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REPORT

REVIEW OF COMPLIANCE MONITORING PROGRAMS WITH RESPECT TO GRAIN ELEVATORS

FINAL REPORT
Date Prepared: March 24, 1980

EPA Contract No. 68-01-4139, Task Nos. 12 and 14
MRI Project Nos. 4310-L(12 and 14)

For

Division of Stationary Source Enforcement
U.S. Environmental Protection Agency
401 M Street, S.W.
Washington, D.C. 20460

Attn: Robert L. King

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MRI – NORTH STAR LABORATORIES 10701 Red Circle Drive, Minnetonka, Minnesota 55343 • 612 933-7880

MRI WASHINGTON, D.C. 20006 – Suite 250, 1750 K Street, N.W. • 202 293-3800

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MIDWEST RESEARCH INSTITUTE 425 VOLKER BOULEVARD, KANSAS CITY, MISSOURI 64110 • 816 753-7600

PREFACE

Midwest Research Institute has carried out a study for the Division of Stationary Source Enforcement, Environmental Protection Agency, to review presently existing compliance monitoring programs as they relate to grain elevators and to develop alternative strategies for monitoring this industry.

This report presents the results of the study including characteristics of the grain elevator industry, and emissions thereof, SIP review, and the development and discussion of a more streamlined enforcement strategy.

Mr. V. Ramanathan, Associate Chemical Engineer, Energy Systems Section, served as the Project Leader, and Mr. D. Wallace, Associate Environmentalist, contributed significantly to the task. The assistance provided by Dr. K. P. Ananth and Mr. P. Gorman and the valuable guidance offered by the Task Manager, Mr. Robert L. King, throughout the project are gratefully acknowledged.

Approved for:

MIDWEST RESEARCH INSTITUTE

M. P. Schrag

M. P. Schrag, Director
Environmental Systems Department

March 24, 1980

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SECTION 1

INTRODUCTION

BACKGROUND

This study was conducted to evaluate the problems associated with compliance monitoring of grain elevators and to examine alternate inspection and monitoring strategies that state and local agencies might utilize in enforcing compliance in grain elevators. The particular objectives of the program were to: (a) characterize the industry with respect to number and location of facilities, emissions potential, and emissions control technology, (b) review current status of compliance monitoring, and (c) recommend alternate monitoring strategies which could potentially reduce the resource requirements for the inspection of grain elevators.

Although the study is directed specifically at compliance monitoring at grain elevators, it is anticipated that the development process and monitoring strategies would be a pilot model for similar source categories.

New Source Performance Standards (NSPS) for new, modified, and reconstructed grain elevators have been promulgated under the authority of Section 111 of the Clean Air Act.[1/] The promulgated NSPS apply only to those large grain elevators with storage capacity greater than 2.5 million bushels and which began construction or modification after August 3, 1978. Less than 5% of the approximately 10,000 elevators operating in the U.S. fall under the above size classifications. The remaining facilities are regulated by state and local agencies.

Enforcement of regulations is a large burden to state and local agencies. Factors such as the large variation in the sizes of individual facilities and widespread geographical dispersion have made development and conduct of a monitoring strategy difficult. The fugitive and intermittent nature of grain elevator emissions and restrictions imposed by some state legislatures have led to difficulties in applying regulations to grain elevators.

An additional factor that imposes a burden on the state enforcement and monitoring personnel from the standpoint of manpower and scheduling limitations is the cyclic nature of grain production. Grain elevators handle peak loads during harvest season, which lasts only for a period of about 3 to 4 weeks. Inspecting all the grain elevators in the state when they are operating at their capacity level imposes a burden on manpower and cost requirements both for the inspection crew of the regulatory agency and the elevator operator.

Another concern results from the recent explosions in grain elevators and the resultant loss of lives and property. These explosions have generated considerable concern with respect to any operation where grain dust is generated and, in particular, contained. The explosions have led federal, state, and local regulatory agencies to review the dust control measures.

The above factors have prompted the EPA-DSSE to issue the subject task assignment for a comprehensive review of federal, state, and local agency enforcement activities with respect to grain elevators and develop alternative compliance monitoring strategies.

SCOPE AND APPROACH

A grain elevator can be defined as a facility which stores grain and serves as a collection and transfer point. For the purpose of this study, grain elevators of all sizes are included--ranging from small country elevators to farmers' co-operative elevators to large city terminal and export terminal elevators. The operations considered include only grain receiving, storage, shipment, and, in some cases, grain scalping and drying. For example, a seed plant, which not only stores and handles grain, but also cleans, sorts, and treats it for making seed, was not considered. Also excluded are feed mills, grain/rice milling plants, and flour mills, even though their operations include storage and transfer.

The geographic area considered theoretically includes the entire United States. The characterization of industry and development of alternative strategy are applicable to all grain elevators in general, irrespective of geographic location. As for the review of SIP's, in order to obtain a broad cross-section of state regulations, the state having the most grain elevators in each of nine EPA regions was selected for review. Region I was not included since it has very few grain elevators. In Region VII the regulations were reviewed for Nebraska and Iowa, in addition to Kansas, because of the large number of elevators in these states.

The program was divided into four major phases. The first phase involved collection of information from literature, industry, and government agency sources to characterize the grain elevator industry, dust emissions from elevator operations, and their dust control aspects. The second phase focused on a comprehensive review of the SIP's of the selected states, including their current enforcement strategy and compliance monitoring programs. The third phase of the study was the development of an alternative strategy for enforcement and for monitoring the grain elevators for compliance with the applicable emission regulations. The fourth phase, which was accomplished under a separate task, was a field evaluation and subsequent revision of the monitoring strategy.

ORGANIZATION OF THE REPORT

The report is organized into two major components. The body of the report is a concise presentation of the results and findings having a direct impact on the compliance monitoring strategy. The appendices present detailed information on various aspects of the grain elevators industry and compliance monitoring of grain elevators.

The body of the report includes: a summary of the overall program (Section 2); conclusions and recommendations of the study (Section 3); a brief survey of grain elevator emissions and emissions control technology (Section 4); an analysis of current regulatory and enforcement practices (Section 5); and an alternative enforcement and compliance monitoring strategy.

The appendices contain a description of the industry structure and grain elevator operations (Appendix A); a detailed analysis of grain elevator emissions (Appendix B); descriptions of grain elevator control techniques (Appendix C); a summary of the regulatory and enforcement approaches of the 11 states surveyed during the study (Appendix D); a detailed description of the development and field evaluation of an alternative inspection and monitoring strategy (Appendix E); and a glossary of industry terms (Appendix F).

SECTION 2

SUMMARY

THE GRAIN ELEVATOR INDUSTRY

The grain elevator industry comprises those facilities involved in the conditioning, transfer, and storage of grains and other agricultural products as they are passed from the farmer to the final processing or exporting facilities. These facilities consist of country, subterminal, and terminal elevators. For purposes of this study farm elevators, those elevators handling grain strictly for on-farm use, and elevator operations at processing facilities are not defined as part of the industry.

Country elevators receive grain from the farmer and ship to subterminal or terminal elevators. Subterminal elevators receive grain from both farmers and country elevators and ship to terminal elevators or directly to processors. The terminal elevators receive grain from country and terminal elevators and either export the grain or ship the grain to processors.

Data from the U.S. Department of Agriculture (USDA), National Grain and Feed Association (NGFA), and the U.S. EPA were examined to determine the number and size of grain elevators. It was found that no precise count of elevators is available. Using the best data from USDA and NGFA the number of grain elevators is estimated to be about 9,000 distributed as follows:

Country - 8,210

Subterminal and terminal - 540

While these elevators are distributed widely with each region having at least one elevator, 90% of these elevators are located in Regions V, VI, VII, and VIII. No one of these regions contains more than 40% of the grain elevators. It is apparent that grain elevator compliance is of concern in more than one region.

GRAIN ELEVATOR EMISSIONS AND EMISSIONS CONTROL

Each of the conditioning and transfer operations in a grain elevator is a potential source of particulate emissions. Available emissions data were surveyed to develop emission factors for each major operation. The best "average" emission factor and range of emission factors are presented below. The emission factors are in units of pounds of dust per ton of grain processed through the operation. The numbers in parentheses represent emission factors for country elevators if they differ from terminal elevators.

	Best "average"	Low	High
Grain unloading (receiving)	1.0	0.8	3.5
Grain loading (shipping)	0.64	0.25	1.26
Conveying to bins (gallery belt/tripper)	1.0	0.11	2.5
Removal from bins (tunnel belt)	1.40	1.0	2.0
Headhouse (legs)	1.50	0.5	2.5
Internal turning	3.90 (2.9)	1.61 (1.5)	7.0 (4.5)
Cleaning	5.8	5.0	7.0
Drying	5.5	4.0	8.0

Two observations are of particular interest with respect to these data. First, the magnitude of the emissions are an indication of a potentially significant impact of the grain elevator emissions on ambient air quality. Second, the wide range of the emissions data limits the reliability of the application of the emission factors to specific grain elevators.

One other facet of grain elevator emissions of particular interest is the relationship of mass emissions concentrations to opacity. Limited data from control device exhaust tests indicate that emissions with 20% opacity are equivalent to a mass concentration of 0.025 gr/scf. If these data can be confirmed, they will have a significant impact on enforcement strategy, in that a visible emissions regulation of 20% is as stringent as most mass emission regulations.

Almost all sources of grain elevator emissions are "fugitive" sources, i.e., sources for which the emissions enter the atmosphere directly or through building openings rather than through well defined ductwork. The control of these emissions requires an efficient capture system to contain the dust connected to an air pollution control device such as a cyclone or fabric filter. Adequate control systems are available for each of the grain elevator operations and have been installed on most moderate to large size grain elevators.

The fact that elevators have installed control systems does not mean that the emissions problem has been solved. Data indicate that the malfunction of control equipment, particularly fabric filters, due to improper operation and maintenance is a significant control problem in the grain elevator industry. Using contacts with personnel from the elevator industry, air pollution control agencies, and control equipment vendors, we were unable to locate any substantive data on possible causes and solutions to these malfunction problems. This area appears to be a candidate for further research efforts.

ANALYSIS OF STATE IMPLEMENTATION PLANS

State air pollution laws from 11 select states were reviewed to identify those applicable to grain elevators. State and local officials were then contacted to identify the enforcement strategies actually utilized by the agencies.

The responses from the contacts with state and local agencies indicate that the primary enforcement tool is the visible emissions regulation (used by 10 of the 11 states contacted). Other regulations frequently used are fugitive dust prohibitions or general nuisance regulations. Although most states had some type of mass emission regulation (either process weight or concentration), only one of the 11 states appears to regularly enforce a process weight regulation. Based on these responses, any alternative monitoring strategy should certainly include provisions for utilizing visible emissions and fugitive dust regulations. Further methods development and education are needed before mass emissions regulations can be used on a regular basis.

Grain elevator regulations for the State of Illinois are of particular interest. These regulations require aspiration on all grain handling operations within the elevator. Control device efficiency is specified for the captured emissions based on elevator size and attainment status of the elevator location. A housekeeping checklist and documentation of proper operation and maintenance procedures are also required. These regulations should be examined carefully in developing a regulatory model for control of grain elevators. The housekeeping and operation and maintenance (O&M) checklists may be a valuable enforcement tool in states with housekeeping and/or malfunction regulations.

DEVELOPMENT OF A COMPLIANCE MONITORING STRATEGY

The development of the compliance monitoring strategy was accomplished in three stages. First, tentative inspection formats and a hypothetical compliance monitoring strategy were developed. The inspection format and strategy were then examined through field evaluation at 38 grain elevators in the State of Nebraska. Finally the results of the field evaluation were analyzed and principles for alternative enforcement/compliance monitoring strategies were developed.

Information from contacts with control agency personnel and MRI personnel utilized in the field evaluation as well as the statistical analysis of the field evaluation data were used as input in developing the following principles for an enforcement/compliance monitoring strategy:

1. The first step in developing an enforcement strategy is to determine: (a) facilities subject to regulation; (b) operations within the facilities subject to regulation; and (c) regulations to be utilized. It is strongly suggested that visible emissions or fugitive dust regulations not be enforced against uncontrolled sources; this could lead to uneven enforcement.

2. As a corollary to the above principle, before inspections begin control requirement criteria should be developed to determine which operations in which elevators should be controlled. These criteria should not be based on visible emissions noted during inspections. Some possible criteria are elevator size and elevator location with respect to population or ambient attainment.

3. Only controlled sources should be inspected regarding violation of standards. Uncontrolled sources should be examined periodically to identify any changes in status regarding control requirement criteria.

4. Elevators should be inspected using a level of inspection concept. Three levels of inspection are proposed. Level I is an external inspection of visible emissions from control device exhausts and fugitive emissions from controlled operations. Level II is an internal inspection in which visible emissions are checked, control equipment is determined operational, capture at controlled operations is visually determined, and housekeeping practices are examined. Level III consists of a detailed examination (including internal inspection) of control equipment and exhaust systems and/or emissions testing at control device outlets.

5. Inspections are done systematically starting with Level I and result in step-by-step elimination of monitoring of sources at higher levels if compliance is determined.

6. Levels II and III should never be used at country or subterminal elevators during harvest season.

These principles were then used to develop a model inspection strategy. It is suggested that these principles can be used by state and local agencies to develop an enforcement/compliance monitoring scheme that can best utilize their limited resources.

SECTION 3

CONCLUSIONS AND RECOMMENDATIONS

The major conclusions derived from this investigation and associated recommendations are as follows.

1. Current data on number, size, and location of elevators do not provide a sufficient data base for enforcement purposes. There is a need for a concise and systematic inventory of all grain elevators including their capacity and throughput. (This is currently being addressed on another EPA program.)

2. Existing emissions data are scarce and inconsistent with regard to the method of measurement. If process weight regulations are to be utilized in monitoring grain elevators, an intensive effort is needed to characterize emissions from various elevator operations.

3. Observations during the field evaluations indicate that "continued compliance" is more critical in grain elevators then "initial compliance." That is, after the installation of the control equipment, proper operation and maintenance (O&M) of the equipment appears to be a common problem in grain elevators. Convincing the grain elevators of the real benefits of dust control and educating them on the O&M practices for the control equipment is imperative to an effective monitoring and enforcement strategy.

4. The Levels of Inspection concept has potential for application to grain elevators. Short term visual inspections (Level I) often provide sufficient data to analyze compliance status with respect to visible emissions regulations, while more detailed inspections (Levels II and III) provide additional information on performance of control systems.

5. Visible emissions violations at uncontrolled loading and unloading operations are a result of factors such as amount of dust in the grain and wind speed and direction. As such, any uncontrolled elevator has the potential to violate visible emissions regulations. Since such violations are random occurrances, short term observations of either compliance or noncompliance are not a good indicator of the actual compliance status of an uncontrolled source.

6. Observations during the field evaluation indicate that regulations such as prohibition of excessive malfunctions, housekeeping practices, and requirements for proper operation of control equipment in addition to opacity regulations are an aid to enforcement of continuous compliance.

7. A defined enforcement strategy which indicates the control levels to be required on elevator operations is a prerequisite to an efficient monitoring strategy. This indicates that some type of equipment regulation is preferred for grain elevators. A good example of such a regulation is the State of Illinois Rule 203.9 (see section 5).

SECTION 4

GRAIN ELEVATOR EMISSIONS AND EMISSIONS CONTROL

Grain elevators of all sizes contain a number of sources which emit particulate matter to the atmosphere either directly or through doors, windows, or ducts. A basic understanding of these sources, emissions quantities and characteristics, and emissions control is a prerequisite to developing alternative enforcement/compliance strategies.

Emissions from grain elevators result from the various handling and transfer operations. These emissions are a result of the liberation of field dust and chaff carried in with the grain and fine grain dust caused by abrasion during handling. The main particulate emissions sources in grain elevators are:

1. Grain unloading
2. Grain transfer points including
   - (a) bin discharge onto tunnel belts
   - (b) grain transfer to boots
   - (c) transfer to gallery belt
   - (d) gallery belt trippers
3. Elevator legs
4. Grain cleaning
5. Grain drying
6. Garner and scale bins
7. Grain loading
8. Bin vents

For those readers not familiar with grain elevators, descriptions of these operations are included in Appendix A. The remainder of this section will present a brief summary of emission factors, a discussion of other emissions characteristics impacting on enforcement strategies, and a review of grain elevator emissions control practices.

GRAIN ELEVATOR EMISSION FACTORS

Most grain elevator emissions sources are classified as "fugitive" emissions sources. Fugitive sources are those which, in the absence of air pollution control systems, emit to the atmosphere directly or through doors and windows rather than through well defined ductwork. Since such sources are difficult to test, emissions data from grain elevators are scarce.

Available emissions data have been generated by three basic methods. Early emission factors were estimated by experienced elevator operators based on material balances, or "shrinks."[2,3] Early experimental numbers were generated from a 6-month study of weekly weights of fabric filter catch at a terminal elevator.[4] More recent data were generated by performing emissions tests in ducts upstream from a control device at controlled sources.[5-11] The results of these studies are shown in Table 1.

The data in Table 1 are limited in that they are dependent upon the efficiency of the hooding or take-off system in capturing the dust. If the flow through the system is too low, capture will be inefficient and the emission factor generated will be too low. On the other hand, if the capture velocity is too high, the system will induce particles from the process stream that might otherwise remain in the grain, resulting in excessively high emissions.

Even with these limitations, two observations can be made that are of particular significance when developing monitoring strategies. First the data show a wide range in emission factors. These may be a result of variations such as differences in test method or differences in efficiency of the capture system. However, the differences may simply reflect a wide range in emissions from grain elevator operations. The latter case is supported by data in Reference 4 which show weekly emission factors varying by a factor of 5 or more for most elevator operations. If emissions do in fact vary over such a wide range, the use of average emission factors to enforce process weight violations at a specific elevator is a questionable tool.

The data in Table 1 also show a variation in emission factors based on grain type. These data are substantiated by short-term test data in Reference 4, but data are insufficient to quantify these differences. However, the existence of these differences again limits the use of average emission factors as an enforcement tool for process weight regulations.

A more detailed analysis of grain elevator emission factors is presented in Appendix B.

TABLE 1. SUMMARY OF GRAIN ELEVATOR EMISSION FACTORS

Operation	Emission factor, lb dust/ton grain processed[a] Material balance	Control device catch	Source test
Truck unloading	2.0(3) 0.8(2)	0.64(2)	13.9(11),[b] 0.0398-0.774(11)[c] 0.090(5)[c]
Car unloading	1.0(3) 0.7(2)	1.30(2)	
Car loading	1.0(3) 1.1(2)	0.27(2)[e]	0.68(5),[c] 2.72(5)[d]
Cleaning	5.0(3) 6.0(2)	5.78(2)[e]	0.425(9), 0.18(7), 0.40(8), 0.13(8), 0.11-9.6(11)[b]
Gallery belt transfer	-	0.11(2)	
Tunnel belt	1.5(3) 1.0(2)	1.40(2)	0.36(5),[c] 0.91(5)[e] 0.63(5)[f]
Headhouse	0.5(3)	1.94(2)	0.14(7), 0.10(8) 0.485(9)[g]
Leg			0.77(13), 1.52(5)[c] 1.736(5),[f] 3.075(5)[d]

a/ Numbers in parentheses refer to references (see page 149).

b/ Legumes only.

c/ Wheat only.

d/ soybeans only.

e/ Corn only.

f/ Milo only.

g/ Includes emissions from dump pit and leg boots.

EMISSIONS CHARACTERISTICS

Two characteristics of grain elevator emissions are of particular interest with respect to enforcement strategies: (a) particle size and (b) the relationship of mass emissions to opacity. Most of the particulate emission is composed of particles 50 µm or smaller in size.[2/] Grain dust suspended in the air in the interior of grain elevators consists mostly of highly dispersed particles measuring 5 µm in diameter. A particle size distribution for grain dust emissions is shown in Table 2.[12/] One source sampling study reports a marked difference in the weight percent of minus 10 µm particulates between grain cleaner exhausts and receiving pit exhausts.[11/] The results are presented in Figure 1. Grain cleaner exhausts generally contained less than 10% by weight minus 10 µm particles, while receiving pit exhausts were found to exceed 50% by weight minus 10 µm particles. The particles in the 0.1 to 1.0 µm size range constituted only about 1% of total particulates emitted from grain cleaners but more than 15% of the particulates emitted from receiving hoppers. This finding is of particular significance because it has been well-documented that particles in this size range have the maximum effect on plume opacity.[14/]

TABLE 2. PARTICULATE SIZE DISTRIBUTION OF GRAIN DUST FROM TRANSFER OPERATIONS[12/]

Particle size (µm)	Percent (%) by weight	
	Before cyclone	After cyclone
0 - 44	6.4	58
44 - 74	19.2	11
74 - 104	17.4	10
104+	57.0	21

Data on mass concentration and opacity indicate that the visible emission standard of 20% opacity is more stringent that the particulate emission standard of 0.1 grains per SCF, for both grain cleaners and receiving pits control device exhausts. Sufficient data are not available to establish statistically reliable correlations between grain loading and opacity. In general, however, it is reported that particulate concentrations of 0.1 grains per SCF or greater from the control device exhaust resulted in visible plumes in excess of 50% opaicty from receiving pits and 40% opacity from grain cleaners. In order to meet a visible emission standard of 20% opacity, mass concentrations of less than 0.025 grains per SCF would be required.[11/] More data are needed to substantiate this relationship. However, if it is valid, an opacity regulation of 20% is more stringent than most mass concentration regulations.

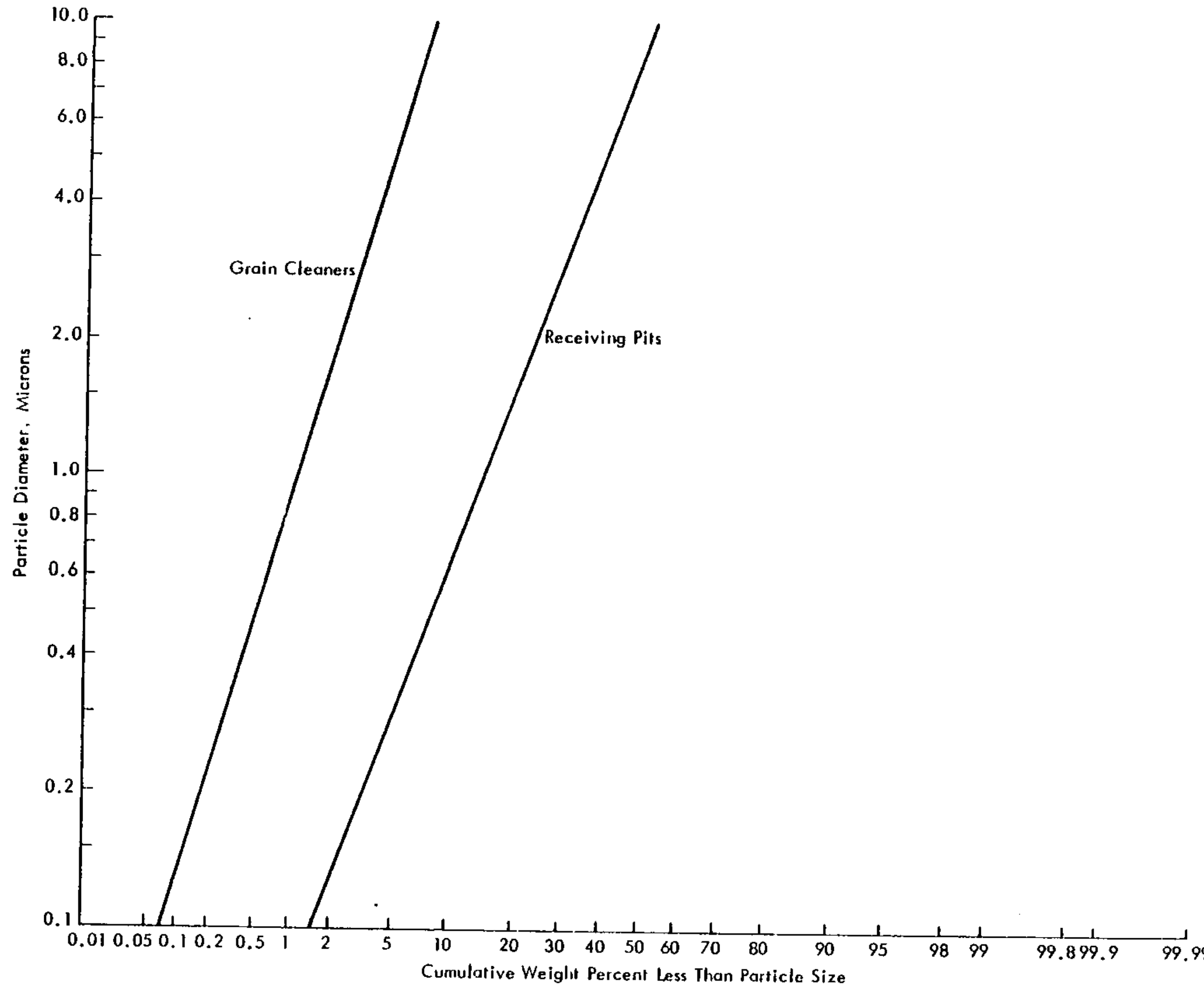


Figure 1. Typical particle size distribution of uncontrolled dust emissions--grain cleaning and receiving.11/

EMISSIONS CONTROL IN GRAIN ELEVATORS

Regulatory control of atmospheric emissions from any industrial process requires three steps: (a) technically and economically feasible measures which reduce emissions from the process to acceptable levels must be developed; (b) these measures must be implemented on those sources which, on the basis of either size or location, are considered to be major emissions problems; and (c) the source must continue to operate and maintain process and control equipment in order to sustain acceptable levels of emissions.

Control techniques for grain elevator emissions sources are available and have been widely implemented. They are described in detail in Appendix C. However, during the field evaluation portion of the study, significant problems were noted in proper operation and maintenance of the control equipment. The existence of these problems has been substantiated in conversations with industry and agency personnel. The paragraphs below describe problems often encountered with grain elevator control equipment.

Excess emissions from grain elevators with control equipment may result from problems in the capture system, particulate cleaning device, or some combination of these. However, problems in a properly designed capture system can generally be easily identified and corrected (i.e., improper damper settings or holes worn in the ducting) and so will not be described in detail.

Operational problems in mechanical collectors (cyclones) can also be identified and corrected relatively easily. The efficiency of a cyclone is dependent on the design parameters of the cyclone and the velocity of the gas stream through the cyclone. A reduction in the gas velocity will result in decreased efficiency. Any factor which causes an increased pressure drop through the control system (such as plugging in the cyclone, improper damper settings in the ductwork, or plugging in the ductwork) will lead to decreased flow through the cyclone and a drop in cyclone efficiency. A specific instance can be identified in Table B-8, Appendix B. One particular cyclone had a pressure drop of 17 in H_2O and a flow of half the design flow. The efficiency of the cyclone was only 47.5%. Periodic checks of cyclone pressure drop, exhaust fan current, the condition of cyclone walls and fan blades, and the exhaust rate at pickup points will provide indicators of any problems that might reduce efficiency.

One other problem with cyclone operation that often occurs is leakage of air into the cyclone from the dust discharge. The inlet and outlet flows at Elevator C, Table B-8, Appendix B indicate extensive leakage through the dust discharge. For all three cyclones efficiency was less than 60%. Thus, dust discharge mechanisms should be checked regularly to control leakage.

The major contributor to noncompliance of controlled grain elevators is the malfunction of fabric filters. This may result from torn bags which cause excess emissions from the control device outlet or plugging of the bags which cause excess emissions at the source. The following paragraphs discuss problems specifically associated with fabric filters in grain elevators.

Based on contacts with industry personnel, environmental control officials, and equipment vendors, it appears that there has been no systematic study of problems associated with baghouse operations in grain elevators. However, several sources indicated that problems do exist, and there is some evidence that operating problems may result in significant periods in which the control equipment is shut down or operating inefficiently.

A listing of the problems identified by persons having experience with grain elevator controls is presented below. These problems are based on specific experiences of these individuals and no documentation is available on the magnitude of the problems on an industry-wide basis.

1. Personnel with the National Grain and Feed Association indicated that bag blinding can be a problem in areas of high humidity, especially in the South. This can be overcome by using an air heating system with the baghouse.

2. This same bag blinding has been experienced in northern climates, especially during the fall. It often results from handling relatively warm, moist grain which has been stored inside the elevator and exhausting the gas stream to a control device located in a cooler outdoor atmosphere.

3. Several persons indicated that dust bridging in the baghouse hopper is a major problem. This had been attributed to poor design of hoppers and improper shutdown procedures. It was suggested that systems be designed so that elevator personnel have easy access to the hopper for inspection and cleaning.

4. Malfunction of the bag cleaning mechanism results in dust buildup on the bags and eventually to total plugging of the systems. During previous elevator visits, MRI personnel have encountered two causes of such failure. At one elevator, the pluse jet control panel located on top of an outdoor baghouse was not installed in a weathertight enclosure. Accumulation of dust and moisture inside the control panel caused shorting in the solenoid valves for the pulse jet system. In another case, moisture in the compressed air line resulted in line freeze-up under cold winter conditions.

This listing of problems is in no way exhaustive, but is included to identify the types of problems associated with baghouse operations in grain elevators. Additional data are needed if the effect of baghouse failures on continual compliance is to be determined. No specific data are available on procedures used to eliminate operational problems on grain elevator fabric filters. However, general baghouse operation and maintenance practices which can be applied to grain elevators are presented in Appendic C.

SECTION 5

ANALYSIS OF STATE IMPLEMENTATION PLAN REGULATIONS

To provide background information for the development of compliance monitoring strategies for grain elevators, an analysis of regulations currently being enforced under SIP's was conducted. In order to obtain a broad cross-section of state regulations, the state in each of nine regions having the most grain elevators was selected for review. Region I was found to have too few grain elevators for inclusion in the study. In Region VII the regulations were reviewed for Nebraska and Iowa, in addition to Kansas, because of the large number of elevators in these states.

For each of the states, the Environment Reporter was surveyed to determine possible regulations which might be applied to grain elevators. After the survey was completed, each state agency and some local agencies were contacted to determine the following:

1. Regulations actually enforced;
2. Size and location of elevators subject to enforcement;
3. Emissions sources within the elevator generally monitored for compliance; and
4. General description of monitoring activities.

GENERAL STATE AND LOCAL REGULATIONS

A summary table of state and local regulations identified from a review of the Environment Reporter and copies of regulations supplied by control agency personnel is presented in Appendix D. The paragraphs below outline the major findings of the regulatory review.

The most frequent state regulations identified during the survey which might be applied to grain elevators are visible emissions regulations and fugitive dust or nuisance regulations. All but one of the 11 states surveyed had some type of visible emissions regulation. (The one state, Texas, is precluded by the regulation from applying visible emissions standards to agriculturally related industries.)

Visible emissions can be classified as one of two types, specific opacity or general limitation on fugitive emissions. Nine of the states have specific opacity regulations requiring emissions to be less than 20% or 40% opacity (Ringlemann 1 or 2, respectively). These regulations are written for all industrial processes and could be applied to any ducted or fugitive emissions source in the grain elevator. Three states also have generally worded regulations which prohibit the escape of visible emissions from handling and storage operations. No maximum allowable opacity is associated with these regulations.

A total of seven of the eleven states have fugitive dust, housekeeping, or nuisance regulations which could be applied to grain elevators. As shown in Table D-1, these regulations differ significantly from general prohibitions of emissions beyond the property line which cause nuisances to specified allowable increments to ambient concentrations. The most well-defined housekeeping standard is from Illinois. Recommended housekeeping practices in Illinois are presented in Table 3. Table 4 shows the elevator checklist prepared by Illinois.

