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EMISSIONS CONTROL IN THE GRAIN AND FEED INDUSTRY VOLUME I - ENGINEERING AND COST STUDY

U.S. ENVIRONMENTAL PROTECTION AGENCY
Office of Air and Water Programs
Office of Air Quality Planning and Standards
Research Triangle Park, North Carolina 27711

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by

Dr. Larry J. Shannon, Richard W. Gerstle, P. G. Gorman, D. M. Epp, T. W. Devitt, and R. Amick

Midwest Research Institute
425 Volker Boulevard
Kansas City, Missouri

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PREFACE

This report was prepared for EPA/OAQPS under Contract No. 68-02-0213, which was monitored by Mr. Kenneth R. Woodard.

The program was performed with MRI as prime contractor and PEDCo-Environmental, Cincinnati, Ohio, as subcontractor. The program was centered in MRI's Physical Sciences Division, Dr. H. M. Hubbard, Director. Dr. A. E. Vandegrift, Assistant Director, Environmental Programs, served as Program Manager and coordinated activities between PEDCo and MRI and between MRI's Physical Sciences Division and Economics and Management Science Division. Dr. Larry J. Shannon, Head, Environmental Systems Section, was Principal Investigator for MRI and Mr. Richard Gerstle was Principal Investigator for PEDCo.

Other MRI staff members who contributed significantly to the program were Mr. Paul Gorman, Mr. Dan Epp, and Miss Christine Guenther. Other PEDCo staff members who contributed were Mr. Timothy Devitt, and Mr. Robert Amick.

Approved for:

MIDWEST RESEARCH INSTITUTE

H. M. Hubbard, Director
Physical Sciences Division

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Several individuals associated with dust control equipment manufacturing companies provided information on control equipment performance, equipment costs, and related information. Foremost in this regard were Mr. Maurice P. Schrag, Hart-Carter Company; Mr. Jack Kice, Kice Metals Company; Mr. Hans Wanzenried, Buhler Corporation; Mr. John R. Danciak, Airotech Sales Company (representative for MikroPul); and Mr. Kenneth Cox, Natkin and Company.

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Members of the industry liaison committee who reviewed the draft of this report are also thanked for their efforts.

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SUMMARY

Activity in this program was directed to an analysis of the technical and economic aspects of emissions control in the grain and feed industry. The main objective of the study was to provide an improved technical and economic basis which the Environmental Protection Agency could utilize to formulate new source performance standards and other guidelines for emissions control in the grain and feed industry. Industry structure and statistics, the nature and sources of emissions, technical problems associated with emissions control, cost of dust control equipment, and the overall economic impact of air pollution control were among the major topics investigated in the program. The salient results of the program are highlighted in the following sections.

INDUSTRY STRUCTURE

In the broadest sense the grain and feed industry could be defined to include all the operations involved from the points where the raw materials are grown (i.e., the farmer) to the points where all the final products are prepared for sale or shipment to the consumer. For the purposes of this study, however, a narrower scope of operations was considered. Specific operations considered in this study were: (1) grain harvesting as it relates to dust emissions in subsequent grain handling steps; (2) grain elevators; (3) flour milling (i.e., wheat, durum, dry corn, rye, and oat); (4) rice milling; (5) corn wet milling; (6) soybean processing; (7) commercial rice drying; (8) alfalfa dehydration; and (9) feed mills. Excluded from this study were operations directly associated with the production of items intended for human consumption (e.g., cereal preparation, bread and bakery products, distilled alcoholic beverages).

In recent years, the cultivation, harvesting, transporting, and processing of grains and grain products have been transformed from a predominately rural and semi-agricultural endeavor into a complex and vital industry in the United States (i.e., the agribusiness industry). Operations conducted in the grain and feed industry range from the relatively simple harvesting, handling, and transporting of grain to storage facilities (i.e., grain elevators) to the diverse, dynamic corn wet milling industry. Chapter 2 presents a comprehensive discussion of the structure and statistics of the individual segments of the grain and feed industry.

NATURE AND SOURCES OF ATMOSPHERIC EMISSIONS

There is a significant difference between atmospheric emissions arising from grain and feed industry operations and those of other industries; namely, the majority of emissions are due to raw material handling rather than raw material processing. Furthermore, some of the sources are of a "fugitive" type. That is, the emissions are those that become airborne because of ineffectual or nonexistent hooding or pollutant containment systems rather than those that penetrate an air pollution control device. Other characteristics of emissions from the grain and feed industry are the intermittent nature of many of the specific operations, and the day-to-day variability of emissions from a specific operation.

The sources of atmospheric emissions from grain and feed plants can be grouped into three broad categories: (1) grain handling, cleaning, and storage; (2) grain processing; and (3) product handling and shipping.

Almost all grain and feed industry plants handle, clean, and store grain as part of their operations. Unloading, conveying, weighing, transferring and cleaning of grain are the individual steps involved in the first category. There is a wide variation in the extent to which the different plants in the grain and feed industry engage in these activities. Grain dust, seeds, chaff, various types of pollens and mold spores, and dirt comprise the main portion of the emissions from the first category of sources.

The types of operations involved in the processing of grain in grain and feed plants range from very simple mixing steps to complex processes which are characteristic of industrial processing plants. Included are such diverse processes as: (a) simple mixing processes in feed mills; (b) dehydration in alfalfa dehydration plants; (c) grain milling in flour mills; (d) solvent extracting in soybean processing plants; and (e) a complex series of processing steps in a corn wet milling plant. Potential atmospheric emissions from processing operations include hulls, bran, flour, various ingredients used to manufacture feed, hexane vapor, and various organic materials (e.g., acids, aldehydes).

Transfer and loading operations comprise the main steps in product handling and shipping. Atmospheric emissions from these steps include grain dust, finished feed materials, flour, soybean meal, and starch particles.

Atmospheric emissions from grain and feed industry operations are not considered to be toxic. They may cause irritation of skin or eyes, and respiratory ailments can be caused by inhalation of particulates of < 5 μm in diameter. At normal low ambient particulate concentrations (< 100 μg/m^3) no evidence exists for adverse effects to healthy people from atmospheric emissions from grain and feed plants. However, people having preexisting respiratory disorders may be affected or disabled by rapid increases above the seasonal mean concentration of atmospheric emissions from grain and feed plants. Chapter 3 and Appendix B discuss the sources and nature of atmospheric emissions in more detail.

CONTROL TECHNOLOGY FOR ATMOSPHERIC EMISSIONS

Methods used for the control of dust emissions from grain and feed operations consist of either extensive hooding and aspiration systems leading to a dust collector or methods for eliminating emissions at the source. The incentives for controlling emissions, in addition to complying with air pollution regulations, include recovery of valuable materials, sanitation, and reducing the fire and explosion hazards.

Where practical, techniques which eliminate the sources of dust emission or which retain it in the process are the most effective. These techniques may require enclosures or covers on bins, tanks, and hoppers, and the replacement of worn-out parts. Emissions can also be eliminated by minimizing the number and size of openings, and maintaining the system's internal pressure below the external pressure; thus air flows into, rather than out of, the openings. When the methods for eliminating the sources of dust emission are not practical, systems are used which capture the dust as it is entrained or suspended in the air, and convey it to a dust collection device.

Adequate design of the emission containment or hooding system is vital for effective air pollution control in grain and feed plants and in most cases the system must be individually tailored for each process. Grain unloading, loading, and drying operations represent some of the more difficult sources for proper dust pick-up, whereas for most other sources the design of the emission containment system is essentially straightforward.

Cyclone collectors, fabric filters and wet scrubbers are used to control emissions from the various grain handling and processing sources. Wet scrubbers have not found wide application because of the associated water pollution potential and because they do not permit direct recycling of the collected material. Due to tightening emission control regulations, fabric filters are now being used on many sources which were formerly controlled by only low efficiency mechanical collectors. High efficiency mechanical collectors are being used on several processes, where the high moisture content of the effluent streams or other process requirements preclude the use of fabric filters.

The fairly dry nature of the dust generated in grain and feed plants, the low temperatures involved, and the relatively large particle size of the dust make cyclone collectors and fabric filters effective for most sources of atmospheric emissions. A variety of these devices have been installed, ranging from single large diameter cyclones to reverse-air fabric filters. Screens have also been used for such unique applications as reducing the emission of large-sized particles (beeswing) from grain drying operations. 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.

With one or two exceptions, control system technology is available for all sources of atmospheric emissions in grain and feed plants. Grain drying and barge and ship loading operations are the major exceptions. Recent work on the control of dust emissions from ship loading operations shows promise of resulting in significant reduction of emissions from those operations. While fabric filter systems are the most efficient dust collectors for a majority of the sources of atmospheric emissions, operational problems (e.g., blinding of the fabric) sometimes occur when grains of high moisture content are being handled. Fabric filter systems on grain receiving pits are especially prone to operational problems when wet grains are received at grain elevators.

The characteristics of the various types of control devices suitable for use on emission sources in grain and feed processing operations are discussed in detail in Chapter 4.

COST OF DUST CONTROL EQUIPMENT

The total installed cost of dust control equipment for a given source in grain and feed plants is highly variable depending upon such factors as:

- Type of installation, new or existing plant;
- Type of labor used, plant or contract labor; and
- Type of process controlled; amount of ductwork required; and geographical location.

Existing plants may have much of the hooding systems and ductwork already installed and require only the installation of a new control device and fan. Thus the total installed cost for upgrading the controls on such a facility might be less than for a new plant. On the other hand, such factors as space limitations, the necessity of working around existing process equipment, and providing additional structural support for the dust collectors, increase the total installed cost. In general, the cost to a new plant, where the control system is an integral part of the plant design, is less expensive than the control cost for older plants. Because of the large variability in costs, the cost to control an individual facility must be determined by careful evaluation of the particular requirements of that facility.

Approximate cost ranges for controlling specific types of emission sources are:

1. Grain handling	\$1.50 - 4.00/cfm
2. Grain milling	\$1.50 - 3.00/cfm
3. Grain drying	\$0.25 - 0.75/cfm
4. Pellet coolers	\$1.20 - 3.00/cfm
5. Germ, feed and gluten drying	\$2.00 - 5.00/cfm
6. Soybean meal drying	\$2.00 - 6.00/cfm

The preceding figures represent only the normal cost range, which would be applicable to perhaps 90% of the various source types. There are, however, installations which may cost twice the high value in each range because of circumstances peculiar to that installation. Additional information on the costs of control equipment is presented in Chapter 4.

ECONOMIC IMPACT OF DUST CONTROL

The initial intent of the analysis was to determine the economic impact of dust control systems only for new facilities in accordance with the directives of the Clean Air Act of 1970. However, since there are few new facilities being constructed when compared to the number of existing facilities in the grain and feed industry, the long-term economic impact of air pollution control regulations in this industry will be borne by existing facilities. In order to accurately reflect the probable economic impact of air pollution control regulations, the analysis was expanded to include both new and existing facilities.

A series of plant financial models was used to perform the analysis of the economic impact. Separate models were developed for each type of plant within the grain and feed industry, and in some cases, for various sizes of operations within each industry segment. The capacities, handling rates, operating hours, and other items listed in the individual plant specifications were selected to represent average or medium-size plants in most instances. The model plant is representative of the particular industry; however, it is not meant to represent the total industry. In each industry segment there are significant variations in the size, configuration and operating characteristics of different facilities. These variations will affect the economic impact which air pollution control requirements will have on specific facilities.

The limited scope of the present study barred a detailed parametric study of the economic impact as a function of plant size and configuration, and the model plants used in the analysis only present a simplified flow diagram for each type of facility. As a consequence, there are some weaknesses and shortcomings in the model plant concept. For example, it was not possible to incorporate variable factors such as:

1. Product mix between plants and within a plant;

2. Alternative processing techniques and equipment selection; and

3. Plant site and layout.

Because of the limitations imposed by the model plant approach, the results of the economic impact analysis should be viewed as indicative of the probable economic impact and not the absolute impact.

The economic impact analysis was performed for two distinct cases of dust control in each industry category:

Case 1 - Installation of the best demonstrated control system currently available for each specific source.

Case 2 - Installation of control systems that generally reflect current industry practices.

The dust control equipment selected for individual emission sources in Case 1 represented MRI's judgment of the "best" demonstrated control system currently available for the specific source. Selections of dust control equipment for Case 2 were based on the understanding of industry practice obtained during the course of the program. In general, cyclone collectors were selected in Case 2 except for those sources where industry practice (e.g., fabric filters being used in the mill house of a flour mill) indicated that fabric filter systems were generally being used to improve recovery of intermediate or final products. In selecting the dust control equipment for Cases 1 and 2, consideration was not given to the need to comply with any specific air pollution regulation.

The economic impact of new source performance standards on the grain and feed industry will be different for the various industry segments. In general, the impact on industry resulting from new plant regulations will be small, if for no other reason than few new plants are being built. The industries such as country elevators and feed mills, which have a lower initial investment cost for total plant and equipment, will be affected more severely than industries such as soybean processing and corn wet milling, which have relatively greater investment requirements for a new plant.

Requirements for pollution control equipment on new plants will increase the economies of scale within most of the industries in the grain and feed sector. The investment and annual operating costs for pollution control equipment required on grain handling operations will be essentially the same for plants of the same design, regardless of size. The type and size of control equipment are dependent upon the operations required in receiving, handling and shipping grain rather than upon the volume of grain.

For example, a truck or rail receiving station at the plant will require the same basic control device and cubic feet per minute, regardless of the number of trucks or cars which are unloaded during the year. As a result, in most of the grain and feed industries, the larger plants will tend to be more economical than smaller ones.

For all of the new model plants, the annual operating costs, including electrical charges, maintenance expenses, depreciation expenses and capital charges, were estimated for each pollution control system. For each model plant, a summary of the annual operating costs for the two alternative control systems is given below. The annual control costs are compared to the model plant's net income before taxes.

Annual Costs of Pollution Control Equipment for New Model Plants

Industry Segment	Case 1		Case 2	
	Annual Control Costs ($)	Percent of Net Income	Annual Control Costs ($)	Percent of Net Income
Country elevators	17,642	62.7	14,623	51.8
Inland terminals	75,238	31.6	57,238	24.0
Port terminals	96,209	19.4	71,490	14.5
Feed mills	44,035	20.9	35,610	16.8
Alfalfa dehydration	12,570	23.3	11,123	20.7
Wheat flour mills	98,730	23.5	79,610	19.1
Durum flour mills	154,210	36.7	128,850	30.7
Dry corn mills	117,820	28.1	99,970	23.8
Rice milling	89,550	16.6	65,190	12.1
Rice drying	19,790	35.5	19,750	30.0
Soybean processing	155,650	10.6	130,550	8.9
Corn wet milling	277,090	11.2	264,110	10.4

Investment in best available control equipment for new plants amounts to approximately 15 to 18% of the total investment in plant and equipment for country elevators, feed mills, alfalfa dehydration plants and wheat, dry corn and rice mills. The percentage is smaller for other industries dropping to approximately 3% for corn wet mills and port terminal elevators.

The alternate control equipment specified for each model plant generally reduced the investment costs required for best controls by 15 to 20%. The investment required in control equipment for each of the new model plants analyzed in this study is presented below.

	Investment in Control Equipment for New Model Plants			
	Case 1		Case 2	
Industry Segment	Investment for Control Equipment ($)	Percent of Total Plant Investment	Investment for Control Equipment ($)	Percent of Total Plant Investment
Country elevators	94,040	16.4	80,262	14.0
Inland terminals	354,720	5.9	286,030	4.8
Port terminals	444,830	3.0	355,140	2.4
Feed mills	196,370	16.8	158,680	13.6
Alfalfa dehydration	54,800	17.9	48,550	15.8
Wheat flour mills	330,030	14.0	264,340	11.3
Durum flour mills	458,030	18.3	371,340	14.9
Dry corn mills	430,260	17.2	373,970	15.0
Rice mills	348,640	15.4	260,130	11.5
Rice drying	102,940	9.6	89,013	8.3
Soybean processing	528,250	7.8	439,760	6.5
Corn wet milling	871,900	2.9	827,250	2.7

In most of the model plants, particularly those with milling or grinding operations, some of the equipment required for pollution control also serve as product recovery devices and as such, should not be classified solely as a pollution control cost.

For the plants analyzed, particularly those which handle or process grain, there are a number of control credits or positive impacts which will result from the installation of pollution control equipment. These positive impacts include:

1. Reduction in product shrink (i.e., recovery of product),

2. Reduction of maintenance costs through savings on lubricants and similar materials.

3. Increased life of protective coatings,

4. Labor savings in plant clean-up,

5. Reduction in fire insurance premiums for stocks, property and business interruptions, and

6. Tighter insect and rodent control with attendant reduction in grain losses.

The only control credit which was quantified in the model plant analyses was the reduction in product shrink. A dollar value was assigned to the dust which would be collected from the plant's operation. In most cases, the material collected by pollution control devices has some value. For some of the control devices--particularly on the processing operations--the recovered material can economically justify their installation. The larger the plant, the more likely it is that pollution control equipment can be economically justified.

The economic analysis was extended to determine the impact of installing pollution control equipment on an average existing plant. These extensions allowed for (1) the increased costs to install control equipment on existing plants, and (2) pollution control equipment which is already installed based on plant surveys conducted as part of the study. The investment and annual operating costs for existing plants were used to estimate the total costs to the industry. Because of the number of existing plants, the greater impact would be on the country elevator and feed mill industries.

The annual operating and investment costs for installing control equipment on all existing plants is summarized below.

