, collate the usable data by various source and control equipment parameters and report the results of the data tabulation. While the specific contractor reports should be consulted to determine individual source evaluation methodology and problems encountered in facility selection and onsite data gathering, the highlights of those efforts will be reemphasized in this study.

SOURCE DATA BASE

The 169 facilities surveyed by the original contractors were initially selected based on the following EPA/CEQ source selection criteria:

1. Near equal distribution of sources of the following pollutants: TSP, SO_x, HC.
2. All sources are data rich; i.e., have hard emission data available.
3. All sources are willing to participate in study.
4. Near equal distribution of sources according to uncontrolled emission levels in excess of 25 ton/yr.
5. Near equal distribution of sources according to size of operation, but employing no fewer than 50 people.
6. Near equal distribution of sources across 16 defined industrial categories.
7. Near equal distribution of sources according to ages of process and control system equipment.

8. Near equal distribution of sources according to types of corporate structure; i.e., publicly held corporation, private corporation, publicly owned utility.

9. Consideration for maximizing the variation in:

   a. Types of control systems to be studied

   b. Levels of required control; i.e., collection efficiency

   c. Levels of capital and operating costs in order to achieve desired control.

10. All sources must have been in compliance at sometime during the study period.

An inspection of the individual source reports indicated that sufficient data was available on specific process operations at these facilities to add an additional 17 point sources, for a total of 186 potential data entries.

A detailed review of each source report was then conducted to ensure a consistent interpretation of the selection criteria. Where data were unclear or missing, the contractor responsible for the data was contracted and asked to quantify the informational gaps, especially with respect to the frequency, duration and magnitude (as expressed by percent in excess of the allowable mass emission standard and by absolute tons of emissions per incident) of each excess emission incident. This reveiw eliminated from consideration, a total of 67 data points. This 36 percent reduction in available data entries is a good indication of the difficulty encountered by each contractor in satisfying the various selection criteria. The specific rationale applied in eliminating data points was as follows:

- 18 entries (9.7 percent) - Insufficient data available to make a reasonable estimate on the type and extent of excess emissions incidents.

- 16 entries (8.6 percent) - Source was continually out of compliance for the study period.

- 8 entries (4.3 percent) - Source operated uncontrolled without any pollution control device.

- 8 entries (4.3 percent) - Source had no applicable mass emission regulation.

- 8 entries (4.3 percent) - Source report dealt with a pollutant not considered within the scope of the study (3 were NO_x sources, 5 were odor sources).

- 3 entries (1.6 percent) - No emission control was required for the source to meet compliance levels.

- 3 entries (1.6 percent) - Emission control equipment was vented within the plant and caused no ambient pollutant emission.

- 3 entries (1.6 percent) - Source achieved compliance by switching to a conforming solvent, no excess emission was possible.

The remaining 119 (64 percent) point sources constituted the sample population for this study. For each source, data of both a qualitative and quantitative nature, were gathered. The first dealt with actual excess emissions incidents, their extent and their causes. It is important to note that no source was considered in the study that did not have a quantitative estimate made as to the occurrence or nonoccurrence of an excess emission. Where no such estimate could be made for lack of data upon which to make an estimate, that source was not included in the study population.

The second type of data dealt with process and control equipment parameters including emission and flow rates. These parameters were used to classify individual sources into applicable categories so as to compare sources on a relative basis.

The raw data used for all entries in this report has been computerized and a printout of that data appears in Appendix A of this report. This data can be used by the reader to correlate potential relationships between source and control equipment parameters and the occurrence or nonoccurrence of excess emissions incidents.

In order to ensure the cooperation of the participating sources, it was necessary to maintain their anonymity throughout the study. We have accomplished this by codifying each source according to the major industrial category of which it is a part. We have, therefore, 16 major industrial category codes:

- Steam Generating Plants (Industrial and Utility)
- Pulp and Paper Mills
- Incinerators
- Petroleum Products and Handling
- Cement Plants
- Asphalt Plants
- Iron and Steel Plants
- Aluminum Plants
- Brass and Bronze Plants
- Petrochemical Plants
- Stone, Clay, Glass and Mineral Plants
- Grain Handling Operations

- Lumber and Wood Products Plants
- Surface Coating Operations
- Food and Drug Products
- Other (Mineral Acid Plants and Fertilizer Plants)

Each facility evaluated within a given industrial category has its own individual facility code; e.g., if surveys were conducted at three facilities in category 1.0, they were codified as 1.1, 1.2, and 1.3. A further delineation was made if multiple and duplicate sources were evaluated at any one facility; e.g., four boilers reviewed at facility 1.1 were codified as 1.1.1, 1.1.2, 1.1.3, and 1.1.4. There are no direct references to the geographical location of a given facility, its size or any process-specific parameters which would, of themselves, "fingerprint" the facility.

In addition, each source is prefixed by a code letter indicating the contractor responsible for the data development. These prefixes are: "B" for Booz Allen/PEDCo; "G" for GCA/Technology Division; "P" for Pacific Environmental Services; and "T" for The Research Corporation of New England. As will be seen, this source coding system will be used throughout this report and sources will be identified in each major source and process-related parameter by its source number.

DEFINITION OF KEY TERMS

We have made several references throughout this report to certain terms as they relate to excess emissions. Since these terms form the basis of our findings and conclusions in this study, it is important to define them in a clear, concise manner. We have, therefore, developed the following definitions to provide consistency within our presentations throughout this report:

- Emissions - the absolute quantity of a given pollutant emitted to the atmosphere (example: pounds, tons).

- Excess emissions - the absolute quantity of a given pollutant emitted to the atmosphere in excess of a defined regulatory limit (example: pounds, tons).

- Magnitude - the time rate of an emission of a given pollutant discharged to the atmosphere during an emissions incident (example: lb/hr, ton/yr).

- Frequency - the number of excess emission incidents occurring per year.

- Duration - the period of time attributable to a given emission episode (example: minute, day).

- Allowable emissions - the absolute quantity of a given pollutant that would be emitted to the atmosphere from a pollution control device operating at the maximum emission rate permitted by regulation over a specified time period.

- Emission credits - the numerical difference between regulatory emissions and actual facility emissions (not including excess emissions) over a specified time period (includes both margin of safety and overcontrol).

- Parameter - a process or control equipment related variable which is used to describe the sample population (example: industrial category, control device size).

- Category - the subdivision of a parameter which is provided to more accurately describe the parameter (example: scrubber to describe control device type; 1,000 to 10,000 ton/yr to describe source size).

- Incident - one distinct and separate occurrence of excess emissions.

- Incident indicators - collective term referring to the frequency, duration, and magnitude of a distinct incident.

- Causal Code - a convention used to describe the cause of an excess emissions incident (example: Causal Code 1 - (design) - incident was caused by an inherent design flaw in the control system).

- Normalized excess - the total annual excess emission from a source divided by the annualized allowable emission limitation for that source (includes both margin of safety and overcontrol).

- Normalized credits - the total annual credits for a source divided by the annualized allowable emissions limitation for that source (includes both margin of safety and overcontrol).

We can now proceed to employ any of these definitions, singly or in combination, to consistently characterize the nature of excess emission problems and their association with the operation and maintenance of air pollution control systems.

EVALUATION PARAMETERS

All sources were classified according to four major process and control equipment parameters. This technique was used to more clearly define those sources which have an excess emission problem so that any subsequent regulatory action can be directed at specific problem areas. For the purpose of this study, these parameters are:

- Industrial classification of the source

- Uncontrolled emission rate of the process studied (expressed in ton/yr of potential emissions)

- Type of air pollution control equipment used

- Size of the control equipment

Additional information exists in the data base to provide further source classification according to control equipment age, control equipment capital cost (expressed in 1977 dollars), and source operating and maintenance costs, if desired.

To provide a further delineation of the classification scheme, each parameter was subdivided into categories. Individual sources were then entered by their source code into the appropriate category within each parameter. Consequently, each of the four parameters include data for all 119 sources surveyed. An exact category-by-category summation of incidents data can then be made and specific industrial and control equipment types and sizes can be identified. These category breakdowns are as follows:

- Parameter A - Industrial Classification
    - Steam Generating Plants (Industrial and Utility)
    - Pulp and Paper Mills
    - Incinerators
    - Petroleum Products and Handling
    - Cement Plants
    - Asphalt Plants
    - Iron and Steel Plants
    - Aluminum Plants
    - Brass and Bronze Plants
    - Petrochemical Plants
    - Stone, Clay, Glass, and Mineral Plants
    - Grain Handling Operations
    - Lumber and Wood Products Plants
    - Surface Coating Operations
    - Food and Drug Products
    - Other (including Mineral Acid Plants and Fertilizer Plants)
- Parameter B - Source Size (Uncontrolled Annual Emissions Potential)
    - <100 ton/yr
    - 100 to 500 ton/yr
    - 500 to 1,000 ton/yr
    - 1,000 to 10,000 ton/yr
    - 10,000 to 100,000 ton/yr
    - 100,000 to 500,000 ton/yr

- Parameter C - Control Device Type
  - Electrostatic Precipitator (ESP)
  - Scrubbers
  - Fabric Filters (Baghouses)
  - Other

The "other" category includes such devices as cyclones, afterburners, vapor recovery units, absorbers, and mist eliminators.

- Parameter D - Control Device Size
  - <10,000 acfm
  - 10,000 to 50,000 acfm
  - 50,000 to 100,000 acfm
  - 100,000 to 500,000 acfm
  - 500,000 to 1,000,000 acfm
  - >1,000,000 acfm

EXCESS EMISSION INCIDENT CATEGORIZATION

All data collected relative to excess emissions incidents were defined with respect to five inherent variables: cause of the incident, annual frequency of occurrence, duration in hours of the individual incident, magnitude of the excess as expressed by percent in excess of the applicable regulatory limit and magnitude of the excess as expressed by absolute tons of pollutant released per incident. Subdivisions were provided in the data array for each category to isolate the specific cause of the excess emissions incident and the frequency, duration and magnitude of that incident. This bookkeeping system provided a means of tabulating average values for incident causal factors, and the frequency, duration and magnitude of all incidents for any category or an entire parameter, taken as a whole. In addition, it facilitated comparison between causal codes for individual categories within each parameter.

The cause of each incident was defined by one of the following causal codes:

- Code 1 - Design limitations of the control system. Poor design relative to the size, materials of construction, application, etc., was directly responsible for the incident.

- Code 2 - Process. A change in the process operation or a process upset which directly leads to an increase emission; i.e., startup/shutdown, change in feed material, etc.

- Code 3 - Control equipment. A malfunction or breakdown of the control device or inadequate operation and maintenance of the device which leads to an excess emission; i.e., loss of a precipitator section, bag failure in a fabric filter, pump failure in a scrubber, etc.

- Code 4 - Unforeseen occurrence. Acts that are beyond the control of the equipment operator and lead to an excess emission (i.e., power failure, natural gas shutoff), or a mechanical, electrical failure that could not be foreseen or prevented by normal maintenance practices.

This further refinement of the data allows us to attribute the reason for any excess emissions incident to a specific cause. Any regulatory action that is aimed at reducing the excess emission problem can then be directed to a specific problem area; i.e., design problems, process problems, etc. Individual excess emissions data was first entered by its specific causal code into the applicable category data base. The summation of all four causal codes was then tabulated for each source. The results of this tabulation for our four selected parameters are found in Tables 2 through 5. It should be noted that when summing individual incident data, weighted averages were developed for the duration and magnitude of occurrences. Frequency sums are a straight numerical average.

While most incidents clearly fell into one of these areas, some incidents could be attributed to more than one cause and required the individual contractor to select the single most relevant cause based on the above definitions and his knowledge of the specific conditions at the facility.

The requirement that all excess emissions incidents be quantified by frequency, duration and magnitude values was the single most difficult task faced by the individual contractors. Every effort was made to obtain quality data during the source visits. Operating and maintenance records were inspected, when available, and qualified source personnel including maintenance foreman and plant managers were interview in depth. Hard emission data regarding potential emissions were back calculated from information gathered during these on-site interviews. Sound engineering judgement and objective analysis were used in all emission calculations.

This study, therefore, reflects as accurately as possible the real world situation. The frequency, duration and magnitude of excess emissions incidents cited in this study should be considered a reasonably accurate portrayal of malfunctions that occur in industry today. Since not all excess emissions incidents are noted in plant logs, and maintenance personnel tend to down play the extent and seriousness of any equipment outage, this study may underestimate the extent of control equipment malfunctions. However, inasmuch as great objectivity was used in assembling this data and the information included was both complete and documented, this report does characterize the excess emission problem that exists today.

Individual Causal Code averages were computed using only those sources which reported problems in that Causal Code. This procedure maximized the impact of the computed averages and allowed us to address the severity of the individual problems, when they existed. The number of sources which contributed to each Causal Code average is presented in the appropriate data summaries.

TABLE 2. PARAMETER A - INDUSTRIAL CLASSIFICATION DATA SUMMARY.

Category	Frequency	Duration (hr)	Magnitude (% above allowable)	Number of samples
Causal Code 1 (design)				
1 Industrial and utility boilers	0.8	2381.7	985	2
2 Pulp and paper mills	—	—	—	0
3 Incinerators	—	—	—	0
4 Petroleum products and handling	1.2	1527.4	729	3
5 Cement plants	—	—	—	0
6 Asphalt plants	—	—	—	0
7 Iron and steel plants	13.0	8.6	139	2
8 Aluminum plants	—	—	—	0
9 Brass and bronze plants	—	—	—	0
10 Petrochemical plants	1.0	6000.0	83	1
11 Stone, clay and glass plants	0.5	264.0	108	1
12 Grain handling operations	36.3	18.4	1346	2
13 Lumber and wood product plants	—	—	—	0
14 Surface coating operations	—	—	—	0
15 Food and drug plants	—	—	—	0
16 Other	—	—	—	0
Average	9.6	158.2	1003	Total = 11
Causal Code 2 (process)				
1 Industrial and utility boilers	148.4	3.1	162	6
2 Pulp and paper mills	116.0	5.0	180	2
3 Incinerators	7.3	0.2	542	2
4 Petroleum products and handling	16.1	8.5	88	4
5 Cement plants	30.6	46.5	3949	5
6 Asphalt plants	10.0	0.5	76	2
7 Iron and steel plants	374.0	0.4	148	2
8 Aluminum plants	3.5	0.1	50	1
9 Brass and bronze plants	1.0	1.0	1150	1
10 Petrochemical plants	0.8	520.0	255	2
11 Stone, clay and glass plants	—	—	—	0
12 Grain handling operations	—	—	—	0
13 Lumber and wood product plants	—	—	—	0
14 Surface coating operations	5.4	85.3	679	4
15 Food and drug plants	—	—	—	0
16 Other	30.0	3.8	122	3
Average	65.9	6.6	421	Total = 34

(continued)

TABLE 2 (continued)

Category	Frequency	Duration (hr)	Magnitude (% above allowable)	Number of samples
Causal Code 3 (control O&M)				
1 Industrial and utility boilers	—	—	—	0
2 Pulp and paper mills	—	—	—	0
3 Incinerators	2.8	17.1	587	2
4 Petroleum products and handling	5.9	168.3	174	8
5 Cement plants	20.3	6.1	521	5
6 Asphalt plants	14.8	3.9	630	3
7 Iron and steel plants	6.9	11.4	262	8
8 Aluminum plants	4.0	24.0	67	1
9 Brass and bronze plants	2.0	2.0	1150	1
10 Petrochemical plants	1.0	2160.0	50	1
11 Stone, clay and glass plants	6.2	67.0	297	5
12 Grain handling operations	5.1	4.9	361	2
13 Lumber and wood product plants	28.8	26.6	34	3
14 Surface coating operations	2.5	141.1	3182	5
15 Food and drug plants	1.5	233.0	25	1
16 Other	5.3	18.6	123	4
Average	8.6	45.9	399	Total = 49
Causal Code 4 (unforeseen)				
1 Industrial utility boilers	0.5	336.0	12	1
2 Pulp and paper mills	—	—	—	0
3 Incinerators	0.5	4.0	2998	1
4 Petroleum products and handling	1.4	160.3	548	5
5 Cement plants	4.3	47.1	129	3
6 Asphalt plants	—	—	—	0
7 Iron and steel plants	3.3	15.1	290	4
8 Aluminum plants	—	—	—	0
9 Brass and bronze plants	—	—	—	0
10 Petrochemical plants	—	—	—	0
11 Stone, clay and glass plants	3.5	8.7	68	2
12 Grain handling operations	0.1	168.0	274	1
13 Lumber and wood product plants	—	—	—	0
14 Surface coating operations	0.6	672.6	1533	5
15 Food and drug plants	—	—	—	0
16 Other	0.8	115.2	140	3
Average	1.9	83.9	317	Total = 25

(continued)

TABLE 2 (continued)

	Category	Frequency	Duration (hr)	Magnitude (% above allowable)	Number of samples
$\sum$ all Causal Codes					
1	Industrial and utility boilers	89.3	7.2	163	10
2	Pulp and paper mills	38.5	5.0	180	6
3	Incinerators	3.4	45.9	614	6
4	Petroleum products and handling	9.4	122.6	167	13
5	Cement plants	29.7	31.2	2463	9
6	Asphalt plants	6.5	2.8	458	10
7	Iron and steel plants	84.2	1.6	158	10
8	Aluminum plants	1.9	12.8	59	4
9	Brass and bronze plants	0.6	1.7	1150	5
10	Petrochemical plants	0.6	2554.0	147	6
11	Stone, clay and glass plants	3.9	42.2	253	10
12	Grain handling operations	16.5	16.8	1224	5
13	Lumber and wood product plants	28.8	26.6	34	3
14	Surface coating operations	2.9	154.1	1566	13
15	Food and drug plants	0.5	233.0	25	3
16	Other	18.9	9.0	123	6
	Average	23.7	19.3	438	Total = 119

TABLE 3. PARAMETER B - SOURCE SIZE DATA SUMMARY.

Category (TPY × 10^3)	Frequency	Duration (hr)	Magnitude (% above allowable)	Number of samples
Causal Code 1 (design)				
<0.1	0.5	264.0	108	1
0.1 - 0.5	1.5	2920.0	900	1
0.5 - 1.0	0.8	4912.7	994	2
1.0 - 10	0.8	400.8	6,383	3
10 - 100	24.8	37.5	873	4
100 - 500	—	—	—	0
Average	9.6	158.2	1,003	Total = 11
Causal Code 2 (process)				
<0.1	10.3	23.9	520	3
0.1 - 0.5	2.1	6.0	147	7
0.5 - 1.0	165.8	0.6	161	6
1.0 - 10	71.9	7.65	154	13
10 - 100	86.0	4.5	164	3
100 - 500	3.0	1106.0	96,588	2
Average	65.9	6.6	421	Total = 34
Causal Code 3 (control O&M)				
<0.1	7.4	106.6	162	13
0.1 - 0.5	1.9	41.5	3,023	8
0.5 - 1.0	10.9	30.0	133	8
1.0 - 10	12.1	30.6	322	14
10 - 100	8.8	7.3	252	4
100 - 500	10.8	11.2	1,631	2
Average	8.6	45.9	399	Total = 49
Causal Code 4 (unforeseen)				
<0.1	1.5	26.0	523	3
0.1 - 0.5	1.7	246.0	413	6
0.5 - 1.0	1.3	49.2	391	5
1.0 - 10	1.5	95.0	375	8
10 - 100	4.0	21.5	138	2
100 - 500	5.0	45.6	15	1
Average	1.9	83.9	317	Total = 25

(continued)

TABLE 3 (continued)

Category (TPY × 10^3)	Frequency	Duration (hr)	Magnitude (% above allowable)	Number of samples
$\sum$ all Causal Codes				
<0.1	5.5	85.0	225	24
0.1 - 0.5	1.3	181.6	1,292	31
0.5 - 1.0	68.1	11.4	161	17
1.0 - 10	37.3	11.5	196	30
10 - 100	36.4	13.2	571	11
100 - 500	5.4	218.0	18,913	6
Average	23.7	19.3	438	Total = 119

TABLE 4. PARAMETER C - CONTROL DEVICE TYPE DATA SUMMARY.

Category	Frequency	Duration (hr)	Magnitude (% above allowable)		Number of samples
Causal Code 1					
ESP	0.8	1130.4	170		3
Scrubber	0.5	2765.0	2817		1
Baghouse	24.6	15.8	1941		4
Other	1.2	3097.7	667		3
Average	9.6	158.3	1003	Total =	11
Causal Code 2					
ESP	95.9	11.7	815		9
Scrubber	17.96	8.9	160		13
Baghouse	10.7	0.18	88		3
Other	123.4	2.4	180		9
Average	65.9	6.6	421	Total =	34
Causal Code 3					
ESP	14.3	6.5	438		10
Scrubber	4.2	119.2	348		14
Baghouse	10.6	13.3	312		14
Other	6.8	127.7	535		11
Average	8.6	45.9	399	Total =	49
Causal Code 4					
ESP	2.1	62.2	162		8
Scrubber	1.3	245.7	672		6
Baghouse	3.6	16.1	104		4
Other	1.0	175.9	746		7
Average	1.9	83.9	317	Total =	25
$\sum$ all Causal Codes					
ESP	46.6	14.5	751		22
Scrubber	8.4	40.8	212		36
Baghouse	8.4	12.8	518		35
Other	46.0	20.3	208		26
Average	23.7	19.3	438	Total =	119

TABLE 5. PARAMETER D - CONTROL DEVICE SIZE DATA SUMMARY.

Category (acfm × 10^3)	Frequency	Duration (hr)	Magnitude (% above allowable)	Number of samples
<u>Causal Code 1 (design)</u>				
<10	1.2	2097.7	667	3
10 - 50	0.5	1033.7	10,814	3
50 - 100	—	—	—	—
100 - 500	31.0	20.2	1,893	3
500 - 1000	1.0	2190.0	69	1
>1000	6.0	24.0	100	1
Average	9.6	158.2	1,003	Total = 11
<u>Causal Code 2 (process)</u>				
<10	14.5	4.5	109	3
10 - 50	22.6	10.6	377	13
50 - 100	17.7	10.9	54	5
100 - 500	146.0	5.8	482	12
500 - 1000	60.0	4.0	200	1
>1000	—	—	—	—
Average	65.9	6.6	421	Total = 34
<u>Causal Code 3 (control O&M)</u>				
<10	6.3	143.0	227	11
10 - 50	8.5	38.4	569	17
50 - 100	6.0	8.5	218	6
100 - 500	11.3	22.8	412	12
500 - 1000	17.3	6.2	181	2
>1000	4.0	15.0	100	1
Average	8.6	45.9	399	Total = 49
<u>Causal Code 4 (unforeseen)</u>				
<10	2.8	229.8	390	4
10 - 50	1.1	34.3	674	8
50 - 100	0.7	61.0	664	3
100 - 500	2.0	58.5	144	8
500 - 1000	4.0	48.0	200	1
>1000	5.0	20.0	100	1
Average	1.9	83.9	317	Total = 25

(continued)

TABLE 5 (continued)

Category (acfm × 10^3)	Frequency	Duration (hr)	Magnitude (% above allowable)	Number of samples
$\sum$ all Causal Codes				
<10	4.1	184.3	214	31
10 - 50	9.2	24.4	406	49
50 - 100	14.1	12.0	111	9
100 - 500	86.9	8.1	468	23
500 - 1000	16.6	28.5	192	6
>1000	15.0	20.3	100	1
Average	23.7	19.3	438	Total = 119

Averages for the summation of all Causal Codes were computed using data from the entire 119 source data base. Sources reporting no excess emissions incidents were tabulated in these averages. In all, there were 41 sources (34 percent) which reported no discernable excess emissions. Inclusion of these sources tended to lower average frequency, annual excess emissions and normalized excess emissions averages.

Total annual excess emissions attributable to all causes are listed in Table 6, as are the total annual credits for each source. This data was extracted from the initial contractor's reports. The annualized allowable emissions for each source is also presented. A straightforward presentation of the annual excess emissions and credits data will result in averages for these items which are unduly influenced by the larger sources which tend to have greater absolute excess emissions and emission credits. Both total annual excess and annual credits were divided by their respective annualized allowable emissions to derive "normalized excess" and "normalized credits." This "normalization" technique serves to eliminate large source bias, as these sources will typically have proportionally larger allowable emissions in conjunction with the greater annual excess and greater credits, when compared to the entire sample population. These normalized factors will be dimensionless and will represent the percent of allowable of each item (excess and credits); i.e., a normalized excess of 0.09 indicates that the annual excess is 9 percent of that source's allowable emission rate. Numberical averages of normalized excess and normalized credits were computed for each category. The significance of this data will be discussed in a subsequent section of this report.

RANKING OF SOURCE EXCESS EMISSIONS INCIDENTS

Once average incident indicator values (i.e., frequency, duration and magnitude) were computed and correlated by Causal Code for each category, a display of this data was made for each of the four parameters. The technique used for this display is defined as a "rank ordering" of the frequency, duration and magnitude averages. In this technique, all categories within a parameter are arranged in descending order with respect to the average frequency, duration and magnitude of their incidents. This convention gives a number one rank to the category with the highest frequency, longest duration or largest magnitude percentage. The rank ordering was computed for each individual Causal Code and for normalized excess and normalized credits, within each parameter. Rank ordering allows us to quickly recognize problem categories with respect to frequency, duration and magnitude of excess emissions incidents, and will narrow the area of concern with regards to regulatory response to these incidents. By rank ordering, individual Causal Codes as well as the summation of all causes we can detect the specific reasons for emissions incidents for each category. Rank ordering of normalized excess is accomplished in a slightly different fashion. For normalized excess, the category with the largest decimal (largest percent of allowables) is again ranked number one. Normalized credits, however, are ranked with the smallest decimal (smallest percent of allowable) as number one.

TABLE 6. EXCESS/CREDITS DATA SUMMARY.

Category	Total annual excess (tons)	Annual credits (tons)	Allowables (tons)	Normalized excess (% of allowables)	Normalized credits (% of allowables)
Parameter A					
1 Industrial and utility boilers	72.1	165.9	279.2	0.48	0.48
2 Pulp and paper mills	0.9	275.0	460.9	0.012	0.47
3 Incinerators	0.2	26.4	40.2	0.020	0.47
4 Petroleum products and handling	45.4	196.9	345.3	0.62	0.35
5 Cement plants	38.0	123.5	321.2	0.15	0.37
6 Asphalt plants	2.5	14.3	64.4	0.00071	0.58
7 Iron and steel plants	7.2	145.9	221.1	0.15	0.48
8 Aluminum plants	0.02	16.3	29.1	0.0035	0.57
9 Brass and bronze plants	0.2	18.9	36.4	0.0019	0.59
10 Petrochemical plants	11.5	256.5	378.5	0.25	0.64
11 Stone, clay and glass plants	0.7	33.5	53.9	0.079	0.68
12 Grain handling operations	123.5	180.2	222.9	0.82	0.81
13 Lumber and wood plants	0.4	6.7	23.4	0.0026	0.36
14 Surface coating operations	10.1	68.3	87.0	0.44	0.50
15 Food and drug products	0.1	8.1	16.1	0.0012	0.40
16 Other	4.7	159.6	258.9	0.014	0.65
Parameter B					
(TPY × 10^3)					
<0.1	0.43	3.77	8.14	0.11	0.55
0.1 - 0.5	9.0	23.9	50.3	0.35	0.47
0.5 - 1.0	27.5	87.6	159.5	0.18	0.58
1.0 - 10	34.6	238.6	39.7	0.28	0.56
10 - 100	64.5	233.8	416.6	0.26	0.43
100 - 500	6.5	207.0	376.8	0.15	0.44
Parameter C					
ESP	42.2	203.5	352.2	0.24	0.51
Scrubber	17.2	81.1	146.8	0.27	0.48
Baghouse	20.0	83.1	140.0	0.14	0.65
Other	16.6	111.5	197.2	0.33	0.37
Parameter D					
(acfm × 10^3)					
<10	14.1	16.2	56.5	0.40	0.52
10 - 50	10.0	69.3	122.3	0.14	0.53
50 - 100	3.28	77.5	162.9	0.024	0.41
100 - 500	69.1	189.0	391.9	0.38	0.48
500 - 1000	19.68	317.6	508.9	0.076	0.60
>1000	15.0	1262.0	1723.5	0.0087	0.73
Average for All Sources	22.5	110.9	207.8	0.22	0.50

This change ensures that the category with the smallest credits is ranked first and maintains our established convention, that the smaller the rank, the greater the problem, as sources with fewer credits operate closer to the allowable emission rate and are potentially a greater problem.

INTEGRATION OF RANKINGS

After individual category ranks have been established for frequency, duration and magnitude of excess emissions incidents, we narrowed our scope of investigation to derive an overall worst category with respect to all factors. Again a "ranking" procedure was used. For this we "integrated" the individual rankings for frequency, duration and magnitude into one combined ranking of categories. Once more we maintained the convention that the lower the rank number, the greater the problem of excess emissions and continued source compliance. While several techniques can be used for this integration, we have chosen to arithmetically add the individual rankings of frequency, duration and magnitude for each category, and then rank all categories by this overall number. This procedure was used for all four parameters, and for all Causal Codes within each parameter. While it may be argued that a greater weight should be placed on the number of incidents, their duration or their magnitude, we have decided, for this study, to weight all factors equally. The resultant tables therefore, present a systematic ranking of each parameter due to incidents within a specific Causal Code and indicate which categories appear to have problems attributable to a specific cause.

A slightly different approach was used to integrate normalized credits and normalized excess. As previously stated, the normalized excess were ranked for each parameter by listing the categories in descending order with respect to their numbers (largest value is first). Normalized credits were ranked by listing the categories in ascending order with respect to their numbers (smallest value is first). The numerical difference between these two normalized numbers was then calculated (credits-excess) and these resultant numbers were then ranked, again with the smallest number ranked first. The significance of the difference between normalized values is that it points out the degree to which a category has greater excess than credits, or vice versa. A negative number for the computed difference indicated that this category had more excess emissions than credits, and overall was emitting more pollutant into the ambient air than is allowed by its applicable regulatory limit computed and summed on an annual basis. As the difference becomes increasingly positive, the category has more annual credits than annual excesses and operates further below the allowable limits. Use of normalized values allows us to express the degree to which credits exceed excesses in terms of percent of allowable emissions. Hence, when a source reports a difference of +0.40 it means that emission credits completely offset emission excesses and that the source operated with an annual credit surplus of 40 percent of its regulatory emission limit computed and summed on an annual basis. Stated another way, the source emitted only 60 percent of the emissions it was allowed to emit. Knowledge of this net difference between credits and excess can potentially provide a useful planning tool when developing regulatory control concepts.