Seven of the eleven states had some type of process weight regulations. Five of these states have an industrial process weight standard based on the equations:

$$E = 4.10\ p^{0.67},\ p < 30\ \text{T/hr}$$
$$E = 55.0\ p^{0.11} - 40,\ p > 30\ \text{T/hr}$$

E = Emissions limit (lb/hr)
p = Process weight (T/hr)

One state, Texas, has a process weight of:

$$E = 3.12\ p^{0.985},\ p < 20\ \text{T/hr}$$
$$E = 3.12\ p^{0.287},\ p > 20\ \text{T/hr}$$

The latter regulation indicated that agriculturally related industries (including grain elevators) may comply with the process weight standard or may use another method of compliance which is approved by the director. Finally, Pennsylvania has a source specific mass emissions regulation based on the formula.

$$A = 0.76E^{0.42}$$

where: A = Allowable emissions in lb/hr
E = Emission index = F x w lb/hr
F = Process factor in lb/unit, and
W = Production or charging rate in units/hr

TABLE 3. MINIMUM RECOMMENDATIONS FOR HOUSEKEEPING PRACTICES FOR GRAIN HANDLING FACILITIES

All pollution control equipment, no matter how minor it appears, is scientifically designed to perform properly. Any abuse of this equipment deters proper operation. DO NOT ABUSE THIS EQUIPMENT!! Follow maintenance procedures recommended by the manufacturer.

1. Existing Cyclone Collectors

   A. Cyclone(s) should be checked daily to be sure they are operable and not plugged.

   B. They shall be cleaned as required to insure proper operation.

2. Cleaning and Maintenance

   A. Floors should be kept swept and cleaned from boot pit to cupola floor. Roof or bin decks and other exposed flat surfaces should be kept clean of grain and dust that would tend to rot or become airborne.

   B. Cleaning must be handled in such a manner as not to permit dust to escape to the atmosphere. (Example: Dust and grain swelt up are to be conveyed to a source of disposal and must not be swept out of cupola door. Grain and dust must not be shoveled off bin deck to ground.)

   C. The yard and surrounding open areas including ditches, curbs, etc. should be cleaned before rotting occurs.

   D. Continuing maintenance of a facility should be practiced, such as replacing broken glass and keeping spouts and equipment in a dust tight condition to prevent leakage of dust and grain.

3. Receiving Station (Dump Pit)

   A. Existing aspiration equipment is to be maintained and operated.

   B. Existing dust control devices are to be maintained and operated.

4. Loadout Areas

   A. Sleeves or equivalent should be installed on all loadout spouts. These sleeves are to be of sufficient length to serve the purpose for

(continued)

which they are installed, i.e., controlling dirt and dust from aeration of grain discharging into receiving hoppers, trucks, and rail cars.

B. To aid in eliminating this loadout condition, it is recommended that, where feasible, choke loading is to be used as a normal operating procedure.

5. Head House Area

A. The head house shall be maintained in such a fashion that no visible dust or dirt is allowed to escape to the atmosphere.

6. Property

The yard and driveway of any facility should be asphalted, oiled, or equivalently treated to control dust. This operation is to be done as often as required.

7. Housekeeping check lists shall be developed by the manager, and used to aid in maintenance and housekeeping, (example attached). These checklists will be subject to inspection by the Illinois EPA Surveillance Engineer during routine inspection.

TABLE 4. ELEVATOR CHECKLIST (GUIDE ONLY)

	YES	NO
A. Basement	YES	NO
1. Boots pits cleaned.	____	____
2. Floors cleaned.	____	____
3. Walls cleaned.	____	____
4. Aspiration in good working order.	____	____
B. Ground Level	YES	NO
1. Floors cleaned.	____	____
2. Walls cleaned.	____	____
3. Aspiration in good working order.	____	____
C. Head House and/or Tank Top	YES	NO
1. Floors cleaned.	____	____
2. Walls cleaned.	____	____
3. Aspiration in good working order.	____	____
D. Equipment	YES	NO
1. Cyclones are in good operating condition	____	____
2. Air duct is free of holes.	____	____
3. Leg discharges are maintained and free of holes.	____	____
4. Spouts are maintained and free of holes.	____	____
5. Pit doors are free and operable.	____	____
E. Elevator Grounds	YES	NO
1. Area is policed and all trash is picked up.	____	____
2. Aspiration in good working order.	____	____

Process factors (F) were identified for three grain elevator emissions sources:

Loading and unloading	90 lb/ton grain
Grain Screening and Cleaning	300 lb/ton grain
Grain Drying	200 lb/ton grain

The process weight rates obtained from the equation are present in Table D-1, Appendix D.

Allowable concentrations of particulate in exhaust gases are limited by five of the eleven states. The regulations range from 0.02 to 0.1 gr/dscf of exhaust gas.

Three states have control equipment standards which can be applied to grain elevators. Two states have regulations which require adequate enclosure of handling operations. Illinois has the most detailed regulations for grain elevators. These regulations require capture of emissions from all major emissions sources and require that these be vented to removal devices of specified efficiency.

In summary, each of the 11 states had at least two of the types of regulations which might be applied to grain elevators. Even though the regulations varied considerably from state to state, the initial survey indicates that there is enough similarity between states to justify the investigation of possible uniform compliance monitoring procedures. The one regulation identified during the survey which might present some problem is the preclusion by Texas regulations from the use of visible emissions regulations for compliance of agriculturally related industries.

In addition, the regulations are identified as either specific to grain elevators or general industrial process regulations. A review of the data shows few states have regulations written specifically for grain elevators, but rather rely on the application of general industrial regulations to grain elevators.

CURRENT MONITORING PRACTICES

After the regulations were reviewed, state and local agencies were contacted to determine which regulations are generally enforced, the elevators and sources subject to compliance monitoring, and a general description of monitoring activities. The information obtained from these contacts is presented in detail in Table D-2, Appendix D, and is summarized below.

In almost all states contacted, visible emissions or opacity standards are the primary enforcement tool. The level of enforcement of visible regulations ranged from as complaints are registered to a once per year inspection, to daily observation by local officials (only at terminal and port elevators). Even though several states have concentration or process weight regulations, only North Dakota appears to have required compliance testing. In North Dakota elevators may show compliance either by testing or by comparison with systems already in place. The only other enforcement tool used by the states contacted is an annual inspection with emphasis based somewhat on housekeeping practices. These may be highly structured lists (as Illinois) or general inspections (Nebraska). In general, it appears that most states that we contacted do not have a well-developed program of compliance monitoring for grain elevators.

Several specific monitoring strategies were identified from contacts with state agencies which deserve consideration. These are presented below.

1. Illinois has developed a comprehensive housekeeping checklist. It was included in Tables 3 and 4.

2. Kansas has a program of staggered annual inspections in which an inspector is in each county once per month. While in the area to inspect other facilities, the inspector will check grain elevators for visible emissions problems with a drive by observation.

3. Several states have regulations whereby some level of capture (either no visible emissions or a certain face velocity at openings) is required. This regulation may possibly be combined with a control equipment regulation, process weight regulation, or concentration regulation to insure control.

4. Citizen's complaints were identified by several persons as effective enforcement tools with respect to country elevators.

CONCLUSIONS

Based on the above discussions, several conclusions can be drawn with respect to the development of compliance monitoring strategies. First, almost all states (Texas and Iowa being the exceptions), use visible emissions as the primary enforcement tool. A monitoring strategy which does not include this element will in all probability be seen by state agencies as inadequate. Some type of fugitive emission or nuisance regulation is available to many state agencies and is used as an enforcement tool by several. Some thought should be given to ways that such regulations can be used as a part of grain elevator inspections. Finally, almost all states have some type of mass emissions standard (either process weight or concentration).

However, only one of 11 states appeared to use this regulation consistently. Since mass emission standards are the standard most directly related to the impact of the source on ambient air quality, ways to apply these standards (short of actual emissions testing) should be examined.

SECTION 6

DEVELOPMENT OF AN ALTERNATIVE INSPECTION AND MONITORING STRATEGY

The ultimate objective of this study was to develop a streamlined compliance-monitoring strategy for grain elevators which would utilize the monitoring resources in a more cost effective manner than the presently existing programs under various SIP's. Development of the compliance monitoring strategy was accomplished in three stages. First an experimental strategy, including inspection formats, was developed using the "Levels of Inspection" concept. This experimental strategy was then tested through inspections at 38 grain elevators in the State of Nebraska. Finally, results of the field evaluation were analyzed and an alternative approach to grain elevator enforcement and compliance monitoring was developed.

The following sections describe: (a) the initial development and field evaluation of an alternative compliance monitoring strategy; (b) analysis of the results of the field evaluation; and (c) a description of an alternative enforcement/compliance monitoring strategy.

DEVELOPMENT AND FIELD EVALUATION OF A COMPLIANCE MONITORING STRATEGY

The underlying principles of the "Levels of Inspection" concept as applied to grain elevators are as follows: (a) the inspection efforts are broken down into three levels, which differ in depth and time requirements, (b) the various levels of inspection are scheduled at different times during the year, taking into consideration the seasonal variations in the volume of activity, and (c) decisions concerning the level of compliance monitoring at a particular elevator are based on the potential impact of the emissions from that elevator on ambient air quality and the status of the vicinity of the elevator with respect to the attainment of ambient particulate standards.

The premises outlined above were used to develop an experimental inspection monitoring strategy. The proposed inspection of grain elevators was broken down to three levels, viz., Level I, Level II, and Level III. The major characteristics of the proposed inspection strategy are itemized below.

- "Depth" of inspection increases from low to high inspection levels, i.e., Level I inspection will be cursory and least time consuming, Level II inspection will involve taking a closer look at individual emission points, etc., and Level III will require elaborate examination of control systems.

- Depending on estimated total potential emissions, grain elevator facilities can be grouped into various "severity" levels.

- The above "severity" levels can then be matched against inspection-levels, i.e., low severity sources may be ignored for higher level inspections.

- Inspection will be done systematically and will result in step-by-step elimination of sources for further monitoring at higher levels based on "compliance" at any given level.

- Various levels of inspection will be phased out according to seasonal changes in volume of activity, viz., harvest season and off-season. The potential benefits resulting from such phasing out are: easier and more effective scheduling of inspector's visits to elevators and savings in elevator operator's time spent with the inspector, especially during the peak season.

The experimental strategy was then tested through a field evaluation at elevators in the State of Nebraska in cooperation with personnel from Region VII and Nebraska Department of Environmental Resources. The field evaluation consisted of concurrent Levels I and II inspections of 36 grain elevators of all sizes. In addition eight larger elevators were inspected twice, once before and once after harvest using Level III inspection procedures. The results of the field evaluations were then used to finalize an enforcement/compliance monitoring strategy.

Details of the experimental inspection monitoring strategy and the field evaluation methodology are presented in Appendix E. Specific results of the field inspections were submitted to Region VII in the form of Surveillance Analysis Reports and can be requested through the regional office.

ANALYSIS OF THE RESULTS OF THE FIELD EVALUATION

The primary objective of the field study was an analysis of the value of the various levels of inspection and, based upon the results of the analysis, revision of the monitoring strategy. The original protocol called for a statistical comparison of the cost and benefits of Level I and Level II inspections, with cost measured in amount of time necessary to complete an inspection and benefits measured as the ability of the inspector to correctly ascertain noncompliance. During the course of the field inspections, it became apparent that all costs and benefits of the various levels of inspections could not be sufficiently quantified to be amenable to statistical analysis. Therefore, the analysis presented below combines subjective analyses based upon inspector observations with a statistical analysis.

The remainder of the discussion is divided into three sections as follows:

- Cost of inspections
- Effectiveness of the inspection in identifying control equipment and incidences of noncompliance.
- Additional benefits of inspections.

It should be noted that the number of elevators inspected using Level III procedures was insufficient to include that level in the statistical analysis. However, subjective judgments concerning costs and benefits of Level III inspections have been included in the discussion.

Cost of Inspections

The primary criteria by which inspection costs were evaluated was the amount of time necessary for a single inspector to complete an inspection. Initially, the time necessary to complete Level I and Level II inspections was evaluated for 36 elevators; 12 Class A, 12 Class B, 7 Class C, and 5 Class D (see Appendix E, pages 112 and 113, for definition of elevator classes).

The results of the analysis indicate that Level I inspections are significantly less costly than Level II, and the cost reduction (or time reduced) is a function of elevator type. For the four elevator classes, the times are shown below.

	Time required to conduct Level I inspection (min)		Time required to conduct Level II inspection (min)	
Elevator class	Mean	Range	Mean	Range
A	7	1-12	23	5-45
B	20	7-45	32	10-64
C	16	5-32	65	40-145
D	29	15-39	96	68-125

It should be noted that the difference in time between Level I and Level II inspections is much greater for Class C and D elevators. This results primarily from the fact that most Class A and Class B elevators had no emission control equipment. Thus, for these classes of elevators the primary difference between Level I and Level II was the time required to obtain process data from the elevator operator.

Each elevator class (except B and C for Level I) possesses a unique mean inspection time according to a one-way analysis of variance performed on the data. Individual inspection times vary by about $\pm$ 18 min (Level I) and $\pm$ 44 min (Level II) from the respective means for Level I and Level II. Because of this wide variance, no numerical estimate of the time difference between Level I and Level II can be made with any statistical confidence. However, inspection times for both levels increase on the average according to elevator class, and Level II inspection time is always greater than Level I inspection time.

Based on observations made by the inspectors, the lack of correlation between Level I and Level II inspection times is reasonable. The amount of time necessary to complete a Level I inspection is based on elevator size, amount of activity, and ease of access. In addition to the above factors, Level II time was dependent upon extent of control application, availability of elevator personnel, and willingness of elevator personnel to allow plant access. Given the wide variation in inspection time resulting from these factors, the lack of correlation is not surprising.

Another factor that affects the cost of Level I and Level II inspections is the amount of driving time between elevators. In order to examine this factor, the number of Level I inspections that could reasonably be completed during a day was examined. First, a route was established for the Level I inspector that would allow him to inspect the subject elevators in the same half-day as the Level II inspectors. The Level I inspector was then instructed to perform additional inspections of any elevator along the route. During one 6 hr day, nine inspections including two Class D elevators, were performed. During another 8 hr day, 14 inspections (mostly Class B and C) were performed. Other elevators were sighted during the day but were not inspected in order to meet the Level II schedule. Based on these observations, it is expected that at least 12 and possibly as many as 15 to 20 Level I inspections can be performed in a day. This compares with a maximum of four Level II inspections that could be performed.

Limited data are also available on the cost of Level III inspections. An in-depth type inspection of an elevator fabric filter can require as little as 30 min or as much as 3 hr. The average time requirements during the study were 1 hr, 20 min per filter. During the study it was observed that the two man inspection teams became more efficient after performing two to three elevator inspections and that a second inspection at the same filter usually required less time than an initial inspection. Another factor affecting inspection time requirements is the availability of elevator personnel to assist the inspection teams in energizing or de-energizing a filter system, opening hatches, and locking out electrical components. During the study, PEDCo inspectors were required to wait 20 min at one elevator and 1 hr at another for a plant maintenance man to assist in the inspections. Both of these delays occurred at country elevators during the harvest season.

An in-depth style inspection requires field equipment costing between $500 and $750. Items required include pitot tubes, portable magnehelic guages, a clamp-on ammeter, a phototachometer, a dial thermometer, plus miscellaneous hand tools. Inspectors should also carry proper safety equipment including hard hats, ear protection, dust respirators, and safety goggles and they should be instructed in safety procedures to be used during confined entry situations and in areas subject to dust explosions.

One additional cost factor is the number of persons required to conduct the inspection. Level I inspections can be conducted by only one inspector and require no assistance from elevator personnel. Level II inspections can also be performed by one person. However, for reasons of safety, it is necessary that the inspector be accompanied by elevator personnel or by another inspector. Level III inspections require two persons to conduct the inspection and the assistance of one elevator operator to operate the control equipment.

Effectiveness of Inspections

The comparison of the effectiveness of Level I and Level II inspections was judged by two criteria: (1) the ability to locate and monitor control device exhausts; and (2) the ability to accurately determine compliance status. The ability of the inspector to locate and monitor control device exhausts was first measured by the number of control devices at an elevator and the number of control devices in use. However, the number of control devices in use were found not to differ significantly from a random subset of the total number of control devices. Therefore, the measure was reced to simply the number of control devices identified. The results of the analysis are presented below.

There is a significant association between Level I and Level II findings on identifying the number of control devices. Level I inspections recorded 74% of the control devices (63/85) recorded in Level II inspections, with five false positives and 27 false negatives. Therefore, a Level I identification provides a good estimate of the number of control devices installed.

The number of control devices is dependent on elevator size so that cost/benefit expressions were related to elevator class. Specifically:

- For Class A elevators, Level I will identify 50% of the control devices with no false positives. (Note that since only two control devices were identified in Class A, the results are questionable.)

- For Class B, Level I will identify 100% of the control devices with 16% false positives.

- For Class C, Level I will identify 88% of the control devices with no false positives.

- For Class D, Level I will identify 68% of the control devices with 10% false positives.

The results presented above were supplemented by the following observations of inspectors. First, as suggested by the data, control equipment is often difficult to locate in Class D elevators as it is often located between rows of bins or on top of dump pits not visible from the property line. Second, Level I inspectors noted that for all size elevators, the operating status of control equipment with no visible emissions located on top of the headhouse could not be determined. Thus, the Level I inspector could not determine whether the equipment was operating in compliance or not operating. Thus Level I inspection often can only determine that the source is "not operating out of compliance" rather than that the source is in compliance. The ability to make such a determination is a benefit of Level II which cannot be measured statistically.

The second evaluation criteria was the ability of the inspection to determine compliance. As indicated earlier, the levels of inspection concept assumes that any elevator out of compliance at Level I will be out of compliance at Level II. Therefore, the relative effectiveness of Level I and Level II were examined by statistically testing Level I as a predictor of Level II. Only about 17% (7/36 by Level I, 5/36 by Level II) of the elevators were determined out of compliance. The proportion does not vary significantly with elevator class, based on the X^2 test. In other words, the compliance factor is independent of elevator type. This statement must be somewhat tempered by the fact that the sample size is small for identifying any such variation.

Of the seven Level I "positives" and the five Level II "positives," only one match (elevator where both methods agree on out of compliance) is observed. This one occurrence can be expected by chance (35/36). In other words, the result of a Level I inspection does not predict the outcome of a Level II compliance determination.

Based on the above analysis, the immediate conclusion is that Level I inspections are of little value in predicting compliance (assuming the Level II conclusions are the "true" indicator). However, a more careful analysis of the data leads to a different conclusion. Of the 11 cases of noncompliance identified during Level I and Level II inspections, all were a result of emissions from an uncontrolled source, either an elevator with no control or an uncontrolled operation at an elevator with some control. Thus, all controlled operations were found to be in compliance by both Level I and Level II data.

The information presented above leads to a revision of the original conclusion. For controlled grain elevator operations, the data gathered during the field program are not sufficient to determine the relative effectiveness of Level I and Level II inspections in enforcing against opacity violations. This lack of data on controlled elevators resulted in part from an incorrect assumption during the development of the protocol that all Class B and some Class A elevators would have some type of emissions control. The lack of data was also a result of the absence of noncompliance for controlled elevator operations.

For uncontrolled sources, several conclusions might possibly be reached. The first is, as before, that Level I inspections are of no value in predicting noncompliance (again assuming Level II identifies "true" noncompliance). However, if the data are analyzed under the assumption that both Level I and Level II correctly identify "true" noncompliance, a different conclusion is reached. The conclusion is that for uncontrolled grain elevator operations, noncompliance with respect to visible emissions, is not a continuous status but is a discrete occurrence, dependent on a factor or factors other than the specific operation.

This conclusion is supported by inspector observations and comments from elevator and control agency personnel. During the inspection of one elevator, a MRI inspector observed a series of four truck dumps into a pit open on all four sides. Opacity ranged from less than 10% to 50% with two loads in violation of the 20% standard and two loads in compliance. In addition, elevator and control agency personnel identify some grains as being dustier than others. All this appears to indicate that determination of noncompliance of uncontrolled sources based on opacity will be a somewhat random selection and may often be dependent upon factors outside the elevator's control. This conclusion is supported by the results of Level I and Level II inspections.

The above analyses lead to the following conclusions:

- Level I inspections can be performed in much less time than Level II inspections (with possibly three to four times as many inspections performed on a daily basis).

- Data are insufficient to compare the effectiveness of Level I and Level II with respect to controlled operations.

- Determination of visible emissions compliance of uncontrolled sources (by Level I or II) will probably result in a random selection of elevators for enforcement action, regardless of level used.

Other Benefits of Inspections

Observations of the inspectors indicate that Level II and Level III inspections have benefits which were not measured as part of the analysis performed above. Level II has two additional advantages over Level I. First, as indicated earlier, access to the control equipment will allow the inspector to determine if the equipment is operating in compliance or not operating. If the equipment is not operating, it is possible for the inspector to request that the system be started to ascertain that it is at least mechanically operable. In light of the condition of some of the equipment inspected, this knowledge is certainly beneficial.

The other advantage of Level II is that by entering the elevator, the inspector will obtain some information on operating practices. Poor housekeeping or excessive dust around ventilated operations are signs of possible control problems. An elevator in which such conditions exist should be monitored carefully.

One additional observation of the Level II inspectors was that cooperation was generally hard to obtain. It was felt that this was due primarily to the harvest time demands on the operator. It is recommended that Level II observations not take place during harvest.

The benefits of Level III inspections were not considered as a part of the statistical analysis. However, several advantages of the procedure were identified by the Level III inspectors, including a determination of noncompliance with the malfunction regulation which was not identified by Level I and Level II inspections. Other benefits of the Level III inspections are described below.

The in-depth Level III procedures uncovered many fabric filter problems that were not apparent after the Levels I and II procedures had been completed. Seven filters were not visible from outside the plant boundaries (Elevators 1, 2, 4, and 8) and consequently could not be evaluated by Level I procedures. Level III inspections uncovered five faulty differential manometers which appeared to be operative when judged by Level II procedures (Elevators 4, 5, 6, and 7). Finally, the Level III procedures uncovered serious bag blinding and hopper plugging problems at one filter, which were not apparent after the Level II inspections (Elevator 8). Discovery of the blinding and plugging problems prompted the management of the elevator to initiate early repairs. These malfunctions may not have otherwise been discovered until the filter system had deteriorated into further disrepair.

The in-depth inspection seems appropriate for establishing base-line operating data for a properly operating filter system. Measured base-line values for fan power usage, fan rotation speed, pulse air tank pressure, or differential pressure across the filter medium can be used for comparison at a later date to provide a quick indication of operation or maintenance problems in the filter. The in-depth inspection can be used to document broken or missing bags, blinded bags, plugged hoppers, or poor bag cleaning; these problems often contribute to increased process or fugitive emissions. Finally, the in-depth inspections will indicate the overall level of maintenance performed on a filter. Estimates of filter reliability can be made by noting the condition of the filter and its appurtenances such as the fan, dust conveyors, and instrumentation. Evidence of poor maintenance is an indication that the reliability of a filter is low and that the inspector should schedule frequent visits to the facility.

AN ALTERNATIVE APPROACH TO ENFORCEMENT AND COMPLIANCE MONITORING

The experimental compliance monitoring strategy was modified to reflect the information obtained from the field evaluation. As a result of the difficulties encountered in applying the original strategy during the field inspections, it was decided that a general enforcement/monitoring approach should be developed. In addition it was decided that a generalized approach to developing an enforcement/compliance monitoring strategy had greater value than developing a detailed strategy. The following discussion outlines the key elements of the approach, the approach is then applied to those elevators inspected during the field evaluation.

The initial focus of the approach is the precept that a compliance monitoring strategy cannot be developed apart from an overall enforcement strategy. The inspection of Class A elevators in Nebraska for visible emissions regulations in the absence of a commitment to control these elevators, even if a violation occurred, is an example of the fallacy of inconsistent monitoring and enforcement strategies. Thus, before a monitoring strategy is developed, the basic enforcement approach should be known.

The two elements of enforcement policy which must precede compliance strategy development are the criteria upon which compliance is determined and the desired enforcement response to a noncompliant source. Compliance criteria include:

- Regulations to be enforced
- Facilities subject to enforcement
- Operations subject to regulation

Possible enforcement reactions include:

- Fine for noncompliance
- Require additional control on noncompliant operation
- Prohibit source from operation until noncompliant problem is solved
- Allow source variance from compliance

The development of a specific enforcement strategy for grain elevators is not within the scope of this study. However, the data compiled from the literature and the field evaluation lead to several observations which may be useful to federal, state, and local officials in developing specific strategies.

It is quite likely that any enforcement strategy will depend heavily on visible emissions regulations. Two factors should be given careful consideration in determining the role of visible emissions regulations in the enforcement strategy. First, data from the field evaluation indicate that short term observation of opacity at an uncontrolled source is not an indicator of the continued compliance status at that source. All uncontrolled sources have the potential for incidences of opacity violations. Thus, it is recommended that enforcement of compliance for uncontrolled grain elevator operations not be based on visible emissions regulations.

A second factor to consider is the relationship between opacity and grain loading. Data from Section 4 indicate that a grain loading of 0.025 gr/scf or less is needed to attain an opacity of ≤ 20%.[11/] This makes an opacity regulation of 20% more stringent than any of the concentration regulations identified. In addition, data from Appendix B (Tables B-8, B-9, B-10, and B-11) indicate that most cyclones operating at 85 to 97% efficiency cannot produce a concentration of ≤ 0.025 gr/scf. As a result, cyclone outlets will quite likely violate a 20% visible emissions regulation. It is apparent, then, that a 20% opacity regulation for all sources will force the use of fabric filters on all grain elevators. Given the maintenance problems associated with fabric filters at small elevators that were found during the field evaluation, the requirement of fabric filters at all elevators may not lead to best continuous control of grain elevator emissions.

Also investigated during the study was the use of emission factors to enforce process weight regulations. Three basic problems were encountered. First, the range in emissions factors is so large that the use of an average emission factor for a particular elevator is questionable. Second, if the average emission factors are used (about 10 lb emissions/ton of grain handled) every uncontrolled elevator is noncompliant with all process weight regulations identified during the study. Finally, no feasible method was found to determine control system efficiency to enforce the process weight regulations for controlled sources. It does not appear to be feasible to enforce process weight regulations except through emissions testing of controlled operations. In addition, random application of process weight regulations, in the absence of other criteria, to force installation of control systems will result in uneven enforcement.

Given the problems associated with enforcing opacity and mass emission regulations, it is suggested that an initial determination be made on the degree of control required for a particular elevator. Such a determination should specify the operations to be controlled and extent of control required. The basis for the determination may include such factors as elevator size, elevator location, the potential emissions from various operations (based on emission factors), and the degree of emissions reduction anticipated from the control option. The criteria described above can be combined in a number of different decision-making scenarios that may be appropriate for a particular jurisdiction. It is important that an agency develop a decision scheme that can be applied uniformly (or at least on a logical basis) to all grain elevators located within the agency's jurisdiction.

Finally, the results of the field evaluation indicate that visible emissions are an adequate initial indicator of compliance for controlled operations. However, Level III inspections indicate that other enforcement tools may be necessary to insure proper continuous functioning of the control equipment. It is suggested that an enforcement strategy be based on a combination of opacity regulation and some type of housekeeping/equipment regulation which would regulate proper operation and maintenance of control equipment.

After the enforcement strategy has been completed, a compliance monitoring strategy can be developed. The results of the field evaluation indicate that the Levels of Inspection concept has value in saving inspection time and providing a reasonable analysis of compliance. However, the initial scheme was modified to reflect the results of the field evaluation.

A suggested inspection matrix is shown in Table 5. The matrix is based on the following premises in addition to the basic precepts described earlier:

1. Uncontrolled emissions sources are not monitoried for compliance with fugitive dust and opacity regulations.

2. Level II and Level III inspections should never be performed on country elevators during harvest season.

3. Level I and Level II inspections should obtain sufficient data to assure that the status of the grain elevator with respect to control requirement criteria has not changed.

It is suggested that the monitoring strategy also include a form to be mailed in annually by operations. This form (referred to as "Level 0") would provide the data on which control/no control decisions are based. The Level I and Level II inspections can be used to check submitted data.

Based on the above considerations, an alternate inspection monitoring strategy was developed for those elevators inspected during the field evaluation. This strategy does not reflect the practices of any particular state or local agency nor is the specific strategy necessarily recommended practice for state or local agencies. Rather, it is included to illustrate the type of decision making process that can be used in the development of an enforcement/monitoring strategy.

The general monitoring strategy for the elevators inspected during the field study is presented in Figure 2. To develop this monitoring strategy, the following assumptions were made regarding the enforcement strategy.

- All Class A elevators and those Class B elevators located in attainment areas require no emissions control. All other elevators will require some type of emission control.

- Regulations are available which can require installation and proper operation of control equipment.

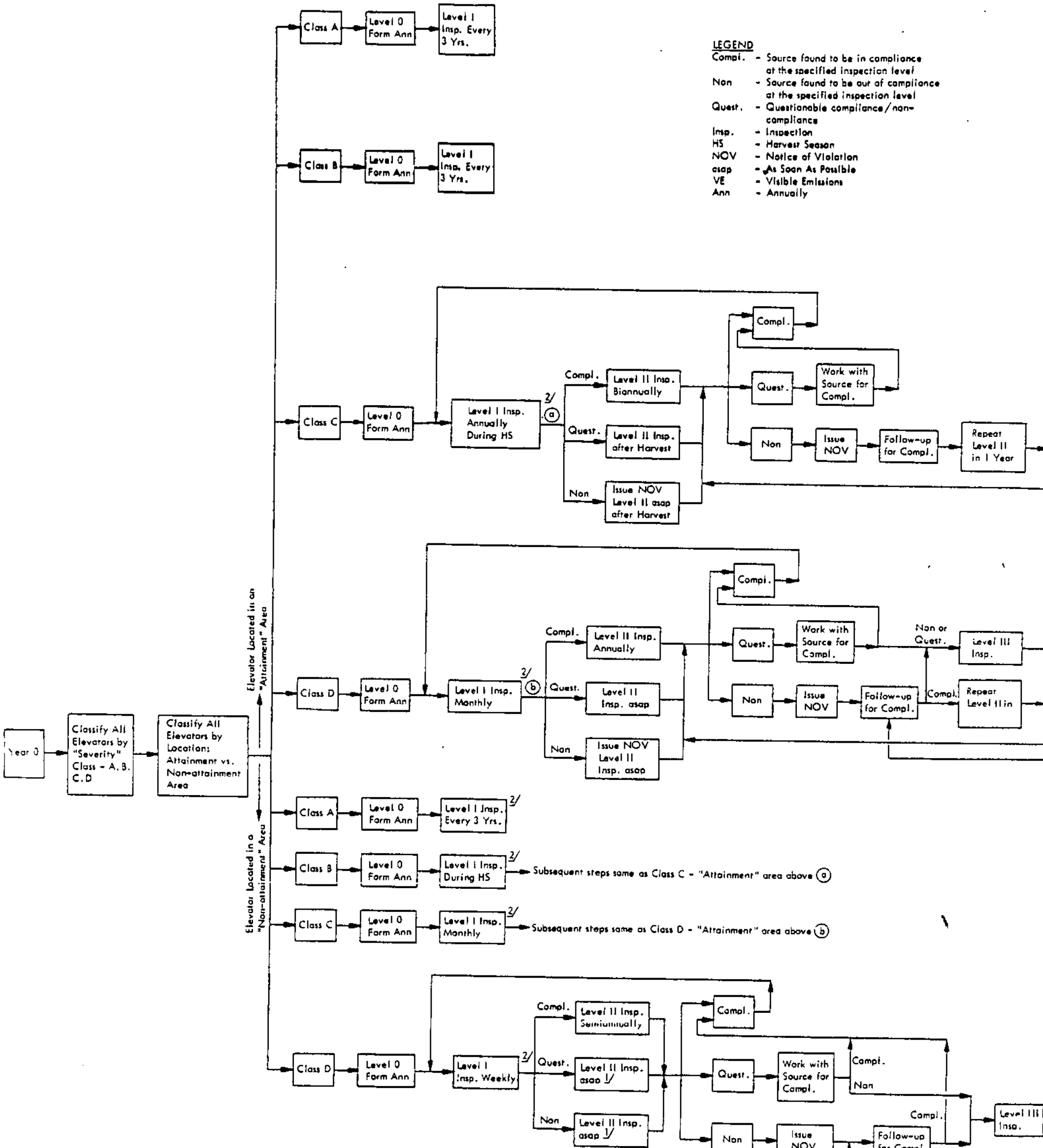
- Visual evidence of excess dust or inefficient capture in the vicinity of controlled operation is evidence of improper operation and a violation of regulations.