	Pollution Controls Applied to Existing Plants			
	Total Annual Operating Cost for Industry		Total Investment Costs for Industry	
Industry Segment	Case 1 ($000)	Case 2 ($000)	Case 1 ($000)	Case 2 ($000)
Country elevators	150,659	105,561	835,942	603,064
Inland terminals	31,892	21,564	151,958	114,235
Port terminals	5,922	1,779	26,897	19,781
Feed mills	205,000	134,400	1,042,000	673,000
Alfalfa dehydration	2,765	2,447	12,792	11,333
Wheat flour mills	15,375	8,075	75,000	40,371
Dry corn mills	8,100	3,900	39,700	21,500
Rice mills	3,157	1,299	14,376	5,640
Rice drying	34,500	29,800	34,500	5,600
Soybean processing	11,388	6,357	46,670	29,900

In general, plants within the grain and feed industry will be able to pass on, rather than absorb, the increased costs from pollution controls. The increase in prices which would result from pollution controls are small when compared to general price increases of commodities within the industry since 1972. Some of the small plants which would have cost increases from pollution control above the average per unit cost for competing plants may have to absorb the control costs.

The installation of pollution controls will not affect the industry structure of industries such as corn wet milling, port terminal elevators and soybean processing which have relatively large plants and a small number of companies. However, industries, particularly country elevators and feed mills, which have a large number of firms with small plants will be affected. Small independent firms will be less likely to have the necessary capital to build and operate new plants.

EPISODE PROCEDURES, SOURCE SURVEILLANCE AND MONITORING, AND FIELD SURVEILLANCE AND ENFORCEMENT

Episode procedures, techniques for source surveillance and monitoring, and general practices for field surveillance of air pollution sources and enforcement of regulations as they pertain to the grain and feed industry were analyzed in this program.

In general the strategies to control emissions from grain and feed plants during air pollution episodes parallel those developed for other industries. The methods of reducing ambient air concentrations caused by grain and feed plants generally consist of curtailing, postponing, or deferring production and operations. Due to the close relationship between various processes in some grain and feed plants, any curtailment in one process will inevitably result in some curtailment of another process. The exact plan to be implemented at any given facility will depend on the process layout and material flow, storage capacities at critical points in the process flow, steam and/or heating requirements, and the degree of existing control on a specific process.

Emission control actions for emergency situations might present some problems for the grain and feed industry. Foremost among the potential problems is the spoilage of raw grains. Corn, soybeans, and other high moisture content grains are dried soon after receipt to prevent deterioration. Thus, spoilage could occur if drying operations are curtailed for more than a day or so. A similar risk applies to grain which must be kept in trucks, railroad cars, or barges due to curtailment of receiving operations. The length of time that a shipment can be stored without drying will vary widely with the moisture content, ambient temperature, and degree of bacterial infestation.

With the exception of grain drying operations, the large majority of grain handling and processing emission sources can be sampled by existing procedures. The EPA Method 5 procedures and particulate sampling train are well suited for use in the surveillance of emission sources at grain and feed plants. Grain dryers present unique sampling problems because of inaccessibility, large exit surface area, low gas velocities, and large particle size of the emitted particulate. Both EPA Method 5 and Hi-Vol sampling procedures have been used to test emissions from grain dryers. At present, no ideal sampling train exists for this application.

Recommended field surveillance and enforcement procedures for grain and feed plants parallel those developed for other industries. Chapter 8 discusses the recommended procedures at some length.

RECOMMENDATIONS FOR FUTURE PROGRAMS

The most important areas where additional research appears warranted can be grouped into the following categories:

1. Dust control systems

2. Source testing methods

3. Emission factors

4. Health and welfare effects

Only those sources which involve the generation of fugitive dust (e.g., grain receiving and loading and product unloading) and some drying or dehydrating operations present problems where additional control technology development would seem justified. Containment of the fugitive dust is the principal problem with regard to the former group of sources. The properties of the effluent stream pose the major difficulties for control of the emissions from drying operations.

Grain dryers present unique sampling problems. No reliable sampling train exists for this application. A program to upgrade sampling procedures for grain dryers is recommended.

Limited data are available on emission factors for uncontrolled sources in the grain and feed industry. To evaluate accurately either the environmental or economic impact of air pollution control regulations on the various segments of the grain and feed industry, the emission factors for each major pollution source should be known. A program to develop emission factors for all major sources of emissions is recommended.

A program is also recommended to further define the effect of airborne emissions from grain and feed industry operations on human health and welfare. Attention should be focused on synergistic effects produced by interaction with other particulate or gaseous components of atmospheric pollution.

CHAPTER 1

INTRODUCTION

PURPOSE OF THE STUDY

The Clean Air Act of 1970 expanded the responsibilities of the Environmental Protection Agency to include the establishment of new performance standards for new stationary sources, the delineation of best emission reduction systems that have been adequately demonstrated for use on various sources, the assessment of the economic impact on U.S. industry of the new performance standards, and the development and promulgation of inspection and monitoring procedures to assure compliance with the new performance standards. To carry out these and other responsibilities, the Environmental Protection Agency has to: (1) ascertain the present status of emissions control in various industries; (2) assess current costs for pollution control equipment; (3) determine what additional progress could be expected by the application of existing or nearly-developed technology; and (4) define areas of research and development necessary for further advances in the control of air pollutants.

This study of the grain and feed industry was conducted to provide an improved technological and economic basis which the Environmental Protection Agency could utilize to formulate new performance standards and other guidelines for air pollution control in the grain and feed industry. The study comprised a review of processing operations, an analysis of the nature and sources of emissions from various processing operations, a comprehensive and systematic evaluation of the technical and economic problems associated with the control of dust emissions, a review of source and ambient air sampling and analysis techniques, and an evaluation of the overall economic impacts of air pollution control in the grain and feed industry.

SCOPE OF STUDY

In the broadest sense the grain and feed industry could be defined to include all the operations involved from the point where the raw materials are grown (i.e., the farm) to the points where the final products are prepared for shipment to the consumer. For the purposes of this study, however, a narrower scope of operations was considered. Specific operations considered in this study were: (1) grain harvesting as it relates to dust emissions in subsequent grain handling steps; (2) grain elevators; (3) feed mills; (4) alfalfa dehydration; (5) grain milling (i.e., wheat, durum, dry corn, rye, and oat); (6) commercial rice drying; (7) rice milling; (8) soybean processing; and (9) corn wet milling. Excluded from this study were operations directly associated with the production of items intended for human consumption (e.g., cereal preparation, bread and bakery products, distilled alcoholic beverages).

ORGANIZATION OF THE STUDY

The study was divided into three major phases. The first phase involved the gathering, compiling, and analysis of information concerning the technical, economic, and operational aspects of facilities in the grain and feed industry. Literature reviews, emissions inventory questionnaires, discussions with industry trade associations and individual companies in the industry, site visits, and discussions with equipment manufacturers (both process and dust control) were used to gather the information.

Approximately 2,300 emissions inventory questionnaires, requesting data on grain handling and processing procedures, dust control equipment performance and cost, and dust emission rates, were sent to various plants in the grain and feed industry. Table 1 presents a breakdown of the response to the questionnaires. Appendix C contains a sample of an emissions inventory questionnaire.

Table 1. RESPONSE TO EMISSIONS INVENTORY QUESTIONNAIRE BY GRAIN AND FEED INDUSTRY FIRMS

Industry Segment	Questionnaires Mailed	Responses
Grain elevators	625	509
Grain milling (wheat, durum, dry corn, rye, rice, oats)	706	606
Soybean processing	121	117
Corn wet milling	15	15
Feed mills	630	561
Alfalfa dehydration	237	213
	2,334	2,021

Overall response - 87%

MRI, PEDCo-Environmental and EPA personnel visited over 100 individual facilities during the course of the program to observe directly the nature of operations in various segments of the grain and feed industry. During these site visits, discussions with plant supervisors and operating personnel provided valuable insight into the many factors that contribute to dust emissions from grain handling and processing equipment.

Information obtained from the emissions inventory questionnaires and site visits was used to compile data on locations, types, and capacities of facilities, plant operating parameters, dust control systems and techniques, dust control equipment performance, costs of dust control equipment, and current status and capabilities of source sampling, monitoring, and analytical techniques for air pollutants.

The second phase focused on a thorough evaluation of the technical and economic problems associated with the control of dust emissions in the grain and feed industry. Current control practice and the best systems for emission reduction for each major source of dust were identified. By using a modeling technique based on flow diagrams for model plants, the cost and effectiveness of best emission reduction systems (fabric filters in most cases) were evaluated for individual facilities. The financial impact of equipping plants with the best emission reduction system was then analyzed for individual plants and for the entire grain and feed industry. A limited analysis of the economic impact of equipping selected emission sources in grain and feed industry plants with cyclone collectors was also conducted.

The final phase of the study was the identification of gaps in technology and the development of recommendations for needed research and development efforts to solve air pollution problems in the grain and feed industry.

In the following chapters of this report, we present a general description of the grain and feed industry (Chapter 2), processes and emissions (Chapter 3), dust control technology and associated costs (Chapter 4), analysis of financial impact of dust control efforts (Chapter 5), air pollution episode procedures and source surveillance methods (Chapters 6 and 7), field surveillance and enforcement (Chapter 8) and research and development recommendations (Chapter 9).

CHAPTER 2

INDUSTRY STATISTICS

INTRODUCTION

A general description of grain production and utilization in the grain and feed industry along with information on the structure and other characteristics of the grain and feed industry is presented in this chapter. The development and growth of the industry, types of business organizations involved in various segments, and the number and location of facilities are among the subjects discussed in the following sections.

GRAIN PRODUCTION

Grain Production and Utilization

Grains are the primary raw materials for some of the industry segments--grain elevators, grain milling, rice milling, and corn wet milling--studied in this program. In addition, feed mills use grain and grain by-products as raw materials. Soybeans and alfalfa, which are not classified as grains, are raw materials for the soybean processing and alfalfa dehydrating industries, respectively.

Trends in the production of feed grains (corn, oats, barley, and sorghum grains); food grains (wheat, rice and rye); and soybeans are shown in Table 2. Corn is the largest crop with approximately three times the quantity of wheat--the second largest crop. Soybeans now rank third in quantity of production and second in cash value.* Soybeans have shown the most significant increase in production over the past 30 years; increasing from 79 million bushels in 1940 to 1,124 million in 1970. Oats is the only crop which has significantly declined in production during this time.

Not all the grain that is harvested is sold from the farm. Substantial portions of some crops are retained on the farms for use as livestock feed and seed. Table 3 shows the quantities sold from farms for the major grains and soybeans. In 1971, 57% of the feed grains, 94% of the food grains, and

* Soybeans are actually classified as an oil seed and not as a grain.

Table 2. QUANTITY AND VALUE OF PRODUCTION OF MAJOR GRAINS1/

	Production Quantity (000,000 bu)						
	1940	1945	1950	1955	1960	1965	1970
Corn	2,207	2,577	2,764	2,873	3,907	4,084	4,099
Wheat	815	1,108	1,109	935	1,355	1,316	1,370
Soybeans	79	193	299	374	555	846	1,124
Grain sorghums	86	96	234	243	620	673	696
Oats	1,246	1,524	1,369	1,496	1,153	927	909
Barley	311	267	304	403	429	392	410
Rice	54	68	86	124	121	170	186
Rye	40	24	21	29	33	33	39

	Farm Value of Production (000,000 bu)						
	1940	1945	1950	1955	1960	1965	1970
Corn	1,519	3,652	4,222	3,849	3,929	4,732	5,441
Wheat	556	1,661	2,042	1,859	2,361	1,775	1,826
Soybeans	70	402	738	831	1,185	2,151	3,205
Grain sorghums	41	115	245	238	515	668	798
Oats	377	1,016	1,081	890	693	585	581
Barley	124	272	358	370	355	395	389
Rice	44	122	197	269	248	376	433
Rye	17	32	28	31	30	33	38

Table 3. PRODUCTION AND FARM DISPOSITION OF GRAIN[1/]
(000,000 bu)

	1971[a/]		1970		1960	
	Production	Sold From Farm	Production	Sold From Farm	Production	Sold From Farm
Corn	5,540	3,106	4,099	2,237	4,314	1,777
Wheat	1,618	1,510	1,370	1,272	1,355	1,287
Soybeans	1,176	1,154	1,124	1,102	555	535
Grain sorghum	895	644	696	556	620	465
Oats	876	338	908	351	1,153	340
Barley	462	336	410	297	429	292
Rye	49	42	39	32	33	26
Rice	187	186	186	185	121	120
Total	10,803	7,316	8,832	6,132	8,580	4,842

a/ Years correspond to crop years.

98% of the soybeans were sold from farms. This is equivalent to approximately 212 million tons.

The supply and distribution of grain for the crop year 1971 are shown in Table 4. The supply of grains is from carryover, production or imports and the distribution or utilization is classified as feed, seed, food and industrial, or export. Exports include the grain equivalent of products (i.e., the grain may first be processed before being exported). The distribution classifications in Table 4 also include the quantities of grains retained on farms for use as feed and seed.

The use of corn for feed is the largest single use of grains. Of a total grain production of 10.6 billion bushels in 1971, approximately 37% is accounted for by corn used for feed. The portion of a crop used for seed is only 2% or less.

Industrial processing of grain accounts for only a small percentage of the total utilization. Industrial uses of grain products include: (a) cornstarch in paper and textile manufacture; (b) adhesives made from dextrin; (c) soybean oil in the manufacture of paint; and (d) the use of grain flours in foundries as a core binder.

The food value of grain greatly exceeds its value for industrial uses. Wheat is the most important crop for human consumption, although its use for livestock feed has increased from 3% of total production in 1960 to 16% in 1971. Rice sold from farms is used entirely for human consumption; however, a part of this is an indirect consumption of rice used in breweries. The use of corn for human consumption is predominately in the whole form (canned and ear corn), as cereals, as hominy, and as cornmeal. Corn flour is not used as much as wheat flour and only about 10% of dry-milled corn which goes to human consumption is ground into flour.

The export market has become an extremely important one since World War II. Wheat exports have amounted to as much as half the wheat harvest in some years. Soybean exports have been one of the more spectacular developments in American agriculture in recent years. From a prewar situation in which the United States imported soybeans, this country now provides over 90% of the soybeans entering the world market.[3/]

Grain Movement

Figures 1, 2, and 3 show the flow of grain from farm to market for wheat, feed grains, and soybeans. Although the percentages in these figures are based on the 1963-64 crop year, they are still generally representative of the patterns of grain movement.

Table 4. SUPPLY AND DISTRIBUTION OF GRAINS, U.S.[2/]
YEAR BEGINNING 1971[b/]
(000,000 bu)

	Supply				Distribution					
Grain[a/]	Carry-over	Production	Imports	Total Supply	Feed	Seed	Food and Industrial	Total Domestic	Exports[b/]	Total Use
Corn	663	5,540	1	6,204	3,882	c/	407	4,289	796	5,085
Wheat	731	1,618	1	2,350	265	64	526	855	632	1,487
Soybeans	99	1,176	-	1,275	1	51	735	787	416	1,203
Grain sorghum	91	895	-	986	711	c/	10	721	123	844
Oats	512	876	4	1,392	719	c/	102	821	24	845
Barley	156	462	15	633	265	c/	143	408	51	459
Rye	28	49	-	77	16	6	8	30	2	32
Total	2,280	10,616	21	12,917	5,859	121	1,931	7,911	2,044	9,955

a/ October - September for corn, soybeans and grain sorghum; July - June for wheat, oats, barley, and rye.
b/ Includes grain equivalent of products.
c/ Included with food and industrial distributions.