To summarize the results of the parameter integrations, we have included tables of "problem area profiles." These tables, one for each Causal Code, summarize the integration results on one page and provide the reader, at one glance, the opportunity to visualize the extent of the excess emission problem. Since certain control device types are not associated with some industries (i.e., grain handling facilities typically do not use scrubbers) these profiles should not be used out of context. They are included to essentially summarize our findings with respect to those categories which may have greater problems in maintaining continued source compliance.

SECTION 2

DISCUSSION OF DATA

PARAMETER A. EXCESS EMISSIONS AS A FUNCTION OF INDUSTRIAL CATEGORY

The following subsections summarize the compilation of data supplied by all four contractors relative to each of the major industrial categories investigated. To maintain consistency within each subsection, our presentations contain the following elements:

- General comparative description of sources surveyed within the category
- Discussion of source representativeness
- General comparative discussion of the nature of excess emissions including average frequency, duration, and magnitude (percent above allowable)
- Comparison of individual category averages to average frequency, duration and magnitude (percent above allowable) of all categories combined.

The information provided in some subsections is more thorough than others because of the number of sources investigated in a given category and/or the availability of data specific to a given facility. Causes of excess emission incidents have been grouped into one of four causal factors. For comparison purposes, we defined these causal factors according to whether they were design, process, control device (operation and maintenance) related or unforeseen. Tables 2, 3, 4, 5 and 6 present a comparison of causal factor values recorded for each category and the overall average for the 119 sources evaluated.

Excess Emissions From Steam Generating Plants

On-site plant surveys were conducted at seven steam generating plants. Since data for four boilers were available at one of the facilities, our total population included 10 separate units. The size of the 10 units surveyed ranged from 173 to 28,400 tons per year of uncontrolled emissions. Emissions from 6 of the 10 plants were controlled by wet scrubbers with the remaining 4 being served by electrostatic precipitators or "other" devices. The size of the control devices ranged from 25,000 to 550,000 acfm.

Most of the 10 units investigated were coal fired, with some wood fired. A survey of utility and industrial steam generating units currently in use in the United States shows that there are 3,677 coal-fired units operating with an average uncontrolled particulate emission rate of 12,771 tons per year.

Of the 10 steam units investigated, 9 (90 percent) reported excess emission incidents, whereas for the sample population (119 sources), 78 (66 percent) had problems, indicating that excess emission incidents are more common for steam generating plants. For all causal codes combined, steam generating plants have far more incidents per year than the average of the sample population with almost four times as many. However, the duration of the incidents are shorter (7 hours versus 19) and the relative magnitudes are less (163 versus 438) than the average of the sample population. Although the average steam generating plant has 3.3 times as many excess emissions as the average of the sample population their credits are also greater. Normalization of the data show that excesses were completely offset by the credits resulting in no net gain or loss.

A total of 892.5 incidents were reported by the sources of this category. Of these, 99.8 percent were process related, with the remaining 0.2 percent due to design flaws and unforeseen events. It should be noted that of the 890 process related incidents found, 882 occurred at one plant which had a regularly reoccurring problem.

No control device operation and maintenance related incidents were reported. In addition, no cases of multiple causal factors occurred. That is, of the nine sources reporting problems none were due to more than one causal factor; two (22 percent) had design problems, six (67 percent) were found to have process related incidents and one (10 percent) reported an unforeseen event.

About twice as many steam generating units reported design related incidents as the average of the sample population. Even though a greater number reported problems, each steam generating unit had fewer incidents per year than the average and each incident had a higher relative magnitude and last almost 15 times longer.

With respect to causal code 2, a larger number of steam generating plants reported process (boiler) related problems than the average of the sample population. Six (60 percent) of the 10 sources identified reported process related incidents. In terms of the average for the sample population, process problems occur twice as often at steam generating plants. Although the frequency is higher, the magnitude of these incidents are less than the average of all sources surveyed.

Even though 41 percent of all the sources surveyed had operational and maintenance problems, no problems due to this causal factor were reported for steam generating plants. Only 1 plant of the 10 (10 percent) investigated had an episode related to an unforeseen event.

Typically, the cyclical nature of the boiler operation is reflected in the high process related frequency of upsets. Startups and shutdowns of boilers, for example, can occur daily and each can result in an excess emission incident.

Excess Emissions From Pulp and Paper Mills

Six of the 119 facilities surveyed were pulp and paper recovery boilers. The size of these boilers ranged from 15,000 to 343,000 tons per year of uncontrolled emissions. Emissions from three of the boilers were controlled by electrostatic precipitators, wet scrubbers were used on two of the units with emissions from the sixth boiler controlled by an absorbing tower with Brink mist eliminators. The control devices ranged from 23,000 to 540,000 acfm. The results of a literature search conducted to determine source representativeness found that there are approximately 120 pulp and paper recovery furnaces in the country with the average unit having an uncontrolled emission rate of 24,257 tons per year.

Of the six boilers investigated, only two reported incidents of excess emissions which were due to process related problems. There were no reported incidents resulting from design, operation and maintenance or unforeseen factors.

The number of pulp and paper mill sources reporting process related incidents is slightly higher than the average of the sample population for causal code 2 problems (33 versus 29 percent). The frequency with which these process related incidents occurred was almost twice the average of the sample population but the relative magnitude of the incidents were lower and the duration was less.

Annual excess emissions from pulp and paper boilers were found to be 0.87 tons compared with 22 tons for all plants combined. Annual credits for this industry were substantial, averaging 275 tons. This is more than twice the average of the sample population. Normalization of these data elements show, that on a yearly basis, when excesses were totally offset by credits, pulp and paper boilers were found to operate with a credit surplus of 46 percent of the allowable emission limitation.

Excess Emissions From Incinerators

Onsite surveys were conducted at six incinerator facilities. The facilities were comprised of municipal, refuse, and industrial type incinerators. The size of the sources investigated ranged from less than 100 to 2,260 tons per year of uncontrolled emissions; two of the six incinerators fell into the less than 100 tons per year category. With respect to control equipment, five of the incinerators were served by wet scrubbers with the sixth unit employing an electrostatic precipitator. Scrubber sizes ranged from 1,200 to 30,800 acfm. The electrostatic precipitator operated at 750,000 acfm, an unusually high flow rate for an incinerator with an annual uncontrolled emission rate of 522 tons.

Four of the six sources reported excess emissions incidents, with one of the four identifying multiple causal factors which were operational and maintenance related and unforeseen. Based on the average of the sample population, incinerator sources appear to have about the same number of incidents. None of the sources investigated reported design problems and in only one (17 percent) case was an unforeseen related problem found. Two sources (33 percent) reported process related incidents and two (33 percent) operation and maintenance incidents were found at two other incinerators.

The frequency with which incidents occur at incinerators was far less than the average of the sample population (3.4 versus 23.7), although the duration and relative magnitude of each incident was greater. However, because the incidents occur so infrequently, annual excess emissions for this industrial category were only 0.22 tons, one one-hundredth of the 22 tons reported as the average of the sample population sources. Credits for sources in this category were well below the average sources of the sample population (26.4 versus 110.9 tons). Since the credits far exceeded excesses, the incinerators were found to operate at only 53 percent of their allowable limit with the remaining 47 percent being credits. A total of 20.5 incidents were reported for all causal cases. Of these, 70.7 percent were process related, 26.8 percent resulted from control O&M problems and 2.4 percent were unforeseen.

Even though causal code 2 problems represent the highest number of incidents occurring per year, incinerators have fewer process related incidents than other plants. The duration of each incident is also less, even though the relative magnitudes are higher. The average annual excess emissions due to process related incidents for all sources are 100 times greater than the excess from incinerators. This wide difference results from the fact that incinerator process related incidents last only 10 minutes, and occur only seven times a year.

Incidents related to control device operation and maintenance problems occur at incinerators three times annually. This is less than half as many times as the average of the sample population. The duration and relative magnitude of these incinerator incidents are lower and higher, respectively, than the average of the sample population. Average annual excess emissions from incinerators due to O&M incidents are far less (0.39 tons) than the average of the sample population (10.6 tons).

Unforeseen incidents occur about one-third as often as incinerators as the average of the sample population. The relative magnitude of the incidents is high, but they last on the average only 4 hours causing a small amount (0.39 tons) of excess emissions. This is much less than the average of the sample population (9.2 tons).

<u>Excess Emissions From Petroleum Products and Handling</u>

Investigations were made at 13 facilities falling into the petroleum products and handling category. The sources surveyed ranged from gasoline tank farms and loading racks to fluid catalytic cracking units. Source sizes ranged from less than 100 to 2,160 tons per year of uncontrolled emissions. Only one source was rated at less than 100 tons per year. Control systems investigated include three electrostatic precipitators, three wet scrubbers and seven "other" types including vapor recovery systems, afterburners, etc. Control equipment sizes ranged from 375 to 410,000 acfm.

As a whole, petroleum products and handling facilities had fewer incidents (2.2) during the year than the average of the sample population (23.7)

The average duration and relative magnitude of the incidents were found to last 123 hours at a rate 1.7 times the allowable standard, respectively. Annual excess emissions (45 tons) were twofold higher than the average of the sample population (22.5 tons). However, because average annualized allowable emission limit is high, annual credits were also high (197 tons), greater than the average of the sample population (110 tons). Consequently, sources surveyed in this category were found to operate with 37 percent of the allowables as credits.

Ninety-two percent of the petroleum products and handling plants investigated were found to have at least one excess emissions incident. Only 1 of the 13 sources studies did not report any incidents of excess emissions. Six of the twelve sources with problems reported incidents due to more than one causal factor. One source, a fluid catalytic cracking unit controlled by an electrostatic precipitator, was found to have an excess incident related to each of the four causal factors reviewed. Most of the sources' problems, however, were related to O&M. Total annual excess emissions due to the O&M incidents were 27.1 tons, well above the average (10.6 tons) for sources having similar problems.

Of the 122.5 incidents reported for all causal codes, 52.7 percent resulted from process upsets, 38.8 percent were due to control O&M problems, 5.7 were unforeseen, and 2.9 resulted from design flaws.

Design related incidents were reported for 3 of the 13 (23 percent) sources investigated, indicating that design problems occur at more sources in the petroleum products and storage industry than the average of the sample population (9.2 percent). When a design incident did occur, it lasted for a long time (1,527 hours) and was of a high relative of magnitude (729 percent above the allowable limit) resulting in a large amount of excess emissions (81 tons). Even though more sources in this category were found to have incidents of excess emissions than for other industries, the annual frequency of those incidents was less than the average of the sample population (1.2 versus 9.5). This accounts for the fact that annual excess emissions (97 tons) related to design problems for petroleum products and handling plants are less than the average of the sample population (118 tons) for this causal factor.

Although the number of sources in this category appear to have the same percentage of process related problems as other industries, excess emission incidents occur less frequently (16.1 versus 65.8). The duration of the incidents is similar to the average of the sample population but the relative magnitude is roughly one-fifth the average for all sources. Excess emissions resulting from process problems at sources in this industry and the average of the sample population are similar.

Control operation and maintenance incidents occur less frequently at the sources of this category but they tend to last almost four times as long with the relative magnitude of about half that of the average of the sample population. Annual excess emissions are more than twice as high as that of the average of the sample population.

Unforeseen problems at sources in this category appear to result in slightly more annual excess emissions (14 tons) than for the overall average (9.2 tons) for this causal factor. This is due to the fact that when an incident occurs at the facility, it lasts twice as long (160 versus 84 hours).

Excess Emissions From Cement Plants

On-site surveys were conducted at seven cement manufacturing plants, all focusing on rotary kilns. Since data for three rotary kilns were available at one of the facilities, our total population included nine separate units. The kilns ranged in size from 792 to 200,000 tons per year of uncontrolled particulate matter. Five of the units were controlled by electrostatic precipitators, with the remaining four employing baghouse controls. Control device sizes ranged from 100,000 to 525,000 acfm.

Based on a literature search, approximately 434 cement kilns are operated in the United States. The average kiln size is 21,686 tons per year of uncontrolled emissions.

Of the kilns investigated, seven of the nine (77 percent) reported incidents, showing that the probability of a cement plant having a problem is greater than that of the sample population (66 percent). Four of the seven were found to have multiple problems; i.e., incidents resulting from more than one causal factor. None of the units reported design problems. Five of the kilns (55 percent) were found to have process related incidents; five (55 percent) had incidents resulting from O&M problems; and three (33 percent) had incidents due to unforeseen events. Compared with the average of these causal factors for all sources investigated, cement plants, specifically rotary kilns, tend to have more excess emission incidents. A total of 267.5 incidents were reported at the sources surveyed. The breakdown of these incidents by causal factors shows that 57.2 percent were process related, 37.9 resulted from control O&M problems and 4.9 percent were unforeseen.

Total annual excess emissions (38 tons) from rotary kilns were found to be greater than of the sample population. In the same trend, the average emission credits were 124 versus 110 tons. Normalization of these two values show that credits offset excess emissions resulting in a net surplus of 22 percent of the average allowable limitation. This 22 percent is slightly lower than the 28 percent surplus found for the average of the sample population.

With respect to process related problems (e.g., change in material feed rate or temperature), cement plants have fewer incidents per year than the average of the sample population but the duration and relative magnitude of each were found to be higher. The higher duration, however, was caused by one plant which had an incident last three-fourths of the year. Similarly, the higher reported magnitude was attributed to an incident at a different plant which lost total control. This resulted in a percent above allowable of 115,900. Annual excess emissions resulting from process related problems are relatively high (30 tons) compared to the average of the sample population (18 tons). Since cement plants require a high degree of control, whenever they encounter a problem, the magnitude of emissions resulting is often very high.

Operational and maintenance incidents were found to occur more often at the rotary kilns that at the average of the sample population (20 versus 9). As expected for these large sources, the relative magnitude of the incidents was higher than the average of the sample population but the duration of the incident was shorter. The combination of the larger number and greater emissions resulted in more O&M related annual excess emissions (32 tons) released from cement plants that from the average of the sample population (11 tons).

The number of unforeseen problems occurring at cement plants is almost 2.5 times greater than those for the average of the sample population. Although they occur more often, the unforeseen incidents do not last as long nor are they of as high a relative magnitude as the similar related incidents found for the average of the sample population. Total annual excess emissions are about the same (9.7 versus 9.2 tons).

Excess Emissions From Asphalt Plants

A total of 10 asphalt plants were investigated. Most of the sources surveyed focused on rotary dryers. Source sizes ranged from less than 100 to 6,300 tons of uncontrolled particulate matter per year. Only one of the 10 was rated at less than 100 tons. Fabric filters (baghouses) were used to control emissions at six of the sources, with wet scrubbers serving the remaining four. The control devices ranged in size from 4,000 to 54,000 acfm. Due to the ever growing number and construction projects in the country and the increasing need for asphalt concrete, a reliable number for those plants currently in operation could not be established. Data was available, however, to estimate average source size, which would be 3600 tons per year of uncontrolled emissions.

The data reported show that 4 of the 10 sources investigated (40 percent) had an excess emission incident. One of the sources reported incidents related to both process and O&M problems. Compared to the sample population, asphalt plants tend to have a fewer number of sources reporting problems. This is one reason why annual excesses from sources in this category were one-tenth that for the average of the sample population. When normalized and excesses are offset, the credit surplus for sources in this industry were found to be 58 percent of the allowable limitation.

No design or unforeseen related incidents were reported for the asphalt sources surveyed. With respect to process problems, 2 of the 10 sources had excess emission incidents. The 20 percent reporting rate identified here was slightly below the 29 percent rate for the sample population. Compared with the average of the sample population, the frequency with which these occur is less for rotary dryers (10 versus 66), as is the duration and relative magnitude. This resulted, as would be expected, in lower annual excesses due to process related problems for asphalt sources than other industries.

Control device operation and maintenance related problems were found to occur more frequently at asphalt plants than for the average of the sample population (14.8 versus 8.6). The duration of the incidents were shorter than the average, but their relative magnitude was higher. These offsetting findings resulted in similar annual excesses due to O&M problems for asphalt sources and the sample population (8.2 and 10.6 tons, respectively).

Excess Emissions From Iron and Steel Plants

For this industrial category, 10 sources were included in the plant evaluations. The sources surveyed were principally electric arc furnaces, and gray iron cupolas. Source sizes ranged from less than 100 to 21,600 tons per year of uncontrolled particulate matter, with 3 of the 10 rated at under 100 tons. The most common control devices used were wet scrubbers, operated by 7 of the 10 sources. Baghouses were used by two sources with one facility controlled by an electrostatic precipitator. Control device sizes ranged from 8,200 to 1,700,000 acfm. The results of a literature survey conducted to determine source representatives show that there are approximately 121 electric are shops and 1493 gray iron cupolas in the country today. The average sizes of these two industrial sources, in terms of uncontrolled emissions, are 3,760 and 120 tons per year.

For the 10 sources investigated, 9 reported excess emission incidents. This finding implies that a greater number of iron and steel plants have more problems controlling emissions than the average of the sample population (90 versus 66 percent). Five of the nine sources reporting incidents were found to have multiple problems.

In addition to having more sources reporting problems than the sample population, incidents associated with iron and steel plants occur more frequently (84 versus 24). However, because the duration and magnitude are less than the average, annual excess emissions are also less. When the credits and excess data are normalized and excesses are offset, iron and steel sources operate within 68 percent of the allowable emission limitation. This means that annual credits are 32 percent of their allowable limit.

Of the total 842 incidents reported, 88.8 percent resulted from process upsets or changes, 6.5 were due to control O&M problems, 3.1 percent resulted from design flaws and 1.5 percent were unforeseen. It should be noted that 93.5 percent (700 incidents) of the process related incidents reported occurred at one source.

Design related problems were found at 2 of the 10 sources surveyed. This is almost double the average number of sources which had similar problems for of all 119 sources. The incidents (13 per year) occur more often than for the average of the sample population (9.5 per year), although the duration and relative magnitude are substantially less. The end result being that excesses from iron and steel sources due to design-related problems are much less (8.6 tons) than those (118 tons) for the average of the sample population.

Incidents resulting from process upsets or changes were found at 20 percent of the iron and steel sources surveyed. Compared with the average of the sample population (29 percent), iron and steel plants have fewer number of sources reporting process-related problems. The frequency of these incidents, however, are greater than the average of the sample population (374 versus 66). It should be noted that the high average frequency reported for this causal code resulted from one plant which was found to have 700 incidents a year. The duration and relative magnitude of the process related incidents were found to be less than those for the average of the sample population resulting in lower than average annual excesses.

O&M related problems were found to cause incidents in 8 of the 10 sources investigated. This is almost twice the number reported for the sample population. The frequency of incidents reported for the iron and steel sources was about the same for the average of the sample population (6.9 versus 8.6). Incident durations and magnitudes were less than the average, causing annual excesses for this industrial category (3.4 tons) to be lower than the average of the sample population (10.6 tons).

Iron and steel sources have more unforeseen related problems than the average of the sample population. Comparatively, 4 of the 10 iron and steel plants had an unforeseen problem whereas for the average of the sample population 2 sources out of 10 reported similar related problems. Among the same line, the frequency of the unforeseen incidents is 1½ times greater for iron and steel sources than the average. The duration and magnitude of the incidents were found to be less than the average of the sample population. These latter two components help to keep annual excesses (4 tons) lower than the average of the sample population (9.2 tons).

Excess Emissions From Aluminum Plants

On-site surveys were made at four aluminum plants. The sources investigated were involved in the melting of aluminum scrap. Source sizes ranged from less than 100 to 212 tons of uncontrolled emissions per year; two of the sources were rated at less than 100 tons. Emissions from two of the operations were controlled by baghouses, one was controlled by an electrostatic precipitator with the fourth employing afterburner control. The control devices ranged in size from 9,940 to 130,000 acfm.

Half of the sources surveyed reported excess emission incidents. This is less than the number of sources in the sample population with problems. The average frequency, duration, and magnitude reported for all causal codes combined under this industrial category were less than the average for all sources. As a result, annual excess emissions from aluminum plants were found to be less than the average of the sample population (46 pounds versus 22 tons). With respect to an allowable emission limitation, aluminum plants show a high degree of control. Average annual credits for the sources surveyed are 16.3 tons compared with an allowable emission limit of 29.1 tons. After normalizing the excesses and credits and offsetting the excesses, the aluminum sources surveyed were found to operate with a credit surplus of 57 percent of the allowable limit.

None of the sources surveyed reported design or unforeseen related incidents. Only one source reported a process related incident which occurred 3½ times annually each lasting an average of 5 minutes at 50 percent above the allowable limit. Aluminum plants are much better controlled than the average of the sample population with this problem. Similarly, only one source was found to have an O&M related incident. This incident occurred four times annually lasting 24 hours at 67 percent above the allowable limit. Similar to the process problem discussed above, aluminum sources have fewer excess emissions resulting from O&M problems than the average of the sample population. The process and O&M information presented should be used with discretion because of the limited data base.

Excess Emissions From Brass and Bronze Plants

For this industrial category, five sources were surveyed. All sources investigated relate to furnace melting operations. The size of the furnaces ranged from less than 100 to 8,400 tons per year of uncontrolled emissions; three of the five were rated at less than 100 tons. Fabric filters (baghouses) were used to control emissions from all five furnaces. The size of the baghouses ranged from 6,000 to 450,000 acfm.

Only one of the five sources surveyed, a copper-melting cupola controlled by two parallel baghouses, reported incidents. The three incidents reported were due to process and control O&M problems. This 1 in 5 ratio is less than the 3.3 in 5 ratio for the sample population. The average frequency (0.6) of the incidents for the two causal factors combined was less than that for the average of the sample population (23.7). Similarly, the duration was shorter than average. The relative magnitude, however, was almost four times higher than the average of the sample population due to total loss of control. With respect to normalized data, once the excess has been offset, brass and bronze plants operate with a credit surplus of 59 percent of the allowable limit.

Process related problems reported for the cupola occurred when the cupola was shut down for emergency maintenance. This occurred once per year lasting 10 minutes. Compared with the average of the sample population for this causal code, brass and bronze sources have a smaller amount of excess emissions.

Control O&M related incidents occurred twice per year, both times due to baghouse fires. With respect to the average of the sample population, brass and bronze plants have fewer O&M related incidents which occur less often and last for a shorter duration of time. The relative magnitude of the incidents is higher in this category but overall these plants have fewer annual excess emissions than the average of the sample population.

Excess Emissions From Petrochemical Plants

For this industrial category, six sources surveyed were used in the data analysis. They ranged in size from less than 100 to 8,600 tons of uncontrolled emissions annually; two of the six were rated at less than 100 tons. Two of the sources were controlled by fabric filters (baghouses), one was served by an electrostatic precipitator with the remaining three employing some "other" type of control (e.g., afterburner or absorber). Control device sizes ranged from 5,500 to 25,000 acfm.

Of the six sources investigated, two were found to have incidents of excess emissions. Both sources reported incidents resulting from more than one causal factor. Based on the average of the sample population for all causal codes, petrochemical plants have fewer excess emission problems, one plant in three reporting a problem versus two in three overall. The frequency and magnitude of the incidents at petrochemical sources are less than average but the durations are longer. It should be pointed out that the long average duration was attributed to two separate incidents occurring at two separate plants for two different causal factors. One, a design related problem lasted 6,000 hours, while the other, a control O&M problem, continued for 2,160 hours.

Annual excess emissions from plants (11.5 tons) in this category are about half those of the average of the sample population. Analysis of the normalized annual credits and excesses show that petrochemical sources operate with an annual credit surplus of 39 percent of the allowable emission limitation. This mode of operation is higher than the average of the sample population (28 percent).

Although only one of the six sources surveyed reported a design problem, this ratio is higher than the average of the sample population. Even though the duration was found to be higher, as discussed above, the frequency, magnitude and resulting annual excess emissions were found to be lower for petrochemical sources than the average of the sample population.

Process related incidents occurred at two of the six sources investigated. This ratio is similar to that of the average of the sample population. The frequency with which the process problems occur are much less than the sample population average (0.75 times versus 65.8) and the magnitude is also less (255 and 421, respectively). However, the duration of each incident is almost 79 times longer than the average of the sample population. With respect to annual excesses, the lower frequency far outweighs the long duration resulting in lower emissions (4.8 tons) than that based on the average of the sample population (18 tons).

Problems related to control O&M were reported for only one of the six (17 percent) sources evaluated. This is a lower percentage than that (41 percent) for the average source of the sample population. The incidents resulting from O&M problems are similar in nature to the process related incidents discussed above. They occur less often and are of smaller magnitude but last longer than the average of the sample population resulting in fewer annual excesses. No unforeseen related incidents were reported at the petrochemical sources investigated.

Excess Emissions From Stone, Clay, Glass and Mineral Plants

Data obtained from 10 on-site plant surveys were analyzed. The size of the sources investigated ranged from less than 100 to 9,240 tons of uncontrolled emissions per year, 3 of the 10 were rated at less than 100 tons. Baghouses were used to control emissions at five of the 10 survey sources. Electrostatic precipitators were operated by three of the sources with the remaining two employing wet scrubbers. Control device sizes ranged from 230 to 23,000 acfm.

Six of the ten sources were found to have at least one type type of causal factor related incident. Of these six, one reported problems resulting from more than one causal factor. The number of sources within this industrial category reporting problems is similar to the average of the sample population. The average frequency with which the problems occur, however, is six times less than the average of the sample population (3.9 versus 23.7). When an incident does happen, it lasts twice as long but is of lower relative magnitude than the average of the sample population.

Sources in this category tend to release small amounts (0.7 tons) of excess emissions annually; well below the average of the sample population (22.5 tons). This, along with the fact that these sources operate with a normalized credit surplus of 60 percent of the allowable limitation indicates that stone, clay, and glass plants are well controlled. A total of 38.7 incidents were reported. Most of these excursions (80.7 percent) resulted from control O&M problems, with 18.1 percent due to unforeseen events and 1.3 percent caused by poor design.

Design related incidents were found at 1 of the 10 plants surveyed. This is about the same as the average of the sample population. The frequency of the problem occurred only once every two years, which is below the average of the sample population (9.5 times a year). Similarly, the magnitude of the incident was less than that for the average of the sample population having the same causal factor-related problems. Although the incidents last longer, total annual excesses were substantially lower than that of the average of the sample population.

No process related incidents were reported for the sources surveyed. With respect to control O&M problems, a greater number of clay and glass sources tend to have problems resulting from this causal factor than other industrial sources. Five of the ten facilities investigated reported O&M related incidents. Based on the average of the sample population, the incidents occur less often and are of lower relative magnitude but last longer. Average excess emissions resulting from the combination of these factors are 14 tons annually, more than that of the average of the sample population (10.6 tons).

Unforeseen problems were reported at two sources (20 percent). This is about the same number as the average of the sample population reporting a similar problem. Although these unforeseen incidents occur more often than the average of the sample population, they do not last as long nor are they as severe, resulting in fewer annual excess emissions than the average of the sample population.

Excess Emissions From Grain Handling Operations

For this industrial category, five sources were included in the data analyses. Source sizes ranged from 1,960 to 19,700 tons per year of uncontrolled particulate matter. All sources were controlled by baghouses, which ranged in size from 10,000 to 325,000 acfm. There are approximately 477 grain terminal elevators in the country. Average uncontrolled emissions from loading and transferring/conveying operations at these sources are 410 tons per year.

Of the five sources investigated, three reported excess emission incidents; two were found to have multiple causal factor-related problems. Based on the average of the sample population, the number of sources in the grain handling category found to have problems are about the same, both reporting approximately 6 of 10 facilities with incidents. The frequency of the incidents and durations are lower than the average of the sample population relative but their magnitudes are substantially higher. Because of the latter, total annual excess emissions (123.5 tons) from plants in this category are greater than the average of the sample population (22.5 tons).

The study found that, of the sources surveyed, normalized excesses exceeded normalized credits indicating that on a yearly basis grain handling facilities operate out of compliance. It should be noted, however, that one source included in the data analysis operated totally uncontrolled for 1,296 hours of the year. This was a design related problem which resulted in 604.5 tons of excess emissions. Consequently, this one plant greatly affected the average values reported.

Design related incidents appear to cause the most problems. Of the total 82.7 incidents which were reported, 72.5 (88 percent) were design related. Associated with the design problems were incidents with very high magnitudes. One source reported a magnitude of 29,515 percent. What this implies is that grain handling facilities are large sources of uncontrolled emissions requiring a high degree of control and that, when a design problem occurs, the source tends to lose total control.

No process related incidents were reported. With respect to control O&M problems, two sources reported problems. This about the same number as the average of the sample population. The average frequency, duration, magnitude, and amount of excess emissions were found to be less than the average of the sample population for this causal code. This implies that grain handling sources have fewer and less severe (lower magnitude) O&M related problems than other industries. This would be expected because baghouses, which were operated by all sources, tend to have the fewest O&M problems.

Only one source reported an unforeseen problem, which is the reporting frequency of the average of the sample population. Overall, the incident indicators identified for this one source are less than those of the average of the sample population.

Excess Emissions From Lumber and Wood Products Plants

Data from three sources in this industrial category were included in the data analyses. Two of the sources were rated at less than 100 tons/year with the third having an uncontrolled emission rate of 650 tons. The largest source was controlled by a baghouse and the other two by "other" devices, those being a cyclone with water sprays and a sand bed filter. The control devices ranged in size from 1,000 to 34,000 acfm.

All three sources reported incidents of excess emissions and each incident related to control operation and maintenance problems. This 100 percent of sources reporting problems is, obviously, greater than the average of the sample population (66 percent). Also, greater than the average of those source reporting a control operating and maintenance problem.