- Sources are required to submit "Level 0" information forms which contain sufficient data to characterize elevators regarding control requirements.

TABLE 5. TEST MATRIX OF THREE-LEVEL INSPECTION STRATEGY FOR GRAIN ELEVATORS

Parameters	Level I	Level II	Level III
Time of Inspection/Season	"Peak" season: Harvest season - for elevators receiving grain directly from farms. This may include country elevators and some terminals. At normal volume of activity - for "non-seasonal" elevators.	Off-season for "seasonal" elevators. For other elevators, at normal volume of activity. (Including those affected by weather[a])	Generally during off-season but at reasonable volume of activity.
Coverage	All elevators	• All elevators under the third level of severity category, i.e., Class C and D elevators • Elevators under the first and second level of severity category, k.e., Class A and B, will be inspected only if found in violation at Level I inspection	Only those elevators which were found in violation at prior inspection levels and if subsequent warnings failed to result in compliance
Elevator Operator's prior knowledge of inspection, i.e., announced or unannounced	Unannounced	Unannounced	Unannounced
Inspection Mode	Walk-around the elevator property line if feasible. If not, enter the property after informing the elevator operator (Class C and D).	Walk-in through the various internal and "open" operations after informing the operator on arrival.	Complete inspection of dust control system after informing the operator on arrival.
Need for elevator operator's time and accompaniement with inspector	No	Yes	Yes
Checklist	(1) Visible emissions check at the following points: • Controlled operations • All control equipment outlets. (2) If any or all of the above points is found likely to be out of compliance, a short test for opacity (about 3-5 min observation) should be done on the "worst" of the above emission points to determine if the source is in violation. If so, a notice should be issued. (3) Criteria for control level determination.	Checklist will include the following parameters related to dust emissions: • Opacity as in Level I • Ventilation/containment systems • Control equipment size (e.g., air/cloth ratio), and operation (e.g., P, inspection ports, valve plugging). • Housekeeping If the completed checklist indicates that the source is in violation of a specific regulation, a warning should be issued to that effect.	Complete inspection of ventilation equipment, dust containment, ducts, and dust control equipment to determine the effectiveness, deficiencies, and needed improvements/modification to meet the applicable regulations.
Estimated inspector's time requirements	(1) 15 min. If necessary, (2) will require and additional 15 min.	About 1/2-3 hr depending on the size of the facility, extent of control system, etc.	1/2-1 day depending on the source size, control system, etc.

a/ e.g., elevators located in some of the Great Lakes areas are not operational during winter due to lake freeze-up. In such cases, Level II inspection will be done during normal operational period.



1/ Level II inspection subject to - "upset" conditions. continued violation at Level I (i.e., Level II only if the source is found Quest. or Non 3 or 4 weeks in a row) and compliance schedule set for the source.

2/ Should a complaint be received, the agency will initiate a Level I inspection as soon as feasible and continue the process from that point.

Figure 2 - Revised compliance monitoring strategy.

APPENDIX A

GRAIN ELEVATOR INDUSTRY CHARACTERIZATION

INTRODUCTION

Grain elevators are involved in the transfer, conditioning, and storage of grains and other agricultural products (primarily soybeans) as they are passed from the farmer to the final processing or exporting facility. As a result of the dispersal of agricultural operations throughout the country, the grain elevator industry potentially impacts on the ambient air quality throughput in the United States.

This section presents the background data on the industry which can be used to help determine the impact of the industry on various areas of the country. The first subsection provides a brief description of the industry structure. The second section describes the operations which can be found in a typical grain elevator.

INDUSTRY STRUCTURE

The primary function of the grain elevator industry is to assist in the movement of grain from the farmer to the processor or exporter. Although the operations conducted at each grain elevator are similar, the elevators are divided into various classifications according to their size, source of grain, and destination of shipments. The paragraphs below describe the classification system that is used for grain elevators and identify characteristics such as size, location, and number of elevators associated with each class.

The U.S. Department of Agriculture identifies two classes of elevators; country and terminal, on the basis that terminal elevators furnish USDA official weights under the supervision of a state inspector. However, the generally used definitions are not so precise. Country elevators are defined as those elevators which receive the bulk of their grain directly from the farm. Terminal elevators are those which ship grain directly to a processor or export the grain. These elevators are often classified as either port or inland terminals. These classifications methods result in a third class of elevators, subterminals. These are elevators which receive the bulk of their shipments from country elevators, but still receive a significant amount of grain from farms. These elevators ship grain to terminal elevators or directly to processors. It must be noted that these definitions are not precise and there is some ambiguity in classifying grain elevators.

In general then, grain moves from the farmer to a country elevator. From there, it goes to a terminal elevator (possibly through a subterminal) and is then shipped to a processor or exported. Typical pathways for wheat, feed grains, and soybeans are shown in Figures A-1 to A-3.

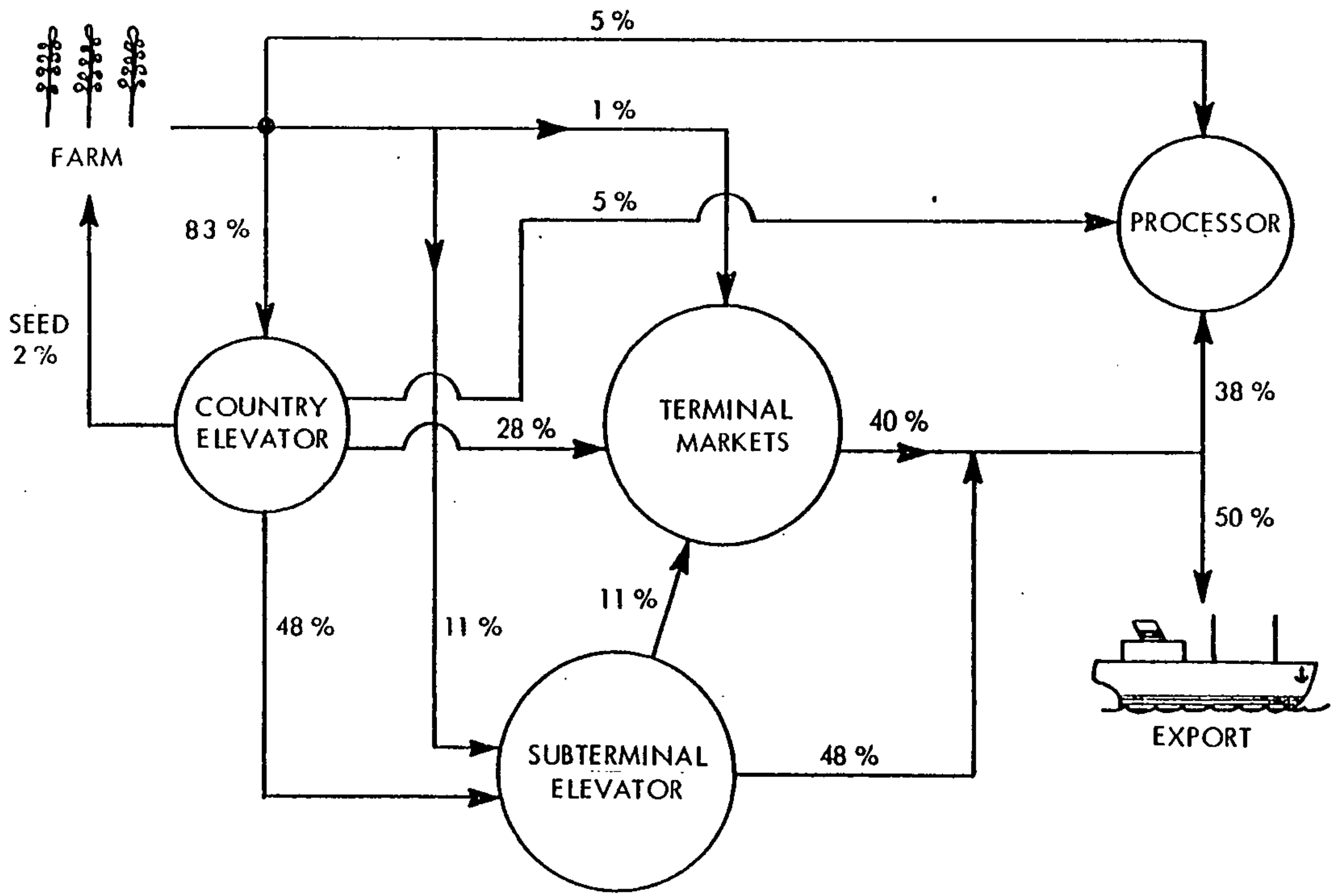


Figure A-1 - Flow of wheat from farm to market.15/

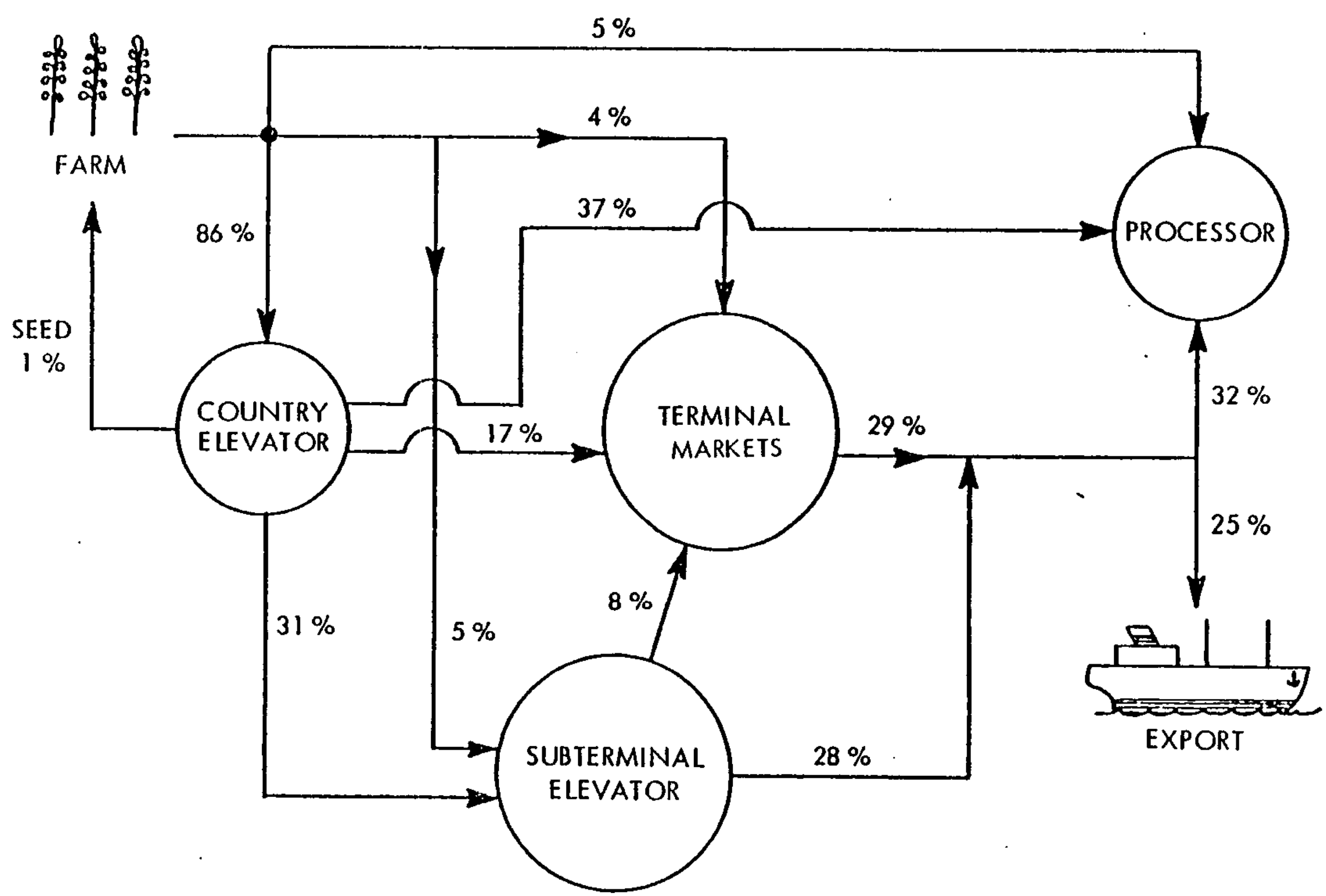


Figure A-2 - Flow of feed grains from farm to market.15/

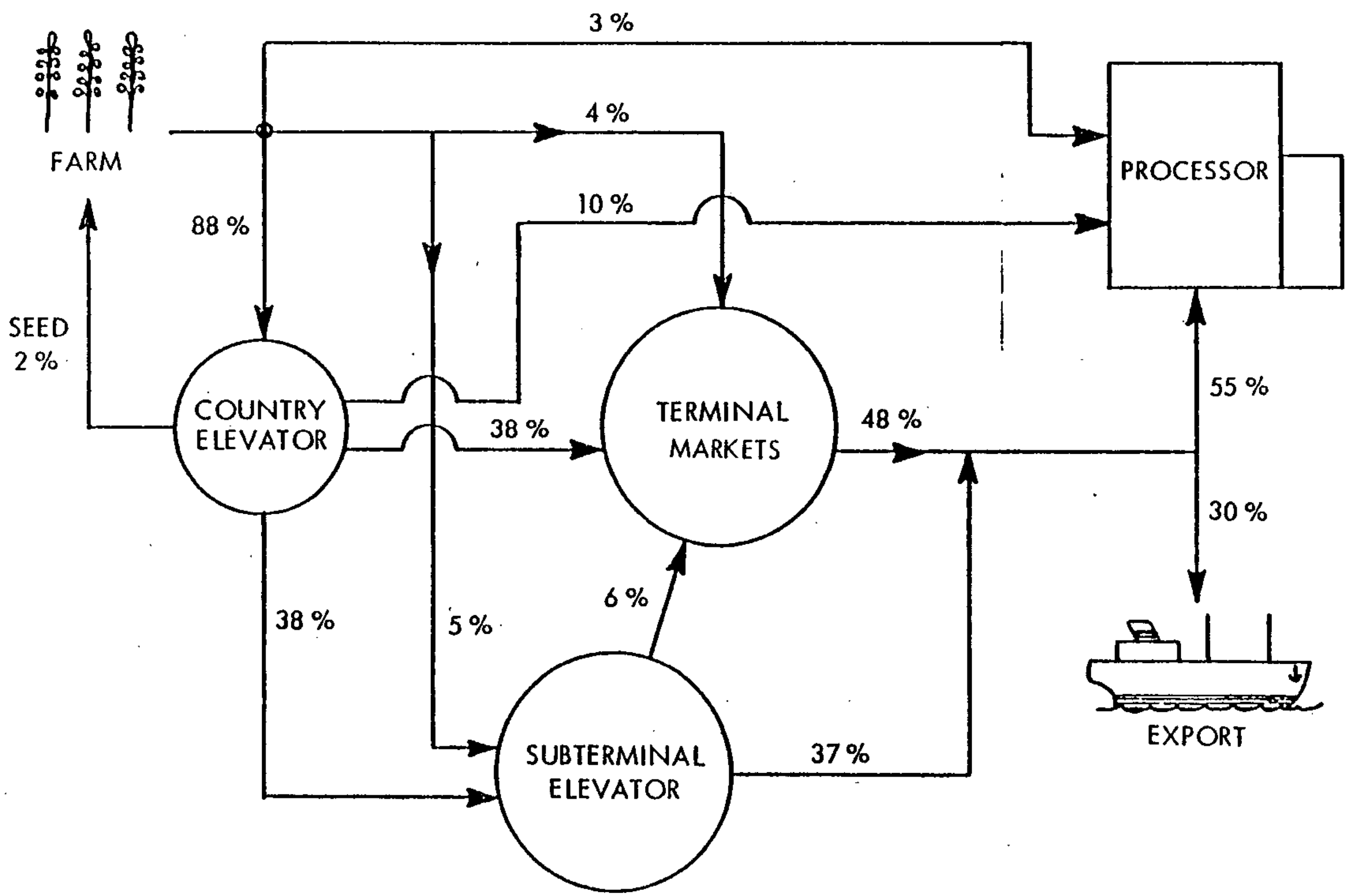


Figure A-3 - Flow of soybeans from farm to market.15/

Precise data are not available on the number, size, and location of grain elevators. The USDA has contracts with many elevators to handle government and price supported grain. The number and capacity of these elevators on a state basis is presented in Table A-1.[16] A total of 6,287 country elevators and 381 terminal elevators are reported by USDA. However, an earlier study by MRI compared the number of country elevators reported by USDA to those listed by State feed and grain associations for 13 of the largest grain producing states.[2] The associations reported 1.306 times as many country elevators as the USDA. Using this multiplier, the total number of country elevators is estimated to be 8,210. A document prepared by the National Grain and Feed Association in 1977 indicated that there were 540 terminal elevators divided into 413 inland terminals, 45 high throughput terminals, and 82 port terminals.[17] Thus, the total number of existing grain elevators is estimated to be about 9,000. We are aware that state and local agencies may have more accurate estimates of elevators. However, such detailed analysis was not within the scope of this study. Additional studies are being conducted by EPA to obtain better identification of grain elevators.

Based on the data in Table A-1, the average storage capacity of country elevators is about 6×10^5 bushels and the average capacity of terminals is about 4.4×10^6 bushels. However, there is significant variation in capacity across the industry. Reference 2 estimated the percentage of country elevators in each size category as follows:

Elevator size (10^3 bu)	Percent of country elevators
0-100	30.8
101-400	45.3
401-600	9.9
601-2,000	14.0

Terminal elevators also vary in size. Capacities in excess of 50 million bushels have been built at a single location. This includes bins, storage tanks, and storage in warehouse type facilities which have been added to the original facility. One facility has a total of 18 million bushels capacity under one roof.[2]

Another measure of "size" of grain elevators is the annual throughput, i.e., the total amount of grain handled by an elevator during a year. The ratio of grain handled to capacity varies between elevators and at each elevator from year to year. The variation at country elevators is primarily dependent upon the amount of grain harvested in the area during the particular year and upon the accessibility of shipping capacity to the elevator.

TABLE A-1.[16] NUMBER AND LOCATION OF GRAIN ELEVATORS[a]

Location	Country elevators		Terminal elevators	
	Number	Capacity (10^3 bu)	Number	Capacity (10^3 bu)
Region I	1	228	-	-
Connecticut	-	-	-	-
Maine	1	228	-	-
Massachusetts	-	-	-	-
New Hampshire	-	-	-	-
Rhode Island	-	-	-	-
Vermont	-	-	-	-
Region II	-	-	6	34,850
New Jersey	-	-	-	-
New York	-	-	6	34,850
Region III	13	6,405	7	22,284
Delaware	4	2,930	-	-
Maryland	3	1,046	2	9,370
Pennsylvania	5	2,399	2	2,621
Virginia	1	30	3	10,293
West Virginia	-	-	-	-
Region IV	202	120,450	10	33,355
Alabama	18	14,544	-	-
Florida	5	2,607	-	-
Georgia	52	21,332	-	-
Kentucky	17	10,945	3	9,787
Mississippi	24	16,278	3	15,681
North Carolina	30	22,829	1	497
South Carolina	26	8,300	-	-
Tennessee	30	23,615	3	7,390
Region V	1,507	957,117	90	441,018
Illinois	608	523,189	22	122,604
Indiana	147	105,645	6	40,462
Minnesota	488	186,800	30	148,279
Michigan	83	37,983	3	12,023
Ohio	144	88,846	22	72,107
Wisconsin	37	14,654	9	45,540

TABLE A-1.[a] (Concluded)

Location	Country elevators		Terminal elevators	
	Number	Capacity (10^3 bu)	Number	Capacity (10^3 bu)
Region VI	763	682,605	90	441,757
Arkansas	101	128,731	8	39,917
Louisiana	27	22,493	6	39,679
New Mexico	14	16,205	-	-
Oklahoma	202	118,826	15	76,859
Texas	419	396,350	61	288,302
Region VII	2,351	1,412,574	132	583,443
Iowa	766	496,525	23	55,514
Kansas	805	472,363	56	320,720
Missouri	198	92,494	20	80,281
Nebraska	582	351,192	33	126,928
Region VIII	1,161	304,551	23	45,877
Colorado	92	55,478	6	13,292
Montana	218	42,719	4	4,405
North Dakota	516	124,548	7	16,226
South Dakota	314	77,720	1	2,242
Utah	3	970	5	9,712
Wyoming	18	3,116	-	-
Region IX	43	49,070	5	20,140
Arizona	13	10,106	-	-
California	30	38,964	5	20,140
Hawaii	-	-	-	-
Nevada	-	-	-	-
Region X	243	231,331	16	51,180
Alaska	-	-	-	-
Idaho	113	55,722	1	732
Oregon	50	38,511	5	14,369
Washington	83	137,098	10	36,079

a/ The elevators represented in this table are those having Uniform Grain Storage agreements with the U.S. Department of Agriculture. The number of country elevators reported is generally low. A better estimate can be obtained by multiplying the number of country elevators by a factor of 1.306 (see text). Note that the number of terminals may also be low according to estimates of National Feed and Grain Dealers Association shown on p. 43.

The volume of grain handled by inland terminals is dependent upon a number of factors, such as quantity of grain harvested, Commodity Credit Corporation movements of grain, quantity of exports, and marketing channels used by grain merchants and processors. In addition, the quantities of grain handled by a specific terminal elevator are affected by transportation and location factors. Because of favorable transportation rates, greater quantities of grain are being shipped from inland terminals by barge. As a result, terminals which are located on navigable waterways are handling a relatively greater volume of grain than terminals which have available only rail and truck transportation.

Typical ratios of grain handled to storage capacity are shown below:15/

Country elevator	2.0:1
Inland terminal	1.4:1
Port terminal	7.6:1

GRAIN ELEVATOR OPERATIONS

Country Elevators

The definition of a country elevator appears to be somewhat arbitrary. However, for the purposes of this discussion, a country elevator will be defined by the following characteristics:

1. Receives grain by truck only, primarily from farmers.
2. Receiving leg handling capacity of 10,000 bu/hr or less.
3. The stored grain is shipped out by truck and/or rail.

Country elevators range in storage capacity from 15,000 bu to more than 2 million bushels. These elevators receive and store the grain with subsequent shipment to terminal elevators, mills, and other processing plants. In addition to storage, the country elevator sometimes includes facilities to clean the grain or to dry it or both.

The grain received at the country elevator is primarily received from the farms that are within a 10-12 mile radius. The trucks which transport the grain from the farm to the elevator usually range in size from 50-300 bu with the average capacity being 200 bu.

The country elevator often consists of upright concrete bins, but wooden bins and flat storage are also common. A cut-away diagram of a representative upright country elevator is shown in Figure A-4. These elevators are usually

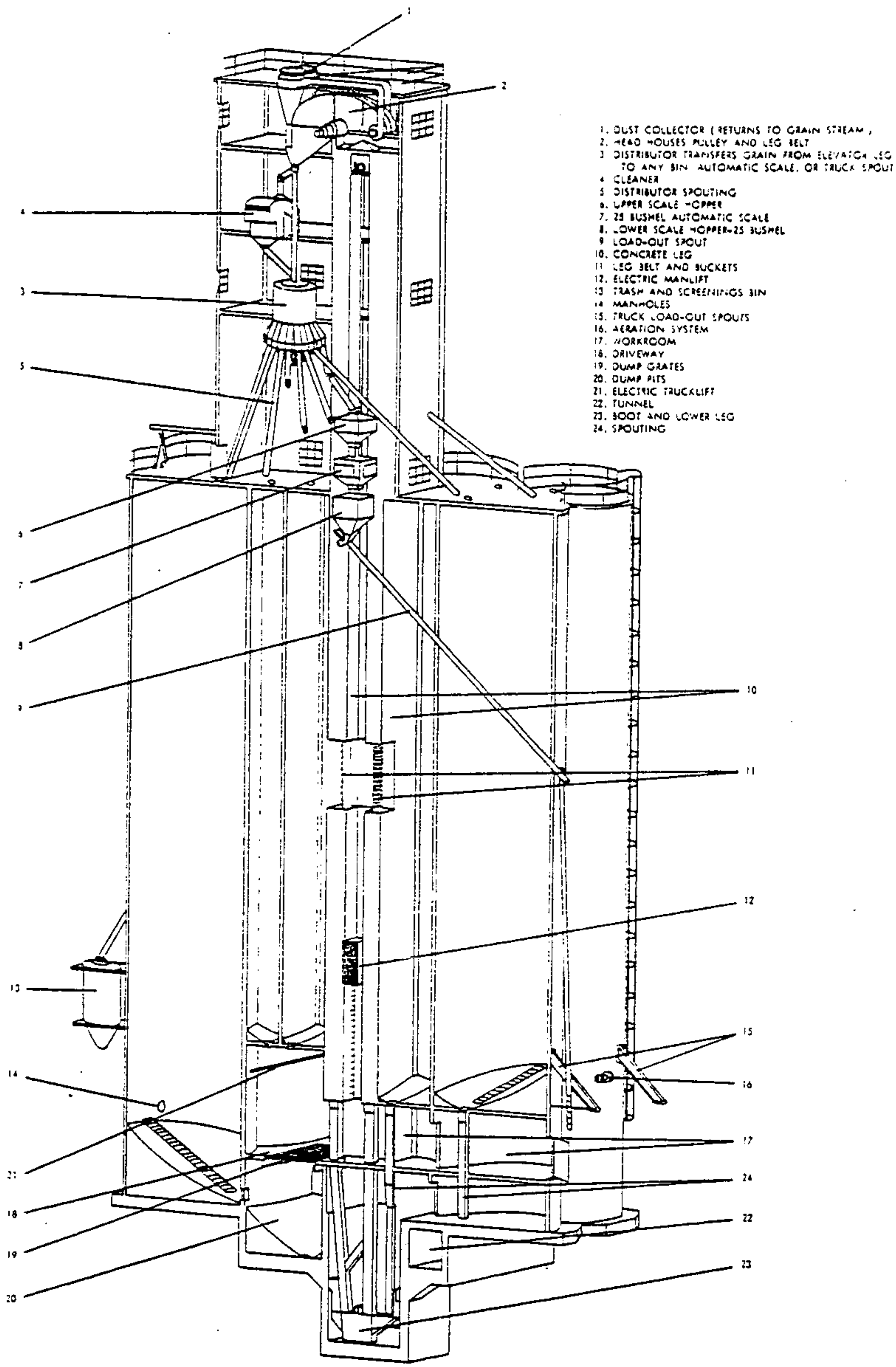


Figure A-4 - Diagram of upright country elevator.

designed to make maximum use of gravity flow to simplify the operation and minimize the use of mechanical equipment. The major piece of mechanical equipment required is the bucket elevator, or "leg," which elevates the grain to the top of the elevator where it is discharged into the distributor head and then directed to the desired bin or into the scale for direct load out. The section of the elevator which performs these functions is referred to as the "headhouse."

The first step in handling the grain after it arrives at the elevator is to weigh-in the loaded truck. After weigh-in, the truck is driven to the unloading station which is often a drive-through tunnel in the center of the elevator similar to that shown in Figure A-4. The trucks are usually unloaded by lifting the front end of the truck with an overhead wench system or hydraulic platform. This causes the grain to flow out the opening in the back of the truck from which it falls through a grating into the receiving pit hopper. Following completion of the unloading and lowering of the truck, the truck is driven back to the scales and reweighed to determine the quantity of grain received.

The grain dumped into the receiving hopper usually flows by gravity to the bottom of the bucket elevator (i.e., the elevator boot). In some cases, the grain is transported from the receiving hopper to the boot by means of belt, drag, or screw conveyors.

The receiving leg, averaging 5,000-7,000 bu/hr, elevates the grain to the top of the headhouse where it is discharged through the distributor head. The distributor head is positioned to direct the grain into the appropriate storage bins or to the cleaning equipment. Grain received from the farm usually contains a variety of impurities and a cleaning operation is sometimes performed prior to sending the grain to storage bins. Various types of screens and aspiration systems can be used to clean the grain.

To remove the grain from the storage bins for load out, it usually flows by gravity back to the elevator boot and is reelevated and discharged through the distributor. This time, however, the distributor may direct the grain in any of three possible ways:

1. The grain may be directed to the interstice bin located directly above the drive-through tunnel and the waiting truck may be loaded at the same position where unloading takes place.

2. The grain might also enter the distributor and fall directly through the load-out spout to a waiting truck or railroad car.

3. The grain is directed to a scale hopper, batch weighed in the scale, and then released through a load-out spout to a waiting truck or railroad car.

An alternate method of loading that is sometimes used is direct loading from individual bins by means of spouts that protrude through the walls of the bins. The usual procedure in this case is to use the scale hopper for both trucks and railroad cards and the interstice bins above the drive-through tunnel for trucks.

The design of many country elevators is similar to that shown in Figure A-4, but many often include an annex storage facility. This annex may consist of several additional bins or a "flat storage" tank or building. In either case, both of these usually serve only as extra storage capacity. This configuration requires installation of a gallery belt and "tripper" to convey the grain from the discharge of the receiving leg to the annex storage bins, and a "tunnel belt" under the bins to convey the grain from the bins back to the boot of the elevator leg.

Certain grains, especially corn, must be "dried" before long-term storage. Elevators that receive grain for long-term storage are equipped with grain drying facilities. Grain dryers generally require the addition of a second leg to elevate the wet grain from intermediate storage bins to the top of the dryer, and a means of conveying the dried grain from the dryer back to the primary leg for elevation to final storage. Grain dryers come in a wide range of capacities, and the size installed in country elevators is dependent upon the quantity of wet grain that is expected to be processed. A typical installation would probably be one dryer with a capacity of 500-1,000 bu/hr.

Terminal Elevators

For the purposes of this discussion, a terminal elevator is assumed to have the following characteristics:

1. Receives grain by truck and rail and may include receiving by barge if located on a navigable river.

2. Receiving leg capacity of 35,000 bu/hr or more.

3. Grain shipped by rail, barge, or ship.

Terminal elevators can be subdivided into at least the following categories:

1. Inland terminal elevator--functioning as a storage or transfer house. Some of the receipts or shipments may be by barge in addition to rail and truck.

2. Export terminal elevator--located at a seaport. Receives grain by truck and rail and possibly barge with shipments by ship.

Storage capacities in terminal elevators are typically in millions of bushels. Capacities in excess of 50 million bushels have been built at a single location. These can include bins added to an original structure or storage in warehouse-type buildings--so-called "flat storage." The largest capacity at a single location under one headhouse is 18 million bushels.

The primary sources of grain received at many terminal elevators are the country elevators. One of the major functions of the terminal operation is to receive the differing grades of grain from the country elevators and to blend these grades so they are suitable for shipment from the terminal to the processor or user.

Another major function of some of the terminal elevators is to receive grain from surrounding country elevators and to ship this grain to other terminal elevators. These are sometimes referred to as "subterminal elevators" and they usually handle large quantities of grain thereby gaining advantage of lower freight rates for large rail shipments or shipment by barge. These elevators may handle up to 20 times their storage capacity each year.

The export terminal elevators receive much of their grain from inland terminal elevators, and these grains are blended and loaded into ships for export.