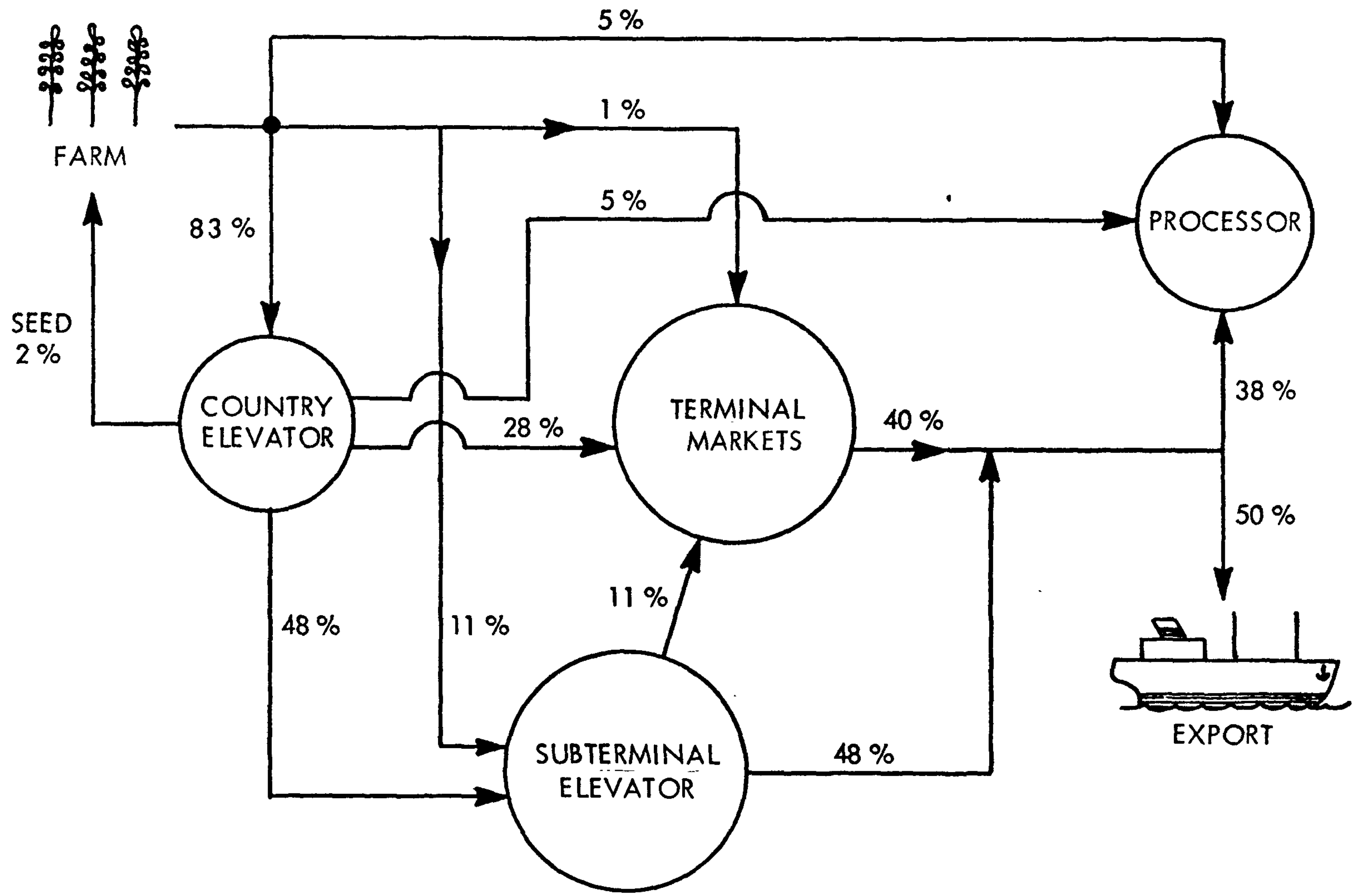

Figure 1. Flow of wheat from farm to market[4/]

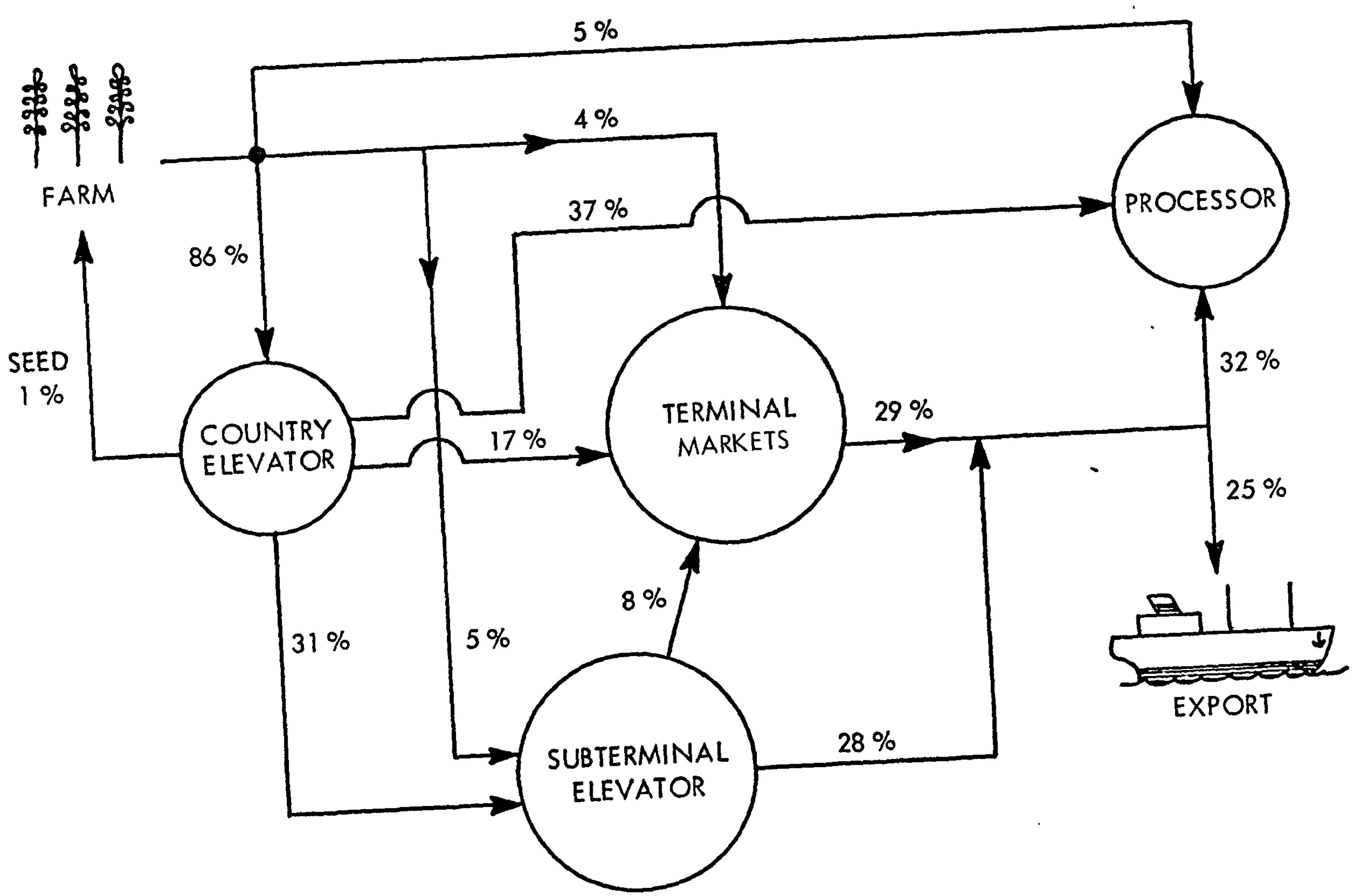

Figure 2. Flow of feed grains from farm to market.[4]

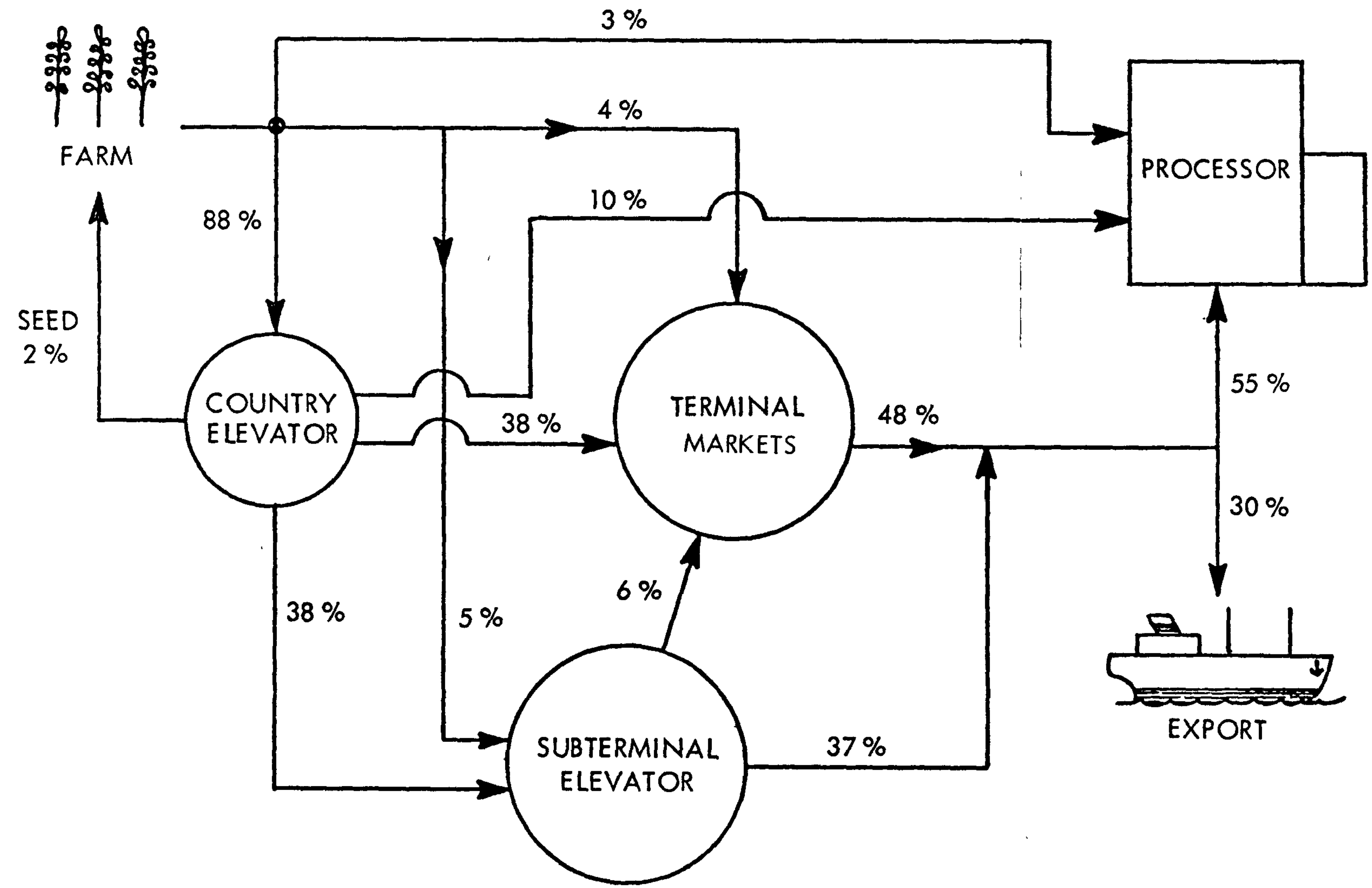

Figure 3. Flow of soybeans from farm to market[3/]

Based on the figures, approximately 85% of the grain sold from farms is handled by country elevators before being shipped to terminal elevators or grain processors. However, as a general trend, larger volumes of grain are bypassing country elevators as a result of improved roads, larger trucks, and increased on-farm storage facilities which encourage the movement of grain to more distant subterminal or terminal elevators and directly to processors.

Country elevators ship 92% of their wheat and 87% of their soybeans to subterminal or terminal elevators. Only 56% of the feed grains are shipped through these terminal markets. The remaining 44% of the feed grains handled by country elevators are shipped directly to processors--primarily feedlots.

Terminal Markets

Grain being transported to market is channeled to towns and cities in which storage capacity has been built up over the years. These cities are typically metropolitan centers in the agricultural areas of the nation. A list of grain-trading centers with volumes of inspected grain receipts and shipments for the year 1970 is shown in Table 5.[5/] Minneapolis and Duluth ranked first and second in volume of grain handled during that year. Listed in the top 10 cities are the comparatively small cities of Hutchinson, Kansas; and Enid, Oklahoma, which are located in the most productive wheat growing region in the nation. These data are from grain exchanges and boards of trade in these cities, and do not include grain not marketed through these organizations. In some cities, a considerable amount of grain bypasses the commodity exchanges. In Peoria, Illinois, for example, only 27 million bushels of grain, all rail receipts, were received through the Peoria Board of Trade; however, 117 million bushels were shipped out--all by barge, under Board aegis. The difference is in the amount of grain driven in trucks directly to barges or to elevators.

The data in Table 5 show the importance of truck transportation at the producing end of grain's farm-to-market journey. Toledo and Indianapolis receive more grain by truck than by rail. In Toledo, truck receipts in 1970 exceeded rail receipts by a ratio of approximately 5 to 1. The amount of truck receipts in Chicago, is nearly three-fourths of the amount of rail receipts. Truck shipments from terminal markets, however, are less than rail and water shipments. Where water transportation is available, such as the Missouri-Mississippi and the Illinois rivers, shipment by barge is important. However, railroads haul the largest ton-mileage.

The importance of barge traffic in the Midwest is indicated by the barge receipts at New Orleans. In 1966, when the Port of New Orleans exported nearly 500 million bushels of grain (see Table 6), over 200 million bushels of corn were shipped from various towns on the Illinois River in the down-river direction.[6/]

Table 5. GRAIN RECEIPTS AT TERMINAL MARKETS, 1970[5/]

	Grain Received (000,000 bu)				Grain Shipped (000,000 bu)			
	Rail	Truck	Barge	Total	Rail	Truck	Barge	Total
1. Minneapolis, Minnesota	na	na		404	na	na	na	na
2. Duluth, Minnesota	168	80	1[a/]	249			230[a/]	230
3. Kansas City, Missouri	194	28		222	101	3	20	124
4. Chicago, Illinois	109	75	14[b/]	198	17		95[b/]	112
5. New Orleans, Louisiana	71	1	110	182			182	182
6. Hutchinson, Kansas	na	na		142	na	na	na	na
7. Toledo, Ohio	17	84		101	17	2	63[a/]	82
8. Lincoln, Nebraska	na	na		99	41	na		41
9. Enid, Oklahoma	81	8		89	84	8		92
10. Buffalo, New York	16		71[a/]	87			2	2
11. Omaha, Nebraska	63	23		86	75	2	2	79
12. Wichita, Kansas	70	2		72	38	na		38
13. St. Louis, Missouri	30	31	9	70	na	na	na	na
14. Milwaukee, Wisconsin	na	na	na	51	na	na	na	na
15. St. Joseph, Missouri	na	na	na	49	na	na	na	na
16. Indianapolis, Indiana	12	33		45	10	na		na
17. Sioux City, Iowa	22	17		39	10	2	3	15
18. Galveston, Texas	34	1	2	37	neg.	neg.	36	36
19. Peoria, Illinois	27	na		27	neg.	neg.	117	117

a/ Lake vessels only.
b/ Includes lake vessels.
na - Not available.

Table 6. FREIGHT TRAFFIC IN PORT TERMINALS, FOREIGN EXPORTS AND COASTWIDE SHIPMENTS[6/]

Port	Amount of Grain Loaded			
	1966 Rank	1966 (000,000 bu)	1971 Rank	1971 (000,000 bu)
New Orleans, Louisiana	1	496	1	463
Houston, Texas	2	218	2	312
Duluth-Superior, Minnesota	3	212	3	175
Portland, Oregon	4	123	5	85
Galveston, Texas	5	111	11	35
Corpus Christi, Texas	6	104	8	52
Chicago, Illinois	7	98	6	70
Pascagoula, Mississippi	8	87	15	21
Beaumont, Texas	9	78	7	62
Baltimore, Maryland	10	64	13	24
Toledo, Ohio	11	62	4	86
Norfolk, Virginia	12	61	10	39
Seattle-Tacoma, Washington	13	44	9	40
Longview, Washington	14	42	12	25
Mobile, Alabama	15	40	18	16
Long Beach, California	16	39	23	4
Philadelphia, Pennsylvania	17	33	14	24
Milwaukee, Wisconsin	18	23	19	16
Kalama, Washington	19	21	16	21
Lake Charles, Louisiana	20	19	21	13
Albany, New York	21	15	22	5
Sacramento, California	22	11	17	19
Brownsville, Texas	23	10	20	15
Charleston, South Carolina	24	9	24	4
Orange, Texas	25	5	25	2

Some terminal markets function as distribution centers by shipping out most of the grain received. In Enid, Oklahoma, shipments in 1970 exceeded receipts by about 3 million bushels. This difference was made up from grain held in storage from previous harvests. Other terminal markets where shipments are much less than receipts are processing centers where grain is delivered to various processing plants. For example, Buffalo, New York, processes nearly all the grain received into flour before it is shipped. Kansas City is both a distribution center and a processing center. Of 222 million bushels received in Kansas City in 1970, 124 million were shipped on to other points; however, about 100 million bushels, or 45% of the receipts, were retained for processing.

Also of importance as grain handling centers are the seaports at which grain is loaded for export. Table 6 lists seaports where grain is a major export item. Over 50% of exports were from ports on the Gulf of Mexico in 1966 and 1971. In both years, New Orleans was the most important grain export center. At some ports, one grain accounts for nearly all of the shipments. For example, Lake Charles, Louisiana, ships mostly rice; while grain sorghums (milo) make up most of the grain shipments from Corpus Christi.

GRAIN ELEVATORS

Grain elevators transfer, condition and store grain and other crops (primarily soybeans) which move from the farm to various processors and export markets. In general, elevators are classified as either country or terminal elevators. The U.S. Department of Agriculture distinguishes between country and terminal elevators on the basis that terminals furnish official weights, that is, a weight of receipts or shipments which is made under the supervision of a state inspector. For this study, country and terminal elevators as defined above will be analyzed separately. In addition, terminal elevators will be separated into inland and port terminals. Port terminals are defined as those which are located on major waterways or seaports and are engaged in the exporting of agriculture products.

Country elevators generally receive grain or soybeans as they are harvested in fields within a 10- to 20-mile radius of the elevator. The country elevators unload, weigh, and store the grain as it is received from the farmer. In addition, the country elevator may dry or clean the grain before it is shipped to terminal elevators or processors.

Terminal elevators receive most of their grain from subterminal or country elevators and ship to processors, other terminals, and exporters. The primary function of an inland terminal elevator is to store grain in quantity without deterioration and to bring it to commercial grade so as to conform to the needs of buyers. As with country elevators, terminals dry, clean and store grain. In addition, they can sort and blend grain to meet buyer specifications.

The port terminal can provide the same basic functions as an inland terminal and, in addition, serves as an export point for grain, soybeans and other agriculture products.

Number and Capacity of Elevators

Data on the exact number of grain elevators are not available; however, the U.S. Department of Agriculture and Department of Commerce both collect industry data. Elevators approved for storage of grain under government loans are listed monthly by The Agricultural Stabilization and Conservation Service (ASCS) of the U.S. Department of Agriculture. Table 7 contains the ASCS data for the number and storage capacities of country and terminal elevators. These numbers represent a large percentage of the number of elevators and almost all of the storage capacity. However, not all elevators are registered under the uniform grain storage agreement, and some companies will register more than one country elevator with similar freight rates as one unit. The data show that the number of both country and terminal elevators has decreased each year since 1969. However, the total storage capacity of country elevators has increased because the average capacity per country elevator has grown from 363,000 bushels in 1969 to 422,000 in 1972.