With respect to control O&M related problems, the lumber and wood sources surveyed had seven times as many incidents as the average of the sample population. It is important to note that one source, that controlled by the sand bed filter, had 71 percent of the incidents reported. The average duration and magnitude of the O&M incidents were less than that of the average of the sample population. These latter two indicators explain why the average annual excesses (0.4 tons) from these sources were found to be less than the average of the sample population (10.6 tons). Based on the analyses of the normalized credits and excesses, sources in this industrial category operate with a credit surplus of 36 percent of the allowable emission limitation.

Excess Emissions From Surface Coating Operations

For this industrial category, data from 13 sources were analyzed. The sources ranged in size from less than 100 to 2000 tons of uncontrolled emissions per year; four being less than 100 tons. Eight sources used some "other" device to control emissions, whereas two sources operated electrostatic precipitators, two were served by wet scrubbers, with the thirteenth source being controlled by a baghouse. The control device sizes ranged from 3,500 to 80,700 acfm.

Of the nine sources reporting incidents, three had excess emission excursions related to more than one causal code. The 69 percent (9 of 13 sources) reporting incidents is similar to the average of the sample population (66 percent). Excess emission incidents occurring at surface coating sources happen less frequently but last longer and are more severe than the average of the sample population. These latter two incident indicators do not appear to be as important as the frequency because average annual excesses from surface coating sources is about half that of the average of the sample population (10.1 versus 22.5 tons). Looking at the normalized data, sources in this industrial category, on an annual basis, tend to operate close to their allowable emission limitation having only a 6 percent credit surplus.

No design related incidents were reported by the sources surveyed. Process related problems, however, accounted for 58 percent of reported incidents, with 4 of the 13 sources (31 percent) reporting excursions. Although the incidents did not occur as frequent as the average of the sample population, the average duration and magnitude were greater. All things considered, surface coating sources were found to have fewer excess emissions resulting from process problems than the average of the sample population (1.8 tons versus 18.4 tons).

Control operation and maintenance related problems accounted for 34 percent of the reported incidents, occurring at 5 of the 13 (38 percent) sources surveyed. The 38 percent reporting incidents is similar to the 41 percent based on the average of the sample population. The frequency with which an incident occurs is less but the duration and magnitude are higher when one compares surface coating sources with the average incident indicators of the sample population. Because the incidents occur only 2.5 times per year, excesses due to O&M problems are lower for surface coatings sources than other industrial facilities. It should be noted that the average duration and magnitude are high because one source reported an incident which lasted an entire year (8,760 hours) while two sources reported magnitudes of over 2,000 percent (one at 30,456 percent).

Surface coating sources have a higher number of unforeseen problems than the average of sample population. Approximately 39 percent (5 of 13) of the sources surveyed reported unforeseen related incidents. Although more sources reported incidents, these incidents occurred less frequently, roughly once every 2 years. Annual excess emissions are higher than the average of the sample population, apparently due to the severity and length of the incidents (1,533 percent above the standard and 673 hours, respectively). Similar to the O&M incident indicators discussed above, the high averages for duration and magnitude were attributed to only one or two sources which had major problems.

Excess Emissions From Food and Drug Plants

Data analysis was conducted on three food and drug sources. The sources included pet food drying ovens, a meat smokehouse, and dry products handling at a gum manufacturing plant. Source sizes were 9.2, 120, and 159 tons per year of uncontrolled emissions. In the order presented above, source control device types were a fume incinerator, wet scrubber, and baghouse. The size of the control units ranged from 4,000 to 11,000 acfm.

Only one of the sources surveyed, the meat smokehouse, reported an incident, which resulted from a control operation and maintenance problem. Because only a few sources were surveyed in this category, with only one reporting problems, the data presented should be used with discretion. The O&M related incident is less severe and occurs less frequently than the average of the sample population. However, the incident tends to last longer. For this category, annual excess emission are totally offset by annual credits resulting with the sources operating with a net surplus of 40 percent of the allowable emission limitation.

Excess Emissions From "Other" Plants

Data analyzed for the category, which includes mineral acid and ammonia phosphate fertilizer plants, were obtained from six sources. The sources were comprised of four fertilizer plants and two sulfuric acid plants. Plant sizes ranged from 100 to 5,880 tons per year of uncontrolled emissions. Control device types included three wet scrubbers, one baghouse and two "other" units. The size of the control equipment ranged from 4,500 to 149,000 acfm. With respect to source representativeness, there are 150 sulfuric acid and 41 ammonia phosphate plants in the United States. The average size of the plants in these two industries are 283 and 3,591 tons per year of uncontrolled emissions, respectively.

With regard to the sources surveyed, four of the six (66 percent) reported an excess emission incident. This is the same number as the average of the sample population. Overall average incident indicators, which include frequency, duration, magnitude and annual excesses, were less than those found for the average of the sample population. Consequently, it was not unusual to learn that "other" sources generally operate with a credit surplus of 64 percent of their allowable limitation. This would indicate a high degree of control with few problems. Of the 113.7 incidents reported, 79 percent were process related, 19 percent control operation and maintenance related, and 2 percent were due to unforeseen problems.

Design related incidents were not found at any of the sources investigated. Concerning process related problems, three (50 percent) of the six facilities reported incidents, which is higher than the average of the sample population (29 percent). Similar to the overall average of all causal factors discussed above, process related incidents at "other" sources occur less frequently, are shorter in duration and less severe than the average of the sample population. This means that annual excess emissions resulting from these incidents are also less than the average of the sample population.

Causal code 3 (control O&M) had the greatest number of sources reporting problems. Of the six sources investigated four (66 percent) were found to have O&M problems. This is more than the average of the sample population reporting O&M problems. The average of the incident indicators for "other" sources with O&M related problems are all less than those of the average of the sample population.

Unforeseen problems were found at three of the six (50 percent) sources. This is more than twice the average of the sample population. Although they tended to last longer, the frequency, magnitude and excesses associated with those incidents were less than the average of the sample population.

PARAMETER B. EXCESS EMISSIONS AS A FUNCTION OF SOURCE SIZE

To determine whether source size has any bearing on the amount of excess emissions released from a source, we have summarized the average frequency, duration and magnitude data for the incidents reported according to specific size ranges. The following size cutoffs were selected in an effort to distribute the number of sources uniformly within each size category (numbers are in tons of uncontrolled emissions per year):

- <100
- 100 to 500
- 500 to 1,000
- 1,000 to 10,000
- 10,000 to 100,000
- 100,000 to 500,000

A comparative discussion of the types of sources found in each size category and the average incident indicators will be presented, starting with the smaller sources and ending with the larger ones. Data relative to this parameter is found in Tables 3 and 6.

Size Category - <100 tons per year

Sources falling into this category have typically been placed low on the state and local agencies priority lists with respect to their compliance status and emission control. Of the 119 sources evaluated, 24 or 20 percent emitted less than 100 tons/yr of pollutant per year. The 24 sources were represented by eleven different industrial categories, surface coating plants having the greatest number (four sources). Of the incidents reported for the sources of this category, 73 percent were control operation and maintenance related, 23 percent were caused by process problems, 3 percent were due to unforeseen, with the remainder (<1 percent) attributed to design flaws. Based on an analysis of the normalized data, sources less than 100 tons per year were found to operate with an annual credit surplus of 44 percent of their allowable emission limitation. This is almost double that (28 percent) found for the average of the sample population.

Focusing on the Control O&M and Process related incidents, 13 (54 percent) of the 24 sources identified reported causal code 3 (O&M) problems, whereas 3 (12.5 percent) of the 24 were found to have causal code 2 (process) related problems. Compared with the average of the sample population, O&M related incidents were reported by a higher proportion of sources in the less than 100 tons per year size category. Conversely, the average of the sample population has a larger number of sources reporting process related problems than those sources less than 100 tons per year.

Process related incidents at these smaller sources occur less frequently but have a higher relative magnitude and last longer than those at the average of the sample population. Because they are small to begin with, total annual excess emissions from these sources are minimal compared with those from other sources.

With respect to control O&M, the incidents do not occur as often and they are of lower relative magnitude but again tend to last longer than the incidents found for the average of the sample population.

Size Category - 100 to 500 tons per year

Data analysis was conducted on 31 sources which fell into this size category. Eleven of the sixteen industrial categories are represented. Of the 31 sources identified, five are surface coating sources and four are steam generating units which were located at the same plant. Causes of the incidents reported at sources in this size category tend to be equally distributed between process, control operation and maintenance and unforeseen related problems. The percent of incidents attributed to each of these causal factors are 35.4, 36.6, and 24.4, respectively, with 3.5 percent due to design related problems.

Comparing the sum of all causal factors for this size category and the average incident indicators for all sources of the sample population, an excess emission incident occurs much less frequently but last substantially longer and is of higher relative magnitude than the average of the sample population. Because the incidents last longer and on a relative basis are quite severe, 100 to 500 tons per year sources operate with the lowest annual credit surplus (12 percnet of their allowable emission limitation). This is roughly half the surplus (28 percent) found for the average of the sample population.

Only one of the 31 sources identified reported a design related incident. The incident occurs three times every 2 years, each one expected to last 2,920 hours resulting in emissions nine times the standard. Based on the average of the sample population reporting design problems, 100 to 500 tons per year sources have fewer incident per year and are of lower relative magnitude but tend to last almost 20 times longer. All things considered, annual excesses would be about the same for the average of the sample population and the 100 to 500 tons per year source.

With respect to process related incidents, 7 of the 31 (22.6 percent) 100 to 500 tons per year sources reported a problem. This 22.6 percent is close to the number of sources (29 percent) of the sample population process related incidents. Concerning the average incident indicators, sources reporting in the 100 to 500 tons per year category have fewer incidents per year than the average source of the sample population each being of lower relative magnitude and shorter duration.

Like the process related incidents, control operation and maintenance related excursions do not occur as often nor for as long as the average of the sample population, but they are of a much higher relative magnitude. This latter case results basically from one source reporting an incident which was 30,456 percent above its allowable limit. The incident occurred only once, lasting 5 minutes.

Of the 31 sources identified in this size category, 6 (19.4 percent) reported an unforeseen related incident. For the sample population, this is about the same number of sources reporting a similar type of problem. The average incident reported for 100 to 500 tons per year sources occurred about as frequently and of nearly the same relative magnitude as the average of the sample population but tended to last longer.

Source Category - 500 to 1000 tons per year

As shown in Table 3, 17 (14 percent) of the 119 sources investigated had an uncontrolled emission rate of between 500 to 1000 tons per year. These sources represent 10 industrial categories, with steam generating plants being the most common occurring with three sources. Of the 1089.7 incidents reported by these sources, 91 percent were process related, 8 percent were control operation and maintenance related, with the remaining 1 percent made up by design and unforeseen problems. With respect to the average incident indicators for all causal factors, sources in the size category would have about as many incidents which would last the same length of time but would be of lower relative magnitude than the incidents reported for the average of the sample population.

Analysis of the normalized data for sources in this size category reveals that 500 to 1000 tons per year facilities were found to operate annually with an average credit surplus of 40 percent of their allowable limitation.

Focusing only on causal codes 2 and 3, 500 to 1000 tons per year sources were found to have more process related incidents but fewer control O&M related problems than the average of the sample population. It is important to note that the higher number of process related incidents reported for the sources in this category resulted from one source, a steam generating unit, which was found to have 882 excess emission excursions due to grate cleaning. These incidents represent 89 percent of all process related problems reported for this size category and 81 percent of all incidents found to occur at 500 to 1000 tons per year sources. The average process related incident reported for these sources was shorter and of lower relative magnitude than those calculated for the average of the sample population. The percent (29.0) of sources reporting process problems is the same as the percent (29.0) of sources of the sample population reporting similar problems.

Concerning control O&M, 8 (47 percent) of the 17 sources investigated reported problems. This is a slightly higher percent than that (41 percent) found for the average of the sample population. Each incident occurred more often but lasted for a shorter period of time and was of lower relative magnitude than a similar related incident for the average of the sample population.

Source Category - 1,000 to 10,000 tons per year

Of the 119 sources surveyed, 30 (25 percent) were rated at 1,000 to 10,000 tons per year of uncontrolled emissions. For the 16 industrial categories surveyed 12 were represented in this size category. Petroleum products and handling plants and grain handling operations had the greatest number of sources identified with five and four facilities apiece. With respect to the 1,119 incidents reported, 83.5 percent were process related, 15.2 percent were due to control O&M problems with the remaining 1.3 percent attributed to design flaws and unforeseen events. A breakdown of each causal code shows that 10 percent of the 30 sources reported a design related incident, 43.3 percent had process related problems during the year, 46.7 percent were found to have had control O&M related incidents and 26.7 had some unforeseen event occur. Approximately 70 percent of all sources reported at least one incident. Comparing the computed numbers above with the corresponding values for the sample population, (9.2, 29, 41, 21, and 66), plants in this size category tend to have a greater number of sources experiencing problems. Based on the average for all causal codes of the sample population, incidents reported by the 1,000 to 10,000 ton category occur more often but are of lower relative magnitude and last for a shorter period of time.

The following discussion will only cover incidents related to process and control O&M problems which were found to occur with the greatest frequency. Concerning process problems, sources in the 1,000 to 10,000 tons per year range have more incidents per year than the average of the sample population. However, one source, a basic oxygen furnace of the steel industry, reported a process related incident which occurred 700 times in 1 year. This one source thus has a significant impact on the average for this causal code. The average duration of the process related incidents for all 1,000 to 10,000 tons per year sources was 7.6 hours at 154 percent above the allowable limit. This is a longer duration but lower relative magnitude than the average of the sample population.

Incidents caused by control O&M problems tend to occur more often at sources in the 1,000 to 10,000 tons per year range, but are shorter and of lower relative magnitude than the average of the sample population.

Source Category - 10,000 to 100,000 tons per year

As shown in Table 3, 11 of the 119 sources analyzed fell into this size category. These 11 sources represent 5 different industrial categories, with 5 of the 11 being pulp and paper recovery boilers. Of the 400 incidents reported, 64.5 percent were process related (89.5 percent of which occurred at two pulp and paper recovery boilers), 24.8 percent were due to design flaws, 8.8 percent resulted from control O&M problems, with the remaining 2 percent due to unforeseen events. The breakdown of each causal code by number of sources with problems is as follows: 36 percent of the sources were found to have designs related incidents, 27.3 percent reported incidents resulting from changes in operations, 36.4 percent had incidents related to control operation and maintenance problems, and 18 percent reported incidents due to unforeseen events. Combining all causal codes together, 72.7 percent of the sources had an excess emission incident. Comparing these percentages with the corresponding values for the sample population (9.2, 29, 41, 21 and 66), a greater number of sources in the 10,000 to 100,000 tons per year size range would have design and overall problems than the average but a fewer number would have process, control O&M and unforeseen related incidents.

With respect to normalized credits and excesses, sources in the 10,000 to 100,000 tons per year size range tend to operate with less of a credit surplus than the average of the sample population (17 percent versus 28, respectively). As expected, on the average annual excess emissions (64.5 tons) are greater from sources in this category than those (22.5 tons) from the average of the sample population. Compared with this overall average, 10,000 to 100,000 tons per year sources have more incidents per year which have a higher relative magnitude but do not last as long.

Incidents which resulted from design flaws occur more often but do not last as long and are of lower relative magnitude than those of the average of the sample population experiencing similar problems. Continuing on with the other causal codes, process related incidents at 10,000 to 100,000 tons per year sources occur more frequently (the reason for the higher frequency has been discussed above), tend to be shorter and not quite as severe as those at the average of the sample population. Control O&M related incidents occur about as frequently as those of the average of the sample population but are shorter and of lower relative magnitude. Incidents due to unforeseen events occur more often at the sources in this category than the average of all sources, but their duration and relative magnitudes are less.

Source Category - 100,000 to 500,000 tons per year

Of the 119 sources investigated, 6 were rated between 100,000 to 500,000 annual tons of uncontrolled emissions. Cement plants, specifically rotary kilns, dominate this category representing 5 of the 6 sources. The sixth source was a pulp and paper recovery boiler which did not have any excess emission incidents. A total of 32.5 incidents were reported, 6 (18.5 percent) resulted from process upsets, 21.5 (66.2 percent) were due to control operation and maintenance problems and 5 (15.4 percent) were due to unforeseen events. No design related incidents were reported. Of the 6 sources classified in this category only 3 (50 percent) reported an incident. Two of these 3 reported incidents due to more than one causal factor. On a causal code by causal code breakdown, 2 sources (33.3 percent) were found to have process related problems, 2 sources (33.3 percent) reported incidents due to control operation and maintenance problems, while only one (16.7 percent) source reported an unforeseen event. On the whole, these larger sources tend to have a fewer number of sources reporting incidents than the number reporting problems from the sample population. Analysis of the normalized data reveals that the sources in this category operate on an annual basis with a credit surplus of 29 percent of their allowable emission limitation.

Considering the sum of all causal codes as one, these large sources have fewer incidents per year than the average of the sample population but they last longer and have a much higher relative magnitude. This latter indicator is common for large sources which require a high degree of control. When a problem does occur, it results in a large quantity of emissions. It should be noted that the average magnitude for all causal codes under this category is biased high due to one source reporting incidents with a magnitude of 115,900 percent above the standard. These incidents, which occurred five times annually and last only 10 minutes each, were process related.

Average incident indicators for the sources reporting problems are shown in Table 3. For the process related incidents, large sources have fewer per year but they last much longer and are of higher relative magnitude than those found for the average of the sample population. Referring to the same Table 3 above, control O&M related incidents occur more often and are of a higher magnitude than those of the average of the sample population but do not last as long. With respect to unforeseen events, large sources were found to have more incidents per year than the average but they did not last as long nor were they as severe.

PARAMETER C. EXCESS EMISSIONS AS A FUNCTION OF CONTROL DEVICE TYPE

In the preceding discussion, we have summarized the causes, frequency, duration, and relative magnitude of excess emissions on a source size basis. This section is devoted to the presentation of our findings on the basis of the generic types of air pollution control devices that were evaluated by the four contractors. Such larger groupings provide us a more extensive population upon which to develop specific and meaningful comparisons and correlations. The following discussions consider only excess emissions associated with the subject control device and its auxiliary equipment.

We do recognize, however, that the potential of a process-derived bias on the control device related excess emission incident data is still possible. For example, fan blade failure is much more likely to occur for those cases where the process exhaust stream is of a corrosive or abrasive nature than for those which are not. The significance of such a bias lessens as the sample population becomes larger and more diversified, however. By aggregating all the data developed by the four contractors, the significance and validity of the conclusions are strengthened and the impact of specific facility or industrial category bias is minimized.

A comparative description of the reported incidents by causal code for each control device type will be presented in this section. Reference will be made to the incident indicators of the average source, which evolved from the data reported for all 119 sources surveyed. The generic control devices investigated are:

- Electrostatic Precipitator
- Scrubber
- Fabric Filter (Baghouse)
- Other (including cyclones, afterburners, vapor recovery units, absorbers and mist eliminators

Refer to Tables 4 and 6 for data summaries pertaining to this parameter.

Excess Emissions Attributable to Electrostatic Precipitator Related Causes

As shown in Table 4, emissions from 22 (18.5 percent) of the 119 sources investigated are controlled by an electrostatic precipitator (ESP). A total of nine industrial categories are represented by these sources, with cement plant rotary kilns comprising 5 of the 22 sources identified. Considering all causal codes, the number of ESP sources reporting problems (77.3 percent) is higher than the number (66 percent) in the average of the sample population reporting a problem. Moreover, 8 of the 17 reported incidents resulting from more than one causal code. The frequency of incidents occurring at ESP sources and their relative magnitude are higher than the average of the sample population, although the duration of the incidents are not as long. Of the 1025.3 incident reported for the four causal codes under this category, 84.2 percent were process related, 13.9 percent resulted from ESP operation and maintenance problems, 1.6 percent were unforeseen related, with the remaining less than 1 percent due to design flaws. It should be noted that 81 percent (700 incidents) of the process related incidents were attributable to one source, that being a basic oxygen furnace of the steel industry.

With respect to the normalized data, ESP sources had the second highest credit surplus, operating on an annual basis with 27 percent of the allowable emission limitation as credits. Normalized credits were 51 percent of the allowable, whereas normalized excesses were 24 percent.

Only three (13.6 percent) of the 22 ESP sources identified reported a design related incident. This is slightly higher than the number of sources reporting a similar related problem from the sample population. This is not surprising considering the sensitive nature of electrostatic precipitators with respect to electrical tuning and their dependence on flue gas conditions. Compared with the incident indicators for the average source, ESP sources have far fewer design related incidents per year and they are of lesser relative magnitude but tend to last quite a bit longer. The longer average duration was attributed to one source that reported on incident which lasted 2,190 hours.

Under process related problems, 9 of the 22 (40.9 percent) sources reported an incident. This is higher than the average of the sample population. The frequency of these indicators is higher at ESP sources than for the average, as are the durations and relative magnitudes. The high frequency as discussed above was due to one source reporting 700 incidents in 1 year.

Electrostatic precipitator operation and maintenance problems were reported at 9 (40.9 percent) of the 22 sources classified in this category. This is the same percent of sources reporting similar related problems in the sample population. Operation and maintenance related incidents were found to occur more often at the ESP sources than the average of the source population, lasting a shorter period of time but are of higher relative magnitude.

With respect to unforeseen events, 36.4 percent (8 of 22) of the ESP sources reported an incident. This is higher than the number in the sample population having a similar related problem. ESP sources have a greater number of these unforeseen related incidents and they last longer but they are not as severe as those for the average of the sample population.

Excess Emissions Attributable to Scrubber Related Causes

Of the 119 sources investigated, 36 (30.3 percent) were controlled by a scrubber. A total of 11 industrial categories are represented, the two most common are iron and steel plants and steam generating plants (seven and six sources, respectivley). Considering all causal codes, 25 (69.4 percent) sources reported an excess emission incident. This is about the same number (66 percent) of sources as in the total sample population reporting an incident regardless of causal code type. Data tabulation showed that 7 of the 25 sources reported incidents resulting from more than one causal code.

Normalization of the excess and credits data revealed that sources controlled by scrubbers operate with an annual credit surplus of 21 percent of their allowable emission limitation. This is slightly less than that (28 percent) found for the average of the sample population.

Of the 300.7 incidents reported, 77.7 percent were process related, 19.5 percent were due to scrubber O&M problems, 2.7 resulted from unforeseen events with the remaining less than 1 percent due to design flaws. Since process and O&M related incidents comprised most of the problems occurring at the sources in this category the remaining discussion will be addressed to these two causal codes.

Process related problems were reported at 13 (36 percent) of the 36 sources identified, which is slightly higher than the number (29 percent) in the sample population reporting similar related problems. Sources in this category have fewer process related incidents per year than the average of the sample population. These incidents tend to last longer but are of lesser relative magnitude.

With respect to O&M problems, 14 (38.9 percent) of the 36 sources controlled by scrubbers reported an incident. This is slightly lower than the number (41 percent) of sources in the sample population reporting O&M problems. Scrubber sources were found to have fewer incidents and of lower relative magnitude than the average of the sample population but they tended to last longer.

Excess Emissions Attributable to Fabric Filter Related Causes

As shown in Table 4, emissions from 35 (29.4 percent) of the 119 sources surveyed are controlled by a fabric filter (baghouse). Of the 16 industries surveyed, 13 are represented in this category. The most commonly occurring sources are asphalt plants (six), brass and bronze plants (five), stone, clay and glass plants (five), and grain handling facilities (five). Taking into consideration all causal codes, the number of baghouse sources reporting problems (48.6 percent) is lower than the number (66 percent) in the sample population which reported a problem. In addition, of the 17 sources reporting excess emission related problems, six reported incidents caused by more than one causal code.

The overall average frequency of occurrence and duration of an incident at a baghouse source is less than the average of the sample population, whereas the relative magnitude is higher. Of the 292.86 incidents reported for all causal codes combined, 50.5 percent were attributed to O&M problems, 33.6 percent were caused by design flaws, 10.9 percent resulted from process related problems and 5 percent were due to unforeseen events.

Analysis of the normalized data for sources classified in this category show that baghouse controlled facilities, as expected, operate with the greatest amount of credits. The annual credit surplus for these sources is 51 percent of the allowable emission limitation. Compared with the other control device type categories, baghouses had the lowest amount of normalized excess emissions (14 percent) and the greatest amount of normalized credits (65 percent).

Only 4 (11.4 percent) of the 35 baghouse sources identified reported design related incidents. However, on a proportional basis this is a higher percentage than the number (9.2 percent) of sources in the sample population reporting a similar related incident. Design related incidents at baghouse sources were found to occur more often than those of the average of the sample population. They tended to be of lower duration but slightly higher relative magnitude than the average. This latter case was attributable to one source reporting an incident that occurred once every 2 years, which had a magnitude of 29,515 percent.

With respect to process related problems, only 3 (8.5 percent) of the 35 sources surveyed were found to have an incident. Compared with the average of the sample population, sources controlled by baghouses will have fewer and less severe process related problems.

Operation and maintenance related incidents were found at 14 (40 percent) of the 35 sources controlled by baghouses. This about the same number (41 percent) as the average of the sample population reporting a similar related incident. These O&M incidents occur more often and last longer at a baghouse controlled facility than the average but tend to be less severe.

Incidents caused by unforeseen events were found to occur at 4 (11.9 percent) of the 35 source surveyed, which is less than the number (21 percent) of sources reporting a similar event from the sample population. Unforeseen events occur more frequently at sources controlled by baghouses but they do not last as long and are of lower relative magnitude.

Excess Emissions Attributable to "Other" Control Device Related Causes

As described earlier, "other" control devices include cyclones, afterburners, vapor recovery units, absorbers, and mist eliminators. Of the 119 sources investigated, 26 (21.8 percent) were controlled by one of the "other" control devices. A total of nine industries are represented in this category. The two most prevalent are surface coating operations with eight sources and petroleum products and handling operations with seven sources. Both of these industries are comprised of sources of pollutants which tend not to employ the three more conventional types of control devices as discussed in the previous subsections. With respect to all causal codes, 19 (73.1 percent) of the 26 sources surveyed reported an excess emission incident. This is slightly higher than that found for the sample population, which had 66 percent of its sources reporting excess emission related problems. In addition, 7 of the 19 sources reported incidents resulting from more than one causal code. Still making reference to all causal codes, the sources of this category have more incidents per year than the average of the sample population but they tend to last for a shorter period of time and are of lower relative magnitude.

Analysis of the normalized data reported for the sources of this category show that facilities controlled by these "other" devices, have, on a relative basis, more problems controlling emissions than those sources controlled by the more common devices. Normalized excesses for these "other" sources are the highest for all control types surveyed, 33 percent of the allowable emission limitation. Likewise, at 37 percent their normalized credits are the lowest of all four control device types. Consequently, sources controlled by these "other" control devices operate annually with a credit surplus of only 4 percent.

A total of 1196 incidents were reported for all four causal codes combined. Of these, 92.9 percent were process related, 6.2 percent were due to operation and maintenance problems, with the remaining less than 1 percent split between design flaws and unforeseen events. For these latter causal codes, three sources (11.5 percent) reported design related incidents and seven (26.9 percent) reported incidents due to unforeseen events. The number of sources reporting problems for each of these respective causal codes is slightly higher than the number in the total sample population reporting similar related problems. However, since the number of incidents related to these two causal codes were so few compared with the number related to process and O&M problems, no further mention of them will be made.

The number of sources reported process related problems (6 of 26 or 23.1 percent) is slightly lower than the number of sources in the sample population having similar related problems. Comparing the average incident indicators, sources controlled by "other" devices have a greater number of excess emissions incidents per year but their duration and relative magnitudes are less than average of the sample population. The high frequency of occurrence is attributed to one steam generating unit which reported 882 incidents per year.

Incidents related to operation and maintenance problems, were reported at 11 (42.3 percent) of the 26 "other" sources identified. This proportion of sources reporting problems is similar to that of the sample population as a whole. The number of O&M related incidents occurring at "other" sources annually is less than the number expected for the average of the sample population. However, the duration and relative magnitudes of each incident would be greater than the average. It should be noted that the high relative value of these latter two incident indicators are attributed to two very large values; one source reported an O&M related incident which lasted 1 year (8,760 hours), while a different source had a similar related excess emission incident which was 30,456 percent above the allowable emission limitation.

PARAMETER D. EXCESS EMISSIONS AS A FUNCTION OF CONTROL DEVICE SIZE

Data analyses were conducted on the 119 sources surveyed with respect to control device size. Categorizing the sources by control device size provided an additional dimension of analysis. The results of this classification scheme will identify problem areas independent of industrial process and control device type. Again we realize that process-derived bias and specific control device related problems will affect the data averages reported within each size category. By integrating the data collected by the four contractors, the impact of biases due to specific control device types and industrial processes are minimized.

The following size categories were selected in an effort to provide an equal spread of the 119 data entries (values presented are in terms of gas flow rate expressed in acfm).

- < 10,000
- 10,000 to 50,000
- 50,000 to 100,000
- 100,000 to 500,000
- 500,000 to 1,000,000
- > 1,000,000

In addition to describing the types of industries found in each category, comparisons will be made between the average incident indicators for each causal code for the sources of a given size range and the average values for the 119 sources of the sample population. These analyses will show which control device sizes have the most excess emissions incidents, what causes the incidents, and compares the extent of the incidents on a relative basis to the average of the sample population. Data for this parameter is presented in Tables 5 and 6.

<u>Control Devices - < 10,000 acfm</u>

As shown in Table 5, 31 (26.1 percent) of the 119 sources investigated employed a control device that was rated at less than 10,000 acfm. A total of 12 of the 16 industries categories surveyed are represented by the size category. The most common sources are petroleum products and handling facilities (seven), with petrochemical and stone, clay and glass plants having four plants apiece. Excess emissions incidents were found to occur at 17 (54.8 percent) of the 31 sources classified in this category; four of the 17 reported multiple problems. Compared with the average of all causal codes for the 119 sources surveyed, the number of sources controlled by these relatively small devices is less than the number (66 percent) in the sample population. Sources with these small control devices have fewer incidents per year than the average of the same population, and they are of lower relative magnitude but they tend to last longer. The longer duration, however, is attributed to four sources having reported incidents that lasted for more than 2,000 hours.