Because of the large storage capacity and high grain handling rates in terminal elevators, belt conveyors are generally used to move grain in these elevators. Figure A-5 illustrates a flow diagram for a representative terminal elevator. The steps in the grain-handling process at a terminal elevator are similar to those in a country elevator. The first step is the unloading of semitrailer trucks, box or hopper railcards, and, in some cases, barges. The truck unloading system usually consists of one or two (or more) drive-through unloading sheds located alongside the elevator. The semitrucks are driven into the shed and onto a hydraulic lift platform with the back of the truck positioned over the unloading grate. The hydraulic lift is then raised to tilt the truck and the grain flows out the back, through the grate, into the receiving pit. The grain is transported from the receiving pit or hopper by belt conveyor (or in some cases, by screw or drag conveyor) to one of the belt conveyors or elevating legs in the basement of the elevator. The truck receiving hopper may have a capacity of 1,000-1,200 bu which is sufficient to handle the largest trucks.

Railroad cars are unloaded by spotting the cars over the grates that are between the tracks alongside the elevator. Sometimes these car unloading areas are fully enclosed, but more often they consist only of a roof over

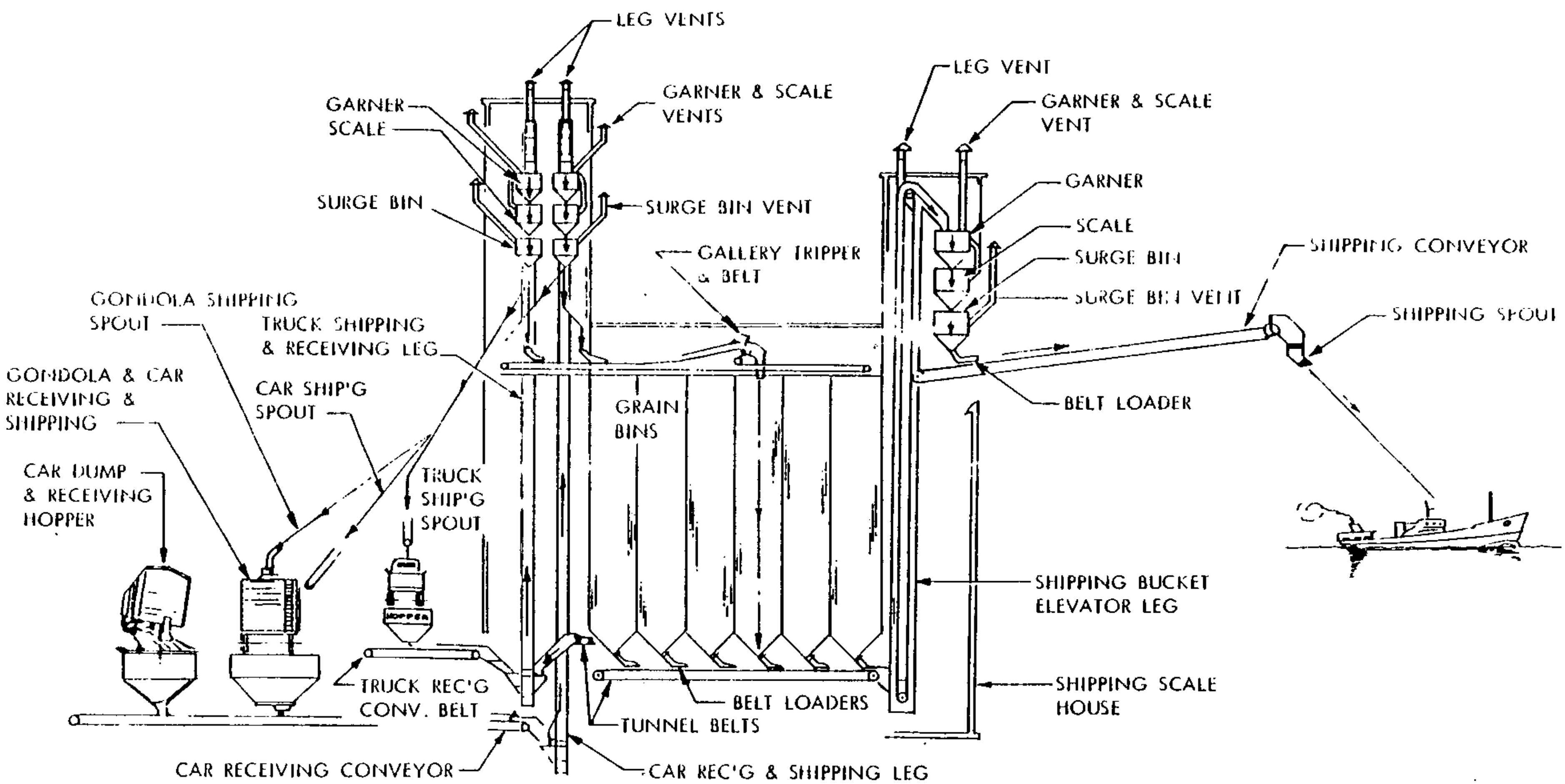


Figure A-5 - Flow diagram for terminal elevator.

the unloading area. The hopper cars are unloaded by opening the doors in the bottom of the car and the grain flows through the between-track grating into the receiving hopper. There are two variations in the hopper car unloading systems. In some cases, the receiving hopper is comparatively small and it quickly fills up and blocks the bottom outlet of the hopper car. In the latter instance, the grain continues to flow out of the car at the rate which the conveyor beneath the receiving hopper carries the grain out of the receiving hopper. This latter type of unloading is termed "choke unloading" and can considerably reduce the quantity of dust generated during unloading in comparison to the other unloading system where all of the grain free-falls into the receiving hopper.

Boxcars are generally unloaded by some method of shoveling the grain out of the car door from which it falls through the grating alongside the track, into the receiving hopper. "Power shovels," consisting of a plowboard attached to a mechanically driven cable, are often used for this purpose. At some terminal elevators, where a considerable number of boxcars are received they may be unloaded by means of a mechanical unloader which clamps the car to a section of track and mechanically rotates and tilts the car. With this system, the grain cascades out of the car door into a receiving hopper. The grain is transported from the receiving hopper to the basement of the elevator, usually by means of a belt conveyor.

Barge unloading, where applicable, is usually accomplished by a bucket elevator (marine leg) that can be lowered into the holds of the barges. At the top of the leg, the grain is discharged onto a series of belt conveyors that carry the grain to the elevator proper. Capacity of the barge unloading system at a terminal elevator can range between 18,000-75,000 bu/hr, although the average is 25,000-30,000 bu/hr.

After the grain is unloaded from cars, trucks, or barges, and transported to the basement of the elevator, it may go directly to the boot of one of the legs or it may be transferred onto one of the basement conveyors that carry it to the boot of the leg. These legs have an average capacity of about 35,000 bu/hr and a large terminal elevator may have up to four or more legs.

At the top of the leg, the grain is discharged into a distributor, or some system of movable spouts, so that the grain may be directed onto one of the gallery belts, into a scale garner for weighing and load out, or into cleaning equipment. If the grain is directed onto a gallery belt, it is conveyed across the top of bins (gallery area) to a "tripper" which discharges the grain into the proper storage bin.

The grain may be withdrawn from one bin, or from several bins simultaneously, by means of slide valves at the bottom of the bins. The grain falls onto a tunnel belt leading back to the legs. If the grain is to be loaded out, it may enter the leg and be discharged to the scale garner or may be discharged directly into one of the load-out spouts for railcars or trucks. If it is to be loaded into a barge or ship, it may by-pass the leg and fall onto the first of a series of conveyors that transport it to the barge or ship loading spouts.

The loading of semitrailer trucks at terminal elevators is similar to that at country elevators except that grain is loaded at a faster rate. The loading area at terminal elevators is often partially enclosed, but it is usually left open at both ends.

Hopper car loading is accomplished in much the same manner as truck loading. However, boxcar loading is a different matter because a high velocity must be imparted to the grain as it passes through the loading spout in order to throw the grain to each end of the boxcar.

Barge or ship loading operations generally require conveying of the grain from storage bins to special loading spouts. In most cases, these loading spouts are located at barge or ship piers some distance from the elevator itself.

APPENDIX B

GRAIN ELEVATOR EMISSIONS

Grain handling in an elevator includes grain receipt, transfer, storage, internal turning, and final shipment. Some elevators clean the incoming grain of foreign matter (FM) and also dry the grain. Virtually every operation in an elevator is a source of particulate emissions due to the dusty nature of grain as well as due to the dirt picked up by grain during harvest and transport. There is a significant difference between atmospheric emissions arising from grain elevator operations and those of other industries; namely the majority of emissions are due to material handling rather than material processing. Furthermore, some of the sources are of a "fugitive" type. That is, the emissions are those that become airborne because of ineffective or nonexistent hooding or pollutant containment systems rather than those that escape from an air pollution control device. Another characteristic of emissions from grain elevators is the intermittent nature of many of the specific operations and the day-to-day variability of emissions from a specific operation. A discussion of emission factors and dust characteristics is presented below.

EMISSION FACTORS FOR ELEVATOR OPERATIONS

Existing data on dust emissions and corresponding particulate emission factors for grain elevators are sparse. The available information consists of gross estimates or material balances for elevator operations as a whole, or were based on a few shortterm tests on certain specific operations. As a result, the available data are inconsistent with respect to their determination procedure and hence the emission factors vary over rather a wide range. Also, potentially contributing to the wide range in available data are the many process factors which affect the quantity of emissions. These factors include:

- Type of grain being handled
- Quality or grade of the grain
- Moisture content of the grain (usually 10-30%)
- Amount of foreign material in the grain (usually 5% or less)
- Amount of moisture in the grain at the time of harvest (hardness)
- Amount of dirt harvested with the grain
- Degree of enclosure at loading and unloading areas
- Type of cleaning and conveying
- Amount and type of control equipment, if any.

Table B-1 presents a comparison of data from various literature sources. The data reported are based on different methods of determination as identified by the footnotes of Table B-1. Data from Reference 1 (in the table) represent closest approximation to direct experimental determination of emissions and are based on the weights of dust collected from fabric filters controlling the emissions from the various individual operations. The emission factors are composite for the four most common types of grain, viz, corn, wheat, milo, and soybeans. The effect of the grain type on long term emission factors was found to be statistically insignificant, even though it is a common belief of elevator operators that soybean and milo emit more dust than corn or wheat. The effect of grain type of dust emissions was found to be somewhat pronounced on a short-term basis, i.e., emission factors determined when loading/unloading a particular grain showed differences between grain types.

Table B-2 presents the best average values along with the range of the low and high values for emission factors for the individual operations based on the available data. The average emission factors are approximate values intended to be representative of a variety of grain types but actual emission factors for a specific source could be different, depending on the various factors discussed above.

The emission factors shown in Table B-2 represent the amount of dust generated per ton of grain processed through each of the designated operations (i.e., uncontrolled emission factors). Amounts of grain processed through each of these operations in a given elevator are dependent on such factors as the amount of grain turned (interbin transfer), amount dryed, and amount cleaned. Because the amount of grain passing through each operation is often difficult to determine, it may be more useful to express the emission factors in terms of the amount of grain shipped or received. It may be assumed that the amount of grain shipped and received are about the same over the long term. Emission factors from Table B-2 have been modified accordingly and are shown in Table B-3 along with the appropriate multiplier that was used as representative of typical ratios of throughput at each operation to the amount of grain shipped or received. The ratios are different for different types of elevators--terminal and country--and are based on a survey of many elevators in the U.S. as reported in Reference 2. However, operating practices in individual elevators are different, so these ratios, like the basic emission factors themselves, would be more valid for a group of elevators rather than individual elevators.

TABLE B-1. COMPARISON OF EMISSION FACTOR DATA

Operation	Emission factor, lb dust/ton grain processed Ref. 1	Ref. 2	Ref. 3	Ref. 4
Truck unloading	0.64	2.0	1.0	0.8
Car unloading	1.30	1.0	1.0	0.7
Car loading	0.27	1.0	1.0	1.1
Cleaning	5.78 (Corn only)	5.0	5.0	6.0
Gallery belt transfer point	0.11	-	-	-
Tunnel belt	1.40	1.5[a]	2.0[b]	1.0[c]
Headhouse	1.49	0.5	-	-

Note:

Ref. 1 Gorman, P. G., "Potential Dust Emissions from a Grain Elevator in Kansas City, Missouri", final report prepared by Midwest Research Institute for EPA, Contract No. 68-02-0228, Task No. 4, May 1974. Best values of the long-term composite emission factors experimentally determined in a terminal elevator. The values represent the amount of dust collected in a well operated fabric filter, and 100% collection of dust by the filter is assumed.

Ref. 2 Thimsen, D. J. and P. W. Aften, "A Proposed Design for Grain Elevator Dust Collection", J of the Air Pollution Control Assn., November 1968. Data represent best estimates by "experienced elevator superintendents" for a General Mills Rialto terminal elevator in South Chicago.

Ref. 3 Compilation of Air Pollutant Emission Factors, USEPA, April 1973. Values specified in this EPA document for terminal elevators are at least partially based on those of Thimsen (Ref. 2 above).

Ref. 4 Results reported for a Cargill Chicago elevator based on calculated material balances ("shrink") over a period of 18 year. See Ref. 1 above.

a/ Value of 1.5 lb/ton was for transferring or turning bins for cooling and may therefore include sources other than just the tunnel belt.

b/ Value of 2 lb/ton is for transferring, conveying, etc.

c/ Identified in Reference 4 as "transferring."

TABLE B-2. GRAIN ELEVATOR EMISSION FACTORS (UNCONTROLLED) AVERAGE AND RANGE[2-10,16]

Emission source operation	Average emission rate,[a] lb/ton processed	Range of emission rate,[a] lb/ton processed	
		Low	High
Grain unloading (Receiving)	1.0	0.8	3.5
Grain loading (Shipping)	0.64	0.25	1.26
Conveying to bins (Gallery belt/tripper)	1.0	0.11	2.5
Removal from bins (Tunnel belt)	1.40	1.0	2.0
Headhouse (Legs)	1.50	0.5	2.5
Internal turning[b]	3.90(2.9)	1.61(1.5)	7.0(4.5)
Cleaning	5.8	5.0	7.0
Drying	5.5	4.0	8.0

a/ Emission factors are in terms of pounds of dust emitted per ton of grain processed by each source.

b/ A distinction is made between the emission factors for internal turnings in terminal elevators and country elevators and the latter are indicated in parentheses. Emission factor for internal turnings is computed by adding those for tunnel belt, gallery belt/trippers, and headhouse(e.g., 1.4 + 1.0 + 1.5 = 3.9) for terminal elevators. For country elevators, it is the total of tunnel belt and headhouse emission factors (e.g., 1.4 + 1.5 = 2.9).

TABLE B-3. UNCONTROLLED EMISSION FACTORS FOR GRAIN ELEVATORS BASED ON AMOUNT OF GRAIN RECEIVED OR SHIPPED[a/]

Emission source - operation	Emission factor (1) lb/ton processed			Terminal elevators: Typical ratio of tons processed to tons received or shipped[a,b/] (2)2/	Terminal elevators: Emission factor (1) x (2) lb/ton received or shipped			Country elevators: Typical ratio of tons processed to tons received or shipped[a,b/] (3)2/	Country elevators: Emission factor (1) x (3) lb/ton received or shipped		
	Average	Low	High		Average	Low	High		Average	Low	High
Grain unloading (receiving)	1.0	0.8	3.5	1.0	1.0	0.8	3.5	1.0	1.0	0.8	3.5
Grain loading (shipping)	0.64	0.25	1.26	1.0	0.64	0.25	1.26	1.0	0.64	0.25	1.26
Conveying to bins (gallery belt/tripper)	1.0	0.11	2.5	1.71	1.71	0.19	4.28	c/	-	-	-
Removal from bins (tunnel belt)	1.40	1.0	2.0	1.32	1.85	1.32	2.64	1.33	1.86	1.33	2.66
Headhouse (legs)	1.5	0.5	2.5	2.32	3.48	1.16	5.80	2.33	3.50	1.17	5.83
Internal turning[d/]	3.9 (2.9)	1.61 (1.5)	7.0 (4.5)	0.71	2.77	1.14	4.97	0.75	2.18	1.13	3.38
Cleaning	5.8	5.0	7.0	0.22	1.28	1.10	1.54	0.08	0.46	0.4	0.56
Drying	5.5	4.0	8.0	0.10	0.55	0.4	0.8	0.25	1.38	1.0	[illegible]
					13.28	6.36	24.79		11.02	6.08	19.19

a/ Assumed that over the long term the amount received is approximately equal to amount shipped.

b/ These are typical values based on averages taken from a survey of many elevators across the U.S. and can be considerably different for any individual elevator or group of elevators in the same locale.

c/ Few country elevators are equipped with gallery belt/trippers. Grain is transferred from leghead to bins through completely enclosed chutes or U-box augers, thus generating little dust. It is reasonable to assume a ratio of 0 for this operation.

d/ Numbers in parentheses are emission factors for country elevators.

The totals at the bottom of the fourth and sixth columns in Table B-3 represent the total potential uncontrolled emissions (average and range) for the whole facility in terminal and country elevators. The values are expressed in terms of pounds of dust per ton of grain received or shipped by the facility. These figures when multiplied by the annual throughput of grain give the potential emissions (average and range) generated by the facility. A more detailed analysis of the emissions data sources is presented below.

Grain elevator emissions data were obtained from four sources: (a) a long-term study of fabric filter catch at Kansas City terminal elevator; (b) a group of compliance test reports supplied by the North Dakota Department of Health; (c) a study of emissions and emissions control at eastern Washington grain elevators; and (d) emissions tests conducted upstream from air pollution control devices in two Kansas grain elevators. The paragraphs below summarize the methodology and results for each of these studies.

Kansas City Terminal Elevator Study[4]

One of the earliest attempts to experimentally develop grain elevator emission factors was a 1973 study by MRI at the Kansas City Terminal elevator. During this study, the weight of dust collected in each of seven fabric filters and the quantity of grain processed by the operations controlled by the filters were used to calculate emission factors. The sources for which emission factors were calculated were:

Truck unloading;

Car unloading;

Car loading;

Corn cleaner;

Gallery belt;

Tunnel belt; and

Headhouse.

Determination of the amount of dust collected by each system was made by mechanical weighers installed on the dust chutes from each filter to continuously monitor the amount of dust being discharged, which was equivalent to the amount of dust being collected by the filters. Readings were taken on the mechanical weighers once each week over a six-month period and the amount of each type of grain processed by the seven grain-handling operations was obtained from the elevator operating records for the corresponding weekly period. Long-term (weekly) composite emission factors were calculated for each operation.

In addition short-term data were compiled for unloading and loading operations to determine the effects of grain type and grain quality (amount of foreign matter and moisture content) on emissions. These data were also compiled using the mechanical weighers, but only the dust collected during a single loading (or unloading) operation was measured. Short-term emissions factors were calculated by grain type for each of three operations: truck unloading, car unloading, and car loading.

The weekly emission factors for a composite of grains processed are summarized in Table B-4. Based on the data in the table and an analysis of the processing data, the following "best" emission factors were developed.

Truck unloading	0.64 lb/ton
Car unloading	1.30 lb/ton
Car loading	0.27 lb/ton
Corn cleaner	5.78 lb/ton
Gallery belt	0.11 lb/ton
Tunnel belt	1.40 lb/ton
Headhouse	1.49 lb/ton

While the quality of these data appears quite good, consideration should be given to the following items before utilizing the data. First, the data are representative of the quantity of emissions captured from a fugitive emissions source. The report indicated that the systems appeared to be effective based on visual observations. However, no specific data on capture efficiency are available.

In addition the "best" emission factors were estimated from a wide range of data. The short-term data suggest that this range represents the real variability of grain elevator emissions. Hence the "best" emission factor is probably not an accurate estimate of actual short-term emissions from a particular operation.

Finally, the emissions factors are representative of a composite of four grains (corn, wheat, soybeans, and milo) processed. Since the short-term results described below suggest differences in emissions by grain types, these emissions factors may not be representative of elevators processing a different mix of grains.

Short-term emissions were measured to examine the effect of grain type and grain properties on emissions. The data did not indicate any relationships between emissions and the amount of foreign matter in the grain or a well defined relationship between emissions and moisture content.

TABLE B-4. SUMMARY OF WEEKLY COMPOSITE EMISSION FACTORS $\left(\frac{\text{pounds of dust}}{\text{ton of grain}}\right)$

Week of	Truck Unloading	Car[a/] Unloading	Car[a/] Loading	Corn Cleaner	Gallery[b/] Belt	Tunnel[c/] Belt	Headhouse
7/9/73	0.547	0.310	0.263	Filter plugged	0.034	Not calculated	0.804
7/16/73	0.678	0.440	0.174	12.95	0.032	2.80	1.349
7/23/73	0.656	0.437	0.230	4.10	0.035	2.60	1.425
7/30/73	0.602	0.363	0.136	7.42	0.126	3.75	1.188
8/6/73	0.554	0.284	0.185	5.68	0.059	1.89	1.000
8/13/73	0.556	1.63	0.173	Filter plugged	0.110	8.18	0.930
8/20/73	0.597	0.922	0.184	Filter plugged	0.152	1.09	Dust collector not operating
8/27/73	0.567	Dust collector not operating	0.213	Filter plugged	0.088	1.76	Dust collector not operating
9/4/73	0.826	Dust collector not operating	0.245	Not used	0.010	2.08	Dust collector not operating
9/10/73	0.642	1.89	0.320	2.76	Not used	Not calculated	1.653
9/17/73	0.471	1.44	0.379	6.96	0.052	4.26	3.029
9/24/73	0.835	1.94	0.368	6.82	0.100	11.49	1.903
10/1/73	0.541	1.01	0.282	4.47	0.084	3.80	1.464
10/7 and 10/15/73	0.249	0.983	0.272	5.07	0.030	8.04	1.678
10/22/73	0.607	0.925	0.201	4.41	0.048	8.37	1.469
10/29/73	0.883	Dust collector not operating	0.291	6.40	0.093	2.21	0.982
11/5/73	0.771	d/	0.110	4.93	0.085	h/	1.602
11/12/73	0.625	d/	0.318	2.35	0.099	4.03	1.410
11/19/73	0.564	0.715	0.357	f/	0.145	1.83	1.544
11/26/73	0.829	e/	0.400	8.13	0.044	2.18	1.939
12/3/73	0.638	1.60	0.285	4.03	0.361	1.43	2.748
12/10/73	0.864	4.51	0.479	--	0.164	4.96	3.777
12/17/73 to 12/21/73	0.395	3.80	0.723	1.79	0.337	15.1	3.514
12/21/73 to 12/28/73	1.26	2.76	0.158	5.11	0.239	1.81	5.067
12/28/73 to 1/7/74	0.252	2.44	0.100	8.68	g/	i/	3.169

a/ Loading and unloading of cars includes both hopper cars and boxcars.
b/ The gallery belt dust collector is connected to only one hood where grain is fed onto the belt.
c/ The emission factor values may be unusually high and show large variation because dust is continually collected from one leg, even though little or no grain may be moved through the tunnel belt.
d/ Dust collector out of service all or part of week; fan motor repairs.
e/ No emission factor calculated because counter-wire on weigher was broken.
f/ No emission factor calculated because unable to determine quantity of grain cleaned.
g/ Not calculated because of low air pressure in cleaning air tank.
h/ No emission factor could be calculated because filter was plugged.
i/ Emission factor not calculated because fan was out of service part of week.

However, the short-term data did show a dependence of emissions upon grain type. The results by grain type for truck unloading, car unloading, and car loading are shown in Tables B-5, B-6, and B-7, respectively. While these data are not sufficient to establish grain specific emission factors, they do indicate a relationship between grain type and emissions. It should be noted, though, that the grain specific emission factors exhibit the same wide variation as the long-term emission factors.

Based on both short- and long-term emissions measurements, it can be concluded that grain elevator emissions exhibit wide variability. This conclusion holds for emissions on a truckload to truckload basis and for long-term emissions.

Grain Elevator Compliance Tests[7-10,13]

As a part of an earlier MRI study, reports from five compliance tests (four in North Dakota and one in Minnesota) were obtained from the North Dakota Department of Environment. These tests measured emissions from controlled sources at the inlet and outlet of control devices, generally cyclones. The testing was done using the ASME Method PTC-27, an older isokinetic sampling method which yields results comparable to EPA Method 5.

The results of testing at five elevators are presented in Table B-8. Data in Table B-8 include gas flow rate, pressure drop across the control device, inlet and outlet particulate concentrations and emission rates, and control device efficiency. Specific comments regarding each of the tests and general conclusions are presented in the following paragraphs.

At elevator A a grain cleaner, cleaning dark Northern spring wheat, was tested. The resulting inlet emission factor was 0.185 lb/ton, and the cyclone efficiency was measured at 47.5%. However, the pressure drop across the cyclone of 17 in H_2O is extremely high. In addition, the test report indicated that the design flow of the system was 8,500 cfm compared to the measured value of 3,300 cfm. These two factors suggest that the system was plugged. The plugging would cause decreased air velocity through the cyclone and decrease cyclone efficiency. In addition the decreased flow would probably result in inefficient capture of the emissions at the source. Thus both the calculated emissions factor and the cyclone efficiency are lower than would be expected with properly operated and maintained equipment.

The testing at elevator B was conducted on a single system serving the distributor head, floor sweeps, boot, automatic scale front pit, back pit, and legs. During the test 13.5 tons/hr passed through the distributor and 13.5 tons/hr passed through the front pit, back pit, and legs.

TABLE B-5. TRUCK UNLOADING, EMISSION FACTORS BY GRAIN TYPE (LB/TON)

	Wheat	Corn	SB	Milo
	0.081	0.128	1.15	0.280
	0.217	0.130	1.63	1.090
	1.06	0.234	1.85	0.610
	0.73	0.115	2.20	1.23
		0.670	0.87	0.88
		0.70	2.06	0.96
		0.49		1.60
		0.67		
		0.42		
		0.71		
		0.56		
		0.80		
Avg.	0.52	0.47	1.63	0.95
Range	0.081-1.06	0.115-0.80	0.87-2.20	0.28-1.60

Average of all data = 0.83

TABLE B-6. CAR UNLOADING, EMISSION FACTORS BY GRAIN TYPES (LB/TON)

	Wheat		Corn		SB		Milo	
	Hopper	Box	Hopper	Box	Hopper	Box	Hopper	Box
	0.11	0.50	0.77	0.84		1.51	0.12	1.42
			0.88	0.38			0.41	2.08
				0.65			0.59	0.26
								0.98
								0.64
	0.11	0.50	0.83	0.62	-	1.51	0.37	1.08
Avg.	0.31		0.70		1.51		0.81	

Average of all data = 0.76

TABLE B-7. CAR LOADING, EMISSION FACTORS BY GRAIN TYPE (LB/TON)

	Wheat	Corn	SB	Milo	
	0.12	0.34	0.33	0.26	0.38
	0.15	0.20	0.21	0.14	0.34
	0.54	0.18	0.41	0.24	0.36
	0.25	0.31	0.95	0.24	0.39
	0.15	0.31	0.56	0.26	0.37
	0.07	0.27	0.44	0.32	0.39
	0.07	0.36	0.48	0.41	0.22
	0.07		0.59	0.34	0.42
	0.12		0.31	0.35	0.39
			0.12	0.35	0.51
				0.30	0.27
				0.09	0.21
				0.02	0.32
				0.19	0.34
				0.11	0.34
				0.08	0.31
					0.28
Avg.	0.17	0.28	0.44	0.29	
Range	0.07-0.54	0.18-0.36	0.12-0.95	0.02-0.51	

Average of all data = 0.30

TABLE E-8. RESULTS OF GRAIN ELEVATOR COMPLIANCE TESTS

Elevator	Operations tested	Grain type	Control device	Process weight (T/hr)	Gas flow (scfm) Inlet	Gas flow (scfm) Outlet	Pressure drop in H_2O	Concentration (gr/scf) Inlet	Concentration (gr/scf) Outlet	Emissions (lb/T) Inlet	Emissions (lb/T) Outlet	Efficiency (%)
A	Grain cleaner	Wheat	Cyclone	15	3,330	3,330	17	0.098	0.051	0.185	0.097	47.5
B	Distributor, back pit, legs, front pit	Wheat Wheat	Cyclone	27	10,000	10,000	9.0	0.428	0.029	0.116 0.136	0.0092 0.0092	93.2
C	Cleaner	Unknown	Cyclone 1 Cyclone 3	25.9 28.8	2,822 1,487	5,457 2,281	1.0 8.1	0.330 0.302	0.045 0.082	0.268 0.134	0.104 0.057	59.7 57.5
	Distributor, back pit, leg	Unknown	Cyclone	89.7	11,053	12,882	4.4	0.094	0.054	0.099	0.067	31.6
D	Legs (3)	Unknown	Baghouse without filter media	960	9,050	8,900		9.700	0.140	0.783	0.0111	98.6
	Leg	Unknown	Baghouse without filter media	360	7,900	7,500		3.760	0.100	0.708	0.0179	97.5
E	Cleaner	Wheat	Cyclone	36.87	4,920	4,920	4	0.372	0.061	0.425	0.069	83.6
	Dump pit, legs, and headhouse	Wheat, oats, barley	Cyclone	167.5	11,190	11,190	6.5	0.847	0.142	0.485	0.081	83.2

Data are not sufficient to determine the individual impact of these sources. The estimate emissions are 0.14 lb/ton for the distributor head and 0.14 lb/ton for the legs and pits. The efficiency of the cyclone was measured at 93.2%.

Emissions from three different cyclones were tested at Elevator C. Cyclones 1 and 3 served the same grain cleaner, and cyclone 2 served the back pit, leg, and distributor during the testing. The cleaner emissions (the sum of the inlet values for cyclones 1 and 3) were measured at 0.402 lb/ton with efficiencies of 59.7 and 57.5%. Inlet emissions from cyclone 2 were measured at 0.099 lb/ton with a collection efficiency of 31.6%. An important observation, however, is that the outlet flow of all three cyclones is much greater than the inlet flow. The excess flow is probably a result of air leakage into the cyclone through the dust exhaust duct. This leakage will result in inefficient capture and removal efficiency and hence in a low estimate of emissions.

Two different legs were tested at elevator D. The results were consistent at 0.783 lb/ton and 0.708 lb/ton. These emission factors are somewhat higher than previous emission factors, but certainly within the range of what might be expected given the wide variation in grain elevator emissions.

Two different control systems were tested at elevator E. On the first system emissions from a wheat cleaner were measured at 0.425 lb/ton with a cyclone efficiency of 83.6%. The other system controlled the dump pit, legs, and headhouse operations. Emissions were measured at 0.485 lb/ton with a cyclone efficiency of 83.2%.

In examining these data it again must be remembered that the emission factors represent captured emissions from fugitive sources. In some of the tests described above the capture efficiency and hence the emission factors are questionable. The cyclone collection efficiencies are also worthy of note. In the cases where the cyclones appeared to be operating properly, efficiencies in the 80 to 95% range were noted. However, in those cases where flow data indicated obvious problems in cyclone operation, efficiencies fell to 30 to 60%. This would indicate that proper operation of cyclones is important for continuing compliance.

Eastern Washington Grain Elevator Study[11]

A comprehensive study of emissions and emissions control for eastern Washington grain storage and processing facilities was conducted by the Spokane County Air Pollution Control Authority and Washington State Department of Ecology. Various grain handling operations in grain elevators and seed plants were tested for total particulate emissions using EPA Method 5 procedures and for particle size using cascade impactors. Opacity was also recorded during the testing. Both cyclones and fabric filters were examined.

The results of the tests on receiving pits, cleaning operations, and transfer operations are presented in Tables B-9, B-10, and B-11, respectively. The paragraphs below summarize the findings of the study regarding factors effecting emissions, particle size of emissions, mass emissions compared to opacity, and control device efficiency.

Mass emissions data indicate that receiving pit emissions are dependent on grain type, quantity of foreign matter in the grain, and drop height. In particular, the emissions from processing of legumes were significantly greater than those for wheat processing. However, even emissions from only wheat receiving varied by more than an order of magnitude from plant to plant. Emissions from grain cleaning were found to be dependent on the amount of pre-cleaning. Emissions from primary cleaning, also called scalping, were at least 2.5 times as large as emissions from secondary cleaners.