ASCS does not distinguish between inland and port terminals; however, the annual Economic Research Service (USDA) survey, which uses the ASCS numbers as their sample universe, does separate port terminals. The capacities from the ERS survey are listed below.[9/]

UNIVERSE CAPACITY
(000 bu)

	1970-71	1971-72
Inland terminals	1,311,552	1,312,439
Port terminals	352,825	353,825

According to industry sources, of the 477 terminals which were registered in 1972, 64 were port and 413 were inland terminals.

Typical storage capacities at country elevators of recent construction range from 200,000 to 750,000 bushels; however, many older country elevators have a capacity of only a few thousand bushels. The average storage capacity of terminal elevators is 3.8 million bushels; however, capacities in excess of 50 million bushels have been built at a single location. This includes bins added onto the original structures, steel tanks, and storage

Table 7. NUMBER AND CAPACITY OF WAREHOUSES UNDER UNIFORM GRAIN STORAGE AGREEMENT[7/]

	Country Elevators			Terminal			Total	
	Number	Capacity	Average Capacity	Number	Capacity	Average Capacity	Number	Capacity
		(000 bu)			(000 bu)			(000 bu)
September 30, 1969	7,879	2,859,716	363	508	1,854,635	3,651	8,387	4,714,351
September 30, 1970	7,607	2,922,575	384	506	1,880,081	3,716	8,113	4,802,656
September 30, 1971	7,380	2,940,125	398	489	1,835,224	3,753	7,869	4,775,349
September 30, 1972	7,147	3,017,523	422	477	1,814,803	3,805	7,624	4,832,326
Average Yearly % Change 1969-72	- 3.20	+ 1.81	+ 5.15	- 2.08	- 0.72	+ 1.39	- 3.13	+ 0.83

in warehouse-type buildings--so called "flat storage." The largest capacity under one roof is 18 million bushels.

The number of establishments and annual sales volume for country and terminal elevators as reported by the Bureau of Census in the Census of Business are shown in Table 8.[8] The data represent those establishments whose primary source of income was from the direct operation of elevators, and therefore understates the actual number of country elevators. The census data show that from 1948 to 1967 there was a significant decrease in the number of country elevators and an increase in the number of terminals. Combining the census and ASCS data, it can be seen that the number of country elevators has continued to decline from 8,549 in 1949 to 7,147 in 1972, and that the number of terminals reached a peak around 1967 and has steadily decreased since then.

The value of sales from both country and terminal elevators has increased an average of over 2% a year from $6.6 billion in 1948 to $10.0 billion in 1967. However, the value of sales, particularly of terminals, have fluctuated significantly from year to year.

One additional source of data on the total amount of off-farm storage capacity is the Crop Reporting Board, Statistical Reporting Service, USDA. The reported capacity on 1 January 1972, was 5,696,700,000 bushels. This is 18% greater than that reported by ASCS; however, the figures include processor storage facilities as well as elevators.

<u>Transportation Mode</u>

The modes of transportation used by country elevators, inland terminals and port terminals are shown in Table 9. Country elevators receive almost 100% of their grain by truck and ship about equal amounts by truck and rail. In the past few years an increasing quantity of grain has been shipped from country elevators by barge--7% in 1970-71 and 13% in 1971-72.

Depending on their location and facilities, terminal elevators may receive and ship grain by rail, truck, barge, or boat. Inland terminals receive grain primarily by truck and rail, and ship primarily by rail and water.

A significant trend in transportation is the increasing use of water by all three types of elevators. In 1971-72 inland terminals shipped 35% of their grain by water, an increase of 5% from the previous year. The percentage of grain received by water at port terminals increased from 25% in 1970-71 to 40% in 1971-72.

An additional trend in transportation has been the increased use of hopper cars in movement of grain by rail. Hopper cars or "Big John" with capacities of up to six times the normal boxcar are being used in rapidly increasing numbers for shipments of both whole grains and grain products.

Table 8. GRAIN ELEVATORS - NUMBER OF ESTABLISHMENTS AND VALUE OF SALES[8/]

	Country Elevators		Terminal	
	Establishments (number)	Value of Sales ($000)	Establishments (number)	Value of Sales ($000)
1948	8,549	3,795,331	391	2,828,323
1954	6,613	3,225,985	460	1,796,713
1958	7,000	3,037,747	690	2,011,291
1963	7,586	4,952,067	633	2,999,800
1967	6,477	5,590,708	767	4,417,609
Average Yearly % Change	- 1.45	+ 2.06	+ 3.61	+ 2.37

Table 9. RECEIPT AND LOADOUT OF GRAIN BY TRANSPORTATION MODE AT GRAIN ELEVATORS[9]

	Percent Received By			Percent Loadout By		
	Truck	Rail	Water	Truck	Rail	Water
Country elevators						
1970-71	99.8	0.2	-	48	45	7
1971-72	99.8	0.2	-	43	44	13
Inland terminals						
1970-71	40	55	5	15	55	30
1971-72				17	48	35
Port terminals						
1970-71	15	60	25	6		94
1971-72	10	50	40	6		94

Volume of Grain Handled

The volume of grain received and shipped by elevators can change significantly from year to year. The table below shows for the three types of elevators the quantity of grain handled in relation to their storage capacity.

	Ratio of Grain Handled to Storage Capacity[9]	
	1970-71	1971-72
Country elevators	1.8	2.0
Inland terminals	1.2	1.4
Port terminals	7.7	7.6

The table shows that during the 1970-71 crop year, the average country elevator received and shipped a quantity of grain equivalent to 2.0 times its storage capacity. The volume received by country elevators is most directly affected by the quantity of crops harvested and sold from farms. Another factor affecting volume is the percentage of grain sold from farms.

which is handled by country elevators. There has been a slight trend for the farmer to bypass the country elevator and ship his grain directly to processors or to terminal elevators. This trend has resulted from the improved transportation available to the farmer and from the increase in on-farm storage facilities. However, over 80% of the grain sold from farms still goes to country elevators.

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.

Also, there has been a trend for the country elevator to bypass the inland terminal and ship directly to processors or to port terminals. Increasing numbers of rice, soybean, and feed processors are buying directly from country elevators and shipping to their plants. This trend to bypass the terminal elevator is influenced by increasing vertical integration among processors and by the location of new plants nearer the production sources and away from the metropolitan areas.

The turnover rate--7.7 times storage capacity--for port terminals is significantly greater than for other elevators because of the large quantities of grain handled for export. As a result of the large volume of grain exports during the current crop year, the port terminals will handle an even greater volume in 1972-73 than in past years.

The actual quantities of grain handled by elevators are not directly available; however, these quantities can be estimated from a number of sources. The quantities obtained by extending the ERS survey to cover all elevators are listed below:

QUANTITY OF GRAIN HANDLED
(000,000 bu)

	1970-71	1971-72
Country elevator	5,318	5,912
Inland terminal	1,574	1,837
Port terminal	2,717	2,689

The quantities handled at country elevators can also be estimated from the volume of grain sold from farms and the corresponding percentages which go to country elevators. By this method, 5,190 million bushels were handled in 1970-71 and 6,288 million in 1971-72.

Grain Storage

The average volume of grain stored at an elevator during the year as a percentage of its storage capacity is listed below:

AVERAGE OCCUPANCY[10/]
(Percent of Storage Capacity)

	1970-71	1971-72
Country	52.8	55.5
Inland terminal	55.7	51.7
Port terminal	67.0	67.4

By multiplying these percentages times the total storage capacity for each type of elevator, the average quantity stored can be estimated as indicated below:

STORAGE VOLUME

	1970-71	1971-72
	(000,000 bu)	
Country	1,560	1,641
Inland terminal	731	679
Port terminal	236	238
Total	2,527	2,558

The volume of grain stored at country elevators is affected by a number of factors, such as; (1) production and disappearance of grains; (2) availability of government loans to farmers for storage of grains; (3) amount of storage capacity available on farms and at terminal and processor elevators and (4) amount of stocks held by the Commodity Credit Corporation (CCC). The most dramatic changes in these factors during the current crop year have been the increase in exports and the reduction of CCC held stocks. It is difficult at this time to determine the effect of these changes on the future volume stored. However, the reduction in CCC stocks will significantly reduce the amount of CCC storage payments which at the present time is a major source of income for both country and terminal elevators.

Grain Drying and Cleaning

Grain received by elevators can be dried or cleaned before it is stored or shipped to processors. The percentage of grain received which is dried and cleaned and the resulting quantities are presented below. The percentages were obtained from a survey which was conducted as part of this project.

GRAIN DRYING AND CLEANING

	Dried		Cleaned	
	Percentage of Receipts	Quantity (000,000 bu)	Percentage of Receipts	Quantity (000,000 bu)
Country[a/]	25.4	1,351	7.8	415
Inland terminal	9.6	151	22.1	348
Port terminal	1.0	27	14.6	397

a/ The percentages for the country elevators may be too high, because the sample of country elevators included in the survey was biased toward the larger country elevators.

Historically, the drying and cleaning of grain was a function of terminal elevators. Country elevators have begun to offer these services and the quantity of grain dried at country elevators has generally increased over the past decade. New harvesting machinery, such as self-propelled combines and corn picker-shellers has increased the harvesting rate, and as a result, some drying is necessary to keep the grain from spoiling. The volume of grain dried by country elevators can vary greatly from year to year depending upon weather conditions during harvest.

Location

Elevators are located throughout the United States; however, the major concentration is in the grain producing states in the Mid-Plains, South Plains and Great Lakes regions.* The number and capacities of country and terminal elevators under uniform grain storage agreements by state are listed in Table 10. Kansas is the largest grain storage state with 13.2% of the elevators and 15.9% of the total U.S. capacity. Texas has far fewer elevators than Kansas (494 to 1,001); however, it has 14.0% of the total capacity. The five states of Kansas, Texas, Illinois, Nebraska, and Iowa together account for 51.9% of the elevators and 57.7% of the storage capacity.

* Mid-Plains: Nebraska, Kansas, Colorado, Wyoming, Iowa and Missouri; South Plains: Oklahoma, New Mexico, and Texas, plus gulf port facilities; Great Lakes: Wisconsin, Illinois, Indiana, Ohio, Michigan and Minnesota.

Table 10. NUMBER AND CAPACITY OF GRAIN STORAGE FACILITIES UNDER UNIFORM GRAIN STORAGE AGREEMENT BY STATES AS OF SEPTEMBER 30, 1972[7/]
(000 bu)

Rank by Total Capacity	State	Country Number	Country Capacity	Terminal Number	Terminal Capacity	Total Number	Total Capacity
1	Kansas	939	417,433	62	351,908	1,001	769,341
2	Texas	430	394,889	64	280,542	494	675,431
3	Illinois	800	352,102	32	140,025	832	492,127
4	Nebraska	685	331,326	35	121,010	720	452,336
5	Iowa	877	333,968	34	67,165	911	401,133
6	Minnesota	569	148,903	49	163,476	590	312,450
7	Oklahoma	220	95,117	21	82,123	241	177,240
8	Washington	156	111,727	16	42,537	172	154,264
9	Missouri	191	64,660	26	85,126	217	149,786
10	North Dakota	620	128,132	7	16,131	627	144,263
11	Arkansas	81	90,233	9	40,406	90	130,639
12	Ohio	130	57,572	23	64,751	153	122,323
13	Indiana	156	67,012	9	37,828	165	104,840
14	South Dakota	365	79,636	1	2,293	366	81,929
15	Louisiana	25	21,440	8	46,426	33	67,866
16	Wisconsin	20	6,583	9	57,608	29	64,191
17	Colorado	105	43,957	6	13,200	111	57,157
18	Oregon	72	37,218	6	13,470	78	50,688
19	California	30	25,345	6	24,043	36	50,108
20	New York	2	212	8	47,725	10	47,937
21	Montana	259	38,894	7	7,491	266	46,385
22	Idaho	112	41,839	1	732	113	42,571
23	Michigan	122	26,608	7	12,099	129	38,707
24	Tennessee	10	5,935	8	24,352	18	30,287
25	Mississippi	36	15,126	3	15,160	39	30,286
26	North Carolina	17	16,318	1	497	18	16,815
27	Georgia	32	16,267			32	16,267
28	New Mexico	17	15,241			17	15,241
29	Maryland	1	357	3	13,335	4	13,692
30	Kentucky	8	3,350	3	9,767	11	13,137
31	Pennsylvania	6	2,019	4	9,074	10	11,093
32	Virginia	5	595	3	10,271	8	10,866
33	Utah	3	1,008	5	9,712	8	10,720
34	South Carolina	20	10,016			20	10,016
35	Alabama	8	2,954	1	3,700	9	6,654
36	Arizona	8	5,282			8	5,282
37	Wyoming	21	3,823			21	3,823
38	Florida	3	2,016			3	2,016
39	Delaware	3	1,640			3	1,640
40	Maine	2	647			2	647
41	Alaska	1	43			1	43
	Total	7,147	3,017,523	477	1,814,803	7,624	4,832,326

Terminal elevators are located in the principal grain-marketing centers, most of which are in metropolitan areas. However, there has been a trend in recent years to build terminals in rural areas and there have always been terminals in relatively small cities such as Hutchinson, Kansas, and Enid, Oklahoma.

Country elevators are almost exclusively located in rural areas. Table 11 lists the number of country elevators in varying sizes of metropolitan areas as reported by the Bureau of Census in 1967. Of 6,477 country elevators, 5,632 or 87% were located in areas with less than 100,000 inhabitants.

Table 11. COUNTRY ELEVATORS WITHIN METROPOLITAN AREAS - 1967[11/]

Number Inhabitants Within Metropolitan Area	Establishments		Sales	
	Number	Percent	Value ($000)	Percent
1,000,000 or More	101	1.6	77,136	1.4
500,000 - 999,000	174	2.7	227,107	4.1
100,000 - 499,000	570	8.9	574,016	10.3
Less than 100,000 (nonmetropolitan areas)	5,632	87.0	4,712,449	84.3
Total	6,477	100.0	5,590,708	100.0

Industry Structure

Country Elevators - The ownership of country elevators can be grouped into three categories: cooperative, independent, and line. Cooperative elevators are controlled by farmer associations established under cooperative laws. Independent elevators are owned by individual merchants. Line elevators are chains of elevators owned by large merchandising or processing firms. The number and percentage of each type of ownership as reported by the 1963 Census of Business are presented in Table 12. Of 7,653 country elevators, 38% were owned by cooperatives, 28% by line organizations, and 34% by independents. The number of cooperative elevators has grown over the past decade and it is estimated[12/] that by 1980, 60% of the country elevators will be owned by cooperatives. The number of line elevators is projected to increase to 35% by 1980, while the number of independent elevators will decrease to 5%.

Table 12. OWNERSHIP OF COUNTRY ELEVATORS--1963[13/]

	Establishments		Sales Volume	
	Number	Percentage	Dollars (million)	Percentage
Country - Independent	2,572	33.6	8,059	36.2
Country - Line	2,166	28.3	1,833	23.4
Country - Cooperative	2,915	38.1	1,182	40.4
Total	7,653	100.0	11,074	100.0

The concentration of ownership and sales volume in the country elevator industry is very low in comparison to other major industries. Table 13 shows that in 1967 there were 4,409 firms which operated 6,477 elevators. Firms with less than three elevators each accounted for 64.2% of the elevators and 71.3% of the sales. Firms with six or more elevators accounted for only 20% of the total sales volume.

Table 13. CONCENTRATION OF OWNERSHIP OF COUNTRY ELEVATORS[11/]

(Single and Multiunit Firms--1967)

	Establishments			Sales	
Firms With	Firms	Number	Percent	Value ($000)	Percent
1-2 Establishments	4,033	4,160	64.2	3,985,180	71.3
3-5 Establishments	234	597	9.2	485,002	8.7
6-25 Establishments	118	751	11.6	525,840	9.4
26 Establishments or More	24	969	15.0	594,686	10.6
Total	4,409	6,477	100.0	5,590,708	100.0

The presence of a large number and different types of firms has meant that there has been a high level of competition. This competition is reflected in the low operating margins which have been characteristic of country elevators. A summary of the financial condition of 23 regional grain cooperatives[14/] shows that the rate of return as measured by the percent of net savings* before taxes to total assets has varied from 0.4 to 3.6% over the 5 years from 1967 to 1971. These data include terminals as well as country elevators. A survey[15/] of 51 wholesalers of grain with sales of less than $1 million shows that for 1971 the profitability (net profit before taxes/total assets) of individual firms varied from -3.8 to 4.6%. This low rate of return has prevailed despite the fact that many older country elevators have completely depreciated their major fixed assets.

The existence of vertical integration by integrated processing and export firms has forced down the profitability of the nonintegrated country elevator operation, because many of these integrated firms look upon their country elevator operations as supply sources rather than profit centers.

Terminal Elevators - The ownership patterns for terminal elevators in 1963 with a projection to 1980 are shown in Table 14.

Table 14. OWNERSHIP OF TERMINAL ELEVATORS[12/]

	1963 (%)	1980 (%)
Farmer cooperative	20	25
Export integrated merchandisers	25	30
Domestically integrated processors	20	25
Nonintegrated firms	35	20

The percentages represent the operation of terminals rather than actual ownership, because many of the port terminals are owned by the port authorities and leased to grain companies.