Normalization of the excess and credits data for sources in this category shown that "< 10,000 acfm" facilities operate with the second lowest credit surplus of the size categories delineated in this parameter. These sources were found to have an annual surplus of 12 percent of the allowable emission limitation. As shown in Table 5, sources employing control devices < 10,000 acfm operate with the highest amount of annual normalization excesses, that being 40 percent of the allowable emission limit. It is possible that the high amount of excesses are attributed to the operation of complex "other" types of control devices such as vapor recovery units and carbon absorption units which are used at petroleum products and handling plants and petrochemical plants.

A total of 127.2 incidents were reported at the sources falling into this size category. Control device operation and maintenance related problems caused the greatest number of incidents (54.4 percent). The contribution of the other causal factors are 34.2 percent due to process related problems, 8.7 percent resulting from unforeseen events and 2.8 percent due to design flaws.

Design related incidents occurred at 3 (9.6 percent) of the 31 " < 10,000 acfm" sources surveyed. This compares favorably with the average of the sample population. Roughly 9 percent of sources in the sample population reported a design related problem. The frequency with which these design related problems occur at the sources in this category is significantly less than the frequency of incidents for the average of the sample population. However, the duration and relative magnitude of these incidents are much greater than the average. The relatively high values reported for these latter two indicators are due to one source reporting one incident lasting 6000 hours, and two sources having incidents that had magnitudes of 900 percent.

Incidents resulting from process related problems occurred at 3 (9.7 percent) of the 31 sources classified in this category. This is a lower percentage of sources reporting problems than those (29 percent) of the sample population. Sources in this size category were found to have fewer process related incidents per year than the average of the sample population. The incidents also did not last as long nor were they as severe.

Control operation and maintenance related problems occurred at 10 (32.2 percent) of the 31 sources surveyed which is fewer than the number (41 percent) of the sources of the sample population reporting a similarly related problem. Incidents resulting from this causal code did not occur as often and were of lower relative magnitude than those of the average of the sample population, although the duration of the incident tended to be longer than average.

Of the 31 "< 10,000 acfm" sources surveyed, four (12.9 percent) were found to have incidents resulting from unforeseen events, which is fewer than the number in the sample population reporting unforeseen problems. Compared with the overall average incident indicators for this causal code, sources in this category have a greater number of unforeseen incidents occurring per year which last longer and tend to be more severe.

Control Devices - 10,000 to 50,000 acfm

Of the 119 sources investigated, 49 (41.2 percent) were classified into this size category. All of the 16 industries surveyed are represented in this size category except cement plants which are typically controlled by larger devices. Asphalt plants and surface coating operations dominate the category with eight sources apiece. Steam generating plants and stone, clay, and glass plants were next with the most facilities, each having six sources represented. Excess emissions incidents were reported at 29 (59.2 percent) of the 49 sources entered in this category. Compared with the average of the sample population, fewer sources in this category reported excess emissions incidents. Of the 29 reporting problems, eight sources were found to have an incident related to more than one causal code. Taken as a whole, sources classified in this size category have fewer incidents per year, but they last about the same length of time and are about as severe as those at the average of the sample population.

Analysis of the normalized data reveals that sources controlled by devices ranging from 10,000 to 50,000 acfm operate with an annual credit surplus of 43 percent of the allowable emission limitation. This resulted from these sources having relatively few normalized excess emissions; only 2 percent of the allowable standard.

Of the 449 incidents reported for all causal codes, 65.5 percent resulted from process related problems, 32.2 percent were due to control O&M problems, 1.9 percent were unforeseen, with the remaining less than 1 percent due to design flaws. Since most of the incidents reported were process and O&M related, the following discussion will pertain to these two causal codes.

Incidents resulting from process related problems occurred at 12 (24.7 percent) of the 49 sources surveyed. This is fewer than the number of sources of the sample population reporting a similarly related problem. With respect to average incident indicators, sources in this category have fewer incidents that are of lower relative magnitude but last longer than the average of the sample population.

Concerning control device operation and maintenance related incidents, 17 sources (34.7 percent) reported an excess emission excursion due to this causal factor. Compared with the average of the sample population, a fewer number of sources in this category reported O&M problems. The incidents that occur, happen as frequently as the average, but are shorter and of a higher relative magnitude.

Control Devices - 50,000 to 100,000 acfm

Only 9 of the 119 sources surveyed were controlled by devices that were rated at 50,000 to 100,000 acfm. These nine sources represent six industrial categories, surface coating operations comprising the majority with three sources. All nine facilities reported at least one incident with three sources reporting problems due to more than one causal code. Based on the average of all causal codes combined, sources in this size category have fewer incidents per year than the average of the sample population and these incidents tend to be shorter and are of lower relative magnitude.

Normalization of the data revealed that the sources of this category operate with an annual credit surplus of 39 percent of the allowable emission limitation. Of the six control device size categories, the sources of this category operated with the greatest amount of normalized credits, 41 percent of their allowable limitation, thus being the reason for their high credit surplus.

A total of 126.5 incidents were reported for all causal codes combined. A causal code by causal code breakdown shows that 69.9 percent of the incidents reported were process related, 28.5 percent resulted from control O&M problems and 1.6 percent were unforeseen. No design related incidents were reported. Since 98.4 percent of the incidents reported resulted from process and control O&M problems, these two causal codes will be discussed.

Of the nine sources identified, five were found to have incidents related to process changes or upsets. This percentage (55.5) of sources reporting problems is much higher than the number (29 percent) of sources in the sample population reporting a similarly related incident. Compared with the average of the sample population, sources in this control device size range have fewer process related incidents that tend to be less severe but last longer.

Control O&M related incidents were reported at six (66.6 percent) of the nine sources surveyed. This is a higher number (41 percent) than those of the sample population reporting an O&M related incident. The frequency, duration, and magnitude of the O&M incidents are less than those of the average of the sample population.

Control Devices - 100,000 to 500,000 acfm

As shown in Table 5, 23 of the 119 sources investigated were classified in this control device size category. These sources were represented by eight industries, cement plants, and petroleum products and handling operations dominating with seven and five sources apiece. Incidents were reported at 19 (82.6 percent) of the 23 sources. This is a higher percentage of sources reporting incidents than that of the entire sample population. Of the 19 sources having problems, 10 reported incidents due to more than one causal code. Regardless of causal code, when compared with the average of the sample population, facilities in this size category have more incidents per year which are of the same relative magnitude but would tend to last longer.

The annual credit surplus (10 percent) associated with the sources in this category was found to be the lowest of all the size ranges of this parameter. This resulted from these sources having the second highest normalized excess and second lowest normalized credits.

Of the 1997.7 incidents reported for all causal codes, 87.7 percent were process related, 6.8 percent resulted from control O&M problems, 4.7 percent were due to design flaws, and 0.8 percent were unforeseen. Design related problems occurred at 3 (13 percent) of the 23 sources identified. This is more than the number found to report a similarly related problem in the entire sample population. Considering the average incident indicators, sources within this category have fewer incidents per year than the average of the sample population, but each excursion lasts longer and is of higher relative magnitude.

Incidents resulting from process changes or upsets occurred at 12 (52.1 percent) of the 23 facilities classified into this category. The average number of causal code 2 (process) incidents found at these sources was slightly more than twice the number occurring at the average of the sample population (146 versus 65.9). The duration and relative magnitudes of these incidents are very similar at the sources within this category and the average of all sources.

With respect to control operation and maintenance related incidents, 12 (52.2 percent) sources reported excess emission excursions. Like the previous two causal codes, this reporting percentage is higher than that found (41 percent) for the average of the sample population. Although the sources in this category have more incidents per year that tend to be slightly more severe than the average of the sample population, they are also last for a shorter period of time.

Finally, unforeseen events were reported at eight (34.8 percent) sources. This is a substantially higher percentage than the 21 percent of the sources of the sample population reporting similarly related incidents. Comparing the average incident indicator data derived for the sources of this category with the average values for the sample population, sources in this size category have slightly more unforeseen events per year that are shorter in duration and of lower relative magnitude.

Control Devices - 500,000 to 1,000,000 acfm

Of the 119 sources surveyed, six were controlled by control devices that were rated at 500,000 to 1,000,000 acfm. These six sources are represented by four industries, those being pulp and paper recovery boilers (three sources), steam generating plants (one source), cement plants (one source), and incinerators (one source). Only three of the six sources reported excess emissions incidents. Of these three, one (a cement rotary kiln), reported incidents related to more than one causal code, those being process, control O&M, and unforeseen events. This 50 percent reporting rate is less than the average reporting rate (66 percent) for the sample population. With respect to the average for all causal codes, sources of this category have fewer incidents that are of lower relative magnitude than the average of the sample populations but they tend to last longer.

The average credit surplus calculated for these larger sources was 52 percent of their allowable emission limitation. This relatively high percentage resulted from the fact that the sources of this category were found to have normalized credits of 60 percent and excesses of only 8 percent, thus indicating a high degree of continued control.

The breakdown of the 99.5 incidents reported for all causal codes is as follows: 60.3 percent were process related, 34.7 percent resulted from control operation and maintenance problems, 4 percent were unforeseen with the remaining 1 percent due to design flaws. Concerning the various causal codes identified, the steam generating unit reported the only design-related incident. The incinerator was found to have one of the two O&M-related incidents reported, the cement plant having the other. In addition, the cement plant reported the only process and unforeseen related incidents. None of the three pulp and paper recovery boilers were found to have any excess emission excursions. The average values of the incident indicators recorded for each of the four causal codes and overall averages are presented in Table 5. Addressing only the overall averages, these large sources have fewer incidents per year than the average of the sample population, and they are lower in relative magnitude but they tend to last longer.

Control Devices - Greater than 1,000,000 acfm

Only one source of the 119 surveyed had a control device that had a gas flow rate of greater than 1,000,000 acfm. This source, an electric arc shop controlled by a fabric filter (baghouse), reported a total of 15 incidents. Of the incidents reported, six (40 percent) were due to design flaws, four (26.7 percent) resulted from control O&M problems, and five (33.3 percent) were unforeseen. The incident indicators for the three causal codes identified for the source are shown in Table 5.

With the baghouse control device, the electric arc shop operated with an annual credit surplus of 72 percent of the allowable emission limitation. Normalized credits for the source were 73 percent and normalized excesses were only 1 percent of the allowable emission limitation.

RANKING OF PARAMETERS/INTEGRATION OF RANKINGS

A review of the ranking of each parameter is useful, as it points out those categories which stand out with respect to high frequencies, long durations or large magnitudes. This review will logically follow the data presentation and will proceed from the individual Causal Code rankings through ranking of the summation of the Causal Codes and will conclude with the data relative to normalized credits and normalized excess.

The relative severity of the overall excess emissions problem is more clearly visible when we integrate the individual frequency, duration and magnitude ranks. We will again proceed from individual Causal Codes to the summation of all causes and will highlight those areas that stand out. This integration will follow the ranking for each parameter.

Parameter A - Industrial Classification

Category Rankings--

Table 7 presents the rankings for causal code 1. Only 6 of the 16 categories encompassing 11 sources reported design problems. Virtually all (93 percent) of the frequencies in this code are found in two categories: grain handling operations and iron and steel plants. Each of these categories reported two sources with design problems, with one grain handling ductwork design problem accounting for 69 percent of all frequencies. Petrochemical plants are the number one ranked category in the duration of design problems. One continuous emission incident at one plant led to the 6,000 hour upset in this case. Steam generating plants and petroleum products facilities also reported significant durations, with each category averaging more than 9 weeks of continuous plant operation in the upset condition. Grain handling plants also were ranked first with respect to magnitude of upset. The baghouses used for particulate control at one grain elevator were partially bypassed during certain process operations, resulting in a high rate of emissions that greatly influenced the magnitude of incidents. In addition, steam generating plants and petroleum products operations had incidents with emissions 7 to 10 times the allowable limit.

Process-related problems (Causal Code 2) were found to be more widespread, with 12 separate categories involving 34 sources reporting problems. This data is found on Table 8. Iron and steel plants ranked first in frequencies due to a twice per day charging problem at one cupola operation. Steam generating plants also had regular, recurring process upsets (> 2 per week) with one source reporting an excess emission three times per day when it cleans the boiler grates. This was the highest frequency due to any cause in the sample population and accounted for 31 percent of all frequencies. Surface coating operations had the greatest episode duration, primarily due to one long term incident at one facility. Cement plants also had a significant average duration, again resulting from one extended problem at one facility. The remainder of

TABLE 7. PARAMETER A - INDUSTRIAL CLASSIFICATION
CATEGORY RANKINGS
CAUSAL CODE 1 (DESIGN).

Rank	Category	Frequency	Category	Duration (hr)	Category	Magnitude (% above allowable)
1	Grain handling operations	36.3	Petrochemical plants	6000.0	Grain handling operations	1346
2	Iron and steel plants	13.0	Steam generating plants	2381.7	Steam generating plants	985
3	Petroleum products and handling	1.2	Petroleum products and handling	1527.4	Petroleum products and handling	729
4	Petrochemical plants	1.0	Stone, clay and glass plants	264.0	Iron and steel plants	139
5	Steam generating plants	0.8	Grain handling operations	18.4	Stone, clay and glass plants	108
6	Stone, clay and glass plants	0.5	Iron and steel plants	8.6	Petrochemical plants	83
	Pulp and paper mills	–	Pulp and paper mills	–	Pulp and paper mills	–
	Incinerators	–	Incinerators	–	Incinerators	–
	Cement plants	–	Cement plants	–	Cement plants	–
	Asphalt plants	–	Asphalt plants	–	Asphalt plants	–
7	Aluminum plants	–	Aluminum plants	–	Aluminum plants	–
	Brass and bronze plants	–	Brass and bronze plants	–	Brass and bronze plants	–
	Lumber and wood plants	–	Lumber and wood plants	–	Lumber and wood plants	–
	Surface coating operations	–	Surface coating operations	–	Surface coating operations	–
	Food and drug plants	–	Food and drug plants	–	Food and drug plants	–
	Other	--	Other	–	Other	–

TABLE 8. PARAMETER A - INDUSTRIAL CLASSIFICATION CATEGORY RANKINGS CAUSAL CODE 2 (PROCESS).

Rank	Category	Frequency	Category	Duration (hr)	Category	Magnitude (% above allowable)
1	Iron and steel plants	374.0	Surface coating operations	85.3	Cement plants	3949
2	Steam generating plants	148.4	Cement plants	46.5	Brass and bronze plants	1150
3	Pulp and paper mills	116.0	Petroleum products and handling	8.5	Surface coating operations	679
4	Cement plants	30.6	Petrochemical plants	5.2	Incinerators	542
5	Other	30.0	Pulp and paper mills	5.0	Petrochemical plants	255
6	Petroleum products and handling	16.1	Other	3.8	Pulp and paper mills	180
7	Asphalt plants	10.0	Steam generating plants	3.1	Steam generating plants	162
8	Incinerators	7.3	Brass and bronze plants	1.0	Iron and steel plants	148
9	Surface coating operations	5.4	Asphalt plants	0.5	Other	122
10	Aluminum plants	3.5	Iron and steel plants	0.4	Petroleum products and handling	88
11	Brass and bronze plants	1.0	Incinerators	0.2	Asphalt plants	76
12	Petrochemical plants	0.8	Aluminum plants	0.1	Aluminum plants	50
13	Stone, clay and glass plants	–	Stone, clay and glass plants	–	Stone, clay and glass plants	–
13	Grain handling operations	–	Grain handling operations	–	Grain handling operations	–
13	Lumber and wood plants	–	Lumber and wood plants	–	Lumber and wood plants	–
13	Food and drug plants	–	Food and drug plants	–	Food and drug plants	–

the facilities had similar length durations. Cement plants had the greatest average magnitude of upset, primarily due to one of the five plants reporting problems. The plant in reference lost total control when bypassed its control system due to a potential explosive situation. The degree to which the cement plant upsets exceeded regulatory limits (39.5 times the standard) was the highest average for any causal code in Parameter A. Brass and bronze plants also placed high in the magnitude ranking, again on the basis of one plant's experience.

The greatest number of categories (14) reported control equipment problems (Causal Code 3). Table 9 presents this data. Lumber and wood plants topped the frequency ranking with cement plants and asphalt plants next in line. The one petrochemical plant reporting control problems had one continuous episode which gave it the highest rank for duration. This episode lasted approximately 3 months. Food and drug plants, petroleum products facilities and surface coating operations all had significant average incident durations. It is interesting to note that three of these four facilities are generally associated with hydrocarbon emissions. Surface coating operations had the greatest incident magnitude, and this reflects the complete loss of pollutant control at these sources when a control problem occurs.

Unforeseen problems (Causal Code 4) occurred in nine separate categories involving 25 sources. Refer to Table 10 for this data. No one industrial category stands out relative to frequency of occurrence, and as might be expected the average frequencies for this class of problems are the smallest of any of the four Causal Codes. Cement plants had the highest average frequency, followed closely by stone, clay and glass plants and iron and steel facilities. Surface coating operations had the longest incident duration, with an average incident lasting greater than 4 weeks. This was primarily due to natural gas curtailments affecting several facilities with afterburners. Steam generating plants (one source) also had durations lasting greater than 2 weeks. One sludge incinerator source reported a problem with its scrubber causing it to be ranked first in incident magnitude. Outages at surface coating sources, again related to gas curtailment, placed this category second in magnitude, with an excess emission rate which was 15 times the applicable standard.

When all Causal Codes are grouped together, we can distinguish those categories which are "incident prone." In this overview, we must remember that the incident averages were derived using the data from all plants within the category, including those sources which reported no excess emissions incidents. This summary is found in Table 11.

Steam generating facilities and iron and steel plants are ranked first and second with regard to frequency. Each of these categories have twice the number of frequencies of any other category. Nine of the ten steam generating plants reported some type of problem, although the high average frequency for this category is overwhelmingly influenced by the 882 incidents reported by one source. Nine of the ten iron and steel plants also reported some type of excess emission and five of these plants had incidents attributable to more than one causal factor. Iron and steel plant frequency data was also greatly influenced by one cupola operation which reported 700 annual process related incidents.

TABLE 9. PARAMETER A - INDUSTRIAL CLASSIFICATION CATEGORY RANKINGS CAUSAL CODE 3 (CONTROL O&M).

Rank	Category	Frequency	Category	Duration (hr)	Category	Magnitude (% above allowable)
1	Lumber and wood plants	28.8	Petrochemical plants	2160.0	Surface coating operations	318[illegible]
2	Cement plants	20.3	Food and drug plants	233.0	Brass and bronze plants	1150
3	Asphalt plants	14.8	Petroleum products and handling	168.3	Asphalt plants	630
4	Iron and steel plants	6.9	Surface coating operations	141.1	Incinerators	587
5	Stone, clay and glass plants	6.2	Stone, clay and glass plants	67.0	Cement plants	521
6	Petroleum products and handling	5.9	Aluminum plants	27.0	Grain handling operations	361
7	Other	5.3	Lumber and wood plants	26.6	Stone, clay and glass plants	297
8	Grain handling operations	5.1	Other	18.6	Iron and steel plants	262
9	Aluminum plants	4.0	Incinerators	17.1	Petroleum products and handling	174
10	Incinerators	2.8	Iron and steel plants	11.4	Other	143
11	Surface coating operations	2.5	Cement plants	6.1	Aluminum plants	67
12	Brass and bronze plants	2.0	Grain handling operations	4.9	Petrochemical plants	50
13	Food and drug plants	.5	Asphalt plants	3.9	Lumber and wood plants	34
14	Petrochemical plants	1.0	Brass and bronze plants	2.0	Food and drug plants	2[illegible]
15	Steam generating plants	-	Steam generating plants	-	Steam generating plants	-
15	Pulp and paper mills		Pulp and paper mills	-	Pulp and paper mills	-

TABLE 10. PARAMETER A - INDUSTRIAL CLASSIFICATION CATEGORY RANKINGS CAUSAL CODE 4 (UNFORESEEN)

Rank	Category	Frequency	Category	Duration (hr)	Category	Magnitude (% above allowable)
1	Cement plants	4.3	Surface coating operations	672.6	Incinerators	2998
2	Stone, clay and glass plants	3.5	Steam generating plants	336.0	Surface coating operations	1533
3	Iron and steel plants	3.3	Grain handling operations	168.0	Petroleum products and handling	548
4	Petroleum products and handling	1.4	Petroleum products and handling	160.3	Iron and steel plants	290
5	Other	0.8	Other	115.2	Grain handling operations	274
6	Surface coating operations	0.6	Cement plants	47.1	Other	140
7	Steam generating plants	0.5	Iron and steel plants	15.1	Cement plants	129
7	Incinerators	0.5	Stone, clay and glass plants	8.7	Stone, clay and glass plants	68
9	Grains handling operations	0.1	Incinerators	4.0	Steam generating plants	12
	Pulp and paper mills	-	Pulp and paper mills	-	Pulp and paper mills	-
	Asphalt plants	-	Asphalt plants	-	Asphalt plants	-
	Aluminum plants	-	Aluminum plants	-	Aluminum plants	-
10	Brass and bronze plants	-	Brass and bronze plants	-	Brass and bronze plants	-
	Petrochemical plants	-	Petrochemical plants	-	Petrochemical plants	-
	Lumber and wood plants	-	Lumber and wood plants	-	Lumber and wood plants	-
	Food and drug plants	-	Food and drug plants	-	Food and drug plants	-

TABLE 11. PARAMETER A - INDUSTRIAL CLASSIFICATION
CATEGORY RANKINGS
ALL CAUSAL CODES.

Rank	Category	Frequency	Category	Duration (hr)	Category	Magnitude (% above allowable)
1	Steam generating plants	89.3	Petrochemical plants	2554.0	Cement plants	2463
2	Iron and steel plants	84.2	Food and drug plants	233.0	Surface coating operations	1566
3	Pulp and paper mills	38.5	Surface coating operations	154.1	Grain handling operations	1224
4	Cement plants	29.7	Petroleum products and handling	122.6	Brass and bronze plants	1150
5	Lumber and wood products	26.8	Incinerators	45.9	Incinerators	614
6	Other	18.9	Stone, clay and glass plants	42.2	Asphalt plants	458
7	Grain handling operations	16.5	Cement plants	31.2	Stone, clay and glass plants	253
8	Petroleum products and handling	9.4	Lumber and wood products	26.6	Pulp and paper mills	180
9	Asphalt plants	6.5	Grain handling operations	16.8	Petroleum products and handling	167
10	Stone, clay and glass plants	3.9	Aluminum plants	12.8	Steam generating plants	163
11	Incinerators	3.4	Other	9.0	Iron and steel plants	158
12	Surface coating operations	2.9	Steam generating plants	7.2	Petrochemical plants	147
13	Aluminum plants	1.9	Pulp and paper mills	4.9	Other	123
14	Brass and bronze plants	0.6	Asphalt plants	2.8	Aluminum plants	59
15	Petrochemical plants	0.6	Brass and bronze plants	1.7	Lumber and wood plants	34
16	Food and drug plants	0.5	Iron and steel plants	1.6	Food and drug plants	25

Petrochemical plants had incident durations which were 10 times those of any other category. While only two of the six plants in this category had emissions incidents (two per plant), each of the four reported excursions of greater than 5 days, with the longest lasting 6000 hours. In addition, the four incidents involved three separate Causal Codes so no trend was evident in this area. Food and drug plants ranked second in duration of incident, however, this ranking is based on only one incident at one facility. Of greater significance is the third place ranking of surface coating operations. Nine of the thirteen sources surveyed in this category experienced problems, with three of these sources having multicausal incidents. If one includes the fourth ranked category, petroleum products, then three of the four top sources are hydrocarbon emitters. Since hydrocarbons are essentially invisible upon release, one may surmise that the inability of affected area residents and regulatory plant personnel to detect these emissions may play a part in the long duration of each upset episode.

Cement plants ranked first with regards to magnitude of emission during an incident. Seven of the nine plants surveyed had problems with four of these plants experiencing multicausal incidents. The high degree of control required to bring cement plants into compliance (in excess of 99.5 percent) relates to the large magnitude of incidents, as the complete loss of control equipment will result in an emission which may be 500 to 1000 times the applicable regulation. This was the case with one of the plants surveyed. Surface coating operations, grain handling operations and brass and bronze plants all experienced incident magnitudes in excess of 1000 percent, indicating that a problem with their control equipment typically resulted in complete bypassing of that control device.

Integration of Rankings--

The Causal Code 1 integration is provided in Table 12. As can be seen, grain handling operations are ranked first due to their having the greatest number of frequencies and the largest magnitude of emission. A further indication of the connection between poor design and grain handling pollution control is the fact that 40 percent of the grain handling sources surveyed (2 of 5) indicated they experienced an emissions incident directly related to poor design. This is the highest design-related percent of any category. While the magnitude of these incidents is relatively small, the high uncontrolled emission rate of grain transfer leads to a high magnitude of emission release when a problem does develop. Following grain handling operations, steam generating plants and petroleum products facilities had identical integrated ranks. The placement of steam generating facilities was due to the long duration and large magnitude of their incidents while petroleum products was ranked third in each of the individual categories. While petrochemical plants had the longest duration of incident, they experienced relatively fewer problems and the magnitude of emission was less than double the allowable standard.

The integrated ranking for Causal Code 2 is found in Table 13. Cement plants were by far the number one ranked category with respect to process problems. This was due to the large magnitude of emissions released during an incident and the long duration of each problem. While both magnitude and duration averages were strongly influenced by one source in each case, they should be considered representative as five sources reported problems. The large magnitude of emissions incidents is indicative of the degree of control required at

TABLE 12. PARAMETER A - INDUSTRIAL CLASSIFICATION
INTEGRATION OF RANKINGS
CAUSAL CODE 1 (DESIGN).

Rank	Category	Number of samples	Individual ranking: Frequency	Individual ranking: Duration (hr)	Individual ranking: Magnitude (% above allowable)	$\sum$ all ranking
1	Grain handling operations	2	1	5	1	7
2	Steam generating plants	2	5	2	2	9
2	Petroleum products and handling	3	3	3	3	9
4	Petrochemical plants	1	4	1	6	11
5	Iron and steel plants	2	2	6	4	12
6	Stone, clay and glass plants	1	6	4	5	15
7	Pulp and paper mills	0	—	—	—	—
	Incinerators	0	—	—	—	—
	Cement plants	0	—	—	—	—
	Asphalt plants	0	—	—	—	—
	Aluminum plants	0	—	—	—	—
	Brass and bronze plants	0	—	—	—	—
	Lumber and wood plants	0	—	—	—	—
	Surface coating operations	0	—	—	—	—
	Food and drug plants	0	—	—	—	—
	Other	0	—	—	—	—
	Total =	11				

TABLE 13. PARAMETER A - INDUSTRIAL CLASSIFICATION INTEGRATION OF RANKING CAUSAL CODE 2 (PROCESS).

Rank	Category	Number of samples	Individual ranking			$\sum$ all ranking
			Frequency	Duration (hr)	Magnitude (% above allowable)	
1	Cement plants	5	4	2	1	7
2	Surface coating operations	4	9	1	3	13
3	Pulp and paper mills	2	3	5	6	14
4	Steam generating plants	6	2	7	7	16
5	Petroleum products and handling	4	6	3	10	19
5	Iron and steel plants	2	1	10	8	19
7	Other	3	5	6	9	20
8	Petrochemical plants	2	12	4	5	21
8	Brass and bronze plants	1	11	8	2	21
10	Incinerators	2	8	11	4	23
11	Asphalt plants	2	7	9	11	27
12	Aluminum plants	1	10	12	12	34
13	Stone, clay and glass plants	0	–	–	–	–
13	Grain handling operations	0	–	–	–	–
13	Lumber and wood plants	0	–	–	–	–
13	Food and drug plants	0	–	–	–	–
	Total =	34				

these plants and the duration of a process upset can be attributed to the complexity of chemical reactions that takes in a cement kiln and the time frames that may be needed to sort out these problems. Surface coating operations, on the strength of the long duration of their incidents, and pulp and paper mills, due to their consistent high ranking in all categories, were integrated second and third with respect to process-related upsets. While iron and steel plants had the most frequent number of process upsets, these problems were of relatively short duration and low magnitude and on the whole were not as severe as in other categories.

The integration of control-related problems (Causal Code 3) is presented in Table 14. No one category stands out in this area as having a significantly greater problem than the rest. Surface coating operations is ranked first, largely due to the high magnitude of its emissions incidents. This magnitude rank is indicative of the go/no-go status of control equipment at these hydrocarbon sources. It appears that when a problem develops with surface coating controls, the equipment becomes completely inoperative and is bypassed. Stone, clay and glass plants, petroleum products plants and cement plants all were ranked closely behind surface coating operations, although none of these categories ranked first with respect to the incident descriptors. While lumber and wood plants had the greatest incident frequency and petrochemical plants had the longest duration, the ranking of these categories with respect to the other descriptors was low and overall these categories did not have a significant control device problem.

The unforeseen (Causal Code 4) problem integration is presented in Table 15. Surface coating operations lead the category rankings in this Causal Code, due to their long incident duration and second ranking with respect to magnitude. As discussed earlier, both these factors are directly attributable to natural gas shutoffs affecting afterburner performance. Petroleum products ranked second overall, on the basis of a consistent high ranking with each incident indicator. Cement plants placed third, due to their relatively high frequency of unforeseen incident occurrence. While incinerators had the greatest magnitude of emission, their problems were infrequent and relatively short lasting so as to not be a significant problem.