Tables B-9, B-10, and B-11 contain the mean particle diameter for many of the emissions tests. For receiving pits four of the five tests had a mean inlet particle size of 15 μm or less (the size considered to be inhalable. For cleaners, two of the five tests have mean particle size of 10 μm or less, and one of the five has a mean particle size of 16 μm. For handling operations, both tests showed emissions with a mean diameter of 15 μm or less. The study found that grain cleaner exhausts generally contained about 10% by weight minus 10 μm particles, and receiving pit exhausts contained in excess of 50% by weight minus 10 μm particles. The above data indicate that grain elevator emissions contain significant amounts of particulate in the minus 15 μm range. Particulates in this size range have the greatest impact on the human respiratory system.

The study also examined the relationship between mass concentration and opacity. It was found that a visible emissions standard of 20% was more stringent than an emissions standard of 0.1 gr/scf for exhausts from both grain cleaners and receiving pits. Although data were not sufficient to develop statistically reliable correlations between grain loading and opacity, it was generally found that concentrations at or above 0.1 gr/scf resulted in visible emissions in excess of 50% from receiving pit control device outlets and 40% from grain cleaner exhausts. The data indicate that in order to meet a 20% opacity standard at control device outlets, concentrations less than 0.025 gr/scf would be required.

The data in Tables B-9, B-10, and B-11 indicate that the cyclones in eastern Washington generally had efficiencies of at least 95%. The only exception was on a legume cleaner which had an exceptionally low inlet grain loading. However, even with 95% efficiencies most cyclones were not able to achieve outlet loadings of less than 0.025 gr/scf. Thus it is quite likely that even well designed and properly operated cyclones will not be able to consistently meet a 20% opacity limit.

TABLE B-9. SUMMARY OF TEST DATA ON RECEIVING PITS

Site	Process type	Equipment type	Material type	Control equipment: Type	Air flow (scfm)	Pressure drop (in. wc)	Inlet concentration (gr/scf)	Outlet concentration (gr/scf)	Efficiency (%)	Mean particle size: Inlet (μm)	Outlet (μm)	Process weight (lb/ton): Inlet	Outlet
G	Elevator	Receiving pit	Legumes	Long cone cyclone	6,220	7.0	8.57	0.488	94.3	15	1.4	13.9	0.71
H	Elevator	Receiving pit	Wheat	Cyclone	7,550		4.955	0.173	96.5	17	-	0.774	0.009
I	Subterminal elevator	Receiving pit	Wheat	Cyclone			0.50	0.075		7.0	3.0		
J	Elevator	Receiving pit	Wheat	Cyclone	9,000	-	0.20	-	-	12	-	0.156[a/]	-
K	Elevator	Receiving	Wheat	None	2,350[b/]	-	0.383	-	-	4.6	-	0.0398	-

a/ Grain choke feeding into the pit.

b/ Air flow was not adequate to control dust emissions from receiving pit.

TABLE B-10. SUMMARY OF TEST DATA ON GRAIN CLEANERS

Site	Process type	Equipment type	Material type	Control equipment: Type	Air flow (scfm)	Pressure drop (in. wc)	Inlet concentration (gr/scf)	Outlet concentration (gr/scf)	Efficiency (%)	Mean particle size: Inlet (μm)	Mean particle size: Outlet (μm)	Process weight (lb/ton): Inlet	Process weight (lb/ton): Outlet
A	Country elevator	Primary cleaner	Legume	Long cone cyclone	6,550	7.0	4.165	0.088	97.9	16	1.5	6.09	0.13
B	Seed plant	Secondary cleaner	Legume	Cyclone	2,340	1.0	1.00	0.038	96.2	-	-	9.6	0.55
C	Seed plant	Secondary cleaner	Legume	Cyclone	3,400	2.0	0.815	0.029	96.4	30	2	7.75	0.28
D	Seed plant	Secondary cleaner	Legume	None	2,390	-	1.00	-	-	20	-	6.3	-
E	Seed plant	Tertiary cleaner	Legume	None	1,780	-	0.023	-	-	3		0.11	-
F	Seed plant	Primary cleaner	Cereal grain	Long cone	1,502	1.2	2.48	0.034	98.6	-	-	25.2	0.26
L	Seed plant	Secondary cleaner	Legume	Long cone cyclone	2,390	2.0	0.0172	0.0040	76.7	10	2.0	0.115	0.027

TABLE B-11. SUMMARY OF TEST DATA ON TRANSFER OPERATIONS

Site	Process type	Equipment type	Material type	Type	Control equipment					Mean particle size		Process weight (lb/ton)	
					Air flow (scfm)	Pressure drop (in. wc)	Inlet concentration (gr/scf)	Outlet concentration (gr/scf)	Efficiency (%)	Inlet (μm)	Outlet (μm)	Inlet	Outlet
L	Elevator	Elevator	Wheat	Cyclone	12,050	-	0.648	0.028	95.7	15	-	0.488	0.011
M	Terminal elevator	Elevator leg	Oats	Baghouse	5,200	-	0.329	0.0025	99.1	2.4	-	15.1	0.001

Grain Elevator Emission Factor Study[5,6]

As a part of a study to develop emission factors for grain elevators, emissions tests were conducted upstream from control devices at two elevators in Kansas. At the first elevator emission factors were developed for the truck dump and the elevator leg for each of three grains (wheat, milo, and soybeans). At the second elevator emission factors were developed for load-out, the tunnel belt, and the bin vent for each of four grains (soybeans, wheat, milo, and corn).

The sampling was conducted upstream of control equipment using EPA Method 5 procedures. The sampling train was equipped with a cyclone with a cutoff diameter of 5 μm in front of the filter to avoid overloading the filter.

The emission factors shown in Tables B-12 and B-13 represent the "front half" particulate catch from the tests. The "catch > 5 μm" consists of that portion of the total front-half which was captured in the cyclone.

The test reports noted that the cyclone became overloaded in several of the tests possibly leading to inaccurate estimates of size distribution. In addition some of the "particulate" captured in the cyclone consisted of broken grain kernels and chaff. This would indicate that the ventilation system "creates" particulate that would not normally be emitted from a totally uncontrolled source. Thus these emission factors represent emissions from a ventilated source with no control device rather than from a totally uncontrolled source.

Given the above limitations, the data still have some value. In particular these data reinforce the earlier conclusion that emissions are dependent upon grain type. In addition the data exhibit the same variation, although to a smaller degree, from test to test shown in earlier studies.

HEALTH EFFECTS OF GRAIN DUST

Data indicate that dust from grain handling operations have adverse effects on the skin, eyes, and respiratory system of humans. Allergic skin reactions and eye irritation have occurred in workers exposed to high concentrations of grain dust. The most severe impact of grain dust on exposed workers is the effect on the respiratory system. There are two main hypotheses concerning the mechanism of the action of the grain dusts in the respiratory system: fitst, the fine particles in the grain dust may act as a mechanical irritant; second, there may be an antigenic effect due to the organic, or perhaps the inorganic part of the dust, with production of asthmatic reactions in the case of the former and fibrotic changes in the latter.[18] Detailed descriptions of the effects of grain dusts on workers respiratory systems are presented in References 18 through 20.

TABLE B-12. SUMMARY OF EMISSION FACTORS AND APPROXIMATE CATCH SIZE FRACTIONS

		Truck Dump Hopper			Elevator Leg		
		Emission Factor		Approximate Percent	Emission Factor		Approximate Percent
Grain	Run[a]	lb/ton[b]	kg/Mton[b]	Catch > 5 μ	lb/ton[b]	kg/Mton[b]	Catch > 5 μ
Wheat	1-TDW	0.129	0.065	97			
	2-ELW[c]				1.352	0.676	98
	3-TDW	0.050	0.025	93			
	4-ELW[c]				1.680	0.840	99
Milo	5-ELM[c]				3.128	1.564	90
	6-ELM[c]				3.983	1.992	92
	7-ELM[c]				3.302	1.651	94
Soybeans	8-ELS[d]				7.647	3.824	93
	9-ELS[d]				4.653	2.326	88
Wheat	Average	0.090	0.045	95	1.516	0.758	98
Milo	Average	-	-	-	3.471	1.736	92
Soybeans	Average	-	-	-	6.150	3.075	91

a/ _-TD_ = truck dump hopper
_-EL_ = elevator leg
_-__W = wheat
_-__M = milo
_-__S = soybeans

b/ lb/ton = pounds emissions per ton grain handled
kg/Mton = kilograms emissions per metric ton handled.

c/ West leg

d/ East leg

TABLE B-13. SUMMARY OF EMISSION FACTORS AND APPROXIMATE CATCH SIZE FRACTIONS

Grain	Run[d]	Load-Out[a] Emission Factor lb/ton[e]	Load-Out[a] Emission Factor kg/Mton[e]	Load-Out[a] Approximate Percent Catch > 5 μ	Tunnel Belt[b] Emission Factor lb/ton[e]	Tunnel Belt[b] Emission Factor kg/M ton[e]	Tunnel Belt[b] Approximate Percent Catch > 5 μ	Bin Vent[c] Emission Factor lb/ton[e]	Bin Vent[c] Emission Factor kg/M ton[e]	Bin Vent[c] Approximate Percent Catch > 5 μ
Soybeans	1-LOS	3.40	1.70	96	-	-	-	-	-	-
	2-LOS	2.05	1.03	97	-	-	-	-	-	-
Wheat	3-LOW	0.77	0.38	97	-	-	-	-	-	-
	4-TBW	-	-	-	0.37	0.18	97	-	-	-
	5-BVW	-	-	-	-	-	-	0.02	0.01	85
	6-LOW	0.58	0.29	97	-	-	-	-	-	-
	7-BVW	-	-	-	-	-	-	0.02	0.01	79
Corn	8-TBC	-	-	-	0.89	0.45	99	-	-	-
	9-TBC	-	-	-	0.92	0.46	99	-	-	-
Milo	10-TBM	-	-	-	0.58	0.29	99	-	-	-
	11-BVM	-	-	-	-	-	-	0.03	0.02	90
	12-TBM	-	-	-	0.68	0.34	99	-	-	-
Soybeans	Average	2.72	1.36	96	-	-	-	-	-	-
Wheat	Average	0.68	0.34	97	0.37	0.18	97	0.02	0.01	83
Corn	Average	-	-	-	0.91	0.45	99	-	-	-
Milo	Average	-	-	-	0.63	0.32	99	0.03	0.02	90

a/ Includes tunnel belt drop point, pulley hoods, leg cross belt, leg boots, and grain scale.
b/ Includes tunnel belt drop point, pulley hoods, leg cross belt, and leg boot.
c/ Bin vent only; grain scale bin for wheat; standard bin for milo.
d/ _-LO- = Load-out
_-TB_ = Tunnel belt (Bin transfer)
_-BV_ = Bin vent
_-__S = Soybeans
_-__W = Wheat
_-__C = Corn
_-__M = Milo
e/ lb/ton = Pounds emissions per ton grain handled.
kg/Mton = Kilograms emissions per metric ton grain handled.

Data are also available which indicate that many of these same respiratory effects can be found in some persons exposed to airborne dusts emitted from grain elevators. In particular, a study done at the University of Minnesota over a 5-year period concluded that there was considerable support for a hypothesis of asthma attacks induced by respiratory irritation from atmospheric particles from grain handling.[21] Evidence also exists that asthmatic attacks in New Orleans may be attributed in part by airborne effluent from a large grain elevator.[22] A more detailed analysis of the health effects from grain elevators is presented in Reference 15. Reference 15 concludes that at normal low ambient particulate concentrations (< 100 mg/m^3) no evidence exists for adverse effects to healthy people from grain and fuel emissions. However, people having pre-existing respiratory disorders may be affected by rapid increases above the seasonal mean concentration of particulate grain dust.

APPENDIX C

GRAIN ELEVATOR EMISSION CONTROLS

The atmospheric emissions from grain elevators are primarily the particulate (dust) generated during the handling and transfer of grain. Two types of methods are used to reduce these emissions: (a) the process or facility is modified in manner which decreases the amount of dust generated by an operation; and (b) some type of system is used to capture or contain the emissions which are then ducted to an air pollution control device. Controls in elevators often consist of combinations of these methods.

Controls systems for most grain elevator operations are well developed, and are described in detail in the literature.[15,23-25] The subsection below briefly describes the process modifications and/or capture systems which reduce or curtail emissions at the source. The discussions of capture systems is followed by a short discussion of the air pollution control devices used at grain elevators. A brief discussion on operation and maintenance practices applicable to grain elevators concludes the section.

METHODS FOR REDUCING/CONTAINING EMISSIONS AT THE SOURCE

Particulate emissions from country elevators consist of dusts brought into the elevator with the grain or generated by abrasive action on the grain during handling. These dusts may be liberated during each of the following operations.

1. Grain Receiving
2. Grain Dryers
3. Cleaning
4. Garner and Scale Bins
5. Legs
6. Transfer Points (in the Gallery and Tunnel)
7. Grain Shipping

The methods which appear to best reduce or contain the dust at each of these emissions points are described below.

Grain Receiving

Grain receiving is one of the more visible emissions sources at grain elevators. It is also one of the most difficult to control. Grain is received at the elevator in trucks, hopper cars, and boxcars. As the grain is dumped from the transport vehicle into the receiving pit, large volumes of dust are generated over a short time period. This problem is compounded when, as is often the case, two or more sides of the pit area are open to the atmosphere. Wind currents then exacerbate the problem of containing the large volume of dust.

The first step in controlling emissions from grain receiving is to modify the process in such a way that (a) the distance over which the grain is in freefall is as short as possible; and (b) the operation is sufficiently enclosed to eliminate wind currents over the pit.

Reference 24 suggests that emissions from truck dumping can be reduced if operators carefully raise hoists to allow grain to flow evenly from the truck rather than in a large mass. Two other process modifications help contain emissions from truck dumps. Louvres (fixed or moveable) just below the grate level of the pit even the flow of grain into the pit and help contain emissions below grain level. In addition, the pit area should be well enclosed. This includes permanent walls on two sides of the pit and quick close doors on at least one and preferably both ends of the pit.[25] In addition to these process modifications, air should be exhausted from the pit, preferable below the grate level at a rate of at least 100 cfm per square foot of grate area.[15] Data from emissions testing in eastern Washington suggest that fugitive emissions are well controlled at a face velocity of 75 fpm and that velocities of 130 fpm or greater tend to induce grain into the exhaust stream.[11]

The most common boxcar unloading method consists first of breaking the grain door inside the car, which produces a surge of grain and dust as the grain falls into the receiving hopper. After the initial surge of grain, the remaining grain is scooped out of the car using power shovels, a bobcat or some similar means. A surge of dust accompanies each scoop of grain as it strikes the receiving pit.

The other common boxcar unloading technique, used mainly by terminal elevators, is a mechanical car dump which clamps the car to a moveable section of track and rotates and tilts the car to dump the grain out of the car door into a receiving pit.

As with the truck dump, louvres in the dump pit and enclosure of the area will help contain emissions from either type of unloading. If the scoop type unloading is used, it is suggested that emissions can be minimized by keeping the drop distance from the bucket as small as possible.[24]

Undergrate aspiration can be applied to the first unloading method, and will reduce emissions, but large volumes of air are necessary to provide high capture efficiency. A typical railcar unloading system might handle 35,000 to 50,000 bu/hr which would require undergrate aspiration of about 20,000 to 25,000 cfm.[15]

In addition to undergrate aspiration, some elevators have installed aspiration panels near the car door in an attempt to capture the dust emissions. This method is considerably more effective if a flexible closure is used as shown in Figure C-1. This can be reasonably effective even when the unloading area is not enclosed.[15]

The mechanical car dump presents a more difficult dust control problem. Undergrate aspiration has been used to reduce the emission. Aspiration panels near the door have also been used, but their utility is restricted due to clearances necessary for rotation and tilting of the car. Aspiration ducts located at each end of the dump pit have also been used.[15]

Two methods are available for control of emissions from hopper car unloading. The first is a combination of pit enclosure, louvres, and aspiration similar to that in truck dumps. The second is a choke feeding system. With this system a small hopper is placed immediately below the hopper car. The grain is allowed to form a cone between the shallow receiving hopper and the receiving grate. There is a momentary cloud of dust as the hopper fills, but the remainder of the operation is almost dust free.[24]

Grain Drying

Grain dryers present a difficult problem for air pollution control because of the large volumes of air exhausted from the dryer, the large cross-sectional area of the exhaust, the low specific gravity of the emitted dust, and the high moisture content of the exhaust stream. The particles emitted from the dryers, although relatively large, are very light and difficult to collect. "Beeswing," a light flaky material, that breaks off from the corn kernel during drying and handling, is the troublesome particulate emission.

The typical mode of control for grain dryers has been the use of screens at the outlet of the dryer to capture the particulate, 95% of which is greater than 50 μm in diameter. Various screening systems for grain dryers are described in Reference 15. The NSPS effect only those column dryers with column plate performation exceeding 0.094 in. and rack dryers which exhaust gases through screens coarser than 50 mesh. Hence, screens of this size are assumed to efficiently control dryers.

Grain Cleaning

Cleaners and scalpers generated dust emissions through the agitation of material over screens and plates. This operation can be well controlled by full enclosure. The system should then be kept under negative pressure through air exhaust. Systems for both new and retrofit controls are described in Reference 24.

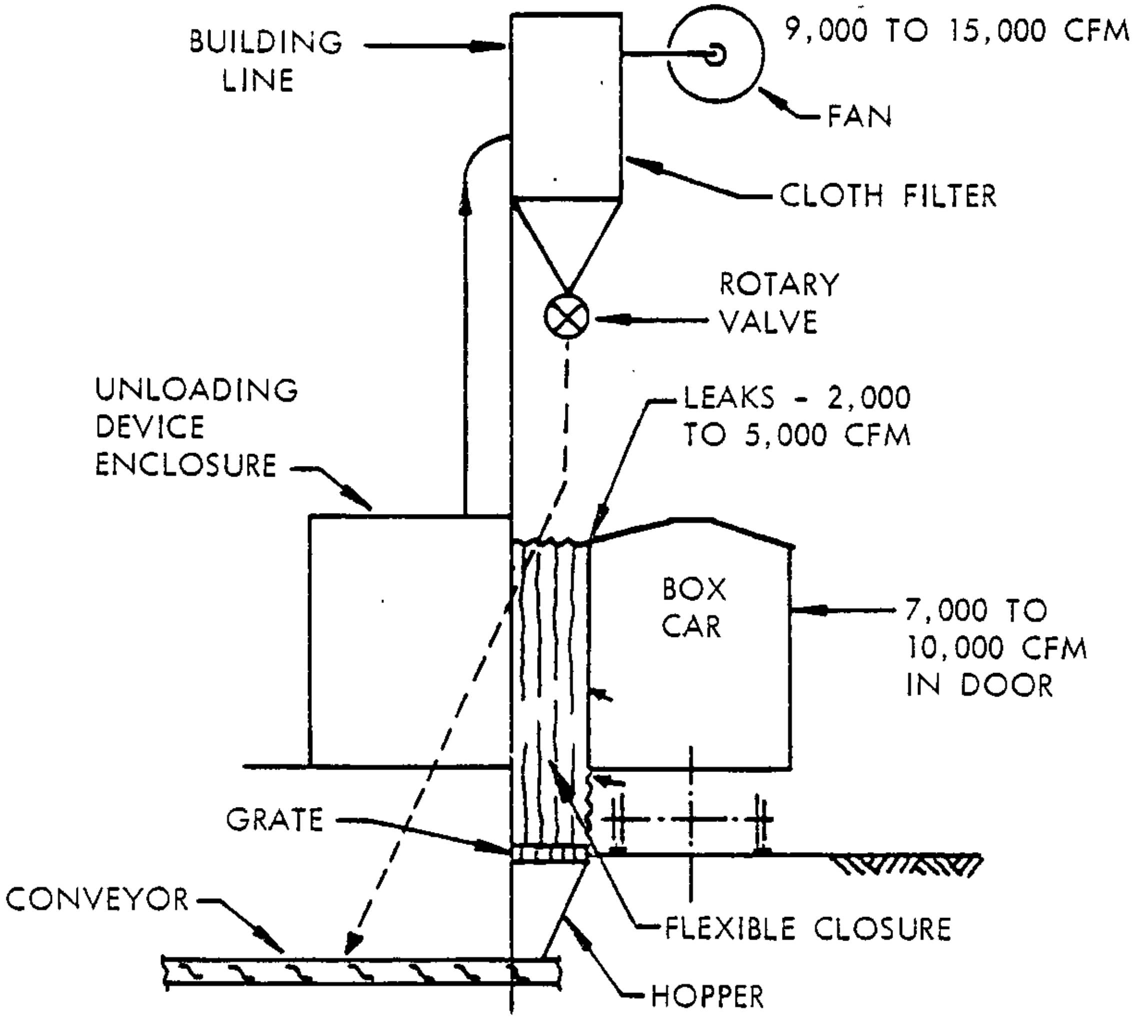


Figure C-1 - Boxcar unloading dust control system.

Scale and Garner

Scale and garner bins should be fully enclosed and intervented to avoid pressure buildups which might cause dust leakage. Air should be exhausted to provide negative pressure within the total scale and garner system. Specific dust control designs for different types of systems are shown in Reference 24.

Legs

The legs at most elevators are bucket elevators which take the grain from the bottom of the elevator to the top from where it is stored or shipped by gravity feed. Dust is generated when grain is dumped into the bottom (boot) of the leg and when it is discharged at the top (head) of the leg. However, the leg is an enclosed system and dust emissions can be contained by maintaining a negative pressure in the leg. This negative pressure can best be maintained at all points in the leg if the up and down sides of the elevator have a common enclosure or some type of interventing. A typical exhaust system for the boot of the leg is shown in Reference 24, and a design for the complete system is presented in Reference 23.

Transfer Points

Transfer points within an elevator include transfers between belts, dump points from the storage bins to the tunnel belt, transfer from the distributor or scales to the gallery belt, and the tripper, a moveable device which transfers the grain from gallery belt to the bins. Dust is generated each time the grain is transferred from one device to another.

Most emissions from transfer points can be controlled by proper hooding that is exhausted to a collector. The hooding designs may vary, but they usually are constructed so as to cover the transfer points and minimize the area open to the surroundings. The quantity of air exhausted from each hood is generally based on open area exposed to the surroundings. If several hoods are used along one belt, they are normally connected to a common exhaust duct and each connection includes a slide gate to provide for proper adjustment of airflow. Hood specifications for various transfer points are shown in References 23 and 24.

One of the more difficult-to-control transfer points is the "tripper" on each gallery belt. This tripper is moved along the belt to discharge the grain into the proper bin, and this is a transfer operation that is difficult to control. As the grain is diverted from the gallery belt by the tripper, it generates dust that is released into the gallery area and escapes through windows and other openings. Proper hooding on the tripper will allow capture of most of the dust emission but the required mobility of the tripper requires special arrangements to exhaust air from the tripper to a collection device. Some terminal elevators have installed an exhaust dust alongside the gallery belt, with connections in the duct at each location where the tripper may be positioned. This requires that the tripper be manually connected to the exhaust duct each time the tripper is moved. Other elevators have eliminated this problem by installing an exhaust duct with a rubber zipper along the length of the duct so that the tripper is always connected to the exhaust duct regardless of its position.15/

One development in control of emissions from transfer points is the use of completely enclosed conveyors and this may be coupled with pressurization of the surroundings to eliminate any possibility of dust escaping into the room. Such units are especially applicable to conveyors in the basement area of the elevators, but they might also be adapted for use in the gallery.15/

Grain Shipping

Grain is shipped from elevators by truck, hopper car, boxcar, ship, and barge. In most operations, large amounts of dust are generated by the free fall of dust over large distances. Because of the varying sizes of the transport vehicles and the openness of the operations, grain shipping activities are the most difficult elevator sources to control.

Most truck loading operations involve the free-fall of grain into the truck with considerable emission of dust. The control of the dust emissions from truck loading is difficult due to the variations in the sizes of the trucks and required movement of the loading spout. At many terminal elevators the truck loading operation is covered and enclosed on two sides and a few of these have aspiration ducts inside this area, but capture efficiency is hampered by the wind-tunnel effect.15/

It may be possible to install a shroud, with aspiration, that covers the top of the truck, but the different sizes of trucks, and the need for the operator to observe the loading, may make this method impractical. However, such a system has been used successfully for hopper car loading.15/

Choke loading may also be used, wherein the grain does not free-fall into the car or truck but instead is restricted by the accumulated grain load or pile by means of a telescoping spout. This loading method does help to reduce the emissions, but may not provide sufficient reduction in the emissions for air pollution control purposes.15/

It would be possible, of course, to use doors at both ends of the loading enclosure and evacuate the air from the enclosed area to a collector.

However, the doors hamper movement of trucks and no elevators are known to use this method.[15]

Two methods of controlling the dust emission from boxcar loading have been used, although they have infrequently been applied. The first method consists of covering the car door with some material and aspirating the air from inside the car to a suitable collector (usually a fabric filter). The second method consists of an aspiration system located near the car door. This second method is not as effective as the first, but it allows the operator to observe and adjust the spout during loading operations. A sketch of one such system is shown in Figure C-2.[15]

The methods used to load hopper cars and to control the associated dust emissions are similar to those used for trucks and the loading may be done in an enclosed area. One dust control method that has been successfully used to control dust from hopper car loading is shown in Figure C-3. This consists of a shroud made of belting material that encloses a portion of the top of the car to within a few inches of the roofline. A second inner shroud encloses the loading spouts and approximately 9,000 cfm of air is aspirated from inside this inner shroud to a control device. The inner shroud comes to within 1 to 2 ft of the roof of the car which allows the operator to observe the loading and control the flow of grain. This system appears to be quite effective and eliminates the need for enclosing the loading area. Similar systems consisting of a collection hood with flexible ducting have been designed to aspirate air from the hopper car during loading.[15]

The control of emissions from ship and barge loading is the most difficult control problem in grain elevators. The grain usually falls a considerable distance into the ships' hold creating a large cloud of dust. Containment of the dust emissions without impairing the operator's control of the loading operation presents a challenge.

Some degree of control can be obtained by using a choke-feeding system when loading grain into the hold. This can be accomplished by keeping the spout 4 to 6 in. in the grain. However, this is not always possible, especially during startup and trimming. During these periods, the hold must be covered with plastic or canvas. Air is aspirated from the hold to maintain negative pressure.

A comprehensive control system for ship loading has been developed at a Cargill, Inc., facility at Pier 86 in Seattle. The system, described below, controls emissions from the loading of bulk carriers, tankers, and t'ween deckers. To develop the loading system, the loading operation was broken down into four main activities: (a) start-up; (b) general filling; (c) trimming; and (d) topping.

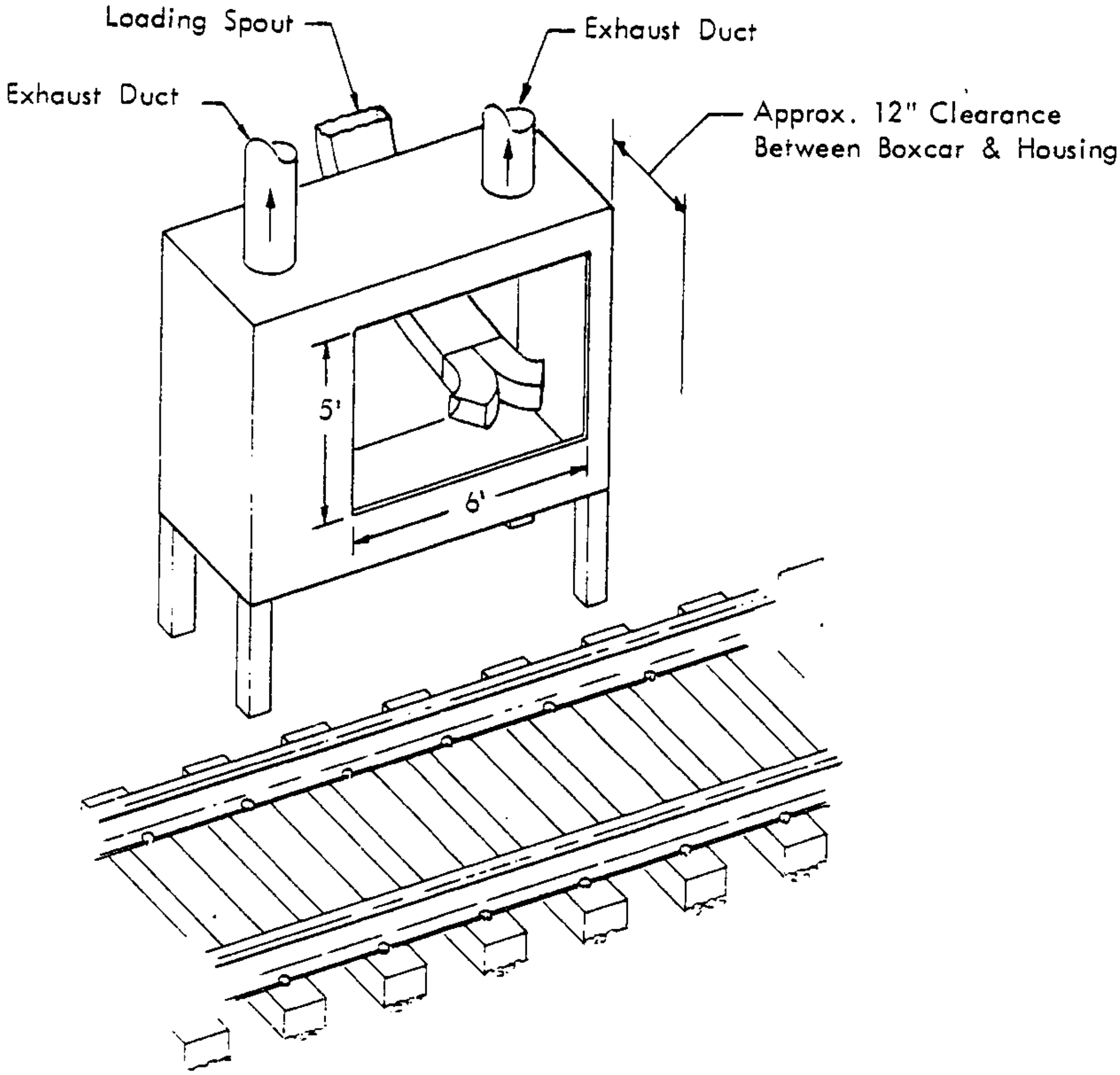


Figure C-2 - Dust control system for boxcar loading.