As in the case with country elevators, vertical integration in the terminal operations is becoming more predominate. Many of the largest grain processors own, lease, or operate terminal and country elevators.

* Net profits as defined by private industry are normally referred to as net savings by cooperatives.

Some of the major reasons why these firms integrate back to elevators are to: (1) have access to specific quantities and qualities of grain, (2) take advantage of government storage programs; (3) have unique transportation arrangements; (4) provide a captive market outlet for grain procurement facilities; and (5) reduce procurement cost of grain.

No data are readily available on the number of firms or concentration in the operation of terminal elevators. However, the concentration is still relatively low with over 100 firms operating terminals throughout the U.S. The competition among terminal firms is high. The presence of strong farmer cooperatives, grain processing, export, and independent operators, together with relatively low profit margins is evidence of this competition.

The profitability of terminals has generally been better than that of country elevators. However, the change in transportation media (from rail to barge) and the development of large country subterminals has destroyed the profitability of some terminals which are located in metropolitan areas without access to water. These terminals have higher operating expenses than their rural counterparts and do not have the advantage of the lower transportation rates available from barge traffic. In addition, many of the subterminals and country elevators are bypassing inland terminal elevators by shipping grain directly to port or processing facilities.

FORMULA FEED INDUSTRY

Introduction

The formula feed industry consists of mills engaged in manufacturing prepared feeds for animals and fowl. Feed milling is a grinding and mixing process in which a variety of whole grains are ground for mixing with high protein concentrates, food industry by-products, vitamins, drugs, and minerals. The resulting feed is usually a formulated blend of ingredients which provides a nutritional and balanced diet for either livestock, poultry or pets.

The formula feed industry is the largest manufacturing industry serving agriculture exclusively, and is one of the top 20 manufacturing industries in the United States. The industry's sales volume as reported by the Bureau of Census was $5.2 billion in 1970 and has increased at an annual rate of 4.5% since 1958. The sales volume from 1958 to 1970 of the major types of feed--poultry feed, livestock feed, and dog and cat food--are shown in Table 15. The principal increases in sales are from the livestock and pet food sectors. The increase in livestock feed reflects the increased consumption of meat products by the American consumer and the increasing proportion of beef cattle finished for slaughter by concentrate feeding. The increase in pet food sales from $305 million in 1958 to $1,047 million in 1970 has been caused by an increase in the number of pets as well as an increased tendency of owners to feed commercial dog and cat foods to their pets.

Table 15. VALUE OF FORMULA FEED SHIPMENTS FROM FEED INDUSTRY[16/]
($000,000)

Year	Poultry Feeds	Livestock Feeds	Dog & Cat Food	Other	Total
1970	1,518.1	2,127.9	1,046.9	545.8	5,238.7
1969	1,478.8	1,900.4	969.7	485.9	4,834.8
1967	1,560.2	1,705.4	699.9	564.2	4,529.7
1963	1,445.0	1,388.4	441.9	451.8	3,677.4
1958	1,474.3	958.9	305.4	337.9	3,076.4
Percent Change 1969-70	2.7	12.0	8.0	12.3	8.4
Average Yearly Change 1958-70	0.2	6.9	10.8	4.1	4.5

The Census of Manufacturers includes only establishments whose largest source of gross income is from the manufacture of poultry feed, livestock feed, pet foods, alfalfa meal, feed supplements, and feed concentrates. Therefore, the Census does not provide full coverage of all feed milling activity.

A major data source on the formula feed industry is a survey conducted by the Economic Research Service and the Agriculture Stabilization and Conservation Service. This survey collected statistics on all known U.S. milling establishments in 1969.[17/] Included in the survey were establishments whose primary source of income was other than formula feed, and also those which are classified as nonmanufacturing by the Bureau of Census. However, the survey does not cover the manufacture of alfalfa meal which is included in the Census of Manufacturers.

A comparison of these two information sources can be made from the total feed production reported by each. The ERS survey reported total feed production in 1969 as 103.9 million tons, while the Bureau of Census in the Annual Survey of Manufacturers reported 1969 feed production of approximately 52.3 million tons. This means that the Bureau of Census data covers only 50% of the total formula feed production quantity.

Another measure of the Census coverage can be obtained by comparing the value of shipments as reported by the Census with the value of feed purchases by farmers as reported by the U.S. Department of Agriculture. In 1970, farmers purchased $7.18 billion in feed, which compares with $4.19 billion reported by the Census as the value of formula feed shipments excluding dog and cat food. Based on this comparison, the Census accounted for approximately 58% of the feed sales.

The ERS survey reported that 7,917 feed manufacturing establishments produced 1,000 tons or more of formula feed and that their total production was 101,115,114 tons. Of this, 68,811,750 tons were classified as primary tonnage and 32,303,364 were classified as secondary tonnage. Primary feed manufacturing is processing and mixing individual feed ingredients, sometimes with the addition of a premix at a rate of less than 100 pounds/ton of finished feed. Examples of specific feed ingredients are feed grains, mill by-products, oilseed meals, and animal proteins. Secondary feed manufacturing is processing and mixing one or more ingredient with formula feed supplements. Supplements are usually used at a rate of 300 pounds or more per ton of finished feed, depending on protein content of the supplement and percentage of protein desired in the finished feed.[17/] The primary tonnage, shown in Table 16, was further broken down as: 56,800,461 tons (82.5%) complete feed; 11,327,366 tons (16.5%) supplement feed; and 683,923 tons (1%) feed premix.

Materials Used

The feed concentrate balance for the U.S. is shown in Table 17. The supply utilization and carryover of the major feed ingredients are presented in this table. Corn, by far the major ingredient, accounts for 58% of the raw material volume. However, the feed industry's growth is closely tied to the introduction and utilization of by-products and high protein concentrates. The utilization of those nonfeed grain ingredients are further detailed in Table 18. The most important by-product has been soybean meal. Its consumption has more than doubled between 1956 and 1971, and now accounts for approximately 62% of all high protein feeds. Large numbers of farmer feeders have shifted from home-produced to commercial feeds. They have insisted on buying improved-quality mixed feeds made possible by advances in animal nutrition. Today, most formula feeds contain between 15 and 25 ingredients, microingredients, and drugs. Nutritional research has shown how livestock and poultry production can be increased per unit of feed by the addition of certain ingredients such as, vitamins, antibiotics, hormones and drugs.

Table 16. FORMULA FEED FROM PRIMARY MANUFACTURING[17/] ESTABLISHMENTS PRODUCING 1,000 TONS OR MORE OF FEED

	Complete Feed (000 tons)	Supplement Feed (000 tons)	Feed Premix (000 tons)	Total Feed (000 tons)	Percent
Starter-Grower Layer-Breeder	11,264	1,256	94	12,613	18.3
Broiler	11,314	212	47	11,572	16.8
Turkey	2,589	276	16	2,881	4.2
Dairy	11,106	1,668	84	12,857	18.7
Beef and Sheep	11,550	3,339	152	15,040	21.9
Hog	5,832	4,255	187	10,274	14.9
All Other	3,146	323	105	3,574	5.2
Total	56,800	11,327	684	68,812	100.0
Percent	82.5	16.5	1.0	100.0	

Table 17. FEED CONCENTRATE BALANCE, NUMBER OF ANIMAL UNITS, AND FEED PER UNIT, AVERAGE 1965-69, ANNUAL 1967-72[18]

Item	1965-69 Average	1967	1968	1969	1970	1971[b]	1972[c]
	Year Beginning[a]						
	(000,000 tons)						
Supply							
Carryover--beginning of year[a]	46.5	37.1	48.3	50.0	48.4	33.0	48.2
Production of feed grains:							
Corn	122.9	133.3	123.0	128.3	114.8	155.1	151.2
Sorghum grain	20.3	21.2	20.7	20.9	19.5	25.1	25.1
Oats	14.1	12.6	15.0	15.2	14.5	14.0	11.7
Barley	9.6	8.9	10.2	10.2	9.8	11.1	10.0
Total production	166.9	176.0	168.9	174.6	158.6	205.3	198.0
Imports of feed grains:	0.3	0.3	0.3	0.4	0.4	0.5	0.3
Wheat fed	4.6	4.3	5.2	6.7	7.2	8.5	5.0
Rye fed	0.3	0.3	0.3	0.3	0.4	0.6	0.6
By-product feeds fed	32.2	31.1	32.9	34.7	34.5	34.4	35.4
Total supply of all concentrates	250.8	249.1	255.9	266.7	249.5	282.3	287.5
Utilization (October-September)							
Concentrates fed[d]							
Corn	96.6	95.5	98.6	103.4	98.7	108.7	114.2
Sorghum grain	16.7	14.9	17.4	18.3	19.3	19.9	21.2
Oats	11.6	10.8	12.0	11.6	12.3	11.6	11.5
Barley	5.4	4.9	5.8	6.3	6.5	6.8	6.6
Wheat and rye	4.9	4.6	5.5	7.0	7.6	9.1	5.6
Oilseed meals	13.7	12.6	14.0	15.8	15.7	15.6	16.8
Animal protein feeds	3.5	3.8	3.5	3.2	3.2	3.2	3.0
Grain protein feeds	2.3	2.3	2.3	2.4	2.4	2.4	2.5
Other by-product feeds	12.7	12.4	13.1	13.3	13.2	13.2	13.1
Total concentrates fed	167.4	161.8	172.2	181.3	178.9	190.5	194.5
Feed grains							
Food, industry and seed	15.7	15.8	16.1	16.3	16.4	16.7	17.0
Exports	22.8	23.0	18.3	21.7	20.2	27.5	32.0
Total utilization	205.9	200.6	206.6	219.3	215.5	234.7	243.5
Utilization adjusted to marketing year[e]	205.6	200.8	205.9	218.3	216.5	232.5	243.5
Carryover--end of year[a]	45.2	48.3	50.0	48.4	33.0	48.2	44.0
Grain-consuming animal units (million)	111.7	111.5	114.0	115.3	118.3	118.4	120.0
Supply of all concentrates per animal unit (tons)	2.24	2.23	2.24	2.31	2.11	2.38	2.40
All concentrates fed per animal unit (tons)	1.50	1.45	1.51	1.57	1.51	1.61	1.62

a/ Corn and sorghum grain October 1; oats and barley July 1.
b/ Preliminary.
c/ Preliminary; estimates based on indications in November 1972.
d/ Total quantities fed, including domestically produced and imported grains and by-product feeds.
e/ Oats and barley July-June; other grains and concentrates October-September.

Table 18. PROCESSED FEEDS: ESTIMATED USE FOR FEED[18/]
AVERAGE 1966-70, ANNUAL 1968-72[a/]

Feed	1966-70 Average	1968	1969	1970	1971[b/]	1972[c/]
	Year Beginning October					
	(000 tons)					
High-protein						
Oilseed meal						
Soybean	12,029	11,525	13,582	13,467	13,178	13,830
Cottonseed	1,757	2,086	1,794	1,692	1,885	2,375
Linseed	214	197	182	258	263	285
Peanut	136	135	122	173	175	200
Copra	100	111	83	99	100	100
Total	14,236	14,054	15,763	15,689	15,601	16,790
Animal proteins						
Tankage and meat meal	2,040	2,021	2,014	2,039	1,891	1,950
Fish meal and solubles	784	835	567	605	749	500
Commercial dried milk products	246	235	230	260	275	300
Noncommercial milk products	378	385	350	330	300	275
Total	3,448	3,476	3,161	3,234	3,215	3,025
Grain protein feeds						
Gluten feed and meal	1,547	1,550	1,574	1,610	1,654	1,700
Brewers' dried grains	343	333	361	361	369	380
Distillers' dried grains	424	437	428	382	404	420
Total	2,314	2,320	2,363	2,353	2,427	2,500
Other						
Wheat millfeeds	4,518	4,469	4,633	4,499	4,364	4,300
Rice millfeeds	469	494	490	436	479	475
Dried and molasses beet pulp	1,393	1,523	1,675	1,509	1,550	1,575
Alfalfa meal	1,588	1,662	1,545	1,584	1,568	1,575
Fats and oils	526	531	545	570	558	575
Molasses, inedible	3,294	3,310	3,450	3,550	3,550	3,600
Miscellaneous by-product feeds[d/]	1,100	1,100	1,100	1,100	1,100	1,000
Total	12,888	13,089	13,438	13,248	13,169	13,100
Grand total	32,886	32,939	34,725	34,524	34,412	35,415

a/ Adjusted for stocks, production, foreign trade and nonfeed uses where applicable.
b/ Preliminary.
c/ Based on November indications.
d/ Allowance for hominy feed, oat millfeeds, and screenings.

Table 19. FORMULA FEED INDUSTRY (CENSUS OF MANUFACTURERS)[11/]

	Companies	Establishments	Employees (000)	Value of Shipments ($000,000)
1967	1,835	2,355[a/]	53.3	4,796.9
1963	2,150	2,590	54.6	3,880.1
1958	2,016	2,379	57.3	2,942.0
Percent Change 1958-67	-9.0	-1.0	-7.0	+63.0

a/ Some of the small establishments in this industry have been misclassified as to industry. This does not significantly affect the statistics other than the number of companies and establishments.

In total, 4.8% of all livestock and poultry production was accounted for by vertical integration and 31.4% by production contracts. This concentration of livestock and poultry production impacts the feed industry by increasing the direct selling of feed to large feeders, increasing the building of smaller capacity mills near the customer, and increasing the use of bulk transport for receiving and delivering feed.

Size of Mills

The production capacity of individual feed mills ranges from 10-12 tons/day to over 1,000 tons/day. The actual production of varying sizes of feed mills as reported by the 1969 ERS survey is listed in Table 20. The 5,300 establishments with production of less than 1,000 tons/year accounted for 40% of the number of establishments but for only 2.6% of the total production. At the other end of the scale, the 176 establishments with production of over 100,000 tons/year accounted for 1.3% of the establishments and 28% of the production.

The total production capacity of feed manufacturing establishments within various size categories is presented in Table 21. Only the 7,917 establishments with production of greater than 1,000 tons/year are listed. Within this group the plants with production between 1,000 and 9,999 tons accounted for 41.8% of the production capacity. The percentage of operating capacity utilized increased from 36.6% for establishments between 1,000-9,999 tons to 129.6% for establishments over 100,000 tons/year. These

Table 20. PRODUCTION OF FEED MANUFACTURING ESTABLISHMENTS[17/] BY SIZE, 1969[a/]

Establishment Size by Production in Tons/Year	Establishments Number	Establishments Percentage	Production Quantity (000 tons)	Production Percentage
0 - 999	5,309	40.1	2,725	2.6
1,000 - 9,999	5,952	45.0	21,617	20.8
10,000 - 24,999	1,073	8.1	15,546	15.0
25,000 - 49,999	415	3.1	14,233	13.7
50,000 - 99,999	301	2.3	20,688	20.0
100,000 and over	176	1.3	28,900	27.9
Total	13,226	100	103,709	100

a/ Numbers from reporting establishments were expanded to represent 100% of the industry.

Table 21. CAPACITY OF FEED MANUFACTURING ESTABLISHMENTS[17/] PRODUCING 1,000 TONS OR MORE OF FEED

Establishment Size by Production in Tons/Year	Number of Establishments	Capacity[a/] Tons	Capacity[a/] Percentages	Percent of Capacity Utilized
1,000 - 9,999	5,952	59,011	41.8	36.6
10,000 - 24,999	1,073	23,256	16.5	66.8
25,000 - 49,999	415	17,559	12.4	81.1
50,000 - 99,999	301	18,952	13.4	109.2
100,000 and over	176	22,296	15.8	129.6
Total	7,917	141,175	100	71.6

a/ Estimates of capacity based on full capacity output for 48 weeks of 40 hr each. Data from reporting establishments expanded to represent 100% of the industry.

significant differences in utilized capacity can be accounted for by the operational economics of the different size plants. Large plants are more automated and require much larger investment in buildings and equipment. To be economically competitive these plants must effectively utilize their equipment by operating multiple shifts. On the other hand, the small feed mill has less capital investment, less transportation costs, and often serves a captive market; therefore, it does not have to operate at capacity to be economically viable.

Less than 75% of the total feed manufacturing capacity--based on operations of 40 hr/week for 48 weeks--was utilized in 1969. If required, most feed mills could operate on a two shift basis which would mean that current production is at only 36% of total capacity.

Plant Location

The number and production volume of feed manufacturing establishments producing 1,000 tons or more of formula feed is listed by state in Table 22. The highest concentration of mills is near the feed grain and livestock and poultry producing areas; however, there are feed mills in almost every state. Iowa has the greatest number of establishments with 9.2% of the nation's total, while Texas has the greatest production volume with 9.0% of the total.

Changes in the location of major livestock and poultry production areas to the south and west of the Corn Belt have forced the formula feed industry to move also. This geographic movement toward major feed-consuming areas contributed to the decentralization of the feed industry. This trend from distant large-scale mills with extensive distribution organizations to local, demand oriented feed mills supplying local production units has been quite significant.