The integration of the rankings for all Causal Codes combined is perhaps the most informative table for each parameter as it not only sums the data for all incidents, but also reflects the input of those sources which reported no excess emissions problems. We must remember that only the average frequency of incident occurrence will be affected by the addition of sources with no reported problems, as the total number of incidents in a category will be now divided by the total number of sources surveyed in that category and not just those sources with problems. The average duration of each incident and the magnitude of pollutant released during an incident are indicators which are functions of the total number of incidents, and not the total number of sources thus the affect of sources reporting no excess emissions incidents will be seen in only one of the three indicator rankings which form our overall integration. Table 16 presents the integration of rankings of all Causal Codes for Parameter A. Cement plants are the industrial classification that have the greatest overall excess emissions incidents problem. Incidents at these facilities account for 9.5 percent of all frequencies, 15.3 percent of all hourly durations, and

TABLE 14. PARAMETER A - INDUSTRIAL CLASSIFICATION INTEGRATION OF RANKINGS CAUSAL CODE 3 (CONTROL O&M).

Rank	Category	Number of samples	Individual ranking			Σ all ranking
			Frequency	Duration (hr)	Magnitude (% above allowable)	
1	Surface coating operations	5	11	4	1	16
2	Stone, clay and glass plants	5	5	5	7	17
3	Petroleum products and handling	8	6	3	9	18
3	Cement plants	5	2	11	5	18
5	Asphalt plants	3	3	13	3	19
6	Lumber and wood plants	3	1	7	13	21
7	Iron and steel plants	8	4	10	8	22
8	Incinerators	2	10	9	4	23
9	Grain handling operations	2	8	11	6	25
9	Other	4	7	8	10	25
11	Aluminum plants	1	9	6	11	26
12	Petrochemical plants	1	14	1	12	27
13	Brass and bronze plants	1	12	14	2	28
14	Food and drug plants	1	13	2	14	29
15	Steam generating plants	0	—	—	—	—
15	Pulp and paper mills	0	—	—	—	—
	Total =	49				

TABLE 15. PARAMETER A - INDUSTRIAL CLASSIFICATION INTEGRATION OF RANKINGS CAUSAL CODE 4 (UNFORESEEN).

Rank	Category	Number of samples	Individual ranking: Frequency	Duration (hr)	Magnitude (% above allowable)	Σ all ranking
1	Surface coating operations	5	6	1	2	9
2	Petroleum products and handling	5	4	4	3	11
3	Cement plants	3	1	6	7	14
3	Iron and steel plants	4	3	7	4	14
5	Other	3	5	5	6	16
6	Grain handling operations	1	9	3	5	17
6	Incinerators	1	7	9	1	17
8	Stone, clay and glass plants	2	2	8	8	18
8	Steam generating plants	1	7	2	9	18
10	Pulp and paper mills	0	—	—	—	—
10	Asphalt plants	0	—	—	—	—
10	Aluminum plants	0	—	—	—	—
10	Brass and bronze plants	0	—	—	—	—
10	Petrochemical plants	0	—	—	—	—
10	Lumber and wood plants	0	—	—	—	—
10	Food and drug plants	0	—	—	—	—
	Total =	25				

TABLE 16. PARAMETER A - INDUSTRIAL CLASSIFICATION INTEGRATION OF RANKINGS ALL CAUSAL CODES.

Rank	Category	Number of samples	Individual ranking			$\sum$ all ranking
			Frequency	Duration (hr)	Magnitude (% above allowable)	
1	Cement plants	9	4	7	1	12
2	Surface coating	13	12	3	2	17
3	Grain handling operations	5	7	9	3	19
4	Petroleum products and handling	13	8	4	9	21
4	Incinerators	6	11	5	5	21
6	Stone, clay and glass plants	10	10	6	7	23
6	Steam generating plants	10	1	12	10	23
8	Pulp and paper mills	6	3	13	8	24
9	Petrochemical plants	6	15	1	12	28
9	Lumber and wood plants	3	5	8	15	28
11	Asphalt plants	10	9	14	6	29
11	Iron and steel plants	10	2	16	11	29
13	Other	6	6	11	13	30
14	Brass and Bronze plants	5	14	15	4	33
15	Food and drug plants	3	16	2	16	34
16	Aluminum plants	4	13	10	14	37
	Total =	119				

53.5 percent of all percentage magnitudes in excess of the regulatory limits. The high uncontrolled emission rate of these facilities is the prime reason for this number one ranking, for even a relatively minor problem with the control equipment can lead to an excess emission. Since 78 percent of those facilities surveyed reported some type of incidents, this ranking cannot be attributed to a random event or an unusual, atypical situation. The extent of the problem at cement plants if further highlighted when compared to the second ranked category, surface coating operations. As a group, these facilities account for only 1.3 percent of all frequencies, 10.5 percent of all hourly durations and 4.7 percent of all magnitudes. Grain handling operations and petroleum products facilities are ranked third and fourth, respectively. It is interesting to note that only three industrial categories generally associated with hydrocarbon emissions were surveyed for this study (petroleum products and handling, petrochemical plants, surface coating operations) yet two of these three are among the top four categories with respect to excess emissions problems. This observation is substantiated by the fact that 69 percent of the surface coating operations and 92 percent of the petroleum products facilities that were surveyed reported emissions incidents. Steam generating facilities, which accounted for 31.7 percent of all frequencies was only ranked sixth overall due to relatively short incident durations and small incident magnitudes. Similarly, petrochemical plants, which ranked first with respect to incident duration and accounted for 16.4 percent of all hours in excess of the standard, ranked only ninth overall, due to a low frequency and a relatively small magnitude. This low overall ranking is confirmed by the fact that only two of the six plants surveyed in this category reported emissions incidents.

Normalized Credits - Normalized Excess--

A final review of emissions data concerning Parameter A must also include the rankings and integration of data concerning normalized credits and normalized excess. This summary is presented in Table 17. The first column of this table presents the normalized credit data. This column represents the extent to which a category is operating below the applicable regulatory emission limitation (its credits) and expresses that extent in terms of percent of allowable emissions. Petroleum products facilities are ranked first in this area by virtue of the fact they normally operate closest to the allowable limit, on an annual basis. They are more likely to exceed the emission limit should any problem, however minor, occur and thus have less margin of error in the operation and maintenance of their control equipment if they are to avoid excess emissions incidents. At the lower end of this ranking are grain handling facilities. Their normalized credit value of 0.81 indicates that their credits are 81 percent of their allowables, or conversely that they typically operate at an emission rate which is only 19 percent (1.00 - 0.81) of the allowable limit. Ideally, these facilities can afford to have minor upsets with process and/or control equipment and still be continually in compliance. As we shall see, this is not always the case.

The second column in Table 17 concerns normalized excess. Here again we have taken the annual excess emissions for each facility and expressed them in terms of percent of allowable emissions. Grain handling operations are the worst category in this regards and rank number one. Excess emissions with these facilities are equal to 82 percent of allowables on an annual basis. Ranked last in this group are asphalt plants which have an excess emission of only

TABLE 17. PARAMETER A - INDUSTRIAL CLASSIFICATION RANKING NORMALIZED CREDITS AND EXCESSES.

Rank	Category	Normalized credits (% of allowable)	Category	Normalized excess (% of allowable)	Category	Credits - excess (% of allowable)
1	Petroleum products and handling	0.35	Grain handling	0.82	Petroleum products and handling	-0.27
2	Lumber and wood products	0.36	Petroleum products and handling	0.62	Grain handling	-0.01
3	Cement plants	0.37	Steam generating plants	0.48	Steam generating plants	0.00
4	Food and drug plants	0.40	Surface coating operations	0.44	Surface coating operations	0.06
5	Pulp and paper mills	0.47	Petrochemical plants	0.25	Cement plants	0.22
5	Incinerators	0.47	Iron and steel plants	0.16	Iron and steel plants	0.32
7	Steam generating plants	0.48	Cement plants	0.15	Lumber and wood products	0.36
7	Iron and steel plants	0.48	Stone, clay and glass plants	0.08	Petrochemical plants	0.39
9	Surface coating operations	0.50	Incinerators	0.02	Food and drug plants	0.[illegible]0
10	Aluminum plants	0.57	Other	0.014	Incinerators	0.45
11	Asphalt plants	0.58	Pulp and paper mills	0.01	Pulp and paper mills	0.46
12	Brass and bronze plants	0.59	Aluminum plants	0.004	Aluminum plants	0.57
13	Petrochemical plants	0.64	Lumber and wood plants	0.003	Asphalt plants	0.58
14	Other	0.65	Brass and bronze plants	0.002	Brass and bronze plants	0.59
15	Stone, clay and glass plants	0.68	Food and drug plants	0.001	Stone, clay and glass plants	0.60
16	Grain handling	0.81	Asphalt plants	<0.001	Other	0.64

1/10 of 1 percent of allowables. This confirms the individual Causal Code rankings and integrations which generally show that asphalt plants do not have a major excess emissions problem.

The final column in Table 17 integrates the rankings of the first two columns. Here we subtract the normalized excess from the normalized credits, and arrive at a figure which shows the net annual credit or excess for an industrial category. These resultant numbers are ranked with regard to severity to the ambient air quality, a negative number indicating a greater excess than credit and hence, a greater problem. To maintain our convention that the lower the numerical rank, the greater the problem with continued source compliance, the categories are ranked with the greatest negative number first and proceeding to the highest positive number. Since we are expressing normalized data, the results may be considered as expressing a percent of allowables. Thus petroleum products plants, with a credits minus excess value of -0.27 have an annual excess emission which is equal to 27 percent of the average annual emission rate for that category. It is interesting to note that only two of the 16 categories had a negative difference, therefore only these two had annual excess emissions which were not completely offset by emission credits. The second of these was grain handling operations which had the best normalized credit ranking, yet more than offset all of these credits with a high annual excess emission. Our overall highest ranked category with respect to excess emissions incidents, cement plants, demonstrated that all of its upsets were completely offset by credits, with an additional credit equal to 22 percent of the allowable emissions to spare.

Parameter B - Source Size

The size of each source, as expressed by the uncontrolled emission rate in tons per year (TPY) of pollutant, was investigated. This annual uncontrolled rate was calculated using the applicable hourly emission rate and the hours per year that the specific process was operated. The uncontrolled emission rate of a source is a value that is reported on most comprehensive data bases (NEDS, E.I.S., etc.). Since our study population covered a wide range of industrial types and included the major industrial pollutant emitters, the results of this parameter analysis may indicate trends that have universal application. Large sources (those with uncontrolled emission rates in excess of 100 TPY) were studied as were those minor sources with uncontrolled rates of less than 100 tons per year. An attempt was made by GCA to divide this parameter into easily identifiable size categories as well as categories size cuts which divided the data base somewhat equally. This category division was therefore subjectively and can be changed, using the raw data in Appendix A, to suit the readers' specific needs.

Category Rankings--

The ranking of the six size categories for Causal Code 1 is presented in Table 18. All categories contained at least one source with design-related problems except for the largest size cut, 100,000 - 500,000 TPY. As the table indicates, there is a wide range between the first and last ranked categories for each indicator. The 10,000 - 100,000 TPY category far exceeds the others with respect to frequency. Four of the 11 sources reporting design problems are within this category and 94 percent of all incidents are in this source size range. Two categories stick out in the duration ranking.

The 500 to 1000 TPY category ranked first, has an average duration that exceeds 205 days continuous operation and is based on data from two sources. The 100 to 500 TPY category ranks second based on the data of one source survey. Each of these categories has an average duration that is seven times as great as the third ranked category. The 10,000 to 100,000 TPY category is notable in the relatively short duration of its emission incidents. The first ranked category for magnitude of design problems is the 1,000 to 10,000 TPY size cut. It far exceeds all other categories and has an average emission that is 64 times the applicable standard. The influence of one incident at a grain handling facility is strongly reflected in this average magnitude. The relatively low magnitude of the smallest size category is noteworthy.

TABLE 18. PARAMETER B - SOURCE SIZE UNCONTROLLED EMISSIONS CATEGORY RANKINGS CAUSAL CODE 1 (DESIGN).

Rank	Category (10^3 ton/yr)	Frequency	Category (10^3 ton/yr)	Duration (hr)	Category (10^3 ton/yr)	Magnitude (% above allowable)
1	10 - 100	24.8	.5 - 1	4921.7	1 - 10	6383
2	.1 - .5	1.5	.1 - .5	2920.0	.5 - 1	994
3	1 - 10	0.8	1 - 10	400.8	.1 - .5	900
4	.5 - 1	0.8	<.1	264.0	10 - 100	873
5	<.1	0.5	10 - 100	37.5	<.1	108
6	100 - 500	—	100 - 500	—	100 - 500	—

Causal code 2 rankings are presented in Table 19. Once again, the top ranked categories for each indicator clearly stand out from the rest. All categories include some sources with code 2 problems although the 1,000 to 10,000 size cut has by far the largest number, with 13 of the 34 sources that reported process problems. The 500 to 1000 TPY category has the highest average frequency of occurrence, with almost twice as many as the number 2 rank. The six sources in this size range that reported incidents included the single highest frequency, 882, for any source in any category. Without this source, this category would have an average of 22.5 incidents and would rank third. The 10,000 to 100,000 TPY and 1,000 to 10,000 TPY size cuts also have significant (> one per week) frequencies. An even greater difference is displayed by the first and second ranked duration categories. The 100,000 to 500,000 TPY category had an average incident duration that was equivalent to 46 days of continuous process operation and was based on two source reports, one of which was a year-long outage. It is interesting to note that the first ranked category in frequency is the last rank in duration, implying that while there are many episodes in this 500 to 1000 TPY size cut, each incident lasts only 1/2 hour. The greatest disparity between first and second place ranks for any causal code and any parameter is found with the magnitude indicator for process problems. Here, the 100,000 to 500,000 TPY category included five incidents at one cement plant. Since this plant normally requires a control efficiency in excess of 99.91 percent to meet the applicable standard, when it operates uncontrolled, the magnitude of the emissions exceed 100,000 percent, and this enormous magnitude is reflected in the average for this size cut. The other categories in this indicator have relatively small magnitudes, with only one additional size cut, the smallest, having magnitudes that are greater than twice the standard.

TABLE 19. PARAMETER B - SOURCE SIZE UNCONTROLLED EMISSIONS CATEGORY RANKINGS CAUSAL CODE 2 (PROCESS).

Rank	Category (10^3 ton/yr)	Frequency	Category (10^3 ton/yr)	Duration (hr)	Category (10^3 ton/yr)	Magnitude (% above allowable)
1	.5 - 1	165.8	100 - 500	1106.0	100 - 500	96,588
2	10 - 100	86.0	<.1	23.9	<.1	520
3	1 - 10	71.9	1 - 10	7.65	10 - 100	164
4	<.1	10.3	.1 - .5	6.0	.5 - 1	161
5	100 - 500	3.0	10 - 100	4.5	1 - 10	154
6	.1 - .5	2.1	.5 - 1	0.6	.1 - .5	147

The category rankings for causal code 3 problems are found in Table 20. Forty-nine sources reported control equipment-related problems, with the smallest size category having the highest percentage of sources that reported this type of problem (54 percent). All categories had similar average frequencies with the 1,000 to 10,000 TPY size cut ranking first. The 100 to 500 TPY category was notable in this comparison in that it had relatively few incidents (less than two per year). The smallest size category had the longest average duration, with the 13 reporting sources having durations ranging from 0.5 to 5,112 hours. The average duration of this category was 2.5 times higher than the second ranked size cut. It is interesting to note that the two categories with the longest durations were the same two with the lowest number of frequencies. This inverse relationship constantly presented itself in the data. If a source reported many frequencies, they very often were of short duration, and the long duration episodes were often once-per-year events. The magnitude of the 100 to 500 TPY category was sufficiently high to rank this source first. All of the eight sources in this category reporting problems had magnitudes in excess of 500 percent above the allowable standard. The largest size category 100,000 to 500,000 TPY also had a significantly high average magnitude, some 16 times the allowable standard.

The rankings for causal code 4 problems is presented in Table 21. The 25 sources that reported unforeseen problems are divided among all six categories, although the two largest size cuts reported on only one source each. The frequencies for these two large size categories were sufficient to rank them first and second. Very little separated the first and last ranked categories with respect to frequency. The 100 to 500 TPY category ranked first

TABLE 20. PARAMETER B - SOURCE SIZE UNCONTROLLED EMISSIONS CATEGORY RANKINGS CAUSAL CODE 3 (CONTROL O&M).

Rank	Category (10^3 ton/yr)	Frequency	Category (10^3 ton/yr)	Duration (hr)	Category (10^3 ton/yr)	Magnitude (% above allowable)
1	1 - 10	12.1	<.1	106.6	.1 - .5	3023
2	.5 - 1	10.9	.1 - .5	41.5	100 - 500	1631
3	100 - 500	10.8	1 - 10	30.6	1 - 10	322
4	10 - 100	8.8	.5 - 1	30.0	10 - 100	252
5	<.1	7.4	100 - 500	11.2	<.1	162
6	.1 - .5	1.9	10 - 100	7.3	.5 - 1	133

TABLE 21. PARAMETER B - SOURCE SIZE UNCONTROLLED EMISSIONS CATEGORY RANKINGS CAUSAL CODE 4 (UNFORESEEN).

Rank	Category (10^3 ton/yr)	Frequency	Category (10^3 ton/yr)	Duration (hr)	Category (10^3 ton/yr)	Magnitude (% above allowable)
1	100 - 500	5.0	.1 - .5	246.4	<.1	523
2	10 - 100	4.0	1 - 10	95.0	.1 - .5	413
3	.1 - .5	1.7	.5 - 1	49.2	.5 - 1	391
4	1 - 10	1.5	100 - 500	45.6	1 - 10	375
5	<.1	1.5	<.1	26.0	10 - 100	138
6	.5 - 1	1.3	10 - 100	21.5	100 - 500	15

with respect to incident duration. Three of the six reporting problems in this size cut had incident durations that exceeded 19 days continuous source operation. No other category had noticeably long incidents. The magnitude indicator for unforeseen problems is the only incident indicator for any causal code in parameters B and D, which demonstrated a complete correlation between category size and magnitude of incidents. The smaller size categories had the highest magnitude and each succeeding size category had a lower magnitude, with the largest size cut having a notably small average magnitude. There was little difference between magnitudes of any size cut, with the exception of the largest size category (100,000 to 500,000 TPY).

The ranking of categories for all causal codes is presented in Table 22. Each indicator in this ranking can be divided into high and low ranges. For frequencies, these ranges comprise the middle sized categories, all of which have relatively high frequencies and the extreme categories, two low and one high, which have relatively few episodes per year. The 500 to 1,000 TPY size cut had by far the highest average frequency, followed by the 1,000 to 10,000 TPY and 10,000 to 100,000 TPY categories. Each of these size cuts has more than seven times the number of frequencies of the fourth ranked group. The ranking of incident duration has the 100,000 to 500,000 TPY category ranked first, with the 100 to 500 TPY size cut a close second. The former category is based on data from three sources, while the latter had 19 sources with some type of emissions problem. The smallest size category is ranked third and its average duration was six times that of the other categories. The 100,000 to 500,000 TPY category also ranks first with respect to magnitude on the basis of the extremely high emissions released during five incidents at a cement plant. The other category that reported magnitudes in excess of 10 times the applicable standard was the 100 to 500 TPY size cut.

TABLE 22. PARAMETER B - SOURCE SIZE UNCONTROLLED EMISSIONS CATEGORY RANKINGS ALL CAUSAL CODES.

Rank	Category (10^3 ton/yr)	Frequency	Category (10^3 ton/yr)	Duration (hr)	Category (10^3 ton/yr)	Magnitude (% above allowable)
1	.5 - 1	68.1	100 - 500	218.0	100 - 500	18,913
2	1 - 10	37.3	.1 - .5	181.6	.1 - .5	1,292
3	10 - 100	36.4	<.1	85.0	10 - 100	571
4	<.1	5.5	10 - 100	13.2	<.1	225
5	100 - 500	5.4	1 - 10	11.5	1 - 10	196
6	.1 - .5	1.3	.5 - 1	11.4	.5 - 1	161

Integration of Rankings--

The integration of causal code 1 rankings is presented in Table 23. As is shown in this table, a three-way tie existed in this integration between the three middle sized categories. Nothing distinguishes any of these categories from the others, and all are ranked high for different reasons. The 500 to 1,000 TPY category had the longest duration and the second highest magnitude but averaged less than one incident per year. The 100 to 500 TPY size cut ranked second in frequency, even though the average occurrence was relatively small, and had long durations and high magnitudes. Finally, the 1,000 to 10,000 TPY category had by far the highest magnitude, yet had a low frequency and only an average relative duration.

TABLE 23. PARAMETER B - SOURCE SIZE UNCONTROLLED EMISSIONS INTEGRATION OF RANKINGS CAUSAL CODE 1 (DESIGN).

Rank	Category (10^3 ton/yr)	Number of samples	Individual ranking: Frequency	Individual ranking: Duration (hr)	Individual ranking: Magnitude (% above allowable)	$\sum$ all ranking
1	.5 - 1	2	4	1	2	7
1	.1 - .5	1	2	2	3	7
1	1 - 10	3	3	3	1	7
4	10 - 100	4	1	5	4	10
5	.1	1	5	4	5	14
6	100 - 500	0	6	6	6	18
	Total =	11				

The integration of causal code 2 rankings is found in Table 24. The largest category 100,000 to 500,000 TPY ranked first based on its number one rank with respect to both duration and magnitude. While there were only three incidents per year for this category, each incident was extremely long and had emissions that were extremely high relative to standards. This ranking highlights the fact that large sources always have the potential for high excess emissions, and should a problem occur which completely disables the control equipment and this problem goes unsolved, a serious episode will follow. Small facilities, with sizes less than 100 tons, ranked second overall, although their average durations and magnitudes do not compare with the large sources. While the 500 to 1,000 TPY category had the most incidents per year, each one is short in duration and low in magnitude, and this category ranked fifth overall.

Table 25 presents the integration for causal code 3 problems. For control-related operating and maintenance problems, the 1,000 to 10,000 TPY category ranks first. This size cut barely ranked first in frequencies and had

TABLE 24. PARAMETER B - SOURCE SIZE UNCONTROLLED EMISSIONS INTEGRATION OF RANKINGS CAUSAL CODE 2 (PROCESS).

Rank	Category (10^3 ton/yr)	Number of samples	Individual ranking: Frequency	Individual ranking: Duration (hr)	Individual ranking: Magnitude (% above allowable)	$\sum$ all ranking
1	100 - 500	2	5	1	1	7
2	<.1	3	4	2	2	8
3	10 - 100	3	2	5	3	10
4	1 - 10	13	3	3	5	11
4	.5 - 1	6	1	6	4	11
5	.1 - .5	7	6	4	6	16
	Total =	34				

TABLE 25. PARAMETER B - SOURCE SIZE UNCONTROLLED EMISSIONS INTEGRATION OF RANKINGS CAUSAL CODE 3 (CONTROL O&M).

Rank	Category (10^3 ton/yr)	Number of samples	Individual ranking: Frequency	Individual ranking: Duration (hr)	Individual ranking: Magnitude (% above allowable)	$\sum$ all ranking
1	1 - 10	14	1	3	3	7
2	.1 - .5	8	6	2	1	9
3	100 - 500	2	3	5	2	10
4	<.1	13	5	1	5	11
5	.5 - 1	8	2	4	6	12
6	10 - 100	4	4	6	4	14
	Total =	49				

only relatively average duration and magnitudes, yet was first overall due to the lack of a consistent showing in all indicators by any one category. While the 100 to 500 TPY category ranked first in magnitude, it ranked last in frequency and had an average duration that ranked it second in this indicator. Overall this category ranked second. Finally, the smallest size category, which ranked first in duration, placed only next to last in both frequency and magnitude and was ranked fourth overall. This entire causal code had no clear cut problem category.

The integration of category rankings for causal code 4 are presented in Table 26. This integration does have one standout category. The 100 to 500 TPY size cut was the only one that ranked in the top three for all indicators and placed first overall. The only indicator in this causal code to have a wide numerical separation between values was that for duration and the 100 to 500 TPY category ranked first here. A third place rank in frequencies and a second place rank in magnitude ensured the overall number one ranking for this category. The 100,000 to 500,000 TPY category barely ranked first for frequency yet ranked fourth in duration and last in magnitude and was ranked fourth overall. Similarly, the smallest category, sources less than 100 TPY, ranked first in magnitude yet fifth in both frequency and duration and was listed third overall.

TABLE 26. PARAMETER B - SOURCE SIZE UNCONTROLLED EMISSIONS INTEGRATION OF RANKINGS CAUSAL CODE 4 (UNFORESEEN).

Rank	Category (10^3 ton/yr)	Number of samples	Individual ranking			$\sum$ all ranking
			Frequency	Duration (hr)	Magnitude (% above allowable)	
1	.1 - .5	6	3	1	2	6
2	1 - 10	8	4	2	4	10
3	<.1	3	5	5	1	11
3	100 - 500	1	1	4	6	11
4	.5 - 1	5	6	3	3	12
5	10 - 100	1	2	6	5	13
	Total =	25				

An integration of the rankings for all causal codes is presented in Table 27. Again, there is a clear cut number one rank. The largest category, 100,000 to 500,000 TPY, is first, based on individual number one ranks in the duration and magnitude indicators. Three of six sources in this category reported problems, and the data from 6.5 incidents formed the averages upon which the two number one ranks was based. It is interesting to note that the frequency number one went to the 500 to 1,000 TPY category, yet that size cut ranked last overall due to last placed rankings in duration and magnitude.

TABLE 27. PARAMETER B - SOURCE SIZE UNCONTROLLED EMISSIONS INTEGRATION OF RANKINGS ALL CAUSAL CODES.

Rank	Category (10^3 ton/yr)	Number of samples	Individual ranking			$\sum$ all ranking
			Frequency	Duration (hr)	Magnitude (% above allowable)	
1	100 - 500	6	5	1	1	7
2	.1 - .5	31	6	2	2	10
2	10 - 100	11	3	4	3	10
4	.1	24	4	3	4	11
5	1 - 10	30	2	5	5	12
6	500 - 1	17	1	6	6	13
	Total =	119				

Normalized Credits/Normalized Excess--

Data on normalized credits and normalized excess are presented in Table 28. All categories had normalized credits that exceeded 40 percent in the allowable annual emission level. The two largest size categories had the lowest normalized credits, and hence the greatest potential problems.

While all categories had excesses which were greater than 10 percent of allowables, the ranking of the individual normalized excess values shifts between different categories.

All categories had emission surpluses after excesses had been subtracted from credits. The smallest size category had the greatest surplus while the second smallest size cut had the least surplus. This data was also compared to the integration ranking from all causal codes to see if some consistency was apparent between problem categories. While the rankings were not similar, two of the top three categories were identical. Both the 100 to 500 TPY and the 10,000 to 100,000 TPY categories were ranked among the top three in both tables. This suggests that these two categories are the main problem areas with regard to specific excess emissions incidents and the degree to which these incidents affect annual emissions surplus.

TABLE 28. PARAMETER B - SOURCE SIZE UNCONTROLLED EMISSIONS RANKING OF NORMALIZED CREDITS AND EXCESSES.

Rank order	Category (10^3 ton/yr)	Normalized credits (% of allowable)	Category (10^3 ton/yr)	Normalized excess (% of allowable)	Category (10^3 ton/yr)	Credits - excess (% of allowable)
1	10 - 100	0.43	.1 - .5	0.35	.1 - .5	0.12
2	100 - 500	0.44	1 - 10	0.28	10 - 100	0.17
3	.1 - .5	0.47	10 - 100	0.26	1 - 10	0.28
4	<.1	0.55	.5 - 1	0.18	100 - 500	0.29
5	1 - 10	0.56	100 - 500	0.15	.5 - 1	0.40
6	.5 - 1	0.58	<.1	0.11	<.1	0.44

Parameter C - Control Type

The general type of air pollution control device used at the sources surveyed provides the next basis for comparison of excess emissions incidents. We have limited the number of devices studied to four generic types:

- Electrostatic precipitators (ESPs)
- Wet scrubbers
- Fabric filters (baghouses)
- Other

Incorporated in the "other" section are conventional, though less common, devices such as cyclones and afterburners as well as newer more complex controls including mist eliminators and vapor recovery units. While combining devices minimizes the specific conclusions that can be drawn from data on these controls, we will benefit by having fewer total control categories. The bias built into a data set which reports the results of only a few source surveys will be minimized by limiting to four, the number of devices investigated. With our 119 source sample population, we will have roughly 30 sources in each category, and extremes of performance will be reduced.

Category Rankings—

Causal Code 1, design data, is ranked on Table 29. Four sources, two iron and steel plants and two grain handling operations reported design problems with baghouses. The repeated frequency of occurrence of these problems caused baghouses to rank first in frequencies, with some 20 times more incidents than the second category "other." Since this Causal Code had the fewest data entries, 11, it can be unduly influenced by one source, and in fact, one baghouse provided 73 percent of all incident frequencies. Even without this source, however, baghouses would have ranked first for this incident indicator. "Other" devices ranked first in duration of design related incidents, although scrubber durations were a close second. Both categories had average durations in excess of 115 days of continued source operation. Problems with a carbon absorption system and two vapor recovery systems lead to the exceptionally long duration experienced in the "other" category. Poor materials of construction utilized on a utility boiler scrubber lead to one continuous outage and a resultant long duration/high magnitude emission excursion for this control category. Baghouses are notable in their relatively short incident duration (only 1.4 percent the duration of the closest category). The one scrubber outage had a magnitude which ranked it first for this incident indicator.

Process-related incident data is found in Table 30. The 34 sources reporting Code 2 problems were fairly evenly divided among control categories with the exception of baghouses which reported only three sources with process incidents. Nine sources in the "other" category reported problems and this category ranked first with respect to frequency of occurrence while ESPs ranked second. If the one boiler source which reported 882 incidents is subtracted from the "other" total, and the cupola problem of 700 incidents is subtracted from the ESP total, our ranking for frequency would remain the same,

TABLE 29. PARAMETER C - CONTROL DEVICE TYPE CATEGORY RANKING CAUSAL CODE 1 (DESIGN).

Rank	Category	Frequency	Category	Duration (hr)	Category	Magnitude (% above allowable)
1	Baghouse	24.6	Other	3097.7	Scrubber	2817
2	Other	1.2	Scrubber	2765.0	Baghouse	1941
3	ESP	0.8	ESP	1130.4	Other	667
4	Scrubber	0.5	Baghouse	15.8	ESP	170

TABLE 30. PARAMETER C - CONTROL DEVICE TYPE CATEGORY RANKING CAUSAL CODE 2 (PROCESS).