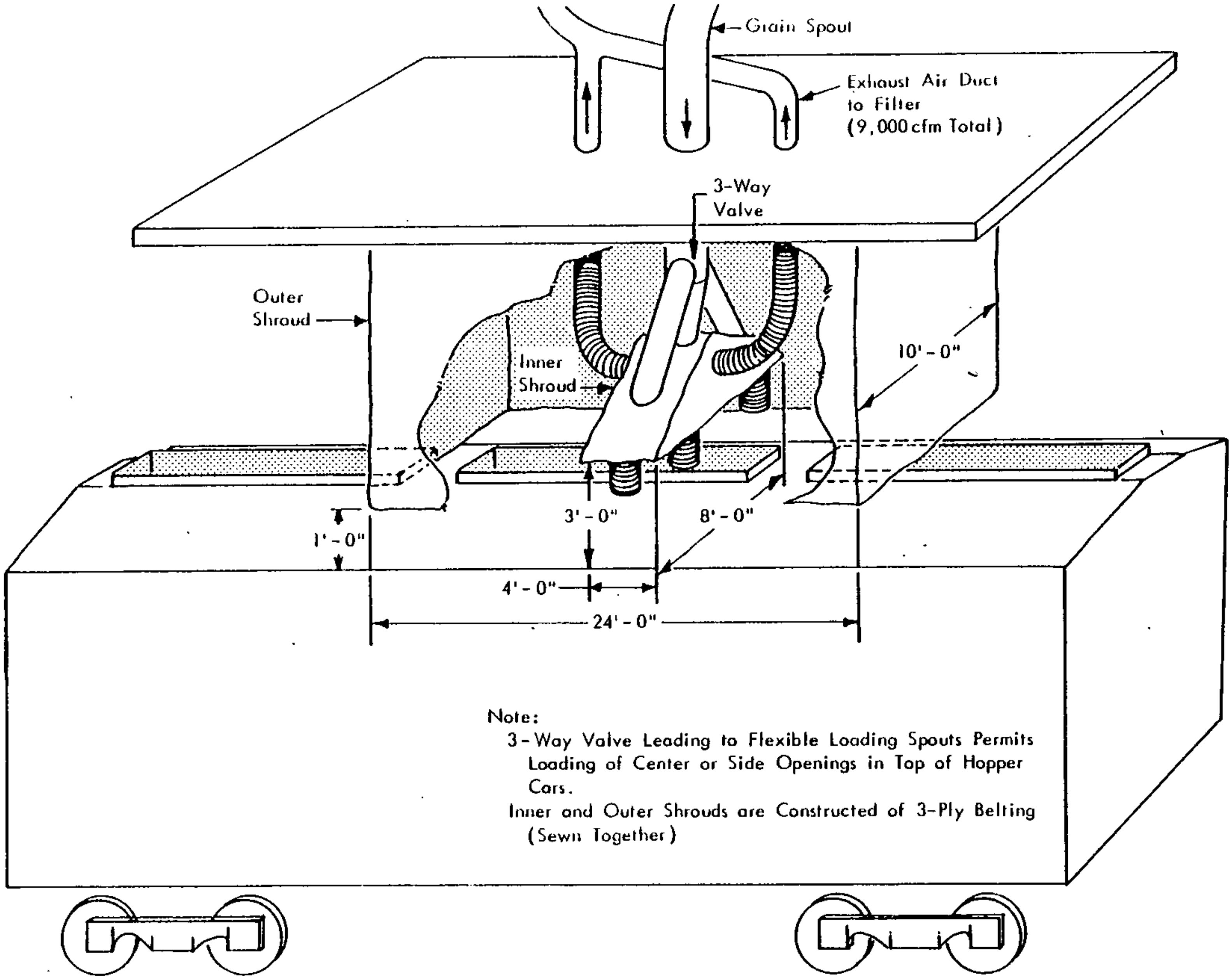


Figure C-3 - Hopper car loading dust control system.

All ships (except tankers) can be started in the following manner: The loading spout can be extended to within 3 ft of the bottom of the ship and pouring started at 1,200 tons/hr. This will build a pile sufficient to bury the spout in less than 2 min. During this period, dust will be emited but the regulation allows for excessive dust emission for 3 min every hr. In some cases, as many as two 10-ft extensions are needed to reach the bottom of the ship.26/

If the spout cannot be placed sufficiently close to the bottom, an alternate method should be used. This consists of inserting the spout in the hatch, closing the hatch covers as far as practical and covering the remaining hole with tarps or plastic. A 10 ft by 10 ft hole can be left open for visual inspection of the filling process. During this time, sufficient air is being drawn up the spout and the incoming air eliminates dust emissions. However, when the grain reaches the extended spout it should be buried and the pile of grain moved around by this method. These two methods will reduce emissions on all bulk carriers or general cargo type ships.26/

After the pile has been started, the general filling operation of evenly distributing the grain across the hold is initiated. From both an operational and dust control standpoint, it is best to keep the spout buried in the grain during this operation; however, when this is not practical, the hatch must be covered to the extent that only a 10-ft x 10-ft opening remains; filling can then be continued.26/

The trimming operation is unique to 'tween deckers and is required when grain cannot fill the voids under the lower decks by general filling. This trimming operation is one of the dustiest and the most difficult of all operations to control. To solve this dust problem, two methods were available; first, the design of the loading gallery at Pier 86 is such that the grain reaches sufficient velocity in the spout to be "thrown" a considerable distance by a simple deflector or spoon; second, the utilization of the long established mechanical trimming machine which throws the grain under the deck by means of a high speed belt at Pier 86. The mechanical trimming machine was found to best control dust emissions as follows.

First, 50% to 60% of the dust generated from the machine was emitted from the top of the machine. Second, about 30% was generated above and below the grain stream. And, third, the remaining 10% to 20% was entrained within the grain stream and could not be captured. To capture the machine-emitted dust, a hood and cover was installed on the machine with appropriate exhaust ducts for air flow.26/

The filling of the top four ft of the hold can produce more dust than any other general filling operation. This is caused when the grain dust which has been generated is captured by the wind before it can settle into the hold. To reduce the dust, it is essential that the spout be buried in the grain at all times. No other feasible method was available to reduce the dust. In fact, the topping operation is greatly improved by this practice as the tonnage is increased and is cleaner than other methods which held the spout above the grain.

Filling of tankers is broken down into two operations; general filling through the "hard hat" and final filling of the void in the tank through the Butterworths.[26] In most cases, the "hard hat" can be filled by inserting the main spout directly in the hole and having the exhaust air go up through the spout. By closing the Butterworths, all the air is exhausted through the "hard hat" and up the spout vacuum system. No other covering is normally necessary; however, if the spout does not fit directly into the "hard hat," covering may be necessary to better direct the grain flow.[26] To fill Butterworths, the spout must be reduced and attached to an airtight 12-in. flexible steel tube; the end is inserted in the Butterworth and filled at a rate not exceeding 600 tons/hr. The damper on the supplementary exhaust duct closes the opening to the loading spout. A 12-in. flexible plastic hose is placed over the duct end and inserted in the farthest Butterworth from the loading as practical. This allows for maximum settling of the dust; there are virtually no emissions from this loading mode.[26]

Some concern has been raised by dock workers about possible explosion hazards created by covering the hold during loading. However, it has been determined, that dust levels in the hold during loading are an order of magnitude below the lower explosion limit for grain dust of 35,000 mg/m^3.

Further details on ship and barge loading controls are presented in References 15 and 26.

DUST CONTROL DEVICES FOR GRAIN ELEVATORS

In each of the cases described above in which air was aspirated from an emissions source, this effluent stream should be ventilated through an air pollution control device for removal of particulate. The two control devices which are used at grain elevators are mechanical collectors, primarily cyclones, and fabric filters. Cyclones have the advantages of ease of maintenance and lower installation and operating costs. The major advantage of the fabric filter is the much higher collection efficiency that is attained. The paragraphs below present brief descriptions of the control devices used at grain elevators.[a]

a/ The paragraphs below are excerpted from Chapter 3 of Reference 15.

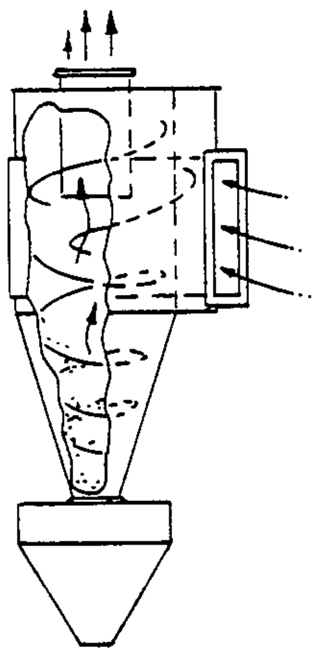
Cyclones--Cyclones have been used extensively for controlling emissions in the grain and feed industry. In the last 5 to 10 years, however, many companies have been installing fabric filters on new sources which were formally controlled only by cyclones and replacing existing cyclones with fabric filters.

Although several relationships between cyclone performance and design and operating parameters have been postulated, none is entirely satisfactory. The variation in collection efficiency with several of these parameters is shown in Table C-1.

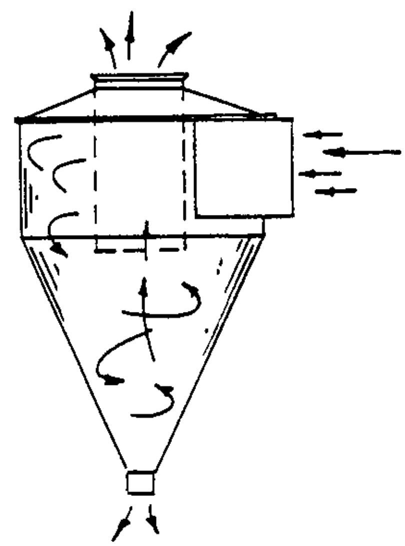
TABLE C-1. CYCLONE DESIGN PARAMETER AND ITS EFFECT ON EFFICIENCY[15]

Increase in parameter	Effect on efficiency
Particle size	Increase
Particle density	Increase
Inlet velocity	Increase
Cyclone body length	Increase
Number of gas revolutions in cyclone	Increase
Ratio of body diameter to exit duct diameter	Increase
Gas viscosity	Decrease
Cyclone diameter	Decrease
Gas density	Decrease

Cyclones are classified as either "high efficiency" or "high throughput." High efficiency cyclones are characterized by a narrow inlet opening, long body length relative to body diameter, and a small outlet diameter relative to the body diameter. Higher collection efficiencies result from the increased energy expended due to the high inlet velocities. High throughput cyclones have larger inlet openings and larger gas exits. Figure C-4 illustrates the geometrical relationships for these types of cyclones. Pressure drop through the low effieicncy units is typically in the range of 0.5 to 2 in. of water, whereas the high efficiency unit operates with 3 to 5 in. pressure drop.



High Efficiency Design



High Throughput Design

Figure C-4 - Cyclone dust collectors.

The low to medium efficiency cyclones are supplied by a variety of vendors, ranging from sheet metal fabricators to established air pollution control equipment manufacturers. Because of their low cost and maintenance requirements, they have been used extensively to control grain receiving and shipping operations, as well as a variety of grain processing emission sources. Collection efficiency for a properly operated and designed unit collecting grain dust may reach 95%. For units which are not properly maintained (e.g., dust accumulations on the walls, air infiltration through the dust discharge), the efficiency will decrease dramatically. Visible emissions can be quite noticeable even for the best operating units.

Collection efficiencies of high efficiency cyclones used on pneumatic conveying systems for grain, feed ingredients, and milled grain of about 99% have been reported. With the exception of flour mill systems, the unit can normally operate with minimum visible emissions; however, significant visible emissions can occur if a dusty load of grain is received.

Figure C-5 shows the typical collection efficiency for both the high throughput and high efficiency cyclones for various particle diameters. Since both types of devices are inefficient for small particle collection, and it is the smaller particles which scatter light most effectively, it is apparent that even the most efficient cyclone will operate with some visible emission if the incoming grain has a significant amount of fine dust or the emission is from a process which has emissions with a small mass mean diameter.

A modification of the conventional high efficiency cyclone, shown in Figure C-6 recycles approximately 60% of the discharge air stream back into the collector through a high energy blower in such a manner to induce a swirling motion around the wall. The introduction of this recycle stream through the high energy jets increases the unit's collection efficiency and forms an air blanket around the inside wall which enables the unit to handle higher moisture content streams.

This unit, the Aerodyne Type S collector, has operated satisfactorily on several types of process dryers. It has also been used to a limited extent on grain receiving operations where its efficiency has been estimated to be about 99%. However, as with other inertial collectors, the unit does not eliminate visible emissions resulting from handling grain with a high percentage of field dirt.

Fabric filters--Fabric filters have been used to control essentially every kind of emission source involving grain handling as well as several grain processing emission sources. The only grain industry sources where they are not used is where the effluent has a high moisture content and where there is a chance of contaminating the recovered product (e.g., pneumatic system which conveys many different types of feed ingredients). Industry

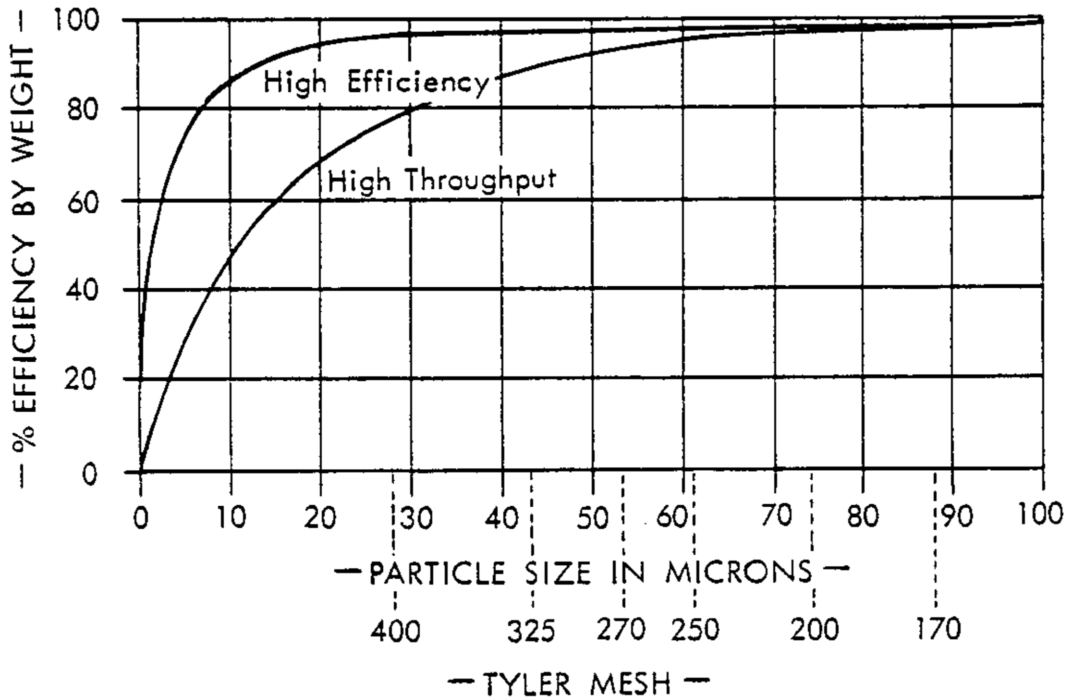


Figure C-5 - Typical collection efficiency curves for high throughput and high efficiency cyclones.

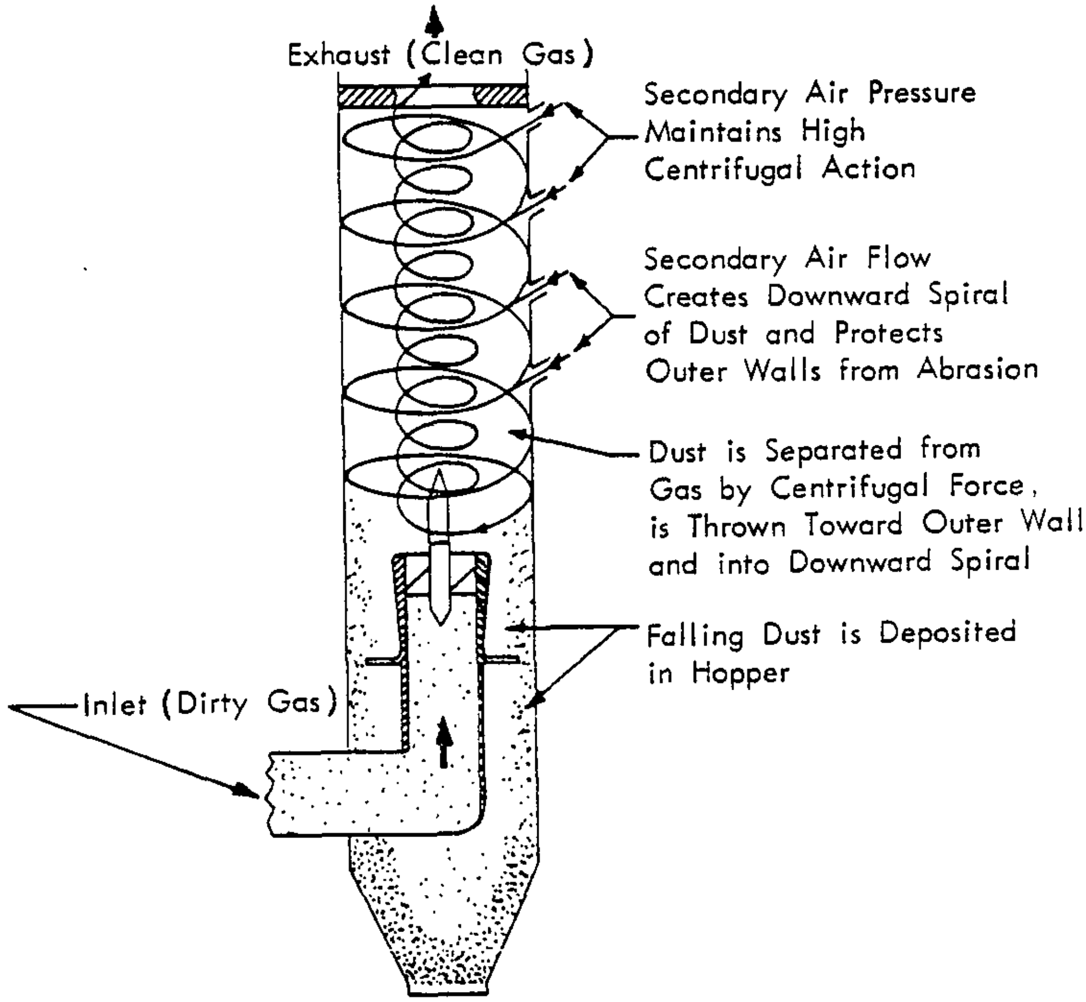


Figure C-6 - Recirculating cyclonic collector.

souces indicate that operational problems have occurred with fabric filter systems installed on receiving pits when wet corn is unloaded. Blinding of the fabric occurs because of the moisture content of the dust.

A number of particle collection mechanisms cause dust collection in a fabric filter system. These mechanisms include interception, impingement, diffusion, and to some extent electrostatic forces. These forces and their effect on particle collection have been the subject of considerable study. Theoretical equations have been developed to predict the pressure drop across the filter and the filter cake but they too are not adequate for use in designing systems. Thus, the design of fabric filter systems depends largely upon the experience gained from previous installations and observations of existing systems.

Fabric filtering systems can be classified in two ways. First is the shape of the filtering surface, either tubular or envelope. The second classification method is by type of bag cleaning mechanism, either mechanical or reverse air flow. Figure C-7 illustrates these basic shapes and the possible configurations of air flow through the filter.

Depending on arrangement, dust may be collected either inside the bag or outside. In the latter case, some type of frame retainer is required to hold the bag in shape. Another classification often used is "low-ratio" vs. "high-ratio," referring to the cubic feet per minute of air per square foot of media. Low ratio filters are generally characterized by a simple cleaning mechanism that does not remove all the dust from the bags, but excessive air flow resistance is prevented by using a large number of bags that maintain velocity through the media less than approximately 3 ft/min. Low ratio filters normally use woven cloth media and rely on the layer of dust (referred to as "dust cake") to reduce the loss of fine dust particles through the small openings between the threads. On the other hand, high ratio filters use more effective systems for cleaning permitting the use of felted media in which the layers of fibers overlay each other, so the passage of most fine particles is prevented without the dust cake. A reduction in the thickness of the dust cake permits higher velocity air flow through the media without excessive resistance, usually in a range between 6-20 ft/min (typically around 10 ft/min for grain dust).

Most new filters are using some method of flow reversal for cleaning since shaker cleaning mechanisms necessitate the use of lower air-to-cloth ratios and have higher maintenance costs. Air flow reversal methods include forcing the dust cake off of the fabric with back pressure; collapsing the cloth with associated flexure and cracking of the dust cake; snapping the cake off with a pulse of compressed air; and blowing it off with an air jet which traverses the outside surface of the cloth. One common system uses a blower to provide the reverse air for cleaning one bank of filter tubes

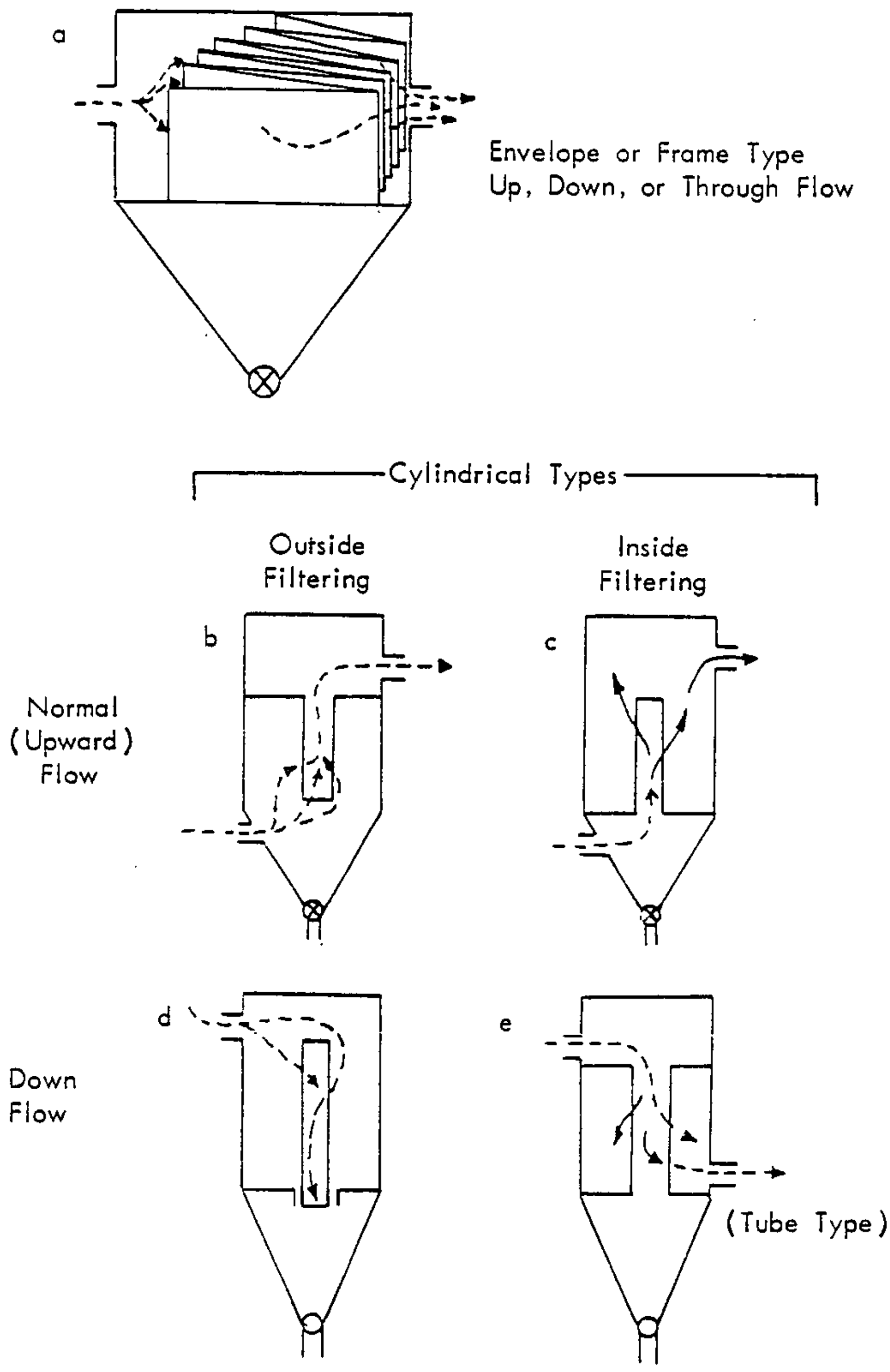


Figure C-7 - Fabric filter configurations.

at a time. This device is sometimes augmented by the compressed air shock as mentioned above, but in several installations this cleaning method has led to fabric blinding because of moisture in the compressed air supply.

The air-to-cloth ratio, sometimes referred to as filter rate, is one of the key design parameters for fabric filters. The ratios are customarily selected on the basis of past experience and consideration of the nature of the operation and the geographical location. For example, high ratios can be used on grain handling sources because of the intermittent nature of the operation, whereas in continuous grain milling operations, lower ratios are normally specified. In humid areas, such as the Gulf Coast, lower ratios are used because of the increased possibility of fabric blinding.

Cotton sateen, wool felt, and dacron felt have all been used as filter fabrics for grain industry emission sources. However, dacron felt is the fabric now recommended by essentially all of the filter manufacturers for these sources. Fabric weights between 16 and 22 oz/yd^2 are typically specified with the heavier weights recommended to minimize dust bleed through.

Fabric filters, when properly designed and operated, operate relatively trouble-free with efficiencies in excess of 99.9% and with no visible emission.

GENERAL BAGHOUSE OPERATION AND MAINTENANCE PRACTICES

Problems with bag blending, buildup of dust in the hopper, and bag tears are often the result of improper startup procedures. This is expecially true for intermittent operations such as those found in grain elevators.

At the first startup of the system, and also whenever new bags have been installed by the maintenance crew, the bags should be checked after a few hours of operation for tension, leaks, and expected pressure differential. Initial temperature changes or the cleaning cycle can pull loose or burst a bag. It is wise to record at least the basic instrument readings during this initial startup with new bags for ready reference and comparison during later startups.

During any startup, transients in the dust generating process and surges to the filter house are probable and ought to be anticipated. Unexpected temperature, pressure, or moisture may badly damage a new installation. In particular, running almost any indoor air or combustion gases into a cold filter can cause condensation on the walls and cloth, leading to blinding and corrosion. Condensation in the filterhouse may void the manufacturer's guarantee. It can be prevented by preheating the filter or the gas.

A typical sequenced startup procedure for a large continuous, automatic, multicompartment fabric filter using either reverse air, shake, or combination cleaning is summarized as follows:[27]

1. Check to see that all system monitoring instruments are reading zero; especially fan motor ammeters and compartment pressure manometers.

2. Close all system dampers except tempering air damper (if used). This includes main compartment isolation dampers, reverse air dampers (if used), and fan modulation dampers.

3. Start material handling system including any motorized airlock devices and screw conveyors. Hoppers should be empty on startup.

4. Sequentially start main fans, allowing each to come to speed before starting next fan.

5. Start separate reverse air fan if used and allow to come to speed.

6. Engage fan modulating damper circuit(s).

7. Engage tempering air damper circuit (if used).

8. Slowly open main-compartment isolation dampers. If dampers are opened too quickly, bags will pop open, ultimately resulting in failure.

9. Engage compartment cleaning recircuit.

10. Check normalcy of readings on system monitoring instruments, especially fan motor ammeters and compartment pressure manometers.

Improper shutdown procedures can also cause bag blinding or dust buildup in the hopper. A typical shutdown procedure is summarized as follows:[27]

1. After process has been stopped and is no longer evolving emissions allow baghouse to track through one complete cleaning cycle; this will purge system of process gas and collected dust.

2. Stop main fans.

3. Stop separate reverse air fan, if used.

4. Allow material removal system to operate for 1 hr or until system is purged of collected material.

Proper use of shutdown procedures is especially important in grain elevators, as improper bag cleaning before shutdown may result in blinding.

General maintenance procedures for fabric filters that can be applied to grain elevators are described below. Table C-2 presents a checklist of items that require regular inspection.

Plant personnel must learn to recognize the symptoms that indicate potential problems in the fabric filter, determine the cause of the problem and remedy it, either by in-plant action or by contact with the manufacturer or other outside resource.

High pressure drop across the system is a symptom for which there could be many causes, e.g., difficulties with the bag cleaning mechanism, low compressed-air pressure, weak shaking action, loose bag-tension, or excessive reentrainment of dust. Many other factors can cause excessive pressure drop, and several options are usually available for corrective action appropriate to each cause. Thus, the ability to locate and correct malfunctioning baghouse components is important and requires a thorough understanding of the system.

TABLE C-2. CHECKLIST FOR ROUTINE INSPECTION OF BAGHOUSE[27]

Component[a]	Check for:
Shaker mechanism(s)	Proper operation without binding; loose or worn bearings, mountings, drive components; proper lubrication
Bags	Worn, abraded, damaged bags; condensation on bags; improper bag tension (S) (RF); loose, damaged, or improper bag connections
Magnehelic gauge or manometer	Steadiness of pressure drop (should be read daily)
Dust removal system	Worn bearings, loose mountings, deformed parts, worn or loose drive mechanism, proper lubrication
Baghouse structure (housing, hopper)	Loose bolts, cracks in welds; cracked, chipped, or worn paint; corrosion
Ductwork	Corrosion, holes, external damage, loose bolts, cracked welds, dust buildup
Solenoids, pulsing valves (RP)	Proper operation (audible compressed air blast)
Compressed air system (RP, PP)	See above; proper lubrication of compressor; leaks in headers, piping
Fans	Proper mounting, proper lubrication of compressor; leaks in headers, piping
Damper valves (S, PP, RF)	Proper operation and synchronization; leaking cylinders, bad air connections, proper lubrication, damaged seals
Doors	Worn, loose, damaged, or missing seals; proper tight closing
Baffle plate	Abrasion, excessive wear

a/ RP-reverse pulse; PP-plenum pulse; S-shaker; RF-reverse flow.

APPENDIX D

SUMMARY OF STATE REGULATIONS

Table D-1 summarizes state regulations applicable to grain elevators. These regulations are classified as one of the following five forms: (a) opacity or visible emissions; (b) process weight; (c) allowable concentration of particulate; (d) type or level of effectiveness control equipment criteria; and (e) fugitive dust nuisance regulations.

Table D-2 presents a summary of the results of telephone contacts with state and local agencies. It identifies the regulations actually enforced and describes enforcement practices.