Characteristics of Feed Manufacturing Firms

In general, the number of companies in the feed industry has decreased over the last decade primarily as a result of the trend toward vertical integration. Estimates of individual manufacturer's tonnage indicate that the top 10 feed manufacturers in 1972 were:

1. Ralston Purina Company
2. Allied Mills
3. Central Soya
4. Cargill-Nutrena
5. Agway
6. ConAgra
7. Farmland Industries
8. Federal
9. Carnation-Albers
10. Gold Kist

Table 22. LOCATION OF FORMULA FEED PLANTS[17/]

State and Region	Establishments Number	Establishments Percent	Production Tons	Production Percentage
Maine	13		502,668	
New Hampshire	6		165,162	
Vermont	12		794,900	
Massachusetts	14		233,574	
Connecticut	5		257,264	
New York	259		2,936,160	
New Jersey	25		375,877	
Pennsylvania	288		2,739,110	
Delaware	20		690,786	
Maryland	65		1,361,881	
NORTHEAST	707	8.9	10,057,382	10.1
Michigan	237		1,594,085	
Wisconsin	510		4,506,266	
Minnesota	402		3,509,848	
LAKE STATES	1,149	14.5	9,610,199	9.5
Ohio	459		3,331,439	
Indiana	493		4,067,681	
Illinois	475		4,464,906	
Iowa	730		6,716,940	
Missouri	302		3,365,509	
CORN BELT	2,459	31.1	21,946,475	21.7
North Dakota	80		412,257	
South Dakota	159		1,315,948	
Nebraska	343		3,584,675	
Kansas	396		4,281,534	
NORTHERN PLAINS	978	12.4	9,594,414	9.5
Virginia	115		1,166,797	
West Virginia	19		85,592	
North Carolina	233		3,238,965	
Kentucky	128		915,811	
Tennessee	113		2,549,350	

Table 22. (Concluded)

State and Region	Establishments Number	Establishments Percent	Production Tons	Production Percentage
APPALACHIAN	608	7.7	7,956,515	7.9
South Carolina	61		542,497	
Georgia	197		4,289,601	
Florida	97		1,515,814	
Alabama	114		2,853,182	
SOUTHEAST	469	5.9	9,201,094	9.1
Mississippi	98		1,973,666	
Arkansas	93		3,342,408	
Louisiana	48		804,335	
DELTA STATES	239	3.0	6,120,409	6.1
Oklahoma	145		1,770,112	
Texas	438		9,048,082	
SOUTHERN PLAINS	583	7.4	10,818,194	10.7
Montana	73		583,486	
Idaho	98		1,065,368	
Wyoming	19		171,522	
Colorado	98		2,442,233	
New Mexico	51		925,830	
Arizona	32		1,275,052	
Utah	44		413,138	
Nevada	8		120,740	
MOUNTAIN	423	5.3	6,977,369	6.9
Washington	56		1,000,640	
Oregon	55		765,166	
California	191		6,966,297	
PACIFIC	302	3.8	8,732,103	8.6
47 States	7,917		101,014,154	

These 10 companies manufactured 27-28% of the U.S. tonnage of formula feed. All of them are highly diversified; as illustrated by the fact that each has major activities in at least four 4-digit SIC industry classifications.

In comparison with other major manufacturing industries, the formula feed industry is highly decentralized. The concentration ratios as reported by the Bureau of Census are shown in Table 23. In 1970 the four and eight largest companies had 24% and 34%, respectively, of the value of industry shipments which are almost the identical percentages as in 1935.

The trend in the industry toward diversification and vertical integration is illustrated by the increase over the last 10 years in the number and size of feed mill establishments which belong to multiplant firms and the decrease in those which are single plant firms. These numbers are shown in Table 24. Feed manufacturing is losing its identity as a separate operation, and is becoming more a part of the total food producing complex.

According to the ERS survey, 46% of the formula feed mills belong to corporations and these mills account for 65% of the total production by feed manufacturers. There are a number of larger farmer cooperatives in the feed industry, and they account for approximately 23% of the establishments and 20.5% of the production. A summary of the ownership pattern of feed mills in 1969 is shown in Table 25.

ALFALFA DEHYDRATING INDUSTRY

Introduction

The dehydration of alfalfa started in this country early in the 20th Century but did not begin to be of commercial importance until the 1930's. During the 1940's, the industry expanded rapidly, and reached a stage of relative maturity in the late 1950's. Alfalfa dehydrators are located throughout the country except in New England and the southeastern states. The center of the industry is in the Northern Plains. Figure 4 illustrates the general distribution of plants in the continental United States as of 1972.

Raw Materials and Products

Alfalfa is the only raw material processed in alfalfa dehydrating plants. Standing alfalfa is mowed and chopped in the field and transferred to a truck which transports the chops to the dehydrating plant. Chapter 3 discusses the operation of the plant.

Table 23. PERCENT OF SHIPMENTS ACCOUNTED FOR BY LARGEST[16] COMPANIES IN THE FEED INDUSTRY

		Value of Industry Shipments				
			Percent Accounted For By			
Year	Companies (number)	Total ($000,000)	4 Largest Companies	8 Largest Companies	20 Largest Companies	50 Largest Companies
1970	(NA)	5,465.3	24	34	(NA)[a]	(NA)
1967	1,835	4,796.9	23	31	42	58
1966	(NA)	4,438.4	23	21	(NA)	(NA)
1963	2,150	3,880.1	22	28	40	54
1958	2,016	2,942.0	22	30	43	56
1954	2,037	2,702.3	21	29	43	(NA)
1947	2,372	2,112.2	19	27	40	(NA)
1935	(NA)	(NA)	23	34	(NA)	(NA)

a/ (NA)--Not available.

Table 24. TYPE OF OPERATION IN FEED INDUSTRY[16/]

	Establishments		Value Added[a/]	
Multi-Unit	Number	Percentage	($000,000)	Percentage
1967	795	33.8	934.4	76.2
1963	754	29.1	671.0	68.1
1958	652	27.4	551.9	75.0
Single Unit				
1967	1,560	66.2	292.4	23.8
1963	1,836	70.9	312.7	31.8
1958	1,727	72.6	247.0	25.0

a/ Value added by manufacture.

Table 25. OWNERSHIP OF FEED ESTABLISHMENTS WITH[17/] PRODUCTION OF OVER 1,000 TONS

	Establishments[a/]		Production	
	Number	Percentage	(000 tons)	Percentage
Corporations	3,617	45.7	65,343	64.7
Partnership	760	9.6	5,949	5.9
Single Owner	1,672	21.1	8,808	8.7
Farmer Cooperative	1,844	23.3	20,702	20.5
Other	24	0.3	205	0.2
Total	7,917	100.0	101,014	100.0

a/ Numbers from reporting establishments were expanded to represent 100% of the industry.

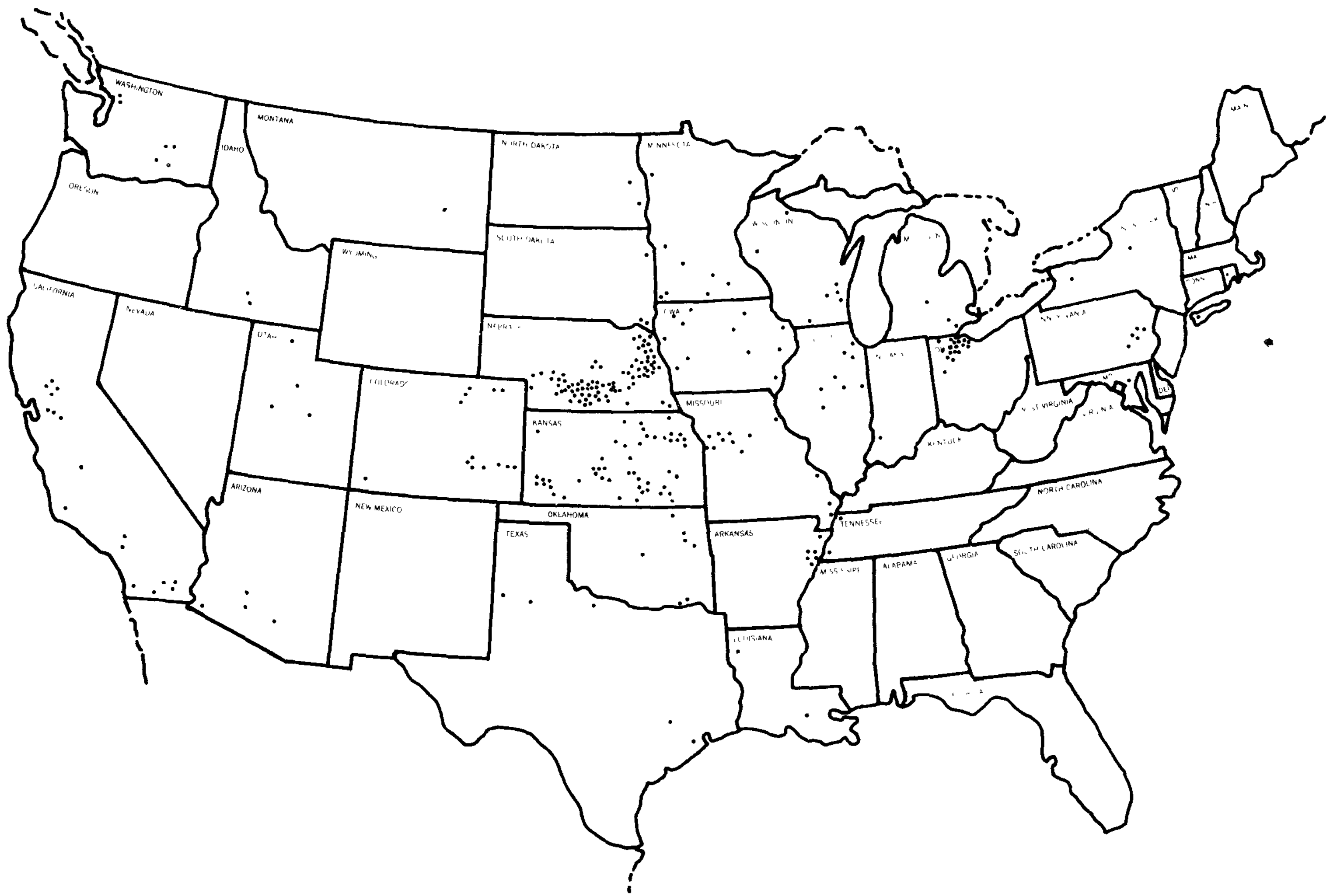

Figure 4. Geographical distribution of alfalfa dehydrating plants (1972).

Dehydrated alfalfa is important for its protein quality, unidentified growth and reproductive factors, pigmenting xanthophylls, and vitamin contributions, although its carotene content is not as important as it has been in past years.

Trends in the production and utlization of alfalfa meal in the United States are shown in Tables 26 and 27. Industry growth, in terms of volume of production and utilization, has been relatively continuous. Since 1948, annual production gains have occurred 15 times; decreases from the preceding year have occurred four times. The gains resulted mostly from adding to industry capacity. Setbacks were mainly caused by adverse weather conditions.

The Northern Plains states account for over 50% of the total U.S. output of dehydrated alfalfa. Table 28 presents data on production in the Northern Plains states for the early and middle 1960's. Nebraska alone accounted for 35-45%.

Table 29 presents information on the value of shipments from alfalfa dehydrating plants in 1963 and 1967. There is some discrepancy between the production figures quoted in Table 29 and those given in Tables 26 and 27. The reason for this discrepancy appears to be that Table 26 covers the seasonal year from May 1 to April 30, whereas Table 27 shows a year as being October through September, and Table 29 reflects the calendar year.

Industry Structure

About 200 firms now operate dehydrating plants--an average of nearly one and one-half each. A limited number of firms each operate more than 20 plants at various locations. The majority, however, have only one plant.

Industry production is concentrated among firms. Twenty percent produce more than 70% of annual tonnage. Approximately 54% of the firms contribute only 12% of the industry production. Firms producing less than 1,000 tons annually represent about 12% of the total number of firms but only 1% of the total production volume.

About three-fourths of the alfalfa dehydrating plants in operation are investor-oriented corporations. The remaining fourth are partnerships, individually owned firms, and cooperatives. Investor-oriented corporations in the alfalfa dehydrating industry consist of owner-operated plants and those that have hired managers. The owner-operated concerns are generally family enterprises or partners who choose to incorporate. They differ little from individual ownerships and partnerships in operations.

Table 26. DEHYDRATED ALFALFA PRODUCTION AND UTILIZATION[19/]
1948-49 TO 1971-72 SEASONS

Season May 1-April 30	Production (000 tons)	Production Percentage Change From Previous Year	Utilization (000 tons)	Utilization Percentage Change From Previous Year
1948-49	732.0	-	709.1	-
1949-50	800.3	9.3	820.3	15.7
1950-51	907.5	13.4	906.6	10.5
1951-52	846.5	-6.7	851.6	-6.1
1952-53	1,020.1	20.5	968.8	13.8
1953-54	855.6	-16.1	899.6	-7.1
1954-55	1,063.7	24.3	1,002.7	11.5
1955-56	1,163.7	9.4	1,135.9	13.3
1956-57	962.3	-17.3	1,036.1	-8.8
1957-58	1,110.7	15.4	1,064.5	2.7
1958-59	1,122.9	1.1	1,167.0	9.6
1959-60	1,171.6	4.3	1,143.2	-2.0
1960-61	1,242.0	6.0	1,122.3	7.0
1961-62	1,277.9	2.9	1,265.3	3.4
1962-63	1,317.8	3.1	1,293.8	2.3
1963-64	1,437.5	9.1	1,409.1	8.9
1964-65	1,575.0	9.6	1,565.3	11.1
1965-66	1,596.7	1.4	1,658.5	6.0
1966-67	1,660.2	4.0	1,650.4	-0.5
1967-68	1,622.0	-2.3	1,514.2	-8.3
1968-69	1,586.5	-2.2	1,660.8	9.7
1969-70	1,737.2	9.5	1,755.4	5.7
1970-71	1,698.1	-2.3	1,742.1	-0.8
1971-72	1,634.0	-3.8	1,613.3	-7.4

Table 27. DEHYDRATED ALFALFA MEAL: PRODUCTION, STOCKS, EXPORTS AND[20] DOMESTIC UTILIZATION U.S., BY MONTHS 1967-71

Year Beginning October and Item	October (000 tons)	November (000 tons)	December (000 tons)	January (000 tons)	February (000 tons)	March (000 tons)	April (000 tons)	May (000 tons)	June (000 tons)	July (000 tons)	August (000 tons)	September (000 tons)
1967-68												
Stocks	818.2	854.7	743.8	628.1	516.2	397.4	299.1	214.8	271.0	493.0	686.2	840.0
Production	145.4	17.8	10.0	15.7	13.8	27.5	38.5	178.7	337.2	346.8	304.7	201.3
Exports	15.3	13.1	13.6	13.4	16.3	11.8	15.2	16.7	26.2	15.6	17.0	26.5
Disappearance	93.6	115.6	112.1	114.2	116.3	114.0	107.6	105.8	89 0	138.0	133 9	125.2
1968-69												
Stocks	889.6	885.6	722.1	587.4	429.0	318.4	216.9	141.4	235.6	441.7	608.7	804.2
Production	111.7	16.9	11.7	7.0	13.4	22.7	34.6	221.5	349.0	353.8	352.7	226.6
Exports	19.5	10.6	11.5	19.1	33.3	11.3	24.4	32.4	18.0	22.5	18.9	19.5
Disappearance	96.2	169.8	134.9	146.3	90.7	112.9	85.7	94.9	124.9	164.3	138.3	169.8
1969-70												
Stocks	841.5	806.5	695.7	555.2	420.0	300.8	197.1	123.4	227.4	463.3	651.5	798.2
Production	118.5	20.3	15.1	9.3	12.0	20.4	37.9	210.2	366.1	366.6	316.0	187.5
Exports	22.8	7.5	13.8	15.5	23.1	21.0	17.3	32.1	22.7	30.5	30.6	49.6
Disappearance	130.7	123.6	141.8	129.0	108.1	103.1	94.3	74.1	107.5	147.9	138.7	112.8
1970-71												
Stocks	823.3	801.0	683.2	518.9	385.6	268.3	145.8	79.6	174.2	379.8	613.9	795.2
Production	131.9	26.1	11.5	12.2	12.3	23.5	34.6	202.8	369.4	359.5	313.1	188.6
Exports	35.8	29.0	12.3	18.9	38.9	26.8	17.3	17.7	22.7	7.3	3.0	11.5
Disappearance	118.4	114.9	163.5	126.6	90.7	119.2	83.5	90.5	141.1	118.1	128.8	147.4
1971-72												
Stocks	802.4	691.8	528.1	388.2	271.9	146.4	81.4	174.4	385.3	617.6	783.9	836.7
Production	102.0	21.8	7.7	7.0	12.3	23.5	34.6	203.7	373.9	361.1	307.1	193.1
Exports	24.4	21.9	49.8	-	-	-	-	-	-	-	-	-
Disappearance	136.3	132.4	171.4	147.4	127.1	146.0	100.5	110.7	163.0	128.8	140.8	140.3

Table 28. NORTHERN PLAINS ALFALFA MEAL PRODUCTION[21]
(000 tons)

State or Region	Years Beginning May 1						
	1960	1961	1962	1963	1964	1965	1966[a]
Nebraska	467.6	463.9	500.3	612.0	663.2	601.2	648.9
Kansas	148.8	160.1	195.4	149.0	163.5	199.6	167.2
Iowa	28.8	34.1	35.1	83.8[b] (Iowa, Minnesota, North and South Dakota, Wisconsin)	99.0[b] (Iowa, Minnesota, North and South Dakota, Wisconsin)	86.9[b] (Iowa, Minnesota, North and South Dakota, Wisconsin)	100.0 (Iowa, Minnesota, North and South Dakota, Wisconsin)
Minnesota	21.6	20.2	21.6				
North and South Dakota	*	*	*				
Wisconsin	*	*	*				
Northern Plains	666.8	678.3	752.4	844.8	925.7	887.7	916.1
All Other States	575.2	599.6	565.4	592.7	649.3	709.0	696.4
U.S. Total	1,242.0	1,277.9	1,317.8	1,437.5	1,575.0	1,596.7	1,612.6

* Included in "All Other States"
a/ Through March 31, 1967.
b/ Reports now issued for these states as an area rather than individually.