Rank	Category	Frequency	Category	Duration (hr)	Category	Magnitude (% above allowable)
1	Other	123.4	ESP	11.7	ESP	815
2	ESP	95.9	Scrubber	8.9	Other	180
3	Scrubber	17.96	Other	2.4	Scrubber	160
4	Baghouse	10.7	Baghouse	0.18	Baghouse	88

but all averages would be within 18 frequencies instead of the 113 frequencies that currently separate the high and low values. ESPs ranked first in duration of incident as well as magnitude of emission based on nine separate source reports. There is not a widespread difference between the categories with regard to duration, and baghouses had an exceptionally short duration averaging only 0.18 hours or 11 minutes per incident. The number one ranking for ESPs in magnitude would be reduced to a number three ranking (magnitude of 144 percent) if the five incidents of uncontrolled cement kiln were subtracted. The baghouses again are ranked last for this indicator.

Control O&M data is found in Table 31. Forty-nine sources were surveyed for this incident indicator, and were evenly distributed among control device types. ESPs ranked first in the frequency of O&M problems, although all of the categories were tightly grouped and no one device stood out. Such was not the case for incident duration. Here, the "other" category and scrubbers both averaged nine times longer incidents than the third ranked baghouses. Three of the eleven "other" sources reported long (3 month) duration problems, although none of the respective control devices were the same. Similarly, 2 of the 14 scrubber sources reported average durations lasting greater than 3 months, with one duration lasting an entire year. Incident magnitudes are all fairly close for this Causal Code, with "other" ranked first. All categories averaged 3 to 5.4 times the applicable standard.

Twenty-five separate sources reported unforeseen problems and this data summary is presented in Table 32. All categories had extremely low frequencies of occurrence, with baghouses having the most and ranking first with 3.6 incidents per year. Six scrubbers reporting problems had the longest incident durations, averaging more than 11 days per outage. Durations at "other" sources were similarly long (1 week) while the two remaining categories averaged less than 3 days per incident. Finally, the "other" category ranked first with the greatest magnitude, as each of the seven sources reporting a problem had a magnitude in excess of 100 percent the allowable. Scrubbers ranked a close second in magnitude, substantially ahead of the third ranked ESPs.

The totals for all Causal Codes, summed collectively are presented in Table 33. Inspection of the data for frequency reveals a two-tiered ranking, with ESPs and "other" each having greater than 5 times the frequency of the remaining categories. Elimination of our often discussed 882 and 700 frequency sources would reduce the averages for ESPs and "other" to 15.5 and 12.6, respectively. Scrubber duration was twice that of any other control device, with several of the sources reporting incidents lasting in excess of 60 days. ESPs ranked first with regard to magnitude. However, this figure is misleading as it is greatly influenced by five upsets at one cement plant. If these five incidents are subtracted from the 1025 total incidents attributable to precipitators, ESPs would have an average magnitude of 187 percent, placing them last in this ranking. As reported, the high ESP ranking is indicative of the large degree of control obtained with precipitators and the concurrent potential for large magnitudes of excess emissions should a prolem develop.

TABLE 31. PARAMETER C - CONTROL DEVICE TYPE CATEGORY RANKING CAUSAL CODE 3 (CONTROL O&M).

Rank	Category	Frequency	Category	Duration (hr)	Category	Magnitude (% above allowable)
1	ESP	14.3	Other	127.7	Other	535
2	Baghouse	10.6	Scrubber	119.2	ESP	438
3	Other	6.8	Baghouse	13.3	Scrubber	348
4	Scrubber	4.2	ESP	6.5	Baghouse	312

TABLE 32. PARAMETER C - CONTROL DEVICE TYPE CATEGORY RANKING CAUSAL CODE 3 (UNFORESEEN).

Rank	Category	Frequency	Category	Duration (hr)	Category	Magnitude (% above allowable)
1	Baghouse	3.6	Scrubber	254.7	Other	746
2	ESP	2.1	Other	175.9	Scrubber	672
3	Scrubber	1.3	ESP	62.2	ESP	162
4	Other	1.0	Baghouse	16.1	Baghouse	104

TABLE 33. PARAMETER C - CONTROL DEVICE TYPE CATEGORY RANKING ALL CAUSAL CODES.

Rank	Category	Frequency	Category	Duration (hr)	Category	Magnitude (% above allowable)
1	ESP	46.6	Scrubber	40.8	ESP	751
2	Other	46.0	Other	20.3	Baghouse	518
3	Scrubber	8.4	ESP	14.5	Scrubber	212
4	Baghouse	8.4	Baghouse	12.8	Other	208

Integration of Rankings--

The integration of Parameter C data is especially informative due to the small number of categories into which the sources are placed and the resultant higher number of sources found in any one category. Data for this parameter is therefore the most representative of those studied.

The integrated ranking of Causal Code 1 problems is found in Table 34. "Other" ranks highest with respect to design problems, followed closely by scrubbers and baghouses. Since the "other" category included data on several types of control devices, we cannot draw conclusions for any one device within this category. What may be inferred, however, from this overall number 1 integrated rank is that design problems are more likely to be a concern with the uncommon and novel devices. The lack of long-term field experience with devices such as vapor recovery systems is shown in this high ranking. The second place rank of both scrubbers and baghouses seems to indicate that these control devices may cause excess emissions if they are not properly designed for a specific application. Use of improper materials of construction was the most common reason cited for design problems with scrubbers and baghouses.

Process-related problems (Causal Code 2) are integrated in Table 35. The control device types are separated by relatively large margins in this integration with ESPs clearly ranked first. Since the process and not the control device is associated with Causal Code 2 problems, this integration only points out those devices which are associated with process problems. Precipitators are generally more capital intensive than scrubbers or baghouses and are typically installed on large facilities which require a high degree of control. The number 1 rank of precipitators in this integration reemphasizes the conclusion of the Parameter B integration: that large sources have greater excess emissions problems.

From a control device standpoint, the integration of control-related problems is more significant. The integration for these Causal Code 3 problems is presented in Table 36. In this causal code, "other" devices ranked first. This indicates that the less conventional control devices have a greater problem with excess emissions due to their actual operation and maintenance. When used in conjunction with the design problem integration, it reemphasizes the point that these less commonly found devices collectively have initial as well as continued problems with their operation and maintenance. This ranking also suggests that these devices may not be properly maintained. Control device complexity or lack of training for maintenance personnel who work with these controls may contribute to this rank.

Unforeseen problems are integrated in Table 37. Scrubbers are ranked first here, closely followed by "other" devices. This integration indicates those devices which are more susceptible to an unforeseen outage due to causes beyond the control of the equipment operator. The number one rank of scrubbers is perhaps indicative of the difficulty encountered by sources in keeping these units on line, through no fault of their own. The nature of scrubber operation, with constant movement of a caustic or acidic solution, makes constant surveillance of these devices critical, as conscientious maintenance practices alone may not be sufficient to eliminate problems.

TABLE 34. PARAMETER C - CONTROL DEVICE TYPE INTEGRATION OF RANKINGS CAUSAL CODE 1 (DESIGN).

Rank	Category	Number of samples	Individual ranking: Frequency	Duration (hr)	Magnitude (% above allowable)	$\sum$ all ranking
1	Other	3	2	1	3	6
2	Scrubber	1	4	2	1	7
2	Baghouse	4	1	4	2	7
3	ESP	3	3	3	4	10
	Total =	11				

TABLE 35. PARAMETER C - CONTROL DEVICE TYPE INTEGRATION OF RANKINGS CAUSAL CODE 2 (PROCESS).

Rank	Category	Number of samples	Individual ranking: Frequency	Duration (hr)	Magnitude (% above allowable)	$\sum$ all ranking
1	ESP	9	2	1	1	4
2	Other	9	1	3	2	6
3	Scrubber	13	3	2	3	8
4	Baghouse	3	4	4	4	12
	Total =	34				

TABLE 36. PARAMETER C - CONTROL DEVICE TYPE INTEGRATION OF RANKINGS CAUSAL CODE 3 (CONTROL O&M).

Rank	Category	Number of samples	Individual ranking: Frequency	Duration (hr)	Magnitude (% above allowable)	$\sum$ all ranking
1	Other	11	3	1	1	5
2	ESP	10	1	4	2	7
3	Baghouse	14	2	3	4	9
3	Scrubber	14	4	2	3	9
	Total =	49				

TABLE 37. PARAMETER - CONTROL DEVICE TYPE INTEGRATION OF RANKINGS CAUSAL CODE 4 (UNFORESEEN).

Rank	Category	Number of samples	Individual ranking: Frequency	Duration (hr)	Magnitude (% above allowable)	$\sum$ all ranking
1	Scrubber	6	3	1	2	6
2	Other	7	4	2	1	7
3	ESP	8	2	3	3	8
4	Baghouse	4	1	4	4	9
	Total =	25				

The integration of the rankings for all causal code problems is found on Table 38. As can be seen, ESP's rank first overall due to their number one rankings with respect to both frequency and magnitude. This ranking, however, is more indicative of the fact that ESPs are associated with problem areas, than it is a statement concerning how well ESPs actually operate. This is especially true concerning the individual magnitude rankings. The five incidents of uncontrolled emission at a cement plant controlled by an ESP were of such magnitude so as to rank these devices first. Without these incidents, the average ESP duration would have been sufficiently low to rank it last for this indicator, and this change in magnitude ranks would have placed ESPs last in the overall integration. Moreover, the cause of these five excursions was process-related, and not due to some problem with the ESP. This situation is presented to remind the reader of the cumulative effects of an uncommon situation. As presented, scrubbers ranked second and baghouses ranked last, as they had for two of the four individual causal code integrations.

Normalized Credits - Normalized Excess--

The rankings for normalized credits, and normalized excess and the integration of their difference is presented in Table 39. As can be seen, the rankings for each of these items is exactly the same. In all cases "other" has the highest rank due to its low normalized credits, its high normalized excess and the small value of the difference. This indicates that these relatively uncommon control devices normally operate closer to the allowable emission rate, have relatively greater excesses, and have a net surplus of credits minus excess which is smaller than the conventional control devices. It is interesting to note that all control device categories had credits which exceeded excesses. On an annual basis, none emitted more pollutant to the ambient air than allowed by applicable mass emission regulations. On the lower end of the rankings were baghouses. With their greater credits and lower excesses, these devices produced a net annual surplus of emissions that far exceeded any control device category.

TABLE 38. PARAMETER C - CONTROL DEVICE TYPE INTEGRATION OF RANKINGS ALL CAUSAL CODES.

Rank	Category	Number of samples	Individual ranking			$\sum$ all ranking
			Frequency	Duration (hr)	Magnitude (% above allowable)	
1	ESP	22	1	3	1	5
2	Scrubber	36	3	1	3	7
3	Other	26	2	2	4	8
4	Baghouse	35	3	4	2	9
	Total =	119				

TABLE 39. PARAMETER C - CONTROL DEVICE TYPE RANKING OF NORMALIZED CREDITS AND EXCESSES.

Rank	Category	Normalized credits	Rank	Category	Normalized excess	Rank	Category	Credits - excess
1	Other	0.37	1	Other	0.33	1	Other	0.04
2	Scrubber	0.48	2	Scrubber	0.27	2	Scrubber	0.21
3	ESP	0.51	3	ESP	0.24	3	ESP	0.27
4	Baghouse	0.65	4	Baghouse	0.14	4	Baghouse	0.51

Parameter D - Control Device Size

Ranking of this parameter will serve to point out those control device sizes, regardless of the type of control device, which are more likely to have excess emissions incidents. Since larger sources are likely to have larger control devices, these rankings will serve to complement the rankings presented for Parameter B, source size. Differences in the category rankings of the two parameters are primarily due to sources which operate intermittently, and have control devices sized to their maximum rated production capacity.

Category Rankings--

Causal Code 1 rankings are provided in Table 40. The 11 sources reporting design problems are somewhat evenly divided among the six categories. The 50,000 to 100,000 acfm category contained no problem sources while the other three categories below 500,000 acfm each reported three sources with incidents. The larger size categories, 500,000 to 1,000,000 acfm and greater than 1,000,000 acfm each contained one source. The 100,000 to 500,000 acfm category had five times the number of frequencies of any other category. The three sources reporting problems in this size range reported 89 percent of all design problems. The one source which was investigated having a control device size in excess of 1 million acfm reported a repeated design-related problem and was ranked second with respect to frequency. Three of the 31 sources in the size range less than 10,000 acfm, reported problems, and the duration of their reported incidents ranked them first with respect to this indicator. Each of these three small devices had incidents lasting in excess of 19 days continued operation. The 500,000 to 1,000,000 acfm and 10,000 to 50,000 acfm categories also had incident durations which exceeded 43 days of continued device operation. The magnitude ranking was led by the 10,000 to 50,000 acfm category. The average magnitude of this category was more than five times greater than the next category. As has been the case with all Causal Code 1 rankings, this large magnitude reflects the input of one atypical, large event.

TABLE 40. PARAMETER D - CONTROL DEVICE SIZE (ACFM) CATEGORY RANKING CAUSAL CODE 1 (DESIGN).

Rank	Category (10^3 acfm)	Frequency	Category (10^3 acfm)	Duration (hr)	Category (10^3 acfm)	Magnitude (% above allowable)
1	100 - 500	31.0	<10	3097.7	10 - 50	10,814
2	>1000	6.0	500 - 1000	2190.0	100 - 500	1,893
3	<10	1.2	10 - 50	1033.7	<10	667
4	500 - 1000	1.0	>1000	24.0	>1000	100
5	10 - 50	0.5	100 - 500	20.2	500 - 1000	69
6	50 - 100	0	50 - 100	0	50 - 100	0

Rankings for Causal Code 2 are presented in Table 41. The 100,000 to 500,000 acfm category ranks first with respect to frequency, and this ranking is significant for two reasons. The average frequency is more than twice that of the second ranked category, and more than half (12 of 23) the sources in this control device size range experienced process problems. Even if one were to discount the 700 incidents at one source, this size range would be the highest ranked category by greater than 50 percent. In general, it appears that the larger sources have a higher incident frequency. Little variation appears among categories with respect to average incident duration, the middle sized categories stand out as having the longest durations, with the 50,000 to 100,000 acfm group ranking number one. No trend was evident with respect to duration and category size. The 100,000 to 500,000 acfm category lead all others with respect to incident magnitude. No one category stood out with regard to this indicator and no correlation could be made between magnitude and control device size.

TABLE 41. PARAMETER D - CONTROL DEVICE SIZE (ACFM) CATEGORY RANKING CAUSAL CODE 2 (PROCESS).

Rank	Category (10^3 acfm)	Frequency	Category (10^3 acfm)	Duration (hr)	Category (10^3 acfm)	Magnitude (% above allowable)
1	100 - 500	146.0	50 - 100	10.85	100 - 500	482
2	500 - 1000	60.0	10 - 50	10.6	10 - 50	377
3	10 - 50	22.6	100 - 500	5.78	500 - 1000	200
4	50 - 100	17.7	<10	4.5	<10	109
5	<10	14.5	500 - 1000	4.0	50 - 100	54
6	>1000	0	>1000	0	>1000	0

Causal Code 3 problems are ranked in Table 42. All categories have similar average frequencies with the 500,000 to 100,000 group heading the list. The average for this category is based on the two sources (out of six) which reported problems. The general trend of these rankings indicates that the larger sources had more problems per year. The duration indicator is lead by the small size category; control devices with size less than 10,000 acfm. Three of the eleven sources reporting operating and maintenance problems in this size category had incidents lasting in excess of 89 days continuous operation. These sources contributed to the high average duration of this category which was almost four times as great as the second ranked category. The 10,000 to 50,000 acfm category was ranked first with regards to incident magnitude. All categories were generally close in this indicator and no clear-cut size category/incident magnitude relationship was evident.

TABLE 42. PARAMETER D - CONTROL DEVICE SIZE (ACFM) CATEGORY RANKING CAUSAL CODE 3 (CONTROL O&M).

Rank	Category (10^3 acfm)	Frequency	Category (10^3 acfm)	Duration (hr)	Category (10^3 acfm)	Magnitude (% above allowable)
1	500 - 1000	17.3	<10	143.0	10 - 50	569
2	100 - 500	11.3	10 - 50	38.4	100 - 500	412
3	10 - 50	8.5	100 - 500	22.8	<10	227
4	<10	6.3	>1000	15.0	50 - 100	218
5	50 - 100	6.0	50 - 100	8.5	500 - 1000	181
6	>1000	4.0	500 - 1000	6.2	>1000	100

The rankings for Causal Code 4 are presented in Table 43. On the basis of one source report for each of the two largest control size categories, they are ranked first and second with regards to frequency of incidents. All categories are grouped closely together with respect to frequency, and no clear-cut category size/frequency of incident relationship is evident. While only four sources in the less than 10,000 acfm category cited unforeseen problems, two of these incidents were in excess of 50 days continuous source opeation this ranking this size category first with respect to incident duration. This duration was almost four times as long as the next ranked category. Two size categories stood out with respect to unforeseen incident magnitude. Seven of eight sources with this type problem in the 10,000 to 50,000 acfm size category reported incidents in excess of 300 percent of the applicable standard causing this category to be ranked first. Three sources in the next largest size range, 50,000 to 100,000 acfm had large magnitude problems, and the average of this category was more than six and one-half times the standard. Generally, the smaller size categories had larger incident magnitudes.

The data for all causal codes considered together is presented in Table 44. An examination of the frequency data reveals that the larger control devices generally have more incidents than the smaller devices. Nineteen of the twenty-three sources in the 100,000 to 500,000 acfm category reported problems and this group ranked first with regards to the frequency of occurrence. Once again this average is affected by the two large frequency sources, but even if we eliminate the sources with 882 and 700 incidents, this category would still rank first. Collectively, the small control devices had fewer incidents, and the smallest category of all had the fewest. This smallest size category, less than 10,000 acfm, had the longest duration as well, with 6 of the 17 facilities reporting problems having average incident durations in excess of 73 days continued source operation. The average duration for this category was 6.5 times higher than the second ranked size classification. No trend was evident between control device size and excess incident duration. The magnitude indicator was headed by the 100,000 to 500,000 acfm category. With the 10,000 to

TABLE 43. PARAMETER D - CONTROL DEVICE SIZE (ACFM) CATEGORY RANKING CAUSAL CODE 4 (UNFORESEEN).

Rank	Category (10^3 acfm)	Frequency	Category (10^3 acfm)	Duration (hr)	Category (10^3 acfm)	Magnitude (% above allowable)
1	>1000	5.0	<10	229.8	10 - 50	674
2	500 - 1000	4.0	50 - 100	61.0	50 - 100	664
3	<10	2.8	100 - 500	58.5	<10	390
4	100 - 500	2.3	500 - 1000	48.0	100 - 1000	200
5	10 - 50	1.1	10 - 50	34.3	100 - 500	144
6	50 - 100	0.7	>1000	10.0	>1000	100

TABLE 44. PARAMETER D - CONTROL DEVICE SIZE (ACFM) CATEGORY RANKING ALL CAUSAL CODES.

Rank	Category (10^3 acfm)	Frequency	Category (10^3 acfm)	Duration (hr)	Category (10^3 acfm)	Magnitude (% above allowable)
1	100 - 500	86.9	<10	184.3	100 - 500	468
2	500 - 1000	16.6	500 - 1000	28.5	10 - 50	406
3	>1000	15.0	10 - 50	24.4	<10	214
4	50 - 100	14.1	>1000	20.3	500 - 1000	192
5	10 - 50	9.2	50 - 100	12.0	50 - 100	111
6	<10	4.1	100 - 500	8.1	>1000	100

50,000 acfm group a close second. Both these categories had double the magnitude of the third place size range, although none of the magnitudes were greater than five times the allowable standard.

Integration of Rankings—

The integration of Causal Code 1 rankings is found in Table 45. The smallest size category, < 10,000 acfm ranks first. This ranking is somewhat surprising as one might expect the larger sources to have greater design problems due to their size and complexity. The three sources upon which this number one ranking was based consisted of two small vapor recovery systems and one carbon absorption system which are relatively complex devices to operate. The 100,000 to 500,000 acfm category had an integrated rank which placed it second. While this size range had the greatest frequency, it had relatively short incident durations which minimized the net ranking. Similarly, the 10,000 to 50,000 acfm category ranked first in magnitude but had relatively few frequencies and a mid-level average incident duration. There was no identifiable correlation between integrated design rank and the size range of the category.

TABLE 45. PARAMETER D - CONTROL DEVICE SIZE (ACFM) INTEGRATION OF RANKINGS CAUSAL CODE 1 (DESIGN).

Rank	Category (10^3 acfm)	Number of samples	Individual ranking: Frequency	Individual ranking: Duration (hr)	Individual ranking: Magnitude (% above allowable)	$\sum$ all ranking
1	<10	3	3	1	3	7
2	100 - 500	3	1	5	2	8
3	10 - 50	3	5	3	1	9
4	>1000	1	2	4	4	10
5	500 - 1000	1	4	2	5	11
6	50 - 100	0	6	6	6	18
	Total =	11				

The integration of Causal Code 2 is found in Table 46. Once again, the overall top ranked category is the 100,000 to 500,000 acfm size range. Since Causal Code 2 problems are process related, this integration is solely an indicator of equipment sizes which are associated with process problems. It cannot be used in itself, to pinpoint who is having a problem or where that problem is. This overall first ranked category was also the number one ranked category for both frequency and magnitude and should not be overly biased as it is based on the input of 12 separate sources. The second ranked category, 10,000 to 50,000 acfm, had consistently high rankings for all indicators and was also based on a relatively large sample (13). The integrated ranking does not appear to be related to size category in any discernable manner.

TABLE 46. PARAMETER D - CONTROL DEVICE (ACFM) INTEGRATION OF RANKINGS CAUSAL CODE 2 (PROCESS).

Rank	Category (10^3 acfm)	Number of samples	Individual ranking: Frequency	Duration (hr)	Magnitude (% above allowable)	$\sum$ all ranking
1	100 - 500	12	1	3	1	5
2	10 - 500	13	3	2	2	7
3	500 - 1000	1	2	5	3	10
3	50 - 100	5	4	1	5	10
5	<10	3	5	4	4	13
6	>1000	0	6	6	6	18
	Total =	34				

The Causal Code 3 integration is presented in Table 47. More sources, 49, reported control equipment operating and maintenance related problems than any other causal code incident. The greatest number of sources in any one category reporting these problems was found in the highest ranked grouping, 10,000 to 50,000 acfm. This category ranked first in magnitude and was close to the top in frequency and duration. The smallest category, less than 10,000 acfm ranked first with respect to duration, but had relatively fewer episodes and ranked third overall behind the 100,000 to 500,000 acfm group, which was consistently high in all indicator ranks. While the large 500,000 to 1,000,000 acfm category had the most frequencies, both the duration and magnitude of these occurrences were minimal. Again no apparent correlation exists between the size of category and integrated rank for this causal code.

The integration for Causal Code 4 data is presented in Table 48. As can be seen, sources in the smallest category, less than 10,000 acfm, appear to have the greatest unforeseen problems. This category ranked first with respect to incident duration and was the only source to consistently rank high in all three incident indicators. The top ranked category in magnitude, 10,000 to 50,000 acfm, had relatively few short incidents while the first rank in frequency, the greater than 1,000,000 category, had the shortest average duration and smallest magnitude ranked last overall.

TABLE 47. PARAMETER D - CONTROL DEVICE SIZE (ACFM) INTEGRATION OF RANKINGS CAUSAL CODE 3 (CONTROL O&M).

Rank	Category (10^3 acfm)	Number of samples	Individual ranking			$\sum$ all ranking
			Frequency	Duration (hr)	Magnitude (% above allowable)	
1	10 - 50	17	3	2	1	6
2	100 - 500	12	2	3	2	7
3	<10	11	4	1	3	8
4	500 - 1000	2	1	6	5	12
5	50 - 100	6	5	5	4	14
6	>1000	1	6	4	6	16
	Total =	49				

TABLE 48. PARAMETER D - CONTROL DEVICE SIZE (ACFM) INTEGRATION OF RANKINGS CAUSAL CODE 4 (UNFORESEEN).

Rank	Category (10^3 acfm)	Number of samples	Individual ranking			$\sum$ all ranking
			Frequency	Duration (hr)	Magnitude (% above allowable)	
1	<10	4	3	1	3	7
2	500 - 1000	8	2	4	4	10
2	50 - 100	3	6	2	2	10
4	10 - 50	8	5	5	1	11
5	100 - 500	8	4	3	5	12
6	>1000	1	1	6	6	13
	Total =	25				

The most significant of the integrations, the one involving all causal codes is found in Table 49. A tie existed for the overall number one ranking between the 100,000 to 500,000 acfm category and the 500,000 to 1,000,000 acfm size group. The former size cut ranked first in both frequency of incident and average magnitude and would have been clearly the top rank except for its last place duration rank. Nineteen of the twenty-three sources in this group reported problems. The other large-size category ranked second in both frequency duration indicators even though three of this group's six sources reported no problems.

TABLE 49. PARAMETER D - CONTROL DEVICE SIZE (ACFM) INTEGRATION OF RANKINGS ALL CAUSAL CODES.

Rank	Category (10^3 acfm)	Number of samples	Individual rankings: Frequency	Duration (hr)	Magnitude (% above allowable)	$\sum$ all ranking
1	500 - 1000	6	2	2	4	8
1	100 - 500	23	1	6	1	8
3	10 - 50	49	5	3	2	10
3	<10	31	6	1	3	10
5	>1000	1	3	4	6	13
6	50 - 100	9	4	5	5	14
	Total =	119				

Normalized Credits/Normalized Excess—

Finally, we review the relationship between normalized credits and normalized excess. This data is presented in Table 50. A general trend is apparent in the normalized credit column. As the size of control device increases, so does the amount of normalized credit. Since our procedure for normalizing both credits and excess has been used to eliminate the bias of large sources, this trend is informative. It seems to indicate that the larger sources are controlled to an increasingly greater degree than required. It can also be inferred that larger control devices are purposely over-designed so as to leave the source with some latitude in meeting state emission regulations, should the design parameters of the equipment be altered for some reason.

A similar general trend, though not a direct correlation, is seen in the normalized excess data. Again, the smaller the source, the greater the excess emissions problem, with the smallest size category having the greatest normalized excess while the largest control devices have the least.

TABLE 50. PARAMETER D - CONTROL DEVICE SIZE (ACFM) RANKING OF NORMALIZED CREDITS AND EXCESSES.

Rank order	Category (10^3 acfm)	Normalized credits	Category (10^3 acfm)	Normalized excess	Category (10^3 acfm)	Credits - excess
1	50 - 100	0.41	<10	0.40	100 - 500	0.10
2	100 - 500	0.48	100 - 500	0.38	<10	0.12
3	<10	0.52	10 - 50	0.14	50 - 100	0.39
4	10 - 50	0.53	500 - 1000	0.08	10 - 50	0.43
5	500 - 1000	0.60	50 - 100	0.02	500 - 1000	0.52
6	>1000	0.73	>1000	0.01	>1000	0.72

The third column in this table, the difference between the normalized values shows a less defined control size/excess emissions correlation. All categories have a net surplus of annual emissions as excesses are more than completely offset by credits. A wide range of surplus exists, however, ranging from 10 percent of allowables for the 100,000 to 500,000 acfm class to 72 percent of allowables for the greater than 1,000,000 acfm category. While this latter large category has the lowest rank in all three normalized areas, this data is based on only one source survey, and care should be taken in interpreting the results. The small emissions surplus of the 100,000 to 500,000 acfm category reinforces the previously discussed number one rank of this category with respect to all causal codes and suggests that sources with control devices in this size range experience the greatest excess emissions problems.

SECTION 3

CONCLUSIONS AND RECOMMENDATIONS

DATA REVIEW

All excess emissions data analyzed for this study was extracted from 119 separate source surveys. In developing our various averages and the resultant category ranks and integrations we have used all sources, including those which reported no excess emissions incidents. A summary of the relevant source and emissions data pertaining to these sources is presented in Table 51. We feel, however, that the true extent of the excess emissions problem is larger than that which is shown by these numbers. Unlike water quality programs which can utilize discharge permit data to quantify pollutant emissions, air programs do not establish explicit ambient emissions levels from each process operation. Shortages of detailed verifiable emission data forced the individual contractors to fill in data gaps with recollections of plant personnel concerning control equipment performance. A conservative tendency was therefore necessarily adopted in making judgements concerning the amount and extent of excess emission episodes. In addition, plant personnel exhibited some lingering hesitation to divulge process and control equipment performance data even though they were instructed that no enforcement action would be taken on the basis of their statements. We feel these factors lead us to underestimate the true extent of the excess emissions problem. The extent of this underestimation cannot be quantified.

A second factor which contributes to an underestimation of the actual excess emissions problem concerns the interpretation of available process and control equipment data by the individual contractors. No widely acceptable methodology exists to determine the affect on stack emissions of a process or control equipment perturbation. Each contractor used what information was available and his best engineering judgment to estimate increases in stack emissions due to a change in process and control equipment parameters. The affect of boiler soot blowing or loss of one bag in a baghouse has not been widely investigated. What is known in these areas was utilized. However, we feel that the emissions estimates which were developed were conservative and tended to underestimate the actual magnitude of source emissions. Since we did not have access to individual contractor methodologies, we cannot be sure of the extent nor the degree of this underestimation. Data from different

TABLE 51. UNMODIFIED DATA SUMMARY

Item	Causal code 1 (design)	Causal code 2 (process)	Causal code 3 (control O&M)	Causal code 4 (unforeseen)	$\sum$ All causal codes
Uncontrolled emissions (tons)	8,048.9	14,566.1	10,406.2	16,314.8	14,603.1
Credits (tons)	178.5	85.3	119.1	202.9	110.9
Excess (tons)	118.3	18.4	10.6	9.2	22.5
Allowable emissions (tons)	310.0	234.2	225.8	337.8	207.8
Frequency	9.5	65.9	8.6	1.9	23.7
Duration (hours)	158.2	6.6	45.9	83.9	19.3
Magnitude (%)	1,003.	421	399	31.7	438
Magnitude (absolute tons)	12.4	0.3	1.2	4.9	1.0
Capital cost (10^3 $)	2,274	1,218	2,067.	1,747.	1,567
O&M cost (10^3 $)	264	177.	267.	192.	170
Control size (10^3 acfm)	273	113.2	145.1	192.3	110.5
Control age	3.2	5.8	5.0	4.8	4.9
Normalized excess	105.5	4.6	12.4	25.8	21.6
Normalized credits	44.1	42.0	42.6	50.1	50.0

contractors on similar sources did vary and we cannot be sure if this variation was due to the nature of the source visited or the way in which available data was converted to emissions estimates. This variation in individual contractor estimates is perhaps best pointed out by the number of sources which reported no emissions incidents. Of the 119 sources surveyed, 41 (34.5 percent) reported no incidents during the study period (1976 to 1977). The percent of these sources in individual contractor summaries varied from 26.8 percent to 64.7 percent of the sources surveyed. We feel this variation is due to different interpretations of the available source data and the identification of a source as having no problems when no substantive data was available on which to make an excess emissions estimate.