TABLE D-1. SUMMARY OF STATE REGULATIONS

Region	State	Emission Source	Opacity or Visible Emissions Regulations	Type	Process Weight Regulations	Type	Concentration Regulations	Type	Control Equipment Regulations	Type	Fugitive Dust or Housekeeping Regulations	Type
II	New York	All	20%, 3 min/hr[1/]	I			0.10 lb part/1000 lb undiluted gas at actual conditions	I				
III	Pennsylvania	All other than those below	20%, no more than 3 min/hr; 60% all times[5/]	I			0.05 gr/dscf[4/]	I			No fugitive dust visible at property line.[7/]	I
		Loading/unloading			$E = 5.05p^{0.42}$[8/]	G						
		Screening/cleaning			$E = 8.34p^{0.42}$[8/]	G						
		Drying			$E = 7.03p^{0.42}$[8/]	G						
IV	North Carolina	All existing	Ringlemann No. 2, no more than 5 min/hr; 20 min/day[9/]	I	$E = 4.10p^{0.67}, p \leq 30$ T/hr[10/] $E = 55p^{0.11}-40, p>30$ T/hr	I						
		All new sources	Ringlemann No. 1, conditions as above[9/]	I	Same as above							
V	Illinois	Grain handling and drying[a/]							Air Pollution Control devices checked daily. Exposed flat surfaces clean.[11/]	G		
	Dump pit[a/]								Aspiration equipment and Air Pollution Control devices maintained and operated.[11/]			
	Headhouse[a/]	Visible quantities of dust not allowed to escape[11/]										
	Cleaning and Separating[b/]										Capture efficiency sufficient to eliminate visible emissions (VE).[11/] Removal efficiency of 90%[c/11/] Removal efficiency of 98%[d/]	
	Dump Pit[b/]										200 fpm minimum face velocity at grate[11/] Removal efficiency 90%[c/] Removal efficiency 98%[d/]	

(continued)

TABLE D-1. (continued)

Region	State	Emission Source	Opacity or Visible Emissions Regulations	Type	Process Weight Regulations	Type	Concentration Regulations	Type	Control Equipment Regulations	Type	Fugitive Dust or Housekeeping Regulations	Type
		Internal transfer[b]							Enclosed to prohibit[11] VE to atmosphere. Removal efficiency 90% [c] Removal efficiency 98% [d]			
		Truck/hopper car-loading[b]							Sleeves 6 in. below sides of receiving vehicle.[11]			
		Boxcar loading[b]							BACT[11]			
		Watercraft loading[b]							Captured and vented to 90%[c/11] Removal device. Captured and vented to 98%[d] Removal device.			
		Column Dryers[b]							Perforation not to exceed 0.094 in.[11]			
		Rack dryers[b]							50 mesh screen and exhaust gas.[11] 90% removal efficiency[c] 98% removal efficiency[d]			
		General									Housekeeping check-list maintained.	G
VI	Texas	All Sources	[e]		$E = 3.12p^{0.985}, p<20$ T/hr[f] $E = 25.4p^{0.287}, p>20$ T/hr	G			No person can permit[13] fine material to be handled, transported, or stored without the installation and use of hoods, fans, & filters.[e,g]	I		
VII	Iowa	All	40%[14]	I	$E = 4.10p^{0.67}$, $p<30$ T/hr[15] $E = 55.0p^{0.11}-40$, $p>30$T/hr	I			Reasonable precautions such as installation and use of containment or control equipment to enclose or otherwise limit emissions[16]	G		
		Handling and transfer					0.1 gr/scf of exhaust gas[7]	G				
	Kansas	Existing elevators	40%[18]	I	$E = 4.10p^{0.67}, p<30$T/hr[19] $E = 55.0p^{0.11}-40, p>30$T/hr	I					Emissions may not cause ambient concentrations at the property line of more than 20 µg/m³ above background[20]	I
		New elevators	20%[18]	I	Same as above							

TABLE D-1. (continued)

Region	State	Emission Source	Opacity or Visible Emissions Regulations	Type	Process Weight Regulations	Type	Concentration Regulations	Type	Control Equipment Regulations	Type	Fugitive Dust or Housekeeping Regulations	Type
	Nebraska	All Sources	20% 21/	I	$E = 4.1p^{0.67}$, $p<30T/hr$ 23/ $E = 55.0p^{0.11}-40$, $p>30T/hr$	I					No handling and storage which produces emissions visible beyond premises 23/	I
VIII	North Dakota	Existing sources	40% 24/	I	$E = 4.1p^{0.67}$, $p<30T/hr$ 25/ $E = 55.0p^{0.11}-40$, $p>30T/hr$	I					No handling, transport, or storage materials which cause emissions which create a nuisance or cause NAAQS to be exceeded.	I
		New sources	20% 24/	I	See above							
IX	Washington	All sources	20% h/ 27/	G			0.10 gr/dscf g/ 27/	G		G	No particulate matter may be deposited beyond property line which interferes with the use and enjoyment of the property 27/	G
X	California i/	All sources	40% 28/								No discharge of such quantities of contaminants which cause injury, detriment, nuisance, or annoyance to any considerable number of persons 29/	I

I = Industrial process regulation.
G = Grain elevator regulation.

a/ Applies to all elevators in the state of Illinois.

b/ Applies only to elevators with annual throughput greater than 3×10^5 bu.

c/ For facilities having annual throughput less than 2×10^6 bu or located outside a major population area.

d/ For facilities having annual throughput greater than 2×10^6 bu and located in a major population area.

e/ Texas is precluded by law from applying visible emissions standards for agriculturally related sources.

f/ By law, elevator operators may request an alternate monitoring method subject to director approval.

g/ Applies only to NSA's where federal ambient particulate standards are exceeded.

h/ Applies only to elevators in sensitive areas.

i/ Regulations for stationary sources are promulgated and enforced by air pollution control districts. However, they must be at least as stringent as the stated regulations.

References - Table D-1

1. New York Rules, Title 6, Chapter III, Subchapter A, Prevention and Control of Air Contamination and Air Pollution, Section 211.3 and 212.7.

2. Ibid, Section 212.3.

3. New York State Dept. of Environmental Conservation, "Instructions for the Preparation and Submission of an Application for a Permit to construct or a Certificate to Operate, Processes and Exhaust and/or Ventilation Systems," Paragraph F.2.

4. Op. Cit. Ref. 1, Section 212.4.

5. Pennsylvania Standards for Air Contaminants, Title 25, Rules and Regulations; Part I, Dept. of Environmental Resources; Subpart C, Protection of Natural Resources; Article III, Air Resource, Section 123.41.

6. Ibid, Section 123.13 (b).

7. Ibid, Section 123.2.

8. Ibid, Section 123.13, Table 1 and Formula (2).

9. North Carolina Rules and Regulations Governing the Control of Air Pollution, Section II Regulations; Rule 2. Visible Emissions

10. Ibid, Section IV, Emission Control Standards, Rule 2.30.

11. Illinois Pollution Control Board Rules and Regulations, Chapter 2, Air Pollution; Part II, Emissions Standards and Limitations for Stationary Sources; Rule 203.9.

12. Texas Regulation I: Control of Air Pollution from Smoke, Visible Emissions and Particulate Matter; Rule 107.2.

13. Ibid, Rule 104.

14. Iowa Department Rules 1973, Environmental Quality Dept., Title I, Air Quality, Chapter 4, Emission Standards for Contaminants, Rule 4.3 (2) d.

15. Ibid, Rule 4.3 (2) a

16. Ibid, Rule 4.3 (2) c.

17. Ibid, Rule 4.4 (7)

18. Kansas Air Pollution Emission Control Regulations, Rule 28-19-50.

References - Table D-1 (continued)

19. Ibid, 28-19-20.

20. Ibid, 28-19-51.

21. Nebraska Air Pollution Control Rules and Regulations.

22. Ibid, Rule 5.

23. Ibid, Rule 14.

24. North Dakota Air Pollution Control Regulations R-23-25-03.

25. Ibid R-23-25-05, Paragraph 5.100.

26. Ibid Paragraph 5.400.

27. Washington Department of Ecology General Regulations for Air Pollution Sources; Washington Administrative Code, Chapter 173-400; Rule WAC 173-400-070 (4).

28. California Health and Safety Code; Part 4, Nonvehicular Air Pollution Control; Chapter 3, Emission Limitations; Paragraph 41701.

29. Ibid, Paragraph 41700.

TABLE D-2. MONITORING STRATEGIES

State	Elevators subject to compliance monitoring	Sources Monitored	Regulations: Opacity	Regulations: Process wt.	Regulations: Concentration	Regulations: Other	Monitoring Comments
California	All elevators	Opacity-Ducted and fugitive grain loading - Fugitive	20-40%		0.01 - 0.1 gr/dscf		Rules are promulgated and enforced by APCD's. There are no rules specific to grain elevators. Inspectors visit elevators at least once per year and more often if there are complaints. Opacity regulation is most frequent enforcement tool.
Illinois	All elevators with potential emissions of greater than 100 T/yr	Grain handling and drying.				Air pollution control devices checked daily Exposed flat surfaces clean.	Compliance Monitoring is conducted only at plants with greater than 100 T/yr particulate emissions. Illinois has a priority schedule for monitoring based on source size, location with respect to containment, and compliance status. Grain elevators are inspected only as they fall into the priority schedule or as citizen complaints are required.
		Dump Pit				Aspiration equipment and Air Pollution Control devices maintained and operated.	The priority schedule is as follows:
		Headhouse				Visible quantities of dust not allowed to escape.	a. Task force priority (35-40 large sources primarily integrated iron and steel plants and large power plants).
		General				Housekeeping checklist maintained.[a/]	b. Non-attainment area, non-compliance source (i) No control program (ii) Control program in litigation (iii) Formal control program
	Annual Throughput greater than 3 x 10^5 bu and potential emissions 100T/yr.	Cleaning and Separating				Capture efficiency sufficient to eliminate visible emissions (VE).	c. Attainment area, non-compliance source (i) No control program (ii) Control program in litigation (iii) Formal control program
	b					Removal efficiency of 90%	d. Non-attainment area/compliance source e. Attainment area/compliance source
	c					Removal efficiency of 98%	Monitoring conducted by 37 engineers and 7 technicians from 3 regional offices.
		Dump Pit				200 fpm minimum face velocity at grate.	
	b					Removal efficiency 90%	
	c					Removal efficiency 98%	
		Internal Transfer				Enclosed to prohibit VE to atmosphere.	
	b					Removal efficiency 90%	
	c					Removal efficiency 98%	
		Truck/Hopper Car Loading				Sleeves 6 in. below sides of receiving vehicle.	
		Boxcar Loading				BACT	
	b	Watercraft Loading				Captured and vented to 90% Removal device	
	c					Captured and vented to 98% Removal device	

(continued)

TABLE D-2. (continued)

State	Elevators subject to compliance monitoring	Sources monitored	Regulations: Opacity	Regulations: Process Wt.	Regulations: Concentration	Regulations: Other	Monitoring comments
		Column Dryers				Perforation not to exceed 0.094 in.	
	b c	Rack Dryers				50 mesh screen and exhaust gas. 90% removal efficiency 98% removal efficiency	
Iowa	Storage capacity greater than 2 x 10^6 bu or in non-attainment area	Corn Dryers Flues or Ducts Dump Pits/Windows			0.1 gr/scf 0.1 gr/scf	Enclosure No visible emissions (Nuisance Regulations)	Primary enforcement tool is nuisance fugitive dust emissions. Enforces only if there are citizen complaints. Staff includes one inspector for each of six regions.
Kansas	All elevators New Existing	Screening All other handling sources	 20% 40%	$E=41p^{0.67}$			All elevators with emissions potential 25 ton/year are inspected once/year spread out over the year. Each inspector is responsible for 15 to 25 counties and goes through each county once/month. Each source is usually examined as the inspector drives through and may be inspected if problems are detected.
Nebraska	All elevators	Any exhaust Total Facility	20%			No VE beyond premises.	Annual inspection (not necessarily during harvest). If the elevator is not in operation inspectors examine housekeeping (no specific checklist). A total of 6 inspectors over 800 elevators.
New York	Constructed prior to 7/1/73; Constructed after 7/1/73	All sources			0.3 lb part/1000 lb undiluted exhaust gas 0.05 gr/ascf		Last of instructions used for monitoring compliance. Regional offices handle field enforcement.
North Carolina	All elevators	All Sources New Existing >30 T/hr <30 T/hr	20% 40%	$E=55p^{0.11} - 40$ $E=41p^{0.67}$			All elevators are forced to comply but inspectors are given a large degree of discretion with location playing a large part in decisions. Generally aspiration required on highly used dump pits. An extended spout is required for loadout. Opacity is most frequently used inspection tool. Some testing has been done.
North Dakota	All elevators	Dryers and Headhouse System New Existing 30T/year 30T/yr	 20% 40%	$E=55p^{0.11} - 40$ $E=41p^{0.67}$		Aspiration on dump pits and headhouse according to guidelines in <u>Industrial Ventilation</u>	Compliance tests are required on vented sources unless a similar control measure has gained approval. (New regulations will probably require specified grain loading and capture requirements.

TABLE D-2. (continued)

State	Elevators subject to compliance monitoring	Sources monitored	Regulations: Opacity	Regulations: Process wt.	Regulations: Concentration	Regulations: Other	Monitoring comments
Pennsylvania	All facilities	All sources				No VE at property line	Enforcement handled at local level. No testing has been conducted. No enforcement cases in grain elevators in recent past.
		Loading/Unloading		$E=5.03p^{0.42}$	0.02 gr/dscf		
		Screening/Cleaning		$E=5.03p^{0.42}$	0.02 gr/dscf		
		Drying		$E=8.34p^{0.42}$	0.02 gr/dscf		
				$E=7.03p^{0.42}$	0.02 gr/dscf		
Texas	All elevators	All sources 20 T/hr		$*E=3.12p^{0.985}$		*Operator may choose alternate compliance measure	State is precluded from using VE or opacity regulations for agricultural sources. Many operators choose alternate compliance measure and often use location as measure.
		20 T/hr		$*E=25.4p^{0.287}$			
Washington	Terminal elevators or country elevators in "sensitive areas"	All sources	20%			No deposition of particulate on adjacent property. Reasonable precaution for handling of materials.	Enforcement is the responsibility of local agencies Major problem with ship loading at port elevators. Envorcement at port elevators by daily observation. Generally all emission points in port elevators were controlled.

a/ See Tables 12 and 13 for checklist.

b/ Facilities having an annual throughput of less than 2×10^6 bu or located outside a major metropolitan area.

c/ Facilities having an annual throughput of greater than 2×10^6 bu and located in a major metropolitan area.

APPENDIX E

DEVELOPMENT AND FIELD EVALUATION OF AN ALTERNATIVE INSPECTION MONITORING STRATEGY

INITIAL DEVELOPMENT OF MONITORING AND ENFORCEMENT PROGRAM

If agencies are to make most efficient use of enforcement resources, it is not reasonbale to apply equal monitoring effort to small country elevators which may handle as little as 25,000 bushels of grain per year and large terminal elevators which handle tens of millions of bushels. Thus, the initial step in developing the compliance monitoring strategy was the identification of criteria which can be used to determine the effort to be expended in monitoring a particular elevator. The primary consideration was that the criteria used should reflect the impact of the elevator on air quality. It was assumed that this impact was directly related to the level of emissions from the elevator.

Characteristics of a grain elevator which effect the quantity of emissions from that elevator include the amount of grain handled, types and extent of operations (e.g., boxcar unloading versus hopper car unloading), types of grain handled, grain handling practices, extent of application of control equipment, type of control equipment, and control equipment operation and maintenance practices. After examining these characteristics, it was determined that for most of these parameters, general industry data were either: (a) insufficient to quantify the effect of differences on emissions; or (b) insufficient to identify an elevator in a discrete class with respect to a parameter. It was then decided that the general monitoring scheme would be developed by using only the amount of grain handled (throughput) as the criteria by which the elevator air quality impact is determined.

The above analysis does not imply that state and local agencies applying the monitoring strategy should disregard the other parameters. In fact, if data on the elevator population in a jurisdiction are sufficient to determine emissions differences based on other parameters, inclusion of these in a modified strategy will improve the effectiveness of the strategy.

Two factors affected the decision to base the classification system on elevator throughput. First, throughput is a parameter that can be obtained and documented relatively easily. All elevators keep records of grain bought and sold and such information can be requested by an agency as a standard procedure. Second, throughput is a good indicator of the potential emissions from an elevator in the absence of controls. While we are aware that most larger elevators have some type of control, throughput is an indicator of the relative impact of elevator, should a control device malfunction.

Using the emissions data presented in Section 4, size ranges were developed for three classes of elevators based on the level of potential uncontrolled emissions: Class A - elevators that never exceed 100 tons/year; Class B - elevators that may or may not exceed 100 tons/year depending on the type of grain handled and operating practices; and Class C - elevators whose uncontrolled emissions definitely exceed 100 tons/year. After conversation with the project officer, a fourth class, Class D, was added to the scheme to separate the large country and subterminal elevators from the large terminal elevators. This latter class was developed because such elevators are generally located in urban areas, and hence the emissions have greater potential for impact on human health and welfare. The various classes of elevators, hereafter called severity classes, are shown in Table E-1.

TABLE E-1. CLASSIFICATION OF ELEVATORS BASED ON SEVERITY OF EMISSIONS

Process throughput Bu/Yr	Severity class
$<0.5 \times 10^6$	A
$\geq 0.5 \times 10^6$ but $\leq 2 \times 10^6$	B
$>2 \times 10^6$ but $\leq 8 \times 10^6$	C
$>8 \times 10^6$	D

Table E-2 presents a test-matrix of the three-level inspection strategy. Several revisions were made to the inspection procedure originally developed. The proposed monitoring strategy is not tied to any specific SIP's. Consequently when applying the strategy to certain state and local air pollution control agency enforcement programs, modification of the present SIP regulations/standards or modification of the strategy may be required.

Based on the three-level inspection strategy, a complete monitoring and enforcement program was developed for use by the state and local agencies on a routine basis. The strategy would include systematic Level I, Level II,

TABLE E-2. TEST MATRIX OF THREE-LEVEL INSPECTION STRATEGY FOR GRAIN ELEVATORS

Parameters	Level I	Level II	Level III
Time of Inspection/Season	"Peak" season: Harvest season - for elevators receiving grain directly from farms. This may include country elevators and some terminals. At normal volume of activity - for "non-seasonal" elevators.	Off-season for "seasonal" elevators. For other elevators, at normal volume of activity. (Including those affected by weather[a/])	Generally during off-season but at reasonable volume of activity.
Coverage	All elevators	• All elevators under the third level of severity category, i.e., Class C and D elevators • Elevators under the first and second level of severity category, k.e., Class A and B, will be inspected only if found in violation at Level I inspection	Only those elevators which were found in violation at prior inspection levels and if subsequent warnings failed to result in compliance
Elevator Operator's prior knowledge of inspection, i.e., announced or unannounced	Unannounced	Unannounced	Unannounced
Inspection Mode	Walk-around the elevator property line if feasible. If not, enter the property after informing the elevator operator (Class C and D).	Walk-in through the various internal and "open" operations after informing the operator on arrival.	Complete inspection of dust control system after informing the operator on arrival.
Need for elevator operator's time and accompaniement with inspector	No	Yes	Yes
Checklist	(1) Visible emissions check at the following points: • Load-in, Load-out - all car, truck, barge/ship, loading and unloading operations and barge-to-elevator conveyors. • Headhouse • Gallery windows • Ground level openings • All control equipment outlets. (2) If any or all of the above points is found likely to be out of compliance, a short test for opacity (about 3-5 min. observation) should be done on the "worst" of the above emission points to determine if the source is in violation. If so, a notice should be issued.	Checklist will include the following parameters related to dust emissions: • Opacity • Ventilation/containment systems • Aspiration velocity - using velometer at grates and boots • Dryer specifications (perforation diameter or mesh size) • Control equipment size (e.g., air/cloth ratio), operation (e.g., ΔP, inspection ports, valve plugging), and maintenance check (e.g., holes in fabric filter bags). • Housekeeping Approximate standard correlations between the above operating parameters and performance factors will be used to predict the extent of control from the above data. If the completed checklist indicates that the source is in violation, a warning should be issued to that effect.	Complete inspection of ventilation equipment, dust containment, ducts, and dust control equipment to determine the effectiveness, deficiencies, and needed improvements/modification to meet the applicable regulations.
Estimated Inspector's time requirements	(1) 15 min. If necessary, (2) will require and additional 15 min.	About 1/2-3 hr depending on the size of the facility, extent of control system, etc.	1/2-1 day depending on the source size, control system, etc.

a/ e.g., Elevators located in some of the Great Lakes areas are not operational during winter due to lake freeze-up. In such cases, Level II inspection will be done during normal operational period.

and Level III inspections and issuance of notice of violations and warnings for compliance. The procedure is based on Severity Classes A, B, C, and D as well as the location of the elevators, viz., attainment area vs. non-attainment area. Figure E-1 presents the complete monitoring scheme.

FIELD EVALUATION

After the compliance monitoring strategy described above was developed, the U.S. EPA issued a second task to MRI to conduct a field analysis of the strategy. The overall objectives of this task were as follows: (a) to assist Region VII in conducting SIP overview inspections of a selected number (30 grain elevators in Nebraska; and (b) to use the collected data in comparing the present inspection procedure with the monitoring scheme developed earlier.

The methodology for meeting the above two goals consisted of four discrete activities which are listed below:

1. Data review and categorization of elevators.

2. Inspection of elevators.

3. Preparation and submission of surveillance reports to Region VII.

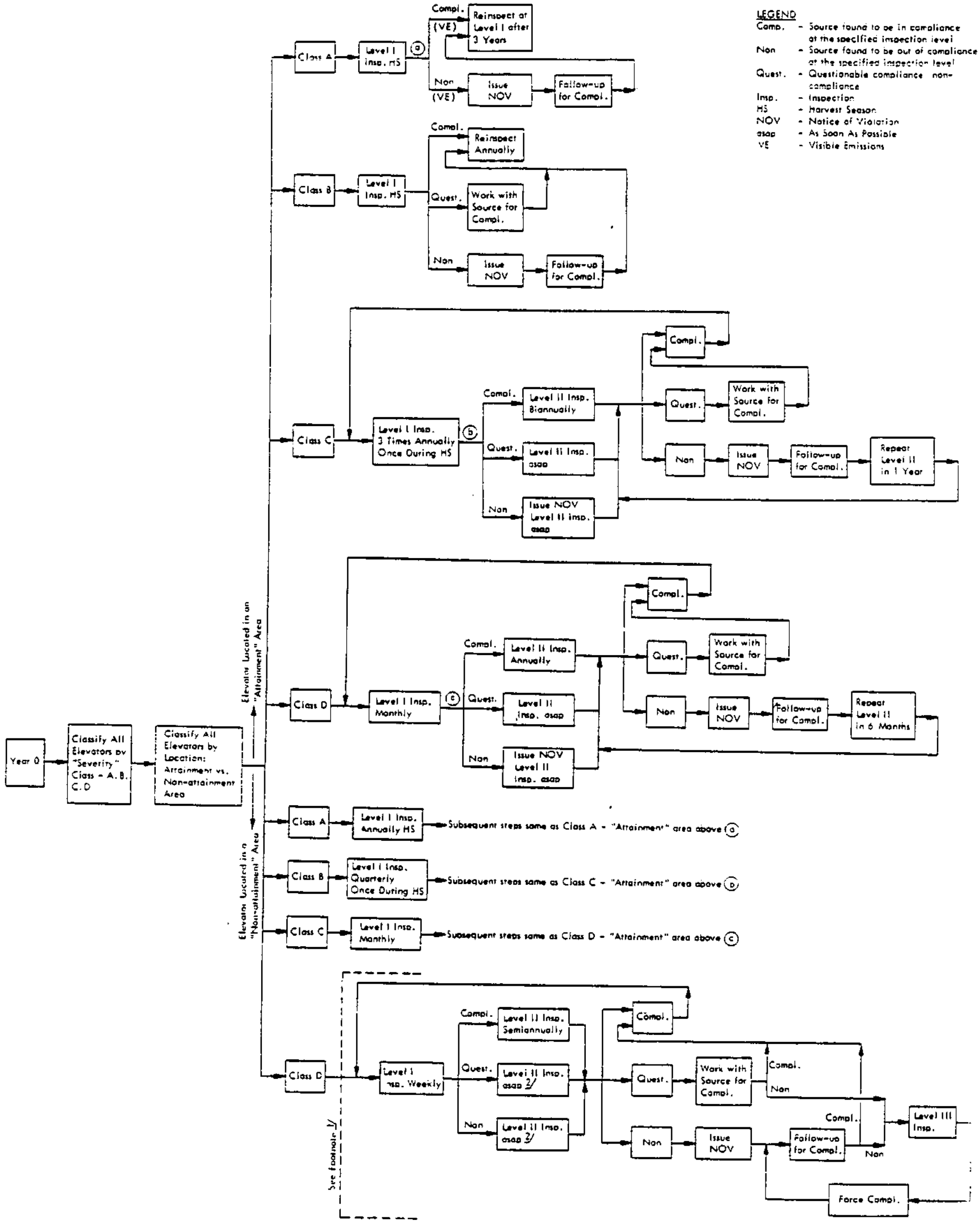
4. Data analysis to compare monitoring strategies.

The subsections below describe the first two activities.

Data Review and Categorization of Elevators

Initial activity focused on selecting the elevators to be used as inspection sites in the evaluation of the monitoring strategy. It was determined that a total of 30 elevators (10 Class A, 10 Class B, five Class C, and five Class D) would be inspected using Level I and Level II procedures. Eight (8) of these elevators (four Class C and four Class D) would also be inspected using Level III procedures.

It was decided that the inspections would focus on the areas surrounding Lincoln, Omaha, and Grand Island, Nebraska. This allowed the most expeditious use of resources and encompassed a sufficient diversity of elevators to provide a representative sample. Records provided by the Nebraska Air Pollution Control Agency, showed a total of 73 elevators were in these areas. The number of elevators in each source severity class is shown below. Other information such as elevator location, the plant contact, storage capacity, and accessibility are presented in Appendix G.



1/ Monitoring strategy shown right of dashed line for Class D - Non-attainment area elevators is only tentative at the present time. Finalization of the strategy will be made subsequent to development of a detailed Level III inspection check-list.

2/ Level II inspection subject to - "upset" conditions, continued violation at Level I (i.e. Level II only if the source is found Quest. or Non 3 or 4 weeks in a row) and compliance schedule set for the source.

Figure E-1 - Compliance monitoring scheme for grain elevators.

Class of Elevator*		Number of Elevators
A		24
B		25
C		17
D		7
	Total	73

* This classification scheme is based on throughput; Class A denotes a throughput of $< 0.5 \times 10^6$ Bu/year, Class B denotes a throughput in the range of $\geq 0.5 \times 10^6$ to $< 2 \times 10^6$ Bu/year, Class C between $>2 \times 10^6$ and $\leq 8 \times 10^6$ Bu/year, Class D $>8 \times 10^6$ Bu/year.

Out of these 73 elevators, a total of 30 with a severity class distribution as described above were chosen randomly for inspection.

Inspection of Elevators

The primary objective of this phase of the program was to develop and carry out a field study that would provide data for analysis of the inspection monitoring scheme described above. This section will provide a detailed description of the field study to provide a sound basis for the analysis of the results and discussions of improvements for future programs of a similar nature. The discussions are divided into the following topics:

- Development of the inspection protocol for Levels I, II, and III
- Development of the field sampling protocol
- Description of the initial group of field inspections
- Revision of inspection and field test protocols
- Description of the second group of field inspections

Development of Inspection Protocol--

As described above, three levels of inspection (Level I, Level II, and Level III) were proposed as a part of the monitoring strategy. The basic premise of the levels of inspection concept is that as the level is increased the more detailed inspection will result in a higher probability of identification of noncompliance. As a corollary, however, increased expenditure results from increased levels of inspection and there is an obvious cost cost associated with the increased probability of compliance. Based on this premise, the following inspection protocol was developed.

The primary consideration in the design of Level I inspections was to minimize inspection time while obtaining a reasonable indication of compliance status. This was best accomplished by minimizing contact with elevator operators and using only visible emissions to evaluate compliance. An inspection form was then developed as shown in Figure E-2. It is assumed that in most cases the inspector will conduct the inspection from the car or by walking around the plant. It is not necessary to contact the plant operator unless the inspector enters the plant boundary.

The objective of the Level II inspection format was to gain as reliable an indication as possible of the compliance status of the elevator without elaborate sampling of the emissions stream or testing of control equipment. The Level II format was designed to include the same visible emissions observations as the ones taken during Level I inspections. In addition, the format included a visual observation of control equipment to ascertain that air locks and cleaning mechanisms were operational and to record readings on permanently mounted instrumentation. Finally, on controlled operations the format was designed to obtain data items such as hood velocities and housekeeping operations which might indicate capture efficiency of the system. It was anticipated that these data might allow the determination of the compliance status with respect to the process weight regulation. The Level II inspection sheet is shown in Figure E-3.

The Level III inspection procedure was developed by PEDCo Environmental Inc., under separate contract to the U.S. EPA. This procedure included all observations taken as a part of Level II. In addition, the procedure included an internal inspection of the fabric filter, measurement of system static pressures using portable instruments, measurement of fan power usage, measurement of fan rotation speeds, and measurement of air velocities in ducts (where pitot tube ports exist).[28/]

It was anticipated that the Level III inspection would provide an indication of the effectiveness of the control equipment and might even identify potential problems and prevent later malfunctions.

Four basic assumptions are inherent to the concept of inspection levels and to development of the three levels described above. A clear understanding of these assumptions is a prerequisite to a thorough analysis of the monitoring strategy.

Figure E-2

LEVEL I INSPECTION SHEET

Time in: ____________
Time out: ____________

Date: ____________ Inspector: ____________
Elevator Name: ____________
Address: ____________
____

Contact (if need to enter property line): ____________
Storage Capacity (from Level II): ______ Throughput (from Level II): ______
Number of Bins: ____________
Number of Control Devices:
Fabric Filters ____________ Cyclone ____________
Description of Location: ____________
____
____

Opacity Readings[a/]

	Activity During Inspection			Opacity
	Yes	No	Unknown	% (0-100)
Rail Load in	___	___	___	___
Truck Dump	___	___	___	___
Load Out	___	___	___	___
Head House	___	___	___	___
Gallery Windows	___	___	___	___
Tunnel Vents	___	___	___	___

Opacity for Control Device Outlets

	In Operation			Type of Device		
Location	Yes	No	Unknown	Cyclone	Fabric Filter	Opacity
________	___	___	___	___	___	___
________	___	___	___	___	___	___
________	___	___	___	___	___	___
________	___	___	___	___	___	___
________	___	___	___	___	___	___
________	___	___	___	___	___	___
________	___	___	___	___	___	___
________	___	___	___	___	___	___

a/ If opacity is lower than 20%, simply note $<$ 20%; otherwise state opacity.

Figure E-3

ORIGINAL LEVEL II INSPECTION SHEET

Date: ____________________

Time In: ____________

Inspector: ____________________

Time Out: ____________

Elevator Name: ____________________

Address: ____________________

____

Contact: ____________________

Process Data

1. Grains processed (note approximate percent)

   Wheat ____ Corn ____

   Barley ____ Milo ____

   Oats ____ Soybeans ____

2. Grain handling and storage capacity

   Number of legs ______

   Capacity of each (bushels/hr) ____, ____, ____, ____

   Number of bins ______

   Total storage capacity ______

3. Grain receiving (note approximate percent)

   Truck ____ Boxcar ____ Hopper car ____

4. Grain shipping (note approximate percent)

   Truck ____ Boxcar ____ Hopper car ____ Barge ____

5. Total annual throughput (bushels) ______

6. Brief process description

Process Opacity Readings

	Activity during Inspection			Opacity
	Yes	No	Unknown	% (0 - 100)
Rail load in	___	___	___	_____
Truck dump	___	___	___	_____
Load out	___	___	___	_____
Head house	___	___	___	_____
Gallery windows	___	___	___	_____
Tunnel vents	___	___	___	_____

Wind direction _____ Speed _____ Sky condition __________

Process Emissions Capture/Containment Data

1. Truck dump pit(s)
   Operating _____ Visible emissions _____
   Number of sides enclosed _____ Direction(s) of open sides _____
   Wind direction _____ Speed _____
   Is the pit aspirated? _____ Total design flow (cfm) __________
   Is the pit louvered? _____ Open area (sq ft) __________
   Measured face velocity (fpm) __________

2. Hopper receiving
   Operating _____ Visible emissions _____
   Is shrouding used? _____
   Number of sides enclosed _____ Direction of open sides _____
   Is the pit aspirated? _____ Design flow (cfm) __________
   Measured face velocity (fpm) __________

3. Boxcar receiving
   Operating _____ Visible emissions _____
   Describe unloading method and capture/containment system:

Estimate effectiveness: __________

4. Boots
   Operating _____ Visible emissions _____
   Aspirated _____ Design flow (cfm) __________

5. Tunnel belt bin discharge
   Operating _____ Visible emissions _____
   Hood design: Belt enclosure _____ Canopy _____
   Pipe pickup _____
   Distance from belt __________
   Design flow (cfm) __________
   Size of opening (sq ft) __________
   Measured face velocity (fpm) __________

6. Tunnel belt transfers
   Operating _____ Visible emissions _____
   Describe capture system (see data on 5):

   Measured face velocity (fpm) __________
   Belt speed (fpm) __________

7. Head of leg/garner
   Operating _____ Visible emissions _____
   Aspirated _____ Design flow (cfm) __________
   Size of takeoff duct __________
   If no aspiration, are legs/garner vented to atmosphere? _____
   If so, opacity of vents: __________
   Leg speed (fpm) __________

8. Cleaner
   Operating _____ Visible emissions _____
   Aspirated _____ Design flow (cfm) __________
   Size of takeoff duct __________
   Vented directly to atmosphere _____
   If so, visible emissions of vent: __________
   Design capacity (bushels/hr) __________
   If cleaner is not enclosed, describe capture/containment system:

9. Scales/hoppers
   Operating _____ Visible emissions _____
   Scale capacity (bushels) __________
   Grain fill rate (bushels/min) __________
   Aspirated _____ Design flow (cfm) __________
   Takeoff duct size __________
   Vented directly to atmosphere _____
   If so, vent visible emissions : __________

10. Distributor
   Operating _____ Visible emissions _____
   Aspirated _____ Design flow (cfm) __________
   Vented directly to atmosphere _____
   If so, exhaust visible emissions: __________

11. Gallery belt/tripper
   Operating _____ Visible emissions _____
   Description of capture/containment system:

   Measured face velocity at openings (fpm) __________
   Vented directly to atmosphere _____
   If so, exhaust visible emissions: __________

12. Bin vents
   Operating _____ Visible emissions _____

13. Truck/hopper car load out
   Operating _____ Visible emissions _____
   Is choke loading used? _____

14. Boxcar load out
   Operating _____ Visible emissions _____
   Aspirated _____ Design flow (cfm) __________
   Description of aspirating system

   Face velocity at opening (fpm) __ _____

15. Barge loading

Operating _____ Visible emissions _____

Aspirated _____ Design flow (cfm) __________

Description of aspiration system

16. Grain drying

Operating _____ Visible emissions _____

Dryer type __________ Design capacity __________

Air volume __________ Screen size __________

Control Device Analysis

1. Number of fabric filters _____
2. Number of cyclones _____
3. For each fabric filter or cyclone, complete an attached data sheet.