Table 29. QUANTITY AND VALUE OF PRODUCTS FROM[16/] ALFALFA DEHYDRATING PLANTS

Year	Quantity (000) short tons	Value ($000,000)
1963	1,726	71.2
1967	1,739	74.6

Those that have hired managers include the industry's large firms. These differ among themselves in that: (1) several have many owners while others have a few; (2) some are organized solely or mainly to dehydrate alfalfa, but others are part of a larger organization whose principal business is not dehydrating; and (3) two or three are multiplant firms, while others operate rather large-scale operations at one site.

Individual ownerships and partnerships among dehydrating organizations are usually small. They include plants operated for many years by original owners. The presence and persistence of these types of organizations demonstrate how easy it has been to enter the industry, even with limited capital, and the ability of small plants to compete.

Cooperatives have several operations of substantial size and a few relatively small ones. Two general types of cooperatives are: (1) those organized by growers as marketing outlets for their alfalfa; and (2) those added to feed mixing cooperatives--the larger group.

Characteristics of Plants

Before 1950, additional new plants were the reason for increased annual production in the industry. After 1950, the industry's annual production continued to increase, but with fewer plants. Construction of larger plants and existing plants operating at high capacity caused the larger output.

Increased plant capacity came about in several ways. Some plants added a drier or complementary equipment to existing facilities. Sometimes the addition was purchased new, but frequently it was obtained from a plant that had closed.

With the development of larger drying units to supplement or replace smaller ones, a number of new plants, including a cooperative, began operations with these high capacity units.

The improved production-capacity ratio in the dehydrating industry can be attributed to the experience operators have gained. Thus, they can use the facilities to better advantage. In addition, there has been a shift in the geographical concentration of operations to areas better suited to growing alfalfa for dehydrating.

Several plants produce more than 35,000 tons of dehydrated alfalfa annually. About two dozen, however, produce less than 1,000 tons a year. Average annual production for each plant during the 1966-67 season was 5,500 tons.

GRAIN MILLING

Introduction

The grain milling industry includes establishments engaged in milling flour or meal from grain. The Census of Manufacturers classifies wheat flour, durum, dry corn, rye, and oat milling in the standard industrial classification (SIC) 2041. Rice milling and corn wet milling are not included.

Grain milling has been transformed from a semi-agricultural and somewhat seasonal occupation into a complex industry. Current features of the grain milling industry are highlighted in the following sections.

Raw Materials and Products

Grain mills process grains into a spectrum of flour and meal products. Table 30 illustrates some of the main products from various grain milling operations while Table 31 presents data on the quantity and value of shipments in 1963 and 1967.[11/] Individual milling operations and their associated raw material product flow patterns are discussed in the next sections.

Wheat Milling - Flour mills draw wheat from wide regions, often from a quarter of the nation, and the destination of their products is even wider in scope. Table 32 presents a summary of commercial wheat milling production from 1965-71, while Table 33 illustrates commercial wheat milling production by geographic areas for the years 1970 and 1971. These data indicate that flour milling has become either a stable or declining industry.

Table 30. PRODUCTS OF GRAIN MILLING PLANTS

Milling Operation	Products
Wheat	Bran, Shorts, Clear Flour, Germ, Patent Flour, Millfeed
Durum	Semolina, Clear Flour, Millfeed
Corn	Germ, Cereal Grits, Brewers Grits, Corn Meal, Corn Cones, Corn Flour, Brewers Flakes, Corebinder, Hominy Feed
Oat	Flour, Quick Flakes, Regular Flakes
Rye	Flour, Meal, Millfeed

Table 31. QUANTITY AND VALUE OF SHIPMENTS FROM GRAIN MILLS IN 1963 AND 1967[11/]

Product	Unit of Measure	Total Shipments Including Interplant Transfers 1967 Quantity	1967 Value ($000,000)	1963 Quantity	1963 Value ($000,000)
FLOUR MILL AND BLENDED AND PREPARED FLOUR PRODUCTS, TOTAL		(X)	2,818.8	(X)	2,481.6
Flour and Other Grain Mill Products, Total		(X)	2,173.9[a/]	(X)	1,976.5[a/]
Wheat Flour, Except Flour Mixes	1,000 Sacks (cwt)	245,703	1,557.7	267,530	1,511.7
White:					
Shipped for export:					
Commercial Dollar Exports, All White Flour Types	1,000 Sacks (cwt)	18,337	108.7		
All Other Exports of White Flour Such as Those Under Public Law 480	1,000 Sacks (cwt)	6,100	35.4		
Domestic Shipments:					
Baker's and Institutional White Bread-Type Flour:					
Shipped in Bulk Cars or Trucks	1,000 Sacks (cwt)	76,608	451.7		
Shipped in Containers, Including Tote Bins	1,000 Sacks (cwt)	35,171	216.7		
Baker's and Institutional Soft Wheat Flour, Including Commercial Bakery, Restaurant, Hospital, Etc.:					
Shipped in Bulk Cars or Trucks	1,000 Sacks (cwt)	19,957	116.6		
Shipped in Containers, Including Tote Bins	1,000 Sacks (cwt)	9,874	58.9		
Family White Flour:					
All Family Flour Other Than Self-Rising, Such as Phosphated, Plain, Bromated, Enriched and All-Purpose, Including All-Purpose Purchased by the U.S. Government for Domestic Donation:				251,023	1,419.8
Shipped in Containers of Less Than 25 lb	1,000 Sacks (cwt)	19,752	169.1		
Shipped in Containers of 25 lb or more	1,000 Sacks (cwt)	7,594	60.1		
Self-Rising Flour:					
Shipped in Containers of Less Than 25 lb	1,000 Sacks (cwt)	3,928	33.3		
Shipped in Containers of 25 lb or More	1,000 Sacks (cwt)	2,504	20.3		
Flour Shipped to Blenders or Other Processors (for Further Processing and/or Packing Before Resale or Shipment):					
For Blending, Use in Mixes, Refrigerated Doughs, Etc.	1,000 Sacks (cwt)	16,410	99.6		
For Processing into Other Food Products Such as Soups, Etc.	1,000 Sacks (cwt)	537	3.0		
For Use in Nonfood Products (Pet Food, Industrial, Etc.)	1,000 Sacks (cwt)	953	4.2		

Table 31. (Concluded)

Product	Unit of Measure	1967 Quantity	1967 Value ($000,000)	1963 Quantity	1963 Value ($000,000)
		Total Shipments Including Interplant Transfers			
Other Than White:					
Whole Wheat	1,000 Sacks (cwt)	1,854	10.8	2,154	11.0
Durum Flour and Semolina	1,000 Sacks (cwt)	12,671	84.9	10,936	62.5
Bulgur	1,000 Sacks (cwt)	b/	b/	c/	c/
Other Wheat Flour, Including Farina	1,000 Sacks (cwt)	5,307b/	34.1b/	1,581	8.1
Wheat Flour, Except Flour Mixes, n.s.k.	1,000 Sacks (cwt)	8,146	50.3	1,836	10.3
Wheat Mill Products Other Than Flour	1,000 Short Tons	(X)	204.3	(X)	199.5
Wheat Mill Feed	1,000 Short Tons	4,242	201.3	4,823	199.5
Wheat Germ	1,000 Short Tons	46	3.0		
Corn Mill Products		(X)	261.8d/	(X)	193.0d/
Corn Products for Human Consumption:					
Whole Cornmeal	1,000 Sacks (cwt)	6,543	36.1	5,042	22.8
Degermed Cornmeal	1,000 Sacks (cwt)	9,867	49.9	7,529	33.8
Corn Grits and Hominy Except for Brewer's Use	1,000 Sacks (cwt)	7,454	40.0	12,807	48.0
Corn Grits and Flakes for Brewer's Use	1,000 Sacks (cwt)	13,028	53.1	10,813	38.5
Cornmeal for Animal Feed	1,000 Sacks (cwt)	5,700	16.0	4,281	11.8
Hominy Feed and Other By-Products of Dry Corn Milling (for Animal Feed)	1,000 Short Tons	948	42.2	698	31.4
Other Corn Mill Products (Corn Flour, Etc.)	1,000 Sacks (cwt)	4,003	23.6	c/	c/
Corn Mill Products, n.s.k.	1,000 Sacks (cwt)	(X)	0.9	1,652	6.7
Other Grain Mill Products, n.e.c		(X)	43.4d/	(X)	46.0d/
Rye Flour	1,000 Sacks (cwt)	2,403	9.5	2,055	8.1
Other Flour (Excluding Wheat, Corn, Rye)	1,000 Sacks (cwt)	3,577	17.5	c/	c/
Other Mill Feed (Oats, Rye, Buckwheat, Etc.)	1,000 Short Tons	189	3.9	c/	c/
Other Grain Mill Products, n.s.k.		(X)	12.5	(X)	37.9e/
Flour and Meal, n.s.k. (for Companies with 10 or More Employees. See Note.)		(X)	86.4	(X)	26.3
Flour and Meal, n.s.k. (for Companies with Less Than 10 Employees. See Note.)		(X)	20.3		

Standard Notes: -Represents zero. (X) Not applicable. (NA) Not available. (D) Withheld to avoid disclosing figures for individual companies.

a/ The product classes 20411 and 20455 were revised to include all phosphated and self-rising flour in 20411. For 1963, 292,000 sacks values at $2.8 million of phosphated flour and 1,650,000 sacks valued at $18.0 million of self-rising flour were shifted from 20455 to 20411.

b/ Data for product code 20411 61 are included with product code 20411 98 to avoid disclosing figures for individual companies.

c/ Separate data for this product description were not requested prior to 1967.

d/ The product classes 20413 and 20416 were revised to include all dry corn mill products in 20413. The following products were transferred from 20416 for 1963: 12,807,000 sacks (cwt) valued at $48.0 million of corn grits and hominy except for brewer's use, 10,813,000 sacks (cwt) valued at $38.5 million of corn grits and flakes for brewer's use, and 698,000 short tons valued at $31.4 million of hominy feed and other dry corn milling by-products.

e/ Includes 182,000 short tons values at $8.5 million of oat millfeed and other oat by-products which was collected separately in 1963.

Table 32. SUMMARY: COMMERCIAL WHEAT MILLING PRODUCTION: 1965 TO 1971[22/]

Year	Wheat Flour Production (1,000 cwt Sacks)	Wheat Ground for Flour (000 bu)	Mill Feed Production (000 tons)	Average Lb Per Cwt Sacks of Flour		Flour Extraction Rate (%)
				Wheat	Mill Feed	
1965	250,384	564,724	4,645	135.3	37.1	73.9
1966	253,000	568,672	4,619	134.8	36.5	74.1
1967	245,240	549,801	4,423	134.5	36.1	74.3
1968	254,185	569,649	4,511	134.5	35.5	74.4
1969	254,094	567,956	4,458	134.1	35.1	74.6
1970	253,094	563,714	4,409	133.6	34.8	74.8
1971	249,810	555,092	4,279	133.3	34.3	75.0

Table 33. COMMERCIAL WHEAT MILLING PRODUCTION, BY GEOGRAPHIC AREAS: 1971 AND 1970[22/]

Geographic Areas	1971: Wheat Ground for Flour (000 bu)	1971 Wheat Flour Production: Total (1,000 cwt Sacks)	1971 Wheat Flour Production: Daily (24 hr) Capacity (cwt Sacks) a/	1971 Wheat Flour Production: Percent of Estimated Annual Capacity b/	1970: Wheat Ground for Flour (000 bu)	1970 Wheat Flour Production: Total (1,000 cwt Sacks)	1970 Wheat Flour Production: Daily (24 hr) Capacity (cwt Sacks) a/	1970 Wheat Flour Production: Percent of Estimated Annual Capacity b/
United States, Total	555,092	249,810	972,736	99.9	563,714	253,094	987,962	99.7
Middle Atlantic Division	69,976	31,891	109,400	113.4	70,730	32,289	118,232	106.3
New York	60,080	27,624	91,377	117.6	60,738	28,075	99,859	109.4
North Central Region	324,363	146,139	549,529	103.5	329,814	148,163	557,884	103.3
Ohio	29,917	13,057	56,645	89.7	29,832	13,101	56,145	90.8
Indiana	15,270	6,632	25,624	100.7	15,377	6,556	25,888	98.5
Illinois	31,737	14,000	49,774	109.4	30,537	13,413	63,658	82.0
Michigan	16,003	7,120	34,029	81.4	16,506	7,275	34,656	81.7
Minnesota	64,041	29,526	106,851	107.5	60,195	27,810	97,911	110.5
Iowa	12,251	5,489	20,951	101.9	12,777	5,769	20,801	107.9
Missouri	51,164	23,385	81,900	111.1	52,095	23,765	78,926	117.2
Nebraska	18,833	8,166	32,023	99.2	18,723	8,076	32,023	98.1
Kansas	76,174	34,815	123,019	110.1	81,533	36,938	129,741	110.8
South Atlantic Division	25,407	11,094	49,800	86.7	19,876	8,820	44,689	76.8
East South Central Division	25,615	11,142	52,409	82.7	26,504	11,544	50,290	89.3
Tennessee	19,080	8,337	32,133	101.0	20,065	8,781	30,314	112.7
West South Central Division	30,434	13,488	59,217	88.6	33,944	15,023	66,032	88.5
Oklahoma	8,247	3,761	16,633	88.0	9,502	4,342	16,633	101.6
Texas	22,187	9,727	42,584	88.9	24,442	10,681	49,399	84.1
Mountain Division	29,118	13,138	64,619	79.1	29,602	13,226	60,764	84.7
Montana	6,691	3,140	12,810	95.4	6,469	2,986	12,855	90.4
Utah	(D)	(D)	29,022	(D)	(D)	(D)	25,122	(D)
Pacific Division	50,179	22,918	87,762	101.6	53,244	24,029	90,071	103.8
Washington	15,767	7,227	30,085	93.5	17,232	7,808	29,985	101.3
Oregon	11,169	5,056	23,025	85.4	12,733	5,695	23,525	94.2
California c/	23,243	10,635	32,552	127.1	23,279	10,526	36,561	112.0

(D) Withheld to avoid disclosing figures for individual companies.
a/ Capacity as reported for December of each year; b/ Estimated annual capacity is obtained by multiplying daily capacity by the number of work days during the year, 255 for 1969, 257 for 1970 and 1971. This figure is calculated on the basis of a 5-day week with allowances for the following holidays unless such holidays fall on Saturday: January 1, May 30, July 4, Labor Day, Thanksgiving Day, and December 25; c/ Data include Hawaii.

Durum Milling - Durum wheat has been grown in the United States since 1900, but it has never accounted for more than 10% of the total wheat acreage.[23] Over four-fifths of the durum crop in the United States has been produced in North Dakota over the past 8-year period (Table 34) with lesser quantities being produced in South Dakota, Minnesota, Montana, and California. Table 35 presents data on durum wheat products for the years 1970 and 1971.

Rye Milling - Rye grain can be grown in any area where wheat is grown. The average yearly production for rye in the U.S. is about 30 x 10^6 bu. The main producing area is the Great Plains as shown by the data in Table 36.

Table 37 summarizes commercial rye milling production for the years 1970 and 1971.

Dry Corn Milling - Both white and yellow corn are milled. The products produced are essentially the same and there is usually little difference chemically or in taste. The high-crop yielding yellow corn hybrids have resulted in yellow corn being usually the lower priced raw material, and this has dictated that millers turn to yellow corn as progress was made in corn breeding. Today only a limited quantity of white corn is grown and the millers that need it for special customers that still desire the white, rice-like, grits probably pay a premium.

Table 38 summarizes data on the supply and use of corn in dry milling operations during the 1964-71 period.

Oat Milling - The processing of oats for hot cereals and industrial uses accounts for only a small portion of the total bushels harvested each year. About 90% of the crop remains on the farm and is fed to poultry and other farm animals. Table 39 summarizes data on the supply and use of oats in processing operations for the 1964-71 period.[20]

Industry Structure

As noted in the Introduction of this section, the U.S. Department of Commerce combines wheat flour, durum, dry corn, rye, and oats milling in the (SIC) Code 2041. As a result, it is not possible to break out some of the data reported in the Census of Manufacturers and discuss individual segments of the grain milling industry. Other information sources provide more details on each segment. Information on the milling industry as a whole is summarized in this section, and each segment will be discussed in more detail in subsequent sections.

Table 34. UNITED STATES DURUM PRODUCTION BY STATES, 1961-69[23/]
(000 bu)

State	1969	1968	1967	1966	1965	1964	1963	1962	1961
	Year								
Minnesota	2,552 (2.4)[a/]	3,128 (3.2)	2,205 (3.3)	1,512 (2.4)	2,883 (4.1)	2,156 (3.3)	1,450 (2.8)	1,683 (2.3)	616 (3.0)
North Dakota	91,773 (86.3)	83,420 (83.4)	54,888 (82.6)	55,120 (87.1)	61,411 (87.9)	56,985 (86.8)	43,752 (85.4)	59,582 (83.0)	16,800 (79.3)
South Dakota	4,914 (4.6)	4,833 (5.0)	4,424 (6.6)	2,556 (4.0)	2,266 (3.2)	1,680 (2.6)	1,526 (3.0)	2,880 (4.0)	1,829 (8.6)
Montana	6,900 (6.5)	7,665 (7.8)	4,560 (6.9)	3,760 (6.0)	3,021 (4.3)	4,512 (6.7)	3,848 (7.5)	6,960 (9.7)	1,428 (6.7)
California	180 (0.2)	455 (0.6)	366 (0.6)	300 (0.5)	285 (0.5)	385 (0.6)	671 (1.3)	704 (1.0)	512 (2.4)
Total Production	106,319 (100.0)	99,501 (100.0)	66,443 (100.0)	63,248 (100.0)	65,886 (100.0)	65,718 (100.0)	51,247 (100.0)	71,809 (100.0)	21,185 (100.0)

a/ The values in parentheses represent the state's percentage of the total production for that particular year.