DATA MODIFICATION

Reviewing the raw excess emissions data presented in Table 51, we see that many of the averages were greatly influenced by one or two typical cases. The effect that the 882 incidents at one boiler facility and the 700 incidents at one iron and steel plant had on average frequency tabulations, or the high incident magnitude averages that resulted from operation of an uncontrolled cement plant were repeatedly cited in Section 2. Since the purpose of this study was to present the typical excess emissions problem that currently exists, we felt that inclusion of these extreme data points would bias the entire sample. Many avenues of data modification were investigated. While the standard statistical procedure in this case is to compute geometric mean values for all pertinent data, we were unable to do this for the frequency, duration, and magnitude data due to the existence of data points with zero values and our inability to use the log of these points. To account for the existing statistical bias, we have chosen to eliminate extreme excess emissions incidents based on the application of best engineering judgement. This methodology involved completely eliminating from the data base those sources which had frequencies in excess of one per day or (364 per year), and those sources with reported incident durations in excess of 4380 hours (½ year of continual plant operation). For our data base, this technique served to eliminate two sources with high frequencies, and three sources with long durations. An additional three sources had individual incidents with long durations, and these incidents, but not the entire source, were deleted. The remaining incidents for these three sources were then used to calculate new source averages.

Finally we addressed the representativeness of the 41 sources which reported no excess emissions problem. Each of the four contractors was contacted and asked to guage the accuracy of the data supplied by these problem-less sources. Specifically, we asked each contractor if, in their opinion, these sources has actually had problem free case histories or could they have had a problem which was unreported. The reluctance of many sources to divulge excess emissions related information, in spite of assurances that this data would not be used in enforcement actions, prompted this question. Collectively, the contractors felt that approximately 42 percent of these sources may have had a problem which went unreported. This figure represented 17 of their sources reporting no emissions incidents. In order to eliminate this bias, 17 sources were randomly selected from this group of 41, and their source records were deleted from the data base. Our overall data base was therefore reduced by 22 sources. New averages were then computed for each item and this modified data summary is presented in Table 52. The effect of this modification procedure on each Causal Code summary can be seen by a comparison of Tables 51 and 52 and will not be discussed. The way in which the average frequency, duration and magnitude of all incidents has been changed is discussed in the following paragraphs.

Twenty two of the 119 sources were eliminated in computing new indicator averages. The modified averages indicate that:

- Frequency is reduced from 23.7 to 12.3 occurrences per year
- Duration is increased from 19.3 to 23.7 hours
- Magnitude increases from 438 to 828 percent

The two highest frequencies of occurrence alone accounted for 57.3 percent of all reported incidents. Elimination of additional frequencies which were associated with long durations accounted for an additional 0.1 percent for an overall reduction of 57.4 percent. The average incidents per source were therefore greatly reduced.

Sources with incident durations in excess of 4380 hours accounted for 46.7 of all hours in the excess mode. Sources with high incident frequencies accounted for an additional 1.1 percent of all hours, for an overall reduction of 47.8 percent. This indicates that long durations were associated with relatively few incidents and the high frequencies are associated with relatively few total hours. These factors tended to cancel each other out when both high frequencies and long durations are eliminated and the average incident duration only changed sightly, rising to 23.7 hours.

While sources with high incident magnitudes were not altered in our data base, the average magnitude of incidents in our modified data base almost doubled. This statistic reflects the fact that excess emissions incidents which occur frequently, or with a prolonged duration, do not have large magnitudes. When these extreme frequency and duration episodes are eliminated the average incident magnitude rises sharply.

TABLE 52. MODIFIED DATA SUMMARY

Item	Causal code 1 (design)	Causal code 2 (process)	Causal code 3 (control O&M)	Causal code 4 (unforeseen)	$\sum$All causal codes
Uncontrolled emissions (tons)	8,801.9	11,677.3	11,117.9	16,314.8	13,341.5
Credits (tons)	196.3	85.5	125.3	202.9	100.1
Excess (tons)	123.8	5.4	11.4	9.2	22.0
Allowable emissions (tons)	333.2	191.0	233.8	337.8	179.2
Frequency	10.4	22.6	8.7	1.9	12.3
Duration (hours)	102.0	5.3	27.1	83.9	23.7
Magnitude (%)	1,012.0	107.5	426.0	317.0	828.0
Magnitude (absolute tons)	11.9	0.2	1.3	4.9	1.8
Capital cost ($ x 10^3)	2,484.3	1,295.7	2,150.9	1,746.7	1,623.3
O&M cost ($ x 10^3)	264.3	204.2	274.5	191.7	180.9
Control size (10^3acfm)	299.7	109.7	148.9	192.3	105.4
Control age	3.3	5.4	4.9	4.8	5.1
Normalized excess	107.9	3.2	12.9	25.8	24.7
Normalized credits	48.5	44.2	43.7	50.1	50.0

PROBLEM AREA PROFILES

In order to give the reader an overview of those areas which have specific excess emissions problems, we have summarized the results of our various parameter integrations. Tables 53 through 57 present the integrated rankings of the four parameters for each causal code. A summary table is also provided for the integration of all causal code data. By combining the integrations of all source types, source sizes, control device types and control device sizes, which have excess emissions problems due to design, process, control or unforeseen causes. The summation number by which each parameter's data was ranked is also provided to serve as a relative guide in comparing categories within a parameter. We call these various combinations "problem area a profiles" inasmuch as they readily identify those source and control equipment areas which we have associated with various excess emissions problems.

We must re-emphasize two points which have to be kept in mind when reviewing these tables. The first is that they were based on our total, unmodified, sample population of 119 sources. As such they may reflect an unusually large value contributed by one source. Questions concerning the factors which contribute to any ranking will be answered by referring to the appropriate discussion in Section 2.

The second point concerns the actual interpretation of each table. These profiles are not to be read by taking the top-ranked category for each parameter and assuming that this is the worst combination for that causal code. For example, referring to Table 53, we should not assume that grain-handling operations with source sizes of 500 to 1000 tons and using "other" types of controls which are sized at less than 10,000 acfm are those with the most design problems. While each of these categories ranks first, it may not follow that they are typically found combined in this way. Grain-handling operations typically use baghouses for controls and are usually large sources with large control devices. In fact, none of the five grain-handling facilities which we surveyed were in the 500-1000 tons/yr category, none used "other" control devices and none utilized control devices sized in the less than 10,000 acfm range.

The profiles presented may be used by regulatory personnel to pinpoint areas in need of closer attention. Table 53 presents the design problem profile. Elimination or minimization of design problems requires a greater in-depth review procedure by control agencies for new sources being installed. If a new design review regulation were to be adopted, state and local agencies might use a table of this nature to focus their attention on specific industrial categories or control device types. Using the rankings of Table 53, emphasis would be placed on samll grain handling and steam-generating plants for design review. Similary, new novel control devices would get first priority when control equipment design reviews are conducted.

TABLE 53. PROBLEM AREA PROFILE OF CAUSAL CODE 1 (DESIGN)

Rank	Parameter A		Parameter B		Parameter C			Parameter D	
	Category	$\sum$ all ranking	Category (10^3 ton/yr)	$\sum$ all ranking	Rank	Category	$\sum$ all ranking	Category (10^3 acfm)	$\sum$ all ranking
1	Grain handling operations	7	0.5 - 1	7	1	Other	6	<10	7
2	Steam generating plants	9	0.1 - 0.5	7	2	Scrubber	7	100 - 500	8
2	Petroleum products and handling	9	1 - 10	7	2	Baghouse	7	10 - 50	9
4	Petrochemical plants	[illegible]	10 - 100	10	3	ESP	10	>1000	10
5	Iron and steel plants	[illegible]	0.1	14				500 - 1000	11
6	Stone, clay	15	100 - 500	18				50 - 100	18
7	Pulp and paper mills	-							
7	Incinerators	-							
7	Cement plants	-							
7	Asphalt plants	-							
7	Aluminum plants	-							
7	Brass and bronze plants	-							
7	Lumber and wood plants	-							
7	Surface coating operations	-							
7	Food and drug plants	-							
7	Other	-							

Table 54 presents the process problem profile. Attention in this area might concern an in-depth study of the higher ranked categories to determine how their plant operations may be altered to reduce the potential of process-related excess emissions incidents. Based on our data, cement plants would be prime candidates for such a study.

Control related problems are profiled in Table 55. Minimization of these problems may entail the adoption of specific operating and maintenance procedures for the high ranking industrial categories and control devices. Our data seems to indicate that hydrocarbon emitting sources may be the best place to start when investigating a recommended method of equipment operation and maintenance. Our data also points out that novel methods of control may be the area that requires the most attention when conducting source inspections. These devices appear to suffer the most from lack of attention.

The profile for unforeseen incidents is presented on Table 56. Here the rankings identify those categories which appear to be more susceptible to uncontrollable emissions incidents. A policy which requires these facilities to have some method of being alerted to process upsets may be in order here. Also, these categories might be required to have an approved backup procedure should their equipment malfunction. While these policies may not eliminate unforeseen incidents, they may reduce their impact once an incident occurs. The data indicates, with respect to unforeseen events, that hydrocarbon sources would be the types of facilities in need of followup studies.

The profile for all causal codes is given on Table 57. As this profile is compiled from all problem areas, these categories may provide a listing of areas in need of heightened daily surveillance by state and local enforcement personnel. The frequency of on-site inspections could possibly be increased for these sources to spot problem areas and to alert plant personnel to the susceptibility of their sources to excess emissions problems. A requirement that these selected categories report all process and control upsets to the local agency might be adopted where it does not currently exist. This would pinpoint the recurring problem sources for the agency and force the source to deal with the problem.

INDICATOR PROFILES

An overview of the problem categories with respect to the excess emission incident indicators, frequency, duration and magnitude, is also informative. Table 58 through 60 present these indicator profiles. The causal code incident data for each of the four parameters is presented in respective tables. Since the cumulative excess emissions problem is influenced by the frequency, duration and magnitude of the individual excess emissions incidents, control strategies that can be developed to minimize the extent of any of these indicators will serve to reduce the overall problem.

Table 58 presents the frequency indicator profile. As can be seen in this table, the distribution of frequencies of incident occurrence are concentrated in relatively few categories. The key to minimizing the total number of frequencies appears to be limiting the repetitious events that constantly cause an excess emission. All of the top-ranked categories are associated

TABLE 54. PROBLEM AREA PROFILE OF CAUSAL CODE 2 (PROCESS)

Rank	Parameter A		Parameter B		Parameter C		Parameter D	
	Category	$\sum$ all ranking	Category (10^3 ton/yr)	$\sum$ all ranking	Category	$\sum$ all ranking	Category (10^3 acfm)	$\sum$ all ranking
1	Cement plant	7	100 - 500	7	ESP	4	10 - 50	6
2	Surface coating operations	13	<0.1	8	Other	6	100 - 500	6
3	Pulp and paper mills	[illegible]	10 - 100	10	Scrubber	8	500 - 1000	10
4	Steam generating plants	16	1 - 10	11	Baghouse	12	<10	10
5	Petroleum products and handling	19	0.5 - 1	11			>1000	13
5	Iron and steel plants	19	0.1 - 0.5	16				18
7	Other	20						
8	Petrochemical plants	21						
8	Brass and bronze plants	21						
10	Incinerators	23						
11	Asphalt plants	27						
12	Aluminum plants	34						
13	Stone, clay and glass plants	-						
	Grain handling operations	-						
	Lumber and wood plants	-						
	Food and drug plants	-						

TABLE 55. PROBLEM AREA PROFILE OF CAUSAL CODE 3 (CONTROL O&M)

Rank	Parameter A: Category	Parameter A: $\sum$ all ranking	Parameter B: Category (10^3 ton/yr)	Parameter B: $\sum$ all ranking	Parameter C: Category	Parameter C: $\sum$ all ranking	Parameter D: Category (10^3 acfm)	Parameter D: $\sum$ all ranking
1	Surface coating operations	16	1 - 10	7	Other	5	10 - 50	6
2	Stone, clay and glass plants	17	0.1 - 0.5	9	ESP	7	100 - 500	7
3	Petroleum products and handling	18	[illegible]	10	Baghouse	9	<10	8
4	Cement plants	1[illegible]	<0.1	11	Scrubber	9	500 - 1000	12
5	Asphalt plants	1[illegible]	0.5 - 1	12			50 - 100	14
6	Lumber and wood plants	21	10 - 100	14			>1000	16
7	Iron and steel plants	22						
8	Incinerators	23						
9	Grain handling operations	25						
9	Other	25						
11	Aluminum plants	26						
12	Petrochemical plants	2						
13	Brass and bronze plants	2[illegible]						
14	Food and drug plants	29						
15	Steam generating plants	-						
15	Pulp and paper mills	[illegible]						

TABLE 56. PROBLEM AREA PROFILE OF CAUSAL CODE 4 (UNFORESEEN)

Rank	Parameter A: Category	Parameter A: $\sum$ all ranking	Parameter B: Category (10^3 ton/yr)	Parameter B: $\sum$ all ranking	Parameter C: Category	Parameter C: $\sum$ all ranking	Parameter D: Category (10^3 acfm)	Parameter D: $\sum$ all ranking
1	Surface coating operations	9	0.1 - 0.5	6	Scrubber	6	<10	[illegible]
2	Petroleum products and handling	11	1 - 10	10	Other	7	500 - 1000	[illegible]
3	Cement plants	14	<0.1	11	ESP	8	50 - 100	[illegible]
4	Iron and steel plants	14	100 - 500	11	Baghouse	9	10 - 50	11
5	Other	16	0.5 - 1	12			100 - 500	[illegible]
6	Grain handling operations	17	10 - 100	13			>1000	13
6	Incinerators	17						
8	Stone, clay and glass plants	18						
8	Steam generating plants	18						
10	Pulp and paper mills	-						
10	Asphalt plants	-						
10	Aluminum plants	-						
10	Brass and bronze plants	-						
10	Petrochemical plants	-						
10	Lumber and wood plants	-						
10	Food and drug plants	-						

TABLE 57. PROBLEM AREA PROFILE OF ALL CAUSAL CODES

Rank	Parameter A		Parameter B		Parameter C		Parameter D	
	Category	$\sum$ all ranking	Category (10^3 ton/yr)	$\sum$ all ranking	Category	$\sum$ all ranking	Category (10^3 acfm)	$\sum$ all ranking
1	Cement plants	1[illegible]	100 - 500	7	ESP	5	500 - 1000	8
2	Surface coating	17	0.1 - 0.5	10	Scribber	7	100 - 500	8
3	Grain handling operations	19	10 - 100	10	Other	8	10 - 50	10
4	Petroleum products and handl[illegible]g	2[illegible]	< 0.1	11	Baghouse	9	<10	10
5	Incinerators	21	1 - 10	12			>1000	13
6	Stone, clay and glass plants	23	0.5 - 1	13			50 - 100	14
7	Steam generating plants	23						
8	Pulp and paper mills	24						
9	Petrochemical plants	28						
10	Lumber and wood plants	28						
11	Asphalt plants	29						
12	Iron and steel plants	29						
13	Other	30						
14	Brass and bronze plants	33						
15	Food and drug plants	34						
16	Aluminum plants	37						

TABLE 58. FREQUENCY INDICATOR PROFILE

Parameter A			Parameter B			Parameter C			Parameter D		
Rank	Category	Frequency	Rank	Category (10^3 ton/yr)	Frequency	Rank	Category	Frequency	Rank	Category (10^3 acfm)	Frequency
1	Steam generating plants	89.3	1	.5 - 1	68.1	1	Baghouse	24.6	1	100 - 500	86.9
2	Iron and steel plants	84.2	2	1 - 10	37.3	2	Other	1.2	2	500 - 1000	16.6
3	Pulp and paper mills	38.5	3	10 - 100	36.4	3	ESP	0.8	3	>1000	15.0
4	Cement plants	29.7	4	<0.1	5.5	4	Scrubber	0.5	4	50 - 100	14.[illegible]
5	Lumber and wood products	28.6	5	100 - 500	5.4				5	10 - 50	9.2
6	Other	18.9	6	.1 - .5	1.3				6	<10	4.1
7	Grain handling operations	16.5									
8	Petroleum products and handling	9.4									
9	Asphalt plants	6.5									
10	Stone, clay and glass plants	3.9									
11	Incinerators	3.4									
12	Surface coating operations	2.9									
13	Aluminum plants	1.9									
14	Brass and bronze plants	0.6									
15	Petrochemical plants	0.6									
16	Food and drug plants	0.5									

with this phenomena. The general approach that may be used in this regard is to ensure that all process and control equipment is maintained and checked on a regular basis, as faulty equipment will constantly malfunction or cause the bypassing of emissions. A requirement that all control equipment have an agency approved operation and maintenance plan is one recommendation that may have application in this situation. A followup requirement that this plan be openly posted near the control device, and that the dates of the last maintenance overhaul be added to this plan may also help. This posted plan could then be inspected as part of a source's annual control agency inspection, with any lack of proper maintenance noted. Sources must be held accountable for the upkeep of their control equipment. As previously discussed, those process operations which cause constant repetitious incident frequencies should also be investigated and new operating procedures adopted, if possible.

The duration indicator profile is presented in Table 59. Limiting the duration of an excess emissions incident requires the quick identification and timely repair of a problem. The best way to ensure a quick response to an excess emission, regardless of pollutant, is to have an automatic, in-stack, pollutant monitor that signals the equipment operator when something has gone wrong. While in-stack devices have been widely used for particulates, similar monitors can be required for the other pollutants as well. This device would be especially relevant to hydrocarbon sources, as two of the top four sources in Parameter A are typically identified with a hydrocarbon emission. The top ranking of "other" control devices in Parameter C confirms this problem area as several of these devices are also associated with hydrocarbon release (vapor recovery systems, afterburners). The colorless nature of this pollutant makes visible detection difficult, if not impossible, and an in-stack device keyed to a certain pollutant concentration may prove useful. Once identified, the problem must be quickly repaired.

Many long-duration incidents would have been minimized had there been sufficient spare parts on-hand. A regulatory requirement mandating that selected key spare parts be stocked on-site, or a committment from a local supplier that such parts can be made available on short notice may help in this area. While it is obviously impractical for a source, especially a small source, to keep spares for all items, requiring them to know where to locate these spares on short notice can minimize incident durations. A third suggestion would be to require the source to shut down his process when a control malfunction occurs. This type of regulation forces the facility to keep similar parts inventories for control as well as process equipment and again leads to shorter incident durations.

The magnitude indicator profile is found in Table 60. Limiting the magnitude of an excess emissions incident is difficult. High magnitude emissions are associated with two primary factors: sources with high uncontrolled emission rates and complete, as opposed to partial, failure of the control device. Obviously nothing can be changed or fixed with sources having high emission rates. One regulatory tool that will help in this area is increased surveillance. Air pollution inspectors can be trained to identify those potential high-magnitude emitting sources and ensure that they are kept under constant surveillance. Increased inspection frequencies will also help ensure that these sources regularly maintain their control equipment. Complete con-

TABLE 59. DURATION INDICATOR PROFILE

Parameter A			Parameter B			Parameter C			Parameter D		
Rank	Category	Duration (hr)	Rank	Category (10^3 ton/yr)	Duration (hr)	Rank	Category	Duration (hr)	Rank	Cateogry (10^3 acfm)	Duration (hr)
1	Petrochemical plants	2554.0	1	100 - 500	218.0	1	Other	3097.7	1	<10	184.3
2	Food and drug plants	233.0	2	.1 - .5	181.6	2	Scrubber	2765.0	2	500 - 1000	28.5
3	Surface coating operations	154.1	3	<.1	85.0	3	ESP	1130.4	3	10 - 50	24.4
4	Petroleum products and handling	122.6	4	10 - 100	13.2	4	Baghouse	15.8	4	>1000	20.3
5	Incinerators	45.9	5	1 - 10	11.5				5	50 - 100	12.0
6	Stone, clay and glass plants	42.2	6	.5 - 1	11.4				6	100 - 500	8.1
7	Cement plants	31.2									
8	Lumber and wood products	26.6									
9	Grain handling operations	16.8									
10	Aluminum plants	12.8									
11	Other	9.0									
12	Steam generating plants	7.2									
13	Pulp and paper mills	4.9									
14	Asphalt plants	2.8									
15	Brass and bronze plants	1.7									
16	Iron and steel plants	1.6									

TABLE 60. MAGNITUDE INDICATOR PROFILE

Parameter A			Parameter B			Parameter C			Parameter D		
Rank	Category	Magnitude (% above allowable)	Rank	Cateogry (10^3 ton/yr)	Magnitude (% above allowable)	Rank	Category	Magnitude (% above allowable)	Rank	Cateogry (10^3 acfm)	Magnitude (% above allowable)
1	Cement plants	2463	1	100 - 500	18,913	1	Scrubber	2817	1	100 - 500	468
2	Surface coating operations	1566	2	.1 - .5	1,292	2	Baghouse	1941	2	10 - 50	406
3	Grain handling operations	1224	3	10 - 100	571	3	Other	667	3	<10	214
4	Brass and bronze plants	1150	4	<.1	225	4	ESP	170	4	500 - 1000	192
5	Incinerators	614	5	1 - 10	196				5	50 - 100	111
6	Asphalt plants	458	6	.5 - 1	161				6	>1000	100
7	Stone, clay and glass plants	253									
8	Pulp and paper mills	180									
9	Petroleum products and handling	167									
10	Steam generating plants	163									
11	Iron and steel plants	158									
12	Petrochemical	147									
13	Other	123									
14	Aluminum plants	59									
15	Lumber and wood plants	34									
16	Food and drug plants	25									

trol device failures can be minimized through equipment design. Control devices which can be compartmentalized enable the source operator to isolate a problem should it develop. This design recommendation may take the form of requiring one extra compartment in baghouse or precipitator installations, or the use of two smaller scrubber fans in series as opposed to one large fan. Any similar control strategy will help in minimizing the magnitude of an emission once a problem develops.

RECOMMENDATIONS

While this study has pointed out many diverse and interesting aspects of the excess emissions problem, it has not been without its problems. The main shortcoming appears to be the size of the sample population investigated. In spite of our ability to combine and analyze the results of four contractors source surveys, we feel that too few sources were interviewed to draw meaningful conclusions in certain areas. The inclusion of 16 categories in Parameter A, for example, made a review of this data highly dependent on the peculiarities of the individual sources within each category. To remedy this problem we feel that a few of the top-ranked industrial categories should be selected for a followup study. This project could follow the same general outline as this report but include at least 20 to 30 sources in each industrial classification so as to add more significance to the results of the data tabulation. This followup might also entail investigating a specific process to determine the cause of excess emissions incidents, investigate how widespread they are in the industry and make recommendations on how these problems might best be minimized.

APPENDIX A

RAW DATA SUMMARY

SOURCE CODE	UNCONTROLLED EMISSION TPY	CREDIT TPY	EXCESS EMISSIONS TPY	ALLOWABLE EMISSIONS TPY	FREQUENCY NO/YR	DURATION HR	MAGNITUDE %	ABS.MAG TON/ EPISODE	CAUSAL CODE	CONTROL CODE	CAPITAL COST 1000$	O&M COST 1000$	CONTROL SIZE ACFM	CNTL AGE YRS	NORMALIZED EXCESS%	NORMALIZED CREDITS%
B 1. 2.	28444.0	89.0	49.30	142.0	1.0	2190.00	69	49.300	1	1	2100	1	550	4	34.7	62.7
B 1. 2.	28444.0	89.0	49.30	142.0	1.0	2190.00	69	49.300	5	1	2100	1	550	4	34.7	62.7
B 1. 3.	825.0	9.4	280.00	225.0	0.5	2765.00	2817	560.000	1	2	70	12	25	4	124.4	4.2
B 1. 3.	825.0	9.4	280.00	225.0	0.5	2765.00	2817	560.000	5	2	70	12	25	4	124.4	4.2
B 2. 1.	200000.0	750.0	0.0	800.0	0.0	0.0	0	0.0	5	1	23300	17	540	2	0.0	93.8
B 2. 2.	39000.0	138.0	0.0	625.0	0.0	0.0	0	0.0	5	1	10933	24	500	2	0.0	22.1
B 2. 3.	27000.0	12.5	0.0	50.0	0.0	0.0	0	0.0	5	2	500		33	2	0.0	25.0
B 2. 4.	16800.0	513.0	0.0	693.0	0.0	0.0	0	0.0	5	1	3600	930	500	5	0.0	74.0
B 4. 2.	1296.0	287.3	52.50	579.0	1.0	504.00	300	52.500	1	1	1169	71	410	8	9.1	49.6
B 4. 2.	1296.0	287.3	10.01	579.0	51.0	5.00	71	0.323	2	1	1169	71	410	8	1.7	49.6
B 4. 2.	1296.0	287.3	4.00	579.0	20.0	3.00	100	0.200	3	1	1169	71	410	8	0.7	49.6
B 4. 2.	1296.0	287.3	7.00	579.0	2.0	48.00	100	3.500	4	1	1169	71	410	8	1.2	49.6
B 4. 2.	1296.0	287.3	73.50	579.0	54.0	15.10	87	1.360	5	1	1169	71	410	8	12.7	49.6
B 4. 3.	828.0	324.0	0.0	363.0	0.0	0.0	0	0.0	5	1	2570	50	290	3	0.0	89.3
B 4. 4.	2160.0	58.3	12.00	726.0	31.0	4.30	55	0.390	2	2	464	70	4	0	1.7	8.0
B 4. 4.	2160.0	58.3	3.00	726.0	20.0	3.00	75	0.150	3	2	464	70	4	0	0.4	8.0
B 4. 4.	2160.0	58.3	15.00	726.0	51.0	3.80	63	0.290	5	2	464	70	4	0	2.1	8.0
B 4. 5.	1980.0	209.0	18.50	396.0	0.5	504.00	300	37.000	2	4	6520	644	11	2	4.7	52.8
B 4. 5.	1980.0	209.0	24.50	396.0	1.0	336.00	300	24.500	4	4	6520	644	11	2	6.2	52.8
B 4. 5.	1980.0	209.0	43.00	396.0	1.5	392.00	300	28.700	5	4	6520	644	11	2	10.9	52.8
B 5. 1.	5940.0	345.7	36.00	669.1	60.0	4.00	200	0.600	2	1	5627	243	525	7	5.4	51.7
B 5. 1.	5940.0	345.7	18.00	669.1	30.0	4.00	200	0.600	3	1	5627	243	525	7	2.7	51.7
B 5. 1.	5940.0	345.7	14.00	669.1	4.0	48.00	200	3.500	4	1	5627	243	525	7	2.1	51.7
B 5. 1.	5940.0	345.7	68.00	669.1	94.0	5.90	200	0.720	5	1	5627	243	525	7	10.2	51.7
B 5. 2.	792.0	201.5	36.00	475.1	60.0	4.00	200	0.600	2	1	945	260	200	8	7.6	42.4
B 5. 2.	792.0	201.5	18.00	475.1	30.0	4.00	200	0.600	3	1	945	260	200	8	3.8	42.4
B 5. 2.	792.0	201.5	14.00	475.1	4.0	48.00	200	3.500	4	1	945	260	200	8	2.9	42.4
B 5. 2.	792.0	201.5	68.00	475.1	94.0	5.90	200	0.720	5	1	945	260	200	8	14.3	42.4
B 6. 1.	6300.0	8.5	24.80	408.0	40.0	4.00	693	0.620	3	3	91	8	30	2	6.1	2.1
B 6. 1.	6300.0	8.5	24.80	408.0	40.0	4.00	693	0.620	5	3	91	8	30	2	6.1	2.1
B 7. 2.	12355.0	56.3	10.00	202.8	20.0	4.00	150	0.500	1	3	850		112	4	4.9	27.8
B 7. 2.	12355.0	56.3	5.00	202.8	10.0	4.00	150	0.500	3	3	850		112	4	2.5	27.8
B 7. 2.	12355.0	56.3	10.00	202.8	3.0	24.00	200	3.300	4	3	850		112	4	4.9	27.8
B 7. 2.	12355.0	56.3	25.00	202.8	33.0	5.80	155	0.760	5	3	850		112	4	12.3	27.8
B 7. 3.	21600.0	1262.0	7.20	1723.5	6.0	24.00	100	1.200	1	3	15000	1860	1700	2	0.4	73.2
B 7. 3.	21600.0	1262.0	3.00	1723.5	1.0	15.00	100	0.750	3	3	15000	1860	1700	2	0.2	73.2
B 7. 3.	21600.0	1262.0	5.00	1723.5	5.0	20.00	100	1.000	4	3	15000	1860	1700	2	0.3	73.2
B 7. 3.	21600.0	1262.0	15.20	1723.5	12.0	20.30	100	1.000	5	3	15000	1860	1700	2	0.9	73.2
B10. 1.	8640.0	1512.0	0.0	2160.0	0.0	0.0	0	0.0	5	4	2500	567	235	1	0.0	70.0
B11. 1.	545.0	24.4	1.35	65.5	0.2	8000.00	12	7.500	3	2	11		9	6	2.1	37.3
B11. 1.	545.0	24.4	1.35	65.5	0.2	8000.00	12	7.500	5	2	11		9	6	2.1	37.3
B11. 4.	372.0	9.2	0.0	36.0	0.0	0.0	0	0.0	5	2			15	5	0.0	25.6
B12. 1.	2700.0	350.0	0.83	450.0	9.1	3.50	274	0.090	3	3	750	250	325	6	0.2	77.8
B12. 1.	2700.0	350.0	0.38	450.0	0.1	168.00	274	6.500	4	3	750	250	325	6	0.1	77.8
B12. 1.	2700.0	350.0	1.21	450.0	9.2	4.60	274	0.130	5	3	750	250	325	6	0.3	77.8
B13. 2.	650.0	8.0	0.24	10.0	24.0	2.00	100	0.010	3	3		6	10	4	2.4	80.0
B13. 2.	650.0	8.0	0.24	10.0	24.0	2.00	100	0.010	5	3		6	10	4	2.4	80.0
B14. 1.	1400.0	60.0	0.0	210.0	0.0	0.0	0	0.0	5	4	643	3	30	2	0.0	28.6
B14. 2.	2000.0	80.0	3.50	300.0	0.2	8760.00	5	17.500	2	4	859	4	10	5	1.2	26.7
B14. 2.	2000.0	80.0	3.50	300.0	0.2	8760.00	5	17.500	3	4	859	4	10	5	1.2	26.7
B14. 2.	2000.0	80.0	27.00	300.0	0.6	168.00	566	45.000	4	4	859	4	10	5	9.0	26.7
B14. 2.	2000.0	80.0	34.00	300.0	1.0	3605.00	342	34.000	5	4	859	4	10	5	11.3	26.7
B14. 3.	210.0	11.0	5.00	70.0	0.3	469.00	1067	15.000	4	1	106	3	11	3	7.1	15.7