FABRIC FILTER DATA SHEET

Filter No.	1	2	3	4
Location	____	____	____	____
	____	____	____	____
Operations Controlled	____	____	____	____
	____	____	____	____
	____	____	____	____
Design Data				
Flow Rate (cfm)	____	____	____	____
Ait-to-cloth Ratio	____	____	____	____
Pressure Drop (in H_2O)	____	____	____	____
Was Device Operating	____	____	____	____
Operational Checklist				
Fan	____	____	____	____
Rotary Valve	____	____	____	____
Plugging	____	____	____	____
Outlet Flow (fpm)	____	____	____	____
Pressure Drop (in H_2O)	____	____	____	____
Visible Emissions	____	____	____	____

CYCLONE DATA SHEET

Cyclone No.	1	2	3	4
Location				
Operations Controlled				
Design Data				
Flow Rate (cfm)				
Diameter				
Height				
Pressure Drop (in H_2O)				
Was Process Operating				
Opacity				
Downdraft through Hopper				
Plugging				
Wall Cleanliness				
Pressure Drop				

The basic assumptions underlying the three levels of inspection developed above are:

1. The probability of identifying an elevator in noncompliance increases with an increase in level of inspection. In fact, any elevator identified as noncompliant in Level I, will also be identified as noncompliant in Level II.

2. Although visible emission regulations are the primary enforcement tool, factors other than external visible emissions can be used to determine noncompliance and effect enforcement against noncompliant elevators (i.e., the capture effectiveness of a hood is a parameter which effects compliance).

3. All sources of emissions are weighed equally in determining the compliance status of a grain elevator (i.e., an opacity of 30% during boxcar loading is equivalent to an opacity of 30% at the outlet of a control device).

4. Controlled and uncontrolled fugitive emissions sources are evaluated by the same criteria.

Development of the Field Test Program

In April 1979, a meeting was held in the offices of the Nebraska Department of Environmental Control (NDEC) to develop procedures for inspection of the 30 elevators. Participants included the project officers from EPA Division of Stationary Source Enforcement and Region VII Surveillance and Analysis Division, a representative from MRI and two representatives from NDEC. The test procedures developed at the meeting are as follows:

1. Surveillance and analysis (S&A) reports, including the Process Summary Sheet, will be submitted to Region VII for each of the elevators inspected. Also, the data sheets from all Level I inspections will be attached for information purposes only. Two copies of each report will be submitted. Further distribution of reports is up to the Region.

2. No enforcement action will result directly from the inspections. However, the Conclusions and Recommendations Section, to be included on a separate sheet with the S&A report, will indicate the compliance/noncompliance status of the source.

3. There will be a crew of three inspectors--one to conduct all Level I inspections, and the other two, all Level II inspections during the 2-week period beginning the middle of July. (Level III inspections will be conducted by PEDCo on 3 C and 3 D elevators, once in June and once in August.) In order to take advantage of the extra time available for the Level I inspector, an undetermined number of elevators located on the route to scheduled elevator facilities will be inspected at Level I. The Data Sheet and Process Summary

Sheet, with a limited amount of information obtainable within the available time, will be submitted to the Region for each of these extra Level I inspections.

4. Letters of authorization to conduct inspections will be provided by the Region. A staff of the Nebraska Air Pollution Control Division will accompany each of the Level II inspectors and possibly the Level I inspector to facilitate entry to the elevators. Region VII may send a representative to a few inspections. Mr. Gene Robinson of NDEC will inform the Nebraska Grain and Feed Association about the program and the inspections to be conducted.

5. Both Level I and Level II inspections will be conducted on an unannounced basis. However, in the event of heavy volume of activity, unavailability of operator's time and operator's objections, Level II inspections will be conducted at a later scheduled time. In such cases, any significant difference in emissions data between Level I and Level II will be analyzed for possible effects of announced versus unannounced inspections.

6. The following additions/modifications will be incorporated to the Level I and II inspections. All inspections will be timed to provide data for cost/benefit analysis of the three inspection techniques. Level I inspections will include qualitative information about the environment in which the elevator is located, viz., vicinity of population, local terrain, attainment versus nonattainment area, etc. The VE will be reported as "less than the applicable standard" if determined so; otherwise, actual 3- to 5-min opacity data will be indicated. During Level II inspections, the instrumentations associated with the dust capture and control systems will be checked for their operation and effectiveness.

It was anticipated that two Level II inspections could be completed each day, one in the morning and one in the afternoon. The schedule was planned so that the Level I inspector would be at an elevator at some time during the same half-day as the Level II inspector. Note that for comparison of the two levels, it must be assumed that the actual compliance status of the elevator is consistent over this half-day time period.

Using the field test guidelines and inspection procedures described above, 38 grain elevators were visited in late July 1979, to perform Level I and Level II inspections. Of the 38 grain elevators visited, 15 were either not in operation or were shutdown; the remaining 23 elevators had the following class breakdown.

Class of Elevator		Number of Elevators
A		3
B		9
C		6
D		5
	Total	23

During June, PEDCo performed Level II inspections on four of the Class C and four of the Class D elevators that were inspected during July.

According to the air pollution control jurisdictional area, the elevators were grouped as follows.

Air Pollution Control Jurisdiction		Number of Elevators
City of Lincoln Air Pollution Control[a]		2
Lancaster County Health Department[a]		5
City of Omaha Air Quality Control		2
Nebraska Department of Environmental Control		14
	Total	23

a/ Administered by the Lincoln-Lancaster County Health Department, Lincoln, Nebraska.

MRI inspectors were accompanied by personnel from the respective air pollution control authorities during most of the inspection visits. The data required for the conventional SIP inspections and for the Surveillance Reports were collected as part of the Level II inspections.

During the inspection, it was found that some of the smaller elevators (Classes A and B) were either not operating or not operating at peak level, as had been expected. This happened primarily because corn and milo, rather than wheat, is the primary crop in much of the area inspected. This means that peak activity occurs in October during the corn and milo harvest. Based on this information, it was decided to conduct only the 23 inspections during July, and after a preliminary evaluation of Level I and II procedures, complete the field inspections during October.

Preliminary Evaluation and Revision of Inspection Format

After the July inspections were completed, the Level I and Level II formats were evaluated with regard to difficulties in completing the inspection. In addition, the forms were reviewed to determine types of information that might be added or deleted.

The only problem identified for the Level I format was that for the larger elevators, it is not possible for the inspector to observe all the control equipment without entering the plant boundary. Thus, the inspector is required to notify the elevator operator of his presence. It was determined that this notification would not significantly hamper the inspection, so no modification was made in the format.

Specific problems were encountered with gathering some of the data on the Level II form. Velometer measurements at some of the aspiration points are not possible due to accessibility problems and for safety reasons. Besides, the inspector may not be able to get an average velocity reading at any time, since the observed velocity at a given pick-up point depends on the position of dampers at all the other pick-up points sharing the same dust control equipment. Consequently, no valid conclusion can be drawn regarding the effectiveness of the dust-capture system in general. It was found during the inspections that it is possible to have a high aspiration velocity at an internal operation, which, by visual inspection, appears quite dusty. Other data including design flow, belt speed, etc., were almost impossible to obtain from the elevator operating personnel. As a result of these difficulties, it was determined that no evaluation of compliance with Rule 5, the Process Weight standard, can be made by using data from Level II to estimate control equipment performance.

As a result of difficulty in obtaining velocity data and other operating data described earlier, minor revisions were made to the Level II inspection format. The revised Level II inspection forms are shown in Figure E-4. Quantitative data which were either unobtainable or do not help in the evaluation of the dust control system were excluded. It is recommended that a qualitative judgment about the operation and maintenance of the dust control system based on a visual inspection of the internal operations, and the cleanliness of the floors and walls be a part of the Level II inspection. Such a subjective judgment can be made after an inspector has visited a few facilities and it is possible to make a distinction between an effective dust capture/control system and an ineffective one.

The revised Level II inspection would require the inspector to include a rough sketch of the various dust control systems in the facility. As shown in the sample presented in Figure E-5, this would be a schematic diagram for each of the dust capture/control systems, showing the various aspiration points and dampers if provided. This diagram will be included during the first visit and will be maintained as a permanent record. During subsequent visits, and design/operational changes made in the system will be noted and the record changed accordingly.

Fiugre E-4

REVISED LEVEL II INSPECTION SHEET

Date: ____________________ Time In: ______________

Inspector: ________________ Time Out: ______________

Elevator Name: ____________________
Address: ____________________
____
Contact: ____________________

Process Data

1. Grains processed (note approximate percent)
   Wheat ________ Corn ________
   Barley ________ Milo ________
   Oats ________ Soybeans ______

2. Grain handling and storage capacity
   Number of legs ________
   Capacity of each (bushels/hr) ____, ____, ____, ____
   Number of bins ________
   Total storage capacity ______________

3. Grain receiving (note approximate percent)
   Truck ____ Boxcar ____ Hopper car ____ Barge ____

4. Grain shipping (note approximate percent)
   Truck ____ Boxcar ____ Hopper car ____ Barge ____

5. Total annual throughput (bushels) ____________

6. Miscellaneous Information:
   Use of grain dryers: yes ____ no ____
   Use of grain cleaners/scalpers: yes ____ no ____
   Source of grain (note approximate percent):
   Direct from farmers ____ Other smaller elevators ____
   Shipment (note approximate percent):
   Flour and feed mills ____ Other bigger elevators ____
   Export ____
   Is any dust collection system used? yes ____ no ____
   If yes, how is the collected dust disposed of:
   Trucked to dump sites ____ Recycled to grain ____
   Sold to ______________________________

Process Opacity Readings

	Activity during inspection Yes	No	Unknown	Opacity % (0 - 100)
Rail load in	____	____	____	____
Truck dump	____	____	____	____
Load out	____	____	____	____
Head house, scale/garner, distributor floors	____	____	____	____
Gallery windows	____	____	____	____

Truck path and property line: clean ____ dusty ____

Wind direction ______ Speed _______ Sky condition _______

Process Emissions Capture/Containment Data

1. Truck dump pit(s)
   Operating _______ Visible emissions _______
   Pit floor and surroundings: clean _____ dusty _____
   Number of sides enclosed _______
   If doors are provided, are they closed during unloading? ________
   Is the pit aspirated? _______
   Is the pit louvered? ________

2. Hopper receiving
   Operating _______ Visible emissions _______
   Receiving floor and surroundings: clean _____ dusty _____
   Is shrouding used? _______
   Number of sides enclosed _______
   If doors are provided, are they closed during unloading? _______
   Is the pit aspirated? _______

3. Boxcar receiving
   Operating _______ Visible emissions _______
   Receiving floor and surroundings: clean _____ dusty ______
   Unloading method and capture/containment system:
   Car tilt and dust enclosure _______
   "Bobcat" type shovel _______ Other _______
   Is aspiration used? ________
   Estimate effectiveness of dust control _________________________

4. Leg and Leg Boot

Operating _____ Visible emissions _____

Boot area floor and walls: clean _____ dusty _____

Aspirated? ______

If aspirated, is it equipped with damper? _____

Are dampers regularly used? _____

5. Tunnel belt bin discharge

Operating _____ Visible emissions _____

Tunnel basement area floor and walls: clean _____ dusty _____

Hood design: Belt enclosure _____ Canopy _____

Pipe pickup _____ Choke feed ______

Distance from belt _______

Is hood aspirated? _______

Damper? _____ Use of dampers ________

6. Tunnel belt transfers

Operating _____ Visible emissions _____

Transfer area floor and walls: clean _____ dusty _____

Aspirated? _____ Damper? _____ Use of damper _____

7. Head of leg/garner

Operating _____

Floor and walls: clean _____ dusty _____

Aspirated? _____

If no aspiration, are legs/garner vented to atmosphere? _________

If so, opacity of vents (from the ground): ______________________

8. Cleaner

Operating ______

Floor and walls: clean _____ dusty _____

Aspirated? _____

If cleaner is not enclosed, describe capture/containment system if any:

9. Scale
   Operating _____
   Scale floor: clean _____ dusty _____
   Aspirated ______

10. Distributor
   Operating _____
   Distributor floor: clean _____ dusty _____

11. Gallery belt/tripper
   Operating _____ Visible emissions _____
   Gallery floor and walls: clean _____ dusty _____
   Description of capture/containment system:

12. Truck/hopper car load out
   Operating _____ Visible emissions ______
   Load out area: clean _____ dusty _____
   Number of sides enclosed ______
   Is choke loading used? ________
   Aspirated ________

13. Boxcar load out
   Operating ______ Visible emissions ______
   Load out area: clean _____ dusty _____
   Number of sides enclosed _______
   Description of loading/aspirating system:

14. Barge loading
   Operating ______ Visible emissions ______
   Aspirated ______
   Description of aspiration system:

15. Grain drying

Operating ______ Visible emissions ______

Dryer type ______ Screen size ______

Control Device Analysis

1. Number of fabric filters ______

2. Number of cyclones ______

3. For each fabric filter or cyclone, complete an attached data sheet. Present, below, a line-schematic of the dust control system including pick up points, damper and control device.

CYCLONE DATA SHEET

Cyclone No.	1	2	3	4
Location	____	____	____	____
	____	____	____	____
Operations Controlled	____	____	____	____
	____	____	____	____
	____	____	____	____
Was Process Operating	____	____	____	____
Opacity (if vented to atmosphere)	____	____	____	____
Plugging	____	____	____	____
Wall leaks	____	____	____	____
Exceptions to satisfactory operation (by visual inspection)	____	____	____	____
Visible emissions	____	____	____	____

FABRIC FILTER DATA SHEET

Filter No.	1	2	3	4
Location				
Cyclone Precatcher				
Operations Controlled				
Was Device Operating				
Operational Checklist				
Fan				
Rotary Valve				
Plugging				
Pressure Drop (in H_2O)				
Exceptions to satisfactory operation (by visual inspection)				
Visible Emissions				

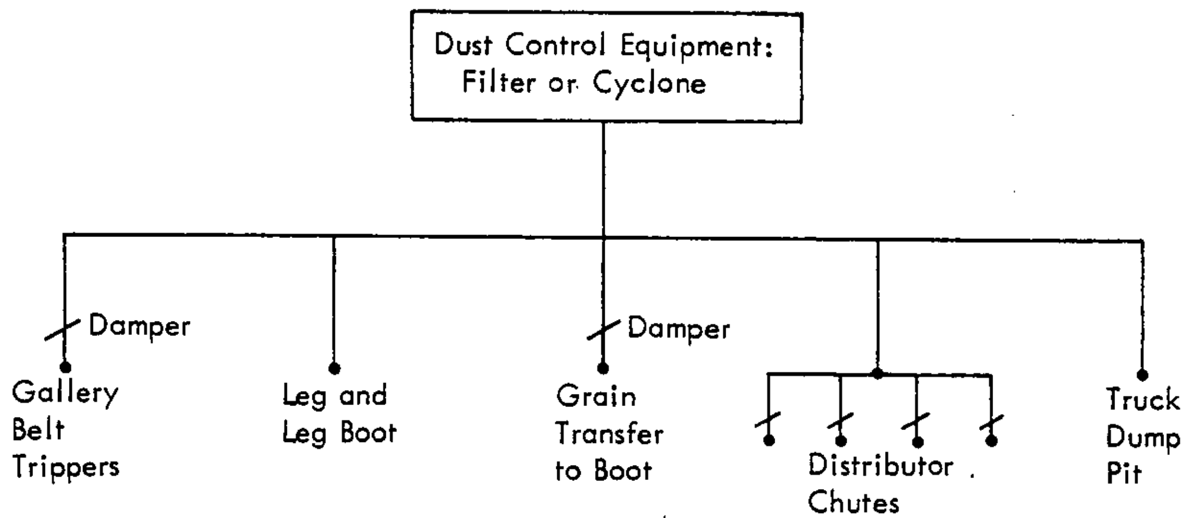


Figure E-5 - Logical layout of dust capture and control system for Level II inspection.

The revised Level II inspection is expected to provide the following general information relative to the dust capture/control system.

1. Identification of:

- Internal and external operations which are aspirated;
- Operations which have no aspiration but other proven methods of dust control are used; and
- Operations where no attempt is made to capture dust.

2. A logical layout of the dust capture and collection system, which will be useful for operational checks and for the identification of any problem in the system when noncompliance is indicated during later visits.

3. A qualitative judgment on the effectiveness of the dust capture and control system. This is based on the visual inspection of internal operations, cleanliness of floors, wall, load-in and load-out areas. The overall effectiveness can be estimated once the inspector gains familiarity with the operation of general dust collection systems in grain elevators.

4. Reasonable conclusions on the regularity of use of the suction system at various pick-up points and on proper use of the entire dust control system, according to operating specifications.

Additional Field Inspections

During October, a second group of Level I and Level II field inspections were conducted to complete the original protocol for the SIP inspections. Level III inspections were repeated at the four Class C elevators which had been inspected during June. Those elevators inspected using Level I and Level II procedures included:

- Nine Class A and three Class B elevators which were inspected with Level I and Level II procedures to complete the SIP inspections.
- Six Class C and three Class D elevators which were inspected with Level I procedures to compare results with those obtained in June.
- Eleven elevators of unknown class which were inspected by Level I procedures on an "as seen" basis by the Level I inspector.

RESULTS OF ELEVATOR INSPECTIONS

Compliance with Rules 13 and 14

The basic findings of each level of inspection in July was that the elevators in Nebraska are generally in compliance with respect to Rule 13, the visible emissions regulation and Rule 14, the prohibition of visible emissions beyond the property line. As shown in Table E-3, only one elevator was determined to be out of compliance. It should be noted that the location of an elevator's property line was often difficult to ascertain, making determination of compliance with Rule 14 questionable. The Level III inspection did identify one Class C elevator which was in violation of Rule 18, that prohibits excessive occurrences of control device malfunctions.

TABLE E-3. GRAIN ELEVATOR COMPLIANCE STATUS WITH RESPECT TO VISIBLE EMISSIONS AND FUTIVE DUST

	Level I Compliance status		Level II Compliance status		Level III Compliance status	
Class	In	Out	In	Out	In	Out
A	3	0	3	0	-	-
B	9	0	9	0	-	-
C	5	1	6	0	4	0
D	5	0	5	0	4	0

As with the July inspections, most of the elevators appeared to be in compliance with the opacity and fugitive emission regulations. As can be seen from Table E-4, a total of 38 of the 48 inspections found the elevators to be in compliance. However, a much greater number of elevators were found out of compliance in October, the "busy season," than had been identified during July. In particular, all six Class C elevators were found in compliance by Level II inspectors and only one was found out of compliance by Level I inspectors during the July inspections. However, three of the six were found out of compliance (all with respect to load-out operations) during October.

TABLE E-4. COMPLIANCE STATUS OF GRAIN ELEVATORS WITH RESPECT TO VISIBLE EMISSIONS AND FUGITIVE EMISSIONS REGULATIONS DURING OCTOBER INSPECTIONS

	Level I Compliance status		Level II Compliance status		Level III Compliance status	
Class	In	Out	In	Out	In	Out
A	8	3	8	1	-	-
B	3	0	1	2	-	-
C	3	3	-	-	4	0
D	2	1[a]	-	-	-	-
Unknown	8	1	-	-	-	-

a/ Source out of compliance was load-out of fabric filter catch.

Elevator Compliance with Nebraska Rule 18[28]

The findings from Level III also address compliance with Nebraska Rule 18, a prohibition of excessive malfunction of control equipment. The exact number and duration of elevator fabric filter breakdowns could not be determined during Level III inspections. However, it was possible to determine the adequacy of fabric filter maintenance programs at the elevators, and from these determinations to assess the probability that breakdowns are unnecessarily frequent. Fabric filter maintenance was judged on the basis of filter appearance at the time of inspection, knowledge of plant personnel in filter system operation, and discussions with plant personnel about maintenance schedules. One elevator was judged to have sufficiently frequent breakdowns to be in violation of Rule 18.

During the June Level III inspections, major maintenance problems were discovered in fabric filter systems at Elevators 3, 6, 7, and 8, and less serious problems were discovered at Elevators 1 and 4. PEDCo inspectors advised the management at each of the six elevators of the filter problems. The management at Elevators 1, 3, 4, and 8 demonstrated that existing maintenance practices would correct the problems within a reasonable amount of time and that the problems would not recur at an excessive frequency. The managers at Elevators 6 and 7 were not aware of their filter problems, did not fully understand the causes of the problems, and had no specific plans to correct the problems.

The filter system at Elevator 6 had a plugged hopper which was completely filled with dust, several filter cleaning solenoids that were inoperative, a differential manometer which was inoperative, several leaks in the filter hatch seals, and a cleaning system air compressor which injected moisture into the filter. The power supply to several solenoids had been disconnected, indicating that malfunctioning solenoids were routinely removed from service rather than repaired. Large accumulations of dust were observed beneath the dust hopper access door indicating that the hopper had also plugged on previous occasions. Plant maintenance personnel did not realize that moisture entering the filter from the compressor and through hatch seals was a probable cause of hopper plugging. They felt that the filter system was not designed properly and they had not instituted a preventive maintenance program for the system.

The October inspection at Elevator 6 revealed that most of the filter problems had been repaired. The plant management had enlisted the filter manufacturer's service department to perform the necessary filter maintenance. As a result, plant personnel were more aware of proper operation and maintenance procedures for the filter and PEDCo inspectors concluded that future malfunctions would not be excessive.

The filter system at Elevator 7 was inoperative during the June inspection. The plant manager explained that the rotary air lock had seized because a filter bag cage had probably broken loose. He further explained that his maintenance personnel had not yet had time to repair the system. It was immediately apparent to PEDCo inspectors that elevator personnel had not investigated the filter malfunction. A brief internal inspection of the filter revealed no fallen bag cages. However, the rotary air lock was inoperative and there was evidence of oil leaking from the cleaning air compressor into the filter. PEDCo also found one torn filter bag which caused visible emissions of up to 20% opacity when the system was temporarily energized.

In contrast to Elevator 6, filter system maintenance at Elevator 7 had not improved by October. The filter was again inoperative and plant personnel were again too busy to attempt repairs. The condition of the filter was relatively unchanged and the knowledge and interest of plant personnel in filter operation and maintenance had not improved. It is apparent that the frequency of malfunction at Elevator 7 constitutes a violation of Rule 18.

Observations Regarding Emissions Control Systems

Several observations were made regarding emissions control at the elevators inspected during July Level II inspections. Almost all of the larger elevators--Classes C and D--were found to be equipped with dust collecting systems. A large number of the systems consisted of fabric filters and some of the filters were also provided with cyclone precatchers. Except for a few elevators, the dust control systems were in operation and the facilities, in general, were in compliance with the opacity (ducted source) and fugitive emissions standards. Some of the facilities, though in compliance, were not running the filters according to the design specifications or at the optimum effective operating specifications. A few of the filters were found to have plugging and baghole problems resulting in complete shutdown of the dust capture and collection systems. The operator had very little knowledge of the operation and maintenance requirements of the system. He had no incentive to repair the equipment and put it back in operation without much delay. The common problem appears to be that owners and operators of such facilities were not convinced about the advantages of a well-operated dust collecting system and the resulting "clean" facility. On the other hand, elevators which had operated an effective control system over a period of time realized the merits of such a system and seemed to be proud of it. It appeared that educating the owners and operators of grain elevators on the merits and worthiness of dust control systems is an important prerequisite to an effective regulatory and monitoring program.

In large elevators, most of the internal operations, such as boot transfers, tunnel belt bin discharge, scales, distributors, etc., were aspirated to the dust control equipment. Even though the dust collector exhaust showed no visible emissions, the internal dust pick-up areas themselves were, in some instances, quite dusty. This was caused by: (a) poor aspiration, i.e., not enough air suction to prevent the dust from flying out of the containing hood; and/or (b) not opening the damper provided in the air take-off duct when the particular operation was on.

Load-out chutes leading into trucks, hopper cars, and boxcars were seldom equipped with aspiration ducts. Choke-loading was almost never used when loading trucks and hopper cars. The general industry trend was toward using exclusively hopper cars, doing away with boxcars because of their difficult and time consuming unloading operation. Boxcars were unloaded mostly by mechanical shovels ("Bobcats" or augers) and the grain freefalls about 5 to 6 ft before reaching the aspirated pit. Mechanical shoveling was invariably a dusty operation compared to the more sophisticated car-tilt systems which were usually provided with rubber dust-capture hoods. It was reasonable to conclude that dust-capture systems for the car load-in and load-out areas were still evolving, at least in the larger elevators that were inspected.

Many of the Class A and Class B elevators that were inspected did not have any dust control system. This finding was particularly surprising since it was expected that even the smaller country elevators would have a cyclone or two to collect the dust from the dump pits. However, the few Class A and Class B elevators that were inspected when in operation, were found to be in compliance with respect to opacity and fugitive emission standards, though some only marginally.

Level III inspectors found that many elevator particulate control systems had operation and maintenance problems which resulted in increased particulate emissions without causing violations of particulate emission regulations (Table E-5). Some of these problems could be corrected with minimal effort and investment by the elevators. Improvements possible in particulate controls generally fit into one of two categories. Some elevators could reduce particulate emissions by providing better containment of fugitives generated at loading and unloading facilities. Other elevators could reduce particulate emissions at dump pits or improve evacuation of tunnels and galleries by maintaining fabric filters in better condition.

Fugitive emissions generated at several truck dump pits could be more effectively contained if elevator personnel had used existing dump shed doors. PEDCo inspectors did not see any dump shed doors in use during any of the Level III inspections. Fugitive emissions at load-out stations were controlled with varying degrees of success. For example, the rail load-out station at Elevator 3 produced significant quantities of fugitive dust because the station was not enclosed and it utilized the free fall method of feed. The rail load-out station at Elevator 1 employed choke type feeding within a shed open only at the ends, which provided greater control of fugitives.

Fabric filter maintenance problems included moisture inleakage through pulse air jet air compressors, inoperative pulse air solenoids, low air pressure in pulse air and reverse air cleaning systems, and temporary scaffolding left in hoppers. These problems often resulted in bag blinding, which reduces capture velocities at dump pits, tunnel belts or galleries. These same problems sometimes led to hopper plugging, causing the filters to be removed from service for repairs. Other filter maintenance problems included torn bags which reduced filter dust removal efficiencies, and inoperative instrumentation which reduced the ability of maintenance personnel to diagnose problems.

TABLE E-5. ELEVATOR FABRIC FILTER MAINTENANCE PROBLEMS AT EIGHT NEBRASKA GRAIN ELEVATORS [28/]

Elevator	Number of filter systems with indicated problems											
	Tears or leaks in bags		Bag blinding or hopper plugging due to moisture in filter		Poor cleaning of filter bags		Filter system instrumentation not operating		Poor capture at dump pit		Elevator management executing proper filter system maintenance program	
	June	October	June	October	June	October	June	October	June	October	June	October
1. Class D terminal elevator, four fabric filter systems inspected.	0	a/	0	-	2	-	0	-	0	-	Yes	-
2. Class D terminal elevator, four fabric filter systems inspected.	0	-	0	-	0	-	0	-	0	-	Yes	-
3. Class C terminal elevator, two fabric filter systems inspected.	2	-	0	-	0	-	0	-	1	-	Yes	-
4. Class D terminal elevator, two fabric filter systems inspected.	0	-	0	-	0	-	1	-	1	-	Yes	-
5. Class C country elevator, two fabric filter systems inspected.	0	0	0	0	0	0	2	0	0	0	Yes	Yes
6. Class C country elevator, one fabric filter system inspected.	0	0	1	0	1	0	1	1	1	1	No	Yes
7. Class C country elevator, one fabric filter system inspected.	1	1	1	1	1	1	1	1	1	1	No	No
8. Class D country elevator, one fabric filter system inspected.	0	0	1	0	0	0	0	0	0	0	Yes	Yes
Terminal elevator totals (four elevators, 17 fabric filter systems).	2	-	0	-	2	-	1	-	2	-		
Country elevator totals (four elevators, five fabric filter systems).	1	1	3	1	2	1	4	2	2	2		
Totals	3		4		5		7		6			

a/ Indicates elevator was not inspected during October.

APPENDIX F

GLOSSARY

GLOSSARY

beeswing: a light flaky material that breaks off from corn kernels during drying, causing a significant nuisance and visible emissions problem.

bin: The primary storage facility in both country and terminal elevators. In newer elevators they generally are concrete silos 70-80 ft high attached to the main elevator facility.

bobcat: A small front end loader used to unload grain from boxcars.

boot: The bottom of the elevator leg.

boxcar: A roofed rectangular freight car with sliding doors on both sides that is used to transport grain.

bulk carrier: A ship which has an empty hull compartmented by a series of bulkheads generally with no internal decks.

butterworth: A small hatch (11-12 in. in diameter) in the deck of a tanker that is used to fill voids in the cargo.

column dryer: A type of dryer in which the grain falls continuously in a double column. Air enters through the bottom and exits both sides.

country elevator: An elevator which receives the bulk of its grain directly from the farmer.

distributor: A device in the elevator headhouse which receives grain from the leg and transfers it to the appropriate bin, belt, scale, or load-out operation.

dump pit: An underground concrete hopper covered by a grate which receives grain from a truck or rail car and transfers it to the leg boot.

gallery: Enclosed area located on top of the bins which contains the belts and auxilliary equipment used to transfer the grain to the bins.

garner: A surge bin which continuously receives grain from the leg and transfers it intermittently to the scale.

hardhat: Large hatch (3 ft in diameter) which is used for the primary filling of a tanker.

headhouse: Structure located at the top of the elevator which contains the drive apparatus and top of the leg where grain is dumped from the buckets.

hopper car: A freight car with a removable top and a floor sloping to one or more hinged discharge doors which is used to transport grain.

inland terminal elevator: An elevator which functions as a storage or transfer house, ships grain by rail, truck, and possibly barge, and has a leg capacity of at least 35,000 bu/hr.

leg: Enclosed bucket elevator which transports grain from the bottom to the top of the elevator.

port terminal: Elevator located at a seaport with at least 35,000 bu/hr receiving leg capacity which receives grain by truck, rail, or barge with shipments by ship.

rack dryer: Type of grain dryer in which air enters from one side and circulates through grain which is falling over a series of racks and exits through the opposite side.

tanker: Ship designed for carrying liquids which can be used for grain transport. The hold has a series of decks which have "hardhat" and "butterworth" hatches for grain loading.

tripper: A device in the gallery which is used to transfer the grain from the conveyor to the proper bin.

tunnel: The area underneath the bins which contains a conveyor belt for transfer of the grain from the bins to the boot.

'tween decker: An older type of ship used to transport grain. The hold has two horizontal cargo decks with a large opening in the center.

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