SOURCE CODE	UNCONTROLLED EMISSION TPY	CREDIT TPY	EXCESS EMISSIONS TPY	ALLOWABLE EMISSIONS TPY	FREQUENCY NO/YR	DURATION HR	MAGNITUDE %	ABS.MAG TON/EPISODE	CAUSAL CODE	CONTROL CODE	CAPITAL COST 1000$	O&M COST 1000$	CONTROL SIZE ACFM	CNTL AGE YRS	NORMALIZED EXCESS%	NORMALIZED CREDITS%
B14. 3.	210.0	11.0	5.00	70.0	0.5	469.00	1067	15.000	5	1	106	3	11	3	7.1	15.7
B16. 1.	1667.0	26.7	0.25	33.3	0.2	1950.00	5	1.500	3	3			36	6	0.8	80.2
B16. 1.	1667.0	26.7	0.25	33.3	0.2	1950.00	5	1.500	5	3			36	[illegible]	[illegible]	80.2
B16. 2.	100.0	27.0	0.0	40.0	0.0	0.0	0	0.0	5	2			6	6	0.0	67.5
B16. 3.	756.0	200.0	1.00	262.0	10.0	2.00	100	0.100	2	4			78	3	[illegible]	76.3
B16. 3.	756.0	200.0	0.10	262.0	1.0	2.00	100	0.100	3	4			78	3	0.0	76.3
B16. 3.	756.0	200.0	1.20	262.0	1.0	36.00	100	1.200	4	4			78	3	0.5	76.3
B16. 3.	756.0	200.0	2.30	262.0	12.0	4.80	100	0.190	5	4			78	3	0.9	76.3
B16. 4.	5880.0	430.6	8.00	564.3	40.0	4.00	200	0.200	2	2			149	3	1.4	76.3
B16. 4.	5880.0	430.6	2.00	564.3	10.0	4.00	200	0.200	3	2			149	3	[illegible]	76.3
B16. 4.	5880.0	430.6	8.00	564.0	1.0	168.00	200	8.000	4	2			149	3	1.4	76.3
B16. 4.	5880.0	430.6	18.00	564.0	51.0	7.20	200	0.350	5	2			149	3	3.2	76.3
B16. 5.	518.3	103.0	3.00	216.0	40.0	4.00	50	0.075	2	2	130	28	65	7	[illegible]	47.7
B16. 5.	518.3	103.0	0.80	216.0	10.0	4.00	50	0.080	3	2	130	28	65	[illegible]	[illegible]	47.7
B16. 5.	518.3	103.0	4.00	216.0	0.5	16.80	100	8.000	4	2	130	28	65	[illegible]	1.9	47.7
B16. 5.	518.3	103.0	7.80	216.0	50.5	0.56	50	0.150	5	2	130	28	65	[illegible]	3.6	47.7
G 1. 2.	942.7	143.4	0.0	172.0	0.0	0.0	0	0.0	5	2	459		40	3	[illegible]	43.4
G 1. 3.	4489.0	1089.8	4.70	1611.0	0.5	336.00	12	9.400	4	1	233		255	[illegible]	0.3	57.6
G 1. 3.	4489.0	1089.8	4.70	1611.0	0.5	336.00	12	9.400	5	1	233		255	[illegible]	0.3	57.6
G 1.11.	286.7	43.5	0.02	58.5	1.5	0.80	42	0.010	2	2	560	120	50	2	0.0	74.4
G 1.11.	286.7	43.5	0.02	58.5	1.5	0.80	42	0.010	5	2	560	120	50	2	0.0	74.4
G 1.12.	173.0	13.5	0.05	43.0	2.0	1.50	72	0.023	2	2	560	120	50	2	0.1	31.4
G 1.12.	173.0	13.5	0.05	43.0	2.0	1.50	72	0.023	5	2	560	120	50	2	0.1	31.4
G 1.13.	191.9	12.3	0.06	45.5	3.0	1.30	87	0.020	2	2	560	120	50	2	0.1	27.0
G 1.13.	191.9	12.3	0.06	45.5	3.0	1.30	87	0.020	5	2	560	120	50	2	0.1	27.0
G 1.14.	202.1	12.2	0.02	46.6	1.5	0.90	62	0.010	2	2	560	120	50	2	0.0	26.2
G 1.14.	202.1	12.2	0.02	46.6	1.5	0.90	62	0.010	5	2	560	120	50	2	0.0	26.2
G 2. 1.	15117.0	15.5	4.45	61.3	196.0	1.60	210	0.023	2	4	1269		23	8	7.3	25.3
G 2. 1.	15117.0	15.5	4.45	61.3	196.0	1.60	210	0.023	5	4	1269		23	8	7.3	25.3
G 4. 1.	238.5	3.5	6.55	24.0	2.0	114.00	895	3.280	3	4	397	8	1	2	27.3	14.6
G 4. 1.	238.5	3.5	6.55	24.0	2.0	114.00	895	3.280	5	4	397	8	1	2	27.3	14.6
G 5. 1.	343330.0	212.3	1.26	477.5	5.0	45.60	15	0.250	4	1	1000	48	430	[illegible]	0.3	44.5
G 5. 1.	343330.0	212.3	1.26	477.5	5.0	45.60	15	0.250	5	1	1000	48	430	[illegible]	0.3	44.5
G 5. 2.	158400.0	72.9	16.65	136.6	5.0	0.16	115900	3.330	2	1	1700	100	250	6	12.2	53.4
G 5. 2.	158400.0	72.9	0.90	136.6	9.0	7.60	72	0.100	3	1	1700	100	250	6	[illegible]	53.4
G 5. 2.	158400.0	72.9	17.55	136.6	14.0	4.94	41439	1.253	5	1	1700	100	250	6	12.8	53.4
G 5. 3.1	76608.0	56.0	11.00	198.5	20.0	7.00	289	0.550	3	3		32	100	17	5.5	28.2
G 5. 3.1	76608.0	56.0	11.00	198.5	20.0	7.00	289	0.550	5	3		32	100	17	5.5	28.2
G 5. 3.2	228000.0	174.3	0.0	525.3	0.0	0.0	0	0.0	5	3		111	300	11	0.0	33.2
G 5. 3.3	136800.0	32.7	0.0	82.1	0.0	0.0	0	0.0	5	3		57	300	2	0.0	39.8
G 5. 4.	145528.0	0.0	66.00	239.0	1.0	6635.00	28	66.000	2	1		75	160	19	27.6	0.0
G 5. 4.	145528.0	0.0	110.50	239.0	12.5	13.80	2754	8.840	3	1		75	160	19	46.2	0.0
G 5. 4.	145528.0	0.0	176.50	239.0	13.5	504.00	2552	13.070	5	1		75	160	19	73.8	0.0
G 6. 1.	247.5	1.3	0.0	2.1	0.0	0.0	0	0.0	5	3	22	3	4	2	0.0	61.9
G 6. 2.	9225.0	19.0	0.01	39.0	0.5	8.00	5	0.008	3	3	123	7	50	3	0.0	48.7
G 6. 2.	9225.0	19.0	0.01	39.0	0.5	8.00	5	0.008	5	3	123	7	54	3	0.0	48.7
G 7. 1.	7050.0	94.3	9.90	172.5	700.0	0.33	135	0.014	2	1			245	7	5.7	54.7
G 7. 1.	7050.0	94.3	3.65	172.5	29.0	7.95	52	0.126	3	1			245	7	2.1	54.7
G 7. 1.	7050.0	94.3	13.55	172.5	729.0	0.63	132	0.019	5	1			245	7	7.9	54.7
G 7. 2.	1399.0	18.7	1.90	38.3	48.0	1.00	339	0.040	2	2	979	50	27	12	5.0	48.8
G 7. 2.	1399.0	18.7	1.90	38.3	48.0	1.00	339	0.040	5	2	979	50	27	12	5.0	48.8
G 7. 3.	4.4	0.6	0.0	0.8	0.0	0.0	0	0.0	5	2	57	10	9	4	0.0	75.0
G 7. 4.	312.2	8.8	7.04	17.6	6.0	27.40	1341	1.300	3	2	307	24	8	1	43.5	50.0

SOURCE CODE	UNCONTROLLED EMISSION TPY	CREDIT TPY	EXCESS EMISSIONS TPY	ALLOWABLE EMISSIONS TPY	FREQUENCY #/YR	DURATION HR	MAGNITUDE %	AHS.MAG TON/EPISODE	CAUSAL CODE	CONTROL CODE	CAPITAL COST 1000$	O&M COST 1000$	CONTROL SIZE ACFM	CNTL AGE YRS	NORMALIZED EXCESS%	NORMALIZED CREDITS%
G 7. 4.	312.2	8.8	7.65	17.6	6.0	27.40	1341	1.300	5	2	307	24	8	1	43.5	50.0
G 7. 5.	168.4	9.5	1.60	25.6	2.5	10.80	558	0.640	3	2	242	90	11	6	6.3	37.1
G 7. 5.	168.4	9.5	0.33	25.6	1.5	3.70	558	0.220	4	2	242	90	11	6	1.3	37.1
G 7. 5.	168.4	9.5	1.93	25.6	4.0	8.10	558	0.480	5	2	242	90	11	6	7.5	37.1
G 8. 1.	87.3	0.2	0.09	6.5	4.0	2.40	67	0.020	3	3	1416	42	52	4	1.4	3.1
G 8. 1.	87.3	0.2	0.09	6.5	4.0	2.40	67	0.020	5	3	1416	42	52	4	1.4	3.1
G10. 1.	37.8	14.2	0.0	15.1	0.0	0.0	0	0.0	5	3	6	1	8	2	0.0	94.0
G11. 1.	8682.0	73.4	65.00	174.2	1.5	35.00	4884	43.300	3	1	829	19	50	20	37.3	42.1
G11. 1.	8682.0	73.4	65.00	174.2	1.5	35.00	4884	43.300	5	1	829	19	50	20	37.3	42.1
G11. 2.	9243.0	84.5	0.0	107.2	0.0	0.0	0	0.0	5	1	478	25	40	1	0.0	78.8
G11. 3.	231.0	45.6	0.31	49.2	6.5	8.00	61	0.050	4	3	26	6	4	13	0.6	93.1
G11. 3.	231.0	45.6	0.31	49.2	6.5	8.00	61	0.050	5	3	26	6	4	13	0.6	93.1
G11. 4.	26.1	9.0	0.09	10.4	0.5	264.00	108	0.180	1	1	2014		42	2	0.9	86.5
G11. 4.	26.1	9.0	0.11	10.4	0.5	24.00	346	0.220	3	1	2014		42	2	1.1	86.5
G11. 4.	26.1	9.0	0.02	10.4	0.5	18.00	156	0.030	4	1	2014		42	2	0.2	86.5
G11. 4.	26.1	9.0	0.22	10.4	1.5	102.00	203	0.140	5	1	2014		42	2	2.1	86.5
G12. 1.	1960.0	4.6	11.70	6.5	0.5	72.00	29515	23.400	1	3	51	3	18	2	180.0	70.8
G12. 1.	1960.0	4.6	11.70	6.5	0.5	72.00	29515	23.400	5	3	51	3	18	2	180.0	70.8
G12. 2.	6603.7	191.6	0.0	211.3	0.0	0.0	0	0.0	5	3	62	12	10	14	0.0	90.7
G14. 1.	61.4	0.0	0.62	6.1	18.0	1.00	737	0.034	2	4	496	48	33	4	10.2	0.0
G14. 1.	61.4	0.0	0.60	6.1	5.0	3.00	900	0.120	3	4	496	48	33	4	9.8	0.0
G14. 1.	61.4	0.0	3.70	6.1	0.5	180.00	900	7.400	4	4	496	48	33	4	60.7	0.0
G14. 1.	61.4	0.0	4.92	6.1	23.5	5.23	776	0.210	5	4	496	48	33	4	80.7	0.0
G14. 2.	41.8	0.2	0.0	0.5	0.0	0.0	0	0.0	5	3	33	5	26	4	0.0	40.0
G15. 1.	120.0	22.1	0.0	25.1	0.0	0.0	0	0.0	5	3	33	6	6	1	0.0	88.0
G15. 2.	9.2	2.4	0.27	7.3	1.5	233.00	25	0.180	3	2	10	1	4	1	3.7	32.9
G15. 2.	9.2	2.4	0.27	7.3	1.5	233.00	25	0.180	5	2	10	1	4	1	3.7	32.9
P 3. 1.	9.3	0.3	0.0	0.6	0.0	0.0	0	0.0	5	2	33	36	1	1	0.0	50.0
P 4. 2.	4.3	0.0	0.68	3.1	1.0	5112.00	44	0.680	3	4				4	21.9	0.0
P 4. 2.	4.3	0.0	0.68	3.1	1.0	5112.00	44	0.680	5	4				4	21.9	0.0
P 4. 3.	360.0	0.0	162.00	36.0	1.5	2920.00	900	108.000	1	4	413	100	1	3	450.0	0.0
P 4. 3.	360.0	0.0	162.00	36.0	1.5	2920.00	900	108.000	5	4	413	100	1	3	450.0	0.0
P 4. 4.	1443.0	54.0	68.70	144.0	1.0	462.00	900	68.700	1	4	993	47	1	3	47.7	37.5
P 4. 4.	1443.0	54.0	12.60	144.0	3.0	28.00	900	4.200	4	4	993	47	1	3	8.7	37.5
P 4. 4.	1443.0	54.0	81.30	144.0	4.0	136.50	900	20.325	5	4	993	47	1	3	56.5	37.5
P 6. 1.	406.0	14.0	0.0	39.4	0.0	0.0	0	0.0	5	2			25		0.0	35.5
P 6. 2.	506.0	10.5	0.0	39.4	0.0	0.0	0	0.0	5	2	103	50	35	14	0.0	26.6
P 6. 4.	2200.0	33.0	0.0	44.1	0.0	0.0	0	0.0	5	3	187		11	4	0.0	74.8
P 8. 1.	180.0	19.6	0.0	19.8	0.0	0.0	0	0.0	5	3	614		37	1	0.0	99.0
P 9. 1.	58.0	10.6	0.0	12.5	0.0	0.0	0	0.0	5	3			50	8	0.0	84.8
P10. 2.	722.7	8.5	0.0	9.2	0.0	0.0	0	0.0	5	3	86	28	1	23	0.0	92.4
P10. 3.	1971.0	4.0	0.0	8.0	0.0	0.0	0	0.0	5	4	489	424	8	5	0.0	50.0
P11. 1.	382.0	78.7	0.0	79.5	0.0	0.0	0	0.0	5	3	150		58	4	0.0	99.0
P11. 2.	0.5	0.4	0.0	0.4	0.0	0.0	0	0.0	5	3			1	11	0.0	100.0
P11. 3.	63.0	5.2	0.17	7.0	12.0	16.00	49	0.014	3	3	130	40	7	4	2.4	74.3
P11. 3.	63.0	5.2	0.17	7.0	12.0	16.00	49	0.014	5	3	130	40	7	4	2.4	74.3
P12. 1.	6739.0	163.8	0.0	183.6	0.0	0.0	0	0.0	5	3	11		23	4	0.0	89.0
P13. 3.	3.6	0.1	0.48	1.2	1.0	2145.00	24	0.480	3	4	12		1	4	40.0	8.3
P13. 3.	3.6	0.1	0.48	1.2	1.0	2145.00	24	0.480	5	4	12		1	4	40.0	8.3
P14. 3.	176.0	11.8	79.70	17.0	1.0	1760.00	964	79.700	4	2		15			468.8	69.4
P14. 3.	176.0	11.8	79.70	17.0	1.0	1760.00	964	79.700	5	2		15			468.8	69.4
T 1. 3.	1304.0	46.8	384.70	1304.0	0.5	5112.00	2007	769.400	2	1	406	3	129	7	27.8	3.4
T 1. 3.	1304.0	46.8	384.70	1304.0	0.5	5112.00	2007	769.400	5	1	406	3	129	7	27.8	3.4

SOURCE CODE	UNCONTROLLED EMISSION TPY	CREDIT TPY	EXCESS EMISSIONS TPY	ALLOWABLE EMISSIONS TPY	FREQUENCY NO/YR	DURATION HR	MAGNITUDE %	ABS.MAGNITUDE TON/EPISODE	CAUSAL CODE	CONTROL CODE	CAPITAL COST 1000$	O&M COST 1000$	CONTROL SIZE ACFM	CNTL AGE YRS	NORMALIZED EXCESS%	NORMALIZED CREDITS%
T 1.11.	643.0	198.4	2.60	329.0	882.0	0.17	162	0.003	2	4	531	38	125	1	0.8	60.3
T 1.11.	643.0	198.4	2.60	329.0	882.0	0.17	162	0.003	5	4	531	38	125	1	0.8	60.3
T 2. 2.	60000.0	221.0	0.75	536.0	35.0	24.00	10	0.021	2	2		882	60	9	0.1	41.2
T 2. 2.	60000.0	221.0	0.75	536.0	35.0	24.00	10	0.021	5	2		882	60	9	0.1	41.2
T 3. 1.	2265.0	84.2	0.11	106.0	2.5	0.19	2035	0.039	2	2	595	8	31	5	0.1	79.4
T 3. 1.	2265.0	84.2	0.11	106.0	2.5	0.19	2035	0.039	5	2	595	8	31	5	0.1	79.4
T 3. 2.	13.4	3.4	0.01	4.0	12.0	0.17	231	0.001	2	2			9	1	0.3	85.0
T 3. 2.	13.4	3.4	0.01	4.0	12.0	0.17	231	0.001	5	2			9	1	0.3	85.0
T 3. 3.	522.0	70.0	0.75	124.0	4.5	20.80	51	0.160	3	1	1000		750	[illegible]	0.6	56.5
T 3. 3.	522.0	70.0	0.75	124.0	4.5	20.80	51	0.160	5	1	1000		750	4	0.6	56.5
T 3. 5.	490.8	0.5	0.0	2.6	0.0	0.0	0	0.0	5	2	35	8	3	4	0.0	19.2
T 3. 6.	396.0	0.0	0.06	4.0	1.0	0.29	2998	0.057	3	2	125	5	16	1	1.5	0.0
T 3. 6.	396.0	0.0	0.39	4.0	0.5	4.00	2998	0.780	4	2	125	5	16	1	9.7	0.0
T 3. 6.	396.0	0.0	0.45	4.0	1.5	1.53	2998	0.298	5	2	125	5	16	1	11.2	0.0
T 4. 1.	368.0	10.9	4.10	55.0	0.5	120.00	567	4.100	3	4	125	11	1	2	7.5	19.8
T 4. 1.	368.0	10.9	4.10	55.0	0.5	120.00	567	4.100	5	4	125	11	1	2	7.5	19.8
T 4. 2.	182.5	10.2	1.80	18.3	1.0	96.00	1038	1.800	3	4	95	7	1	2	9.8	55.7
T 4. 2.	182.5	10.2	5.65	18.3	0.5	120.00	450	11.300	4	4	95	7	1	2	30.9	55.7
T 4. 2.	182.5	10.2	7.45	18.3	1.5	46.40	842	4.970	5	4	95	7	1	2	40.7	55.7
T 4. 3.1	1253.7	15.2	190.10	107.5	1.5	792.00	1067	126.700	3	2	21250	2600	334	1	176.8	14.1
T 4. 3.1	1253.7	15.2	190.10	107.5	1.5	792.00	1067	126.700	5	2	21250	2600	334	1	176.8	14.1
T 4. 3.2	2005.8	1570.2	5.94	1970.1	1.5	792.00	2	4.000	3	2	21250	2600	334	1	0.3	79.7
T 4. 3.2	2005.8	1570.2	5.94	1970.1	1.5	792.00	2	4.000	5	2	21250	2600	334	1	0.3	79.7
T 4. 5.	619.2	16.8	0.78	67.5	2.0	6.00	818	0.390	2	1	671	67	151	2	1.2	24.9
T 4. 5.	619.2	16.8	0.40	67.5	0.5	12.00	818	0.790	4	1	671	67	151	2	0.6	24.9
T 4. 5.	619.2	16.8	1.18	67.5	2.5	9.60	818	0.470	5	1	671	67	151	2	1.7	24.9
T 5. 1.	65301.0	15.8	0.01	87.6	27.0	0.13	25	0.001	2	3	650	54	159	10	0.0	18.0
T 5. 1.	65301.0	15.8	0.01	87.6	27.0	0.13	25	0.001	5	3	650	54	159	10	0.0	18.0
T 6. 1.	3120.0	16.8	0.06	20.8	4.0	0.33	250	0.015	2	3	100	12	31	1	0.3	80.8
T 6. 1.	3120.0	16.8	0.12	20.8	4.0	2.00	75	0.030	3	3	100	12	31	1	0.6	80.8
T 6. 1.	3120.0	16.8	0.18	20.8	8.0	1.17	163	0.023	5	3	100	12	31	1	0.9	80.8
T 6. 2.	2187.0	24.9	0.05	32.9	16.0	0.50	33	0.003	2	2		6	33	17	0.2	75.7
T 6. 2.	2187.0	24.9	0.05	32.9	16.0	0.50	33	0.003	5	2		6	33	17	0.2	75.7
T 6. 3.	210.0	4.4	0.0	14.0	0.0	0.0	0	0.0	5	2	114	25	47	7	0.0	31.4
T 6. 4.	525.0	3.4	0.0	3.8	0.0	0.0	0	0.0	5	3	104	14	45	5	0.0	89.5
T 7. 2.	27.0	1.8	1.04	4.0	1.5	23.00	280	0.690	3	2	370	30	15	3	26.0	45.0
T 7. 2.	27.0	1.8	1.04	4.0	1.5	23.00	280	0.690	5	2	370	30	15	3	26.0	45.0
T 7. 3.	140.0	5.2	4.50	21.1	1.5	45.50	567	3.011	3	2	275	73	31	5	21.3	24.6
T 7. 3.	140.0	5.2	4.50	21.1	1.5	45.50	567	3.011	5	2	275	73	31	5	21.3	24.6
T 7. 4.	32.6	2.2	0.22	4.9	0.5	6.00	567	0.440	3	2	309	9	17	3	4.5	44.9
T 7. 4.	32.6	2.2	1.27	4.9	3.5	5.19	521	0.363	4	2	309	9	17	3	25.9	44.9
T 7. 4.	32.6	2.2	1.49	4.9	4.0	5.29	527	0.370	5	2	309	9	17	3	30.4	44.9
T 8. 1.	212.0	43.6	0.01	87.6	3.5	0.08	50	0.001	2	1	3455		130	3	0.0	49.8
T 8. 1.	212.0	43.6	0.01	87.6	3.5	0.08	50	0.001	5	1	3455		130	3	0.0	49.8
T 8. 2.	5.0	2.0	0.0	2.6	0.0	0.0	0	0.0	5	4	20	22	10	1	0.0	76.9
T 9. 1.	160.0	76.8	0.0	77.0	0.0	0.0	0	0.0	5	3	211	18	80	5	0.0	99.7
T 9. 2.	6.0	0.2	0.0	0.4	0.0	0.0	0	0.0	5	3	212	52	45	4	0.0	50.0
T 9. 3.	90.0	1.1	0.0	2.2	0.0	0.0	0	0.0	5	3	67	3	6	5	0.0	50.0
T 9. 4.	8400.0	6.0	0.17	90.0	1.0	1.00	1150	0.170	2	3	2987	1252	450	15	0.2	6.7
T 9. 4.	8400.0	6.0	0.69	90.0	2.0	2.00	1150	0.345	3	3	2987	1252	450	15	0.8	6.7
T 9. 4.	8400.0	6.0	0.86	90.0	3.0	1.67	1150	0.290	5	3	2987	1252	450	15	1.0	6.7
T10. 1.	1.9	0.4	0.10	0.5	1.0	720.00	100	0.100	2	2	38		11	7	20.0	80.0
T10. 1.	1.9	0.4	0.20	0.5	1.0	2160.00	50	0.200	3	2	38		11	7	40.0	80.0

SOURCE CODE	UNCONTROLLED EMISSION TPY	CREDIT TPY	EXCESS EMISSIONS TPY	ALLOWABLE EMISSIONS TPY	FREQUENCY NO/YR	DURATION HR	MAGNITUDE %	ABS.MAG TON/EPISODE	CAUSAL CODE	CONTROL CODE	CAPITAL COST 1000$	O&M COST 1000$	CONTROL SIZE ACFM	CNTL AGE YRS	NORMALIZED EXCESS%	NORMALIZED CREDITS%
T10. 1.	1.9	0.4	0.30	0.5	2.0	1440.00	75	0.150	5	2	38		11	7	60.0	80.0
T10. 2.	519.3	0.0	64.00	78.0	1.0	6000.00	83	64.000	1	4	168		6	2	82.1	0.0
T10. 2.	519.3	0.0	4.50	78.0	0.5	120.00	566	9.000	2	4	168		6	2	5.8	0.0
T10. 2.	519.3	0.0	68.50	78.0	1.5	4040.00	244	45.700	5	4	168		6	2	87.8	0.0
T11. 2.	956.3	4.3	3.35	9.6	17.0	50.00	70	0.200	3	3	58	2	16	5	34.9	44.8
T11. 2.	956.3	4.3	3.35	9.6	17.0	50.00	70	0.200	5	3	58	2	16	5	34.9	44.8
T12. 1.	19710.0	191.5	596.22	263.0	72.0	18.00	1150	8.281	1	3	2183	20	138	1	226.7	72.8
T12. 1.	19710.0	191.5	8.28	263.0	1.0	18.00	1150	8.281	3	3	2183	20	138	1	3.1	72.8
T12. 1.	19710.0	191.5	604.50	263.0	73.0	18.00	1150	8.281	5	3	2183	20	138	1	229.8	72.8
T13. 1.	95.0	12.0	0.45	59.0	61.5	1.70	8	0.007	3	4	300	39	3[illegible]	2	0.8	20.3
T13. 1.	95.0	12.0	0.45	59.0	61.5	1.70	8	0.007	5	4	300	39	34	2	0.8	20.3
T14. 1.	80.0	3.4	0.03	5.0	6.0	0.50	712	0.004	3	1	48	1	16	1	0.6	68.0
T14. 1.	80.0	3.4	0.03	5.0	6.0	0.50	712	0.004	5	1	48	1	16	1	0.6	68.0
T14. 2.	468.0	23.6	0.01	47.0	3.0	0.13	400	0.001	2	4	781	15	53	5	0.0	50.2
T14. 2.	468.0	23.6	0.01	47.0	3.0	0.13	400	0.001	5	4	781	15	53	5	0.0	50.2
T14. 3.	1779.0	214.0	0.0	267.0	0.0	0.0	0	0.0	5	4	783	70	47	2	0.0	80.1
T14. 4.	688.0	75.2	4.15	103.2	0.5	48.00	2357	8.300	3	4	266	128	58	7	4.0	72.9
T14. 4.	688.0	75.2	0.35	103.2	0.5	4.00	2357	0.700	4	4	266	128	58	7	0.3	72.9
T14. 4.	688.0	75.2	4.50	103.2	1.0	26.00	2357	4.500	5	4	266	128	58	7	4.4	72.9
T14. 5.	383.0	0.0	3.05	57.6	0.5	160.00	532	6.100	2	4	113	202	81	4	5.3	0.0
T14. 5.	383.0	0.0	3.05	57.6	0.5	160.00	532	6.100	5	4	113	202	81	4	5.3	0.0
T14. 6.	50.8	2.1	0.0	2.1	0.0	0.0	0	0.0	5	2	19	6	4	3	0.0	100.0
T14. 7.	300.3	44.0	0.01	450.0	1.0	0.08	30456	0.007	3	4	406	86	29	7	0.0	9.8
T14. 7.	300.3	44.0	0.01	450.0	1.0	0.08	30456	0.007	5	4	406	86	29	7	0.0	9.8
T15. 1.	159.0	0.0	0.0	15.9	0.0	0.0	0	0.0	5	4	112	38	11	5	0.0	0.0
T16. 1.	285.0	170.3	0.0	438.0	0.0	0.0	0	0.0	5	4	18		5	5	0.0	38.9

238 RECORDS PRINTED

CONTROL CODES LEGEND

1 - Electrostatic Precipitator (ESP)

2 - Scrubber

3 - Baghouse

4 - "Other"

* United States Government Printing Office:1981—341-085/4452