Table 35. DURUM WHEAT PRODUCTS: 1971 AND 1970[22]

Item	1971 Jan. 1-June 30	1971 July 1-Dec. 31	1970 Jan. 1-June 30	1970 July 1-Dec. 31
Durum wheat ground (thousand bushels)	15,821	16,415	16,178	15,876
Straight semonlina and durum flour produced (thousand sacks (cwt.))	7,347	7,904	7,501	7,312
Blended semolina and durum flour produced (thousand sacks (cwt.))	(D)[a]	(D)	(D)	(D)

a/ Withheld to avoid disclosing figures for individual companies.

Table 36. YEARLY AVERAGE BUSHEL PRODUCTION OF RYE BY STATES[24]

Minnesota	2,142,000 bu
North Dakota	5,355,000 bu
South Dakota	7,666,000 bu
Montana	471,000 bu
Kansas	1,121,000 bu
Nebraska	2,730,000 bu
Total of six states	19,485,000 bu

Table 37. COMMERCIAL RYE MILLING PRODUCTION, BY MONTHS: 1971 AND 1970[22/]

Year	Rye Flour Production (1,000 cwt sacks)	Rye Ground for Flour (000 bu)	Mill Feed Production (tons)	Average Pounds Per cwt Sack of Flour		Flour Extraction Rate (%)
				Rye	Mill Feed	
1971	2,367	5,281	30,361	124.9	25.7	80.0
1970	2,406	5,467	31,350	127.3	26.0	78.6

Table 38. CORN: SUPPLY AND DISTRIBUTION, UNITED STATES, 1964-71[20/]
(10^6 bushels)

Year Beginning October	Supply: Carry-over Oct. 1	Supply: Production	Supply: Imports[a/]	Supply: Total Supply	Distribution: Processed into Food and Industrial Products: Breakfast Foods	Distribution: Processed into Food and Industrial Products: Cornmeal and Grits[b/]	Distribution: Processed into Food and Industrial Products: Alcohol and Distilled Spirits
1964	1,537	3,484	1	5,022	19	110	28
1965	1,147	4,084	1	5,232	20	111	30
1966	840	4,117	1	4,958	21	117	33
1967	823	4,760	1	5,584	21	117	34
1968	1,162	4,393	1	5,556	22	114	33
1969	1,113	4,583	1	5,697	22	116	31
1970[c/]	999	4,099	4	5,102	22	119	24
1971[c/]	663	5,540	1	6,204			

a/ Grain and grain equivalent of corn products. Compiled from reports of the Bureau of Census.
b/ Estimated quantities used in producing cornmeal (including farm household use), flour, hominy grits and flakes; includes use for food and fermented malt liquors. Based on reports of the Bureau of Census and the Internal Revenue Service.
c/ Preliminary.

Table 39. OATS: SUPPLY AND DISTRIBUTION, UNITED STATES, 1964-71[20/]

Year Beginning July	Supply: Carryover July 1 (000,000 bu)	Supply: Production (000,000 bu)	Supply: Imports[a/] (000,000 bu)	Total Supply (000,000 bu)	Breakfast Foods[b/]: Domestic Use (000,000 bu)	Breakfast Foods[b/]: Exports (000,000 bu)	Breakfast Foods[b/]: Total (000,000 bu)
1964	312	852	4	1,168	45	1	46
1965	277	927	3	1,207	45	1	46
1966	316	801	4	1,121	43	3	46
1967	270	789	3	1,062	44	4	48
1968	273	939	2	1,214	45	4	49
1969	375	950	2	1,327	45	4	49
1970[c/]	490	909	2	1,401	46	3	49
1971[c/]	512	876	2	1,390			

a/ Includes grain and grain equivlent of oat products. Compiled from reports of the Bureau of the Census.
b/ Used in production of oatmeal and other cereal preparations. Based on the reports of the Bureau of the Census.
c/ Preliminary.

General statistics of flour and other grain milling plants for recent years are presented in Table 40. The percent of value of shipments accounted for by the largest companies in (SIC) Code 2041 are shown in Table 41.

Wheat Milling - Flour milling in the United States is carried on by numerous companies. Commercial flour mills are located in many states and Buffalo, New York, is the nation's largest milling center. Buffalo is, in fact, the world's largest. Table 42 shows the distribution of flour mills by state for the year 1973.

Milling consolidations have resulted in several companies attaining multiple plant operating status. The largest wheat flour milling companies in 1973 are shown in Table 43, while Table 44 presents the top 12 milling companies for the same year. Table 44 includes durum and rye products as well as wheat flour. In 1973, as shown in Table 45, 24 mills with capacity in excess of 10,000 cwt/day produced about 36% of the flour in the U.S. In the same year mills with 5,000 cwt/day or greater capacity produced about 75% of the U.S. flour.

Reference 26 indicates that the flour production of mills of less than 400 cwt/day capacity is minimal and of small commercial consequence. A recent triennial survey conducted by the Millers' National Federation indicated that there were 189 mills in the U.S. in 1972, with daily capacity of 400 cwt or more. This is a decrease of 11 mills from the 1969 total and reflects a continuation of a downward trend that has been under way since the 1930's. Table 46 presents numbers of mills, total daily capacity, net change in total and in percentage for 3-year periods in several federation surveys.[26]

Durum Milling - In 1945, the center for durum milling was concentrated in the Upper Midwest near the resource. Since 1945, the industry has become more market oriented in that most new mill capacity has been built closer to their markets. The Upper Midwest is still considered the center of durum milling and maintains 68% of the milling capacity in the United States.

The number of durum mills has remained relatively stable over the past 25 years (Table 47). While the number of durum milling plants remained stable since 1945, the size (capacity) of the mills has changed. Since 1945, the small mills (0-2,000 cwt/day) declined from 27% of the total mills to 8% in 1969 (Table 47). The number of large durum mills (8,000-10,000 cwt/day), which were nonexistent in 1945, comprised 16% of total mill numbers in 1971. Table 48 illustrates the geographical distribution of durum mills in 1971.

Table 40. GENERAL STATISTICS FOR GRAIN MILLING PLANTS[16/]
(1965-70)

Year	All Employees Number (000)	All Employees Payroll ($000,000)	Production Workers Number (000)	Production Workers Man-Hours (000,000)	Production Workers Wages ($000,000)	Value Added ($000,000)	Cost of Materials ($000,000)	Value of Shipments ($000,000)
1965	20.7	133.2	15.1	34.2	90.7	405.8	1,739.4	2,145.5
1966	20.1	133.8	14.7	33.3	90.6	433.9	1,914.9	2,344.9
1967	20.5	142.9	14.8	33.2	95.5	491.3	1,966.0	2,457.4
1968	19.8	147.3	14.4	32.4	98.7	498.6	1,886.0	2,383.4
1969	20.0	155.9	14.5	32.4	105.4	497.3	1,884.3	2,387.0
1970	19.9	160.4	14.2	30.8	108.8	523.9	1,885.2	2,410.1
% Change 1969-70	- 0.5	2.9	- 2.1	- 4.9	3.2	5.3	0.0	1.0
Avg. Rate 1958-70	- 2.9	1.1	- 3.0	- 2.9	1.0	2.4	0.9	1.2

Table 41. PERCENT OF VALUE OF SHIPMENTS ACCOUNTED FOR BY THE LARGEST[16/] COMPANIES IN GRAIN MILLING

Industry and Year		Companies (number)	Value of Industry Shipments[b/] Total ($000,000)	Percent accounted for by[c/] 4 Largest Companies	8 Largest Companies	20 Largest Companies	50 Largest Companies
Flour and Other Grain Mill Products	1970	(NA)	2,410.1	30	46	(NA)	(NA)
	1967	438	2,457.4	30	46	70	89
	1966	(NA)	2,344.9	31	47	(NA)	(NA)
	1963	510	2,176.5	35	50	71	88

(NA) Not available.
(X) Not applicable.

a/ The determination of company affiliation of establishments is based on census reports and publicly available records. Value of shipment totals for establishments have been summarized into company totals in each manufacturing industry. "Largest" companies are determined by each company's value of shipments in the specified industry.

b/ Value of shipments figures are not completely comparable between the years 1963-67 and prior years. They include for all establishments classified in the industry: (a) value of products primary to the industry; (b) value of all secondary products which are primary to other industries; (c) value of miscellaneous receipts such as receipts for contract and commission work on materials owned by others, scrap, salable refuse, repairs, etc.; and (d) value of resales--i.e., products resold in same condition as bought. In 1958 and prior years value of resales was excluded from value of shipments.

c/ The percentages consist of the sum of the value of shipments of the largest four companies (or 8, 20, or 50 companies), divided by the total value of shipments of the industry.

Table 42. WHEAT FLOUR MILLING BY STATES (1973)[25/]

State	Mills	Capacities in Cwt Active	Inactive
Alabama	1	7,300	
Arizona	1	1,000	
California	9	38,600	
Colorado	3	15,200	
Delaware	2	472	
District of Columbia	1	2,000	
Florida	2	9,500	
Georgia	6	5,950	
Hawaii	1	2,200	
Idaho	1	720	
Illinois	7	53,360	
Indiana	8	23,440	
Iowa	3	18,100	
Kansas	21	115,250	6,300
Kentucky	9	4,065	
Maryland	1	400	
Michigan	9	20,600	
Minnesota	11	75,260	
Missouri	8	79,240	
Montana	3	12,000	
Nebraska	7	33,170	
New Jersey	1	4,600	
New Mexico	2	700	
New York	13	86,600	4,000
North Carolina	17	19,730	60
North Dakota	1	5,000	
Ohio	15	68,525	
Oklahoma	4	22,200	
Oregon	4	23,000	
Pennsylvania	37	33,881	
Puerto Rico	1	6,000	
South Carolina	7	3,800	
South Dakota	1	3,000	
Tennessee	18	33,860	
Texas	9	27,040	2,100
Utah	12	27,720	
Virginia	19	17,874	750
Washington	4	27,750	
TOTALS	279	929,107	13,210

Table 43. LARGEST WHEAT FLOUR MILLING COMPANIES[25]
(With Active Daily Capacity of 10,000 Cwt or More)

Company	Mills	Capacity in Cwt
The Pillsbury Company	8	94,700
ConAgra, Inc.	17	88,300
ADM Milling Company	8	67,500
Seaboard Allied Milling Corporation	8	62,250
International Multifoods Corporation	7	57,700
General Mills, Inc.	8	55,100
Peavey Company	4	40,100
Nabisco, Inc.	3	40,000
Dixie-Portland Flour Mills	3	33,000
Ross Industries, Inc.	4	33,000
Bay State Milling Company	5	29,650
The Colorado Milling and Elevator Company	4	29,200
Centennial Mills	3	19,000
Cereal Food Processors, Inc.	2	17,000
Fisher Mills, Inc.	1	15,000
The Mennel Milling Company	5	15,000
Standard Milling Company	2	14,500
Sunshine Biscuits	3	12,150
TOTALS	95	723,150

Table 44. LARGEST WHEAT, RYE AND DURUM MILLING COMPANIES[25/]
(With Active Daily Capacity of 10,000 Cwt or More)

Company	Mills	Capacity in Cwt
The Pillsbury Company	8	94,700 W
ConAgra, Inc.	17	88,300 W
ADM Milling Company	10	79,500 WD
International Multifoods Corporation	11	74,200 WDR
Peavey Company	5	60,600 WDR
Seaboard Allied Milling Corporation	8	63,250 WR
General Mills, Inc.	8	55,100 W
Nabisco, Inc.	3	40,000 W
Dixie-Portland Flour Mills	3	33,000 W
Ross Industries, Inc.	4	33,000 W
Bay State Milling Company	5	31,850 WR
Colorado Milling and Elevator Company	4	29,200 W
TOTALS	86	682,700

W - Wheat Flour.
D - Durum Products.
R - Rye Flour.

Table 45. RELATIVE SIZE OF ACTIVE AND INACTIVE[25/]
WHEAT FLOUR MILLS (1973)

Cwt/Day	Number of Mills	Total Capacity Active	Total Capacity Inactive
Under 200	54	5,845	60
200-399	35	9,469	250
400-999	36	20,093	500
1,000-4,999	78	197,750	12,400
5,000-9,999	52	361,850	-
10,000 and over	24	334,100	-
TOTALS	279	929,107	13,210

Table 46. CHANGES IN WHEAT FLOUR MILLS AND MILLING CAPACITY
1951 - 72[26/]

	No. of Mills	Total Capacity (Cwt/Day)	Net Change	Percent Change
1969-72	189	952,135	+25,055	+2.7%
1966-69	200	927,080	-24,720	-2.6%
1963-66	217	951,800	- 3,600	-0.3%
1960-63	226	955,400	+11,885	+1.2%
1957-60	245	943,515	+10,680	+1.1%
1954-57	256	932,835	+16,100	+1.8%
1951-54	278	916,735	-96,370	-9.5%

Table 47. THE PERCENTAGE DISTRIBUTION OF DURUM MILLS BY CAPACITY[23/] OF PLANTS, UNITED STATES, 1945, 1951, 1961, 1965, 1969, 1971

Mill Size (Capacities in Cwt.)	1945		1951		1961		1965		1969		1971	
	Number of Mills	Percent of Mills	Number of Mills	Percent of Mills	Number of Mills	Percent of Mills	Number of Mills	Percent of Mills	Number of Mills	Percent of Mills	Number of Mills	Percent of Mills
1-2,000	3	27.3	5	38.4	3	27.3	3	27.3	1	8.3	-	-
2,001-4,000	5	45.4	4	30.8	4	36.3	4	36.3	6	50.0	6	46.2
4,001-6,000	2	18.2	3	23.1	3	27.3	2	18.2	3	25.0	5	38.4
6,001-8,000	1	9.1	1	7.7	-	-	1	9.1	-	-	-	-
8,001-10,000	-	-	-	-	1	9.1	1	9.1	2	16.7	2	15.4
TOTAL	11	100.0	13	100.0	11	100.0	11	100.0	12	100.0	13	100.0

Table 48. DURUM MILLING BY STATES

State	Number	Capacity in Cwt
California	1	3,000
Louisiana[a]	1	1,000
Minnesota	5	29,400
New York	2	10,600
North Dakota	1	5,000
Oregon	1	5,000[b]
Pennsylvania[a]	1	5,000
Wisconsin	1	9,000
Totals	13	68,000

a/ Under construction.
b/ Alternates with wheat flour.

The durum milling industry is composed of a small number of companies (Table 49), with the number of companies remaining quite stable over the past 25 years. When evaluated by proportion of total industry capacity operated by the largest firms, the durum milling industry may be considered a highly concentrated industry. Since 1945, the two largest firms have held from 36% of the industry capacity to a high of 54% in 1969. The trend since 1950 has been toward increased concentration of production and market share in the larger firms.

Dry Corn Milling - The number of dry corn mills has decreased in recent years, but the capacity has increased. In 1965, only 152 mills with daily capacities of 50 cwt or more were operating or in standby condition in the U.S. By 1969, the total of both degerming and nondegerming mills had decreased to 115. The listed capacities ranged from 25 to 20,000 cwt/day of meal production.

Reference 33 indicates that 122 mills were in operation in the continental U.S. in 1971, and Table 50 illustrates the geographical distribution of these plants.

The quantity of corn dry milled into grits, meal, and flour and for use in breakfast foods followed a cyclical pattern between 1926 and 1955. Because more grits and meal were used for human consumption and in manufacture of malt beverages, the quantity climbed appreciably between 1955 and 1965 as shown in Table 51. Based on data from the 1967 U.S. Census of Manufacturers, and conversion factors used by U.S. Department of Agriculture, about 80% of the corn dry milled that year for corn meal, flour, grits, and breakfast foods was degermed.

Table 49. NUMBER, CAPACITY, AND CONCENTRATION RATIOS OF THE DURUM MILLING INDUSTRY IN THE UNITED STATES, 1945, 1951, 1961, 1965, 1969[23/]

Year	Number of Companies	Capacity (cwt/day)	Percent of Total Daily Industry Capacity and Amount in Cwt Produced by: 2 Largest Companies	4 Largest Companies	6 Largest Companies
1945	10	35,340	14,500 41%	22,300 63%	28,240 80%
1951	11	39,825	14,500 36%	24,800 62%	30,800 77%
1961	9	36,536	18,100 49%	26,450 72%	32,450 89%
1965	10	41,290	18,200 44%	29,200 71%	35,900 87%
1969	8	51,678	27,800 54%	40,800 80%	48,128 93%

Table 50. GEOGRAPHICAL DISTRIBUTION OF DRY CORN MILLS[33/] IN CONTINENTAL UNITED STATES (1971)

State	Number of Mills
Alabama	3
California	2
Delaware	2
Florida	2
Georgia	5
Illinois	4
Indiana	4
Iowa	1
Kansas	2
Kentucky	13
Mississippi	3
Missouri	3
Nebraska	3
North Carolina	23
New York	1
Ohio	3
Oklahoma	1
Pennsylvania	4
South Carolina	4
Tennessee	18
Texas	6
Virginia	12
West Virginia	1
Wisconsin	2

Table 51. CORN USAGE PATTERN IN DRY CORN MILLS[16/]

Year	Million Bushels/Year
1926-30	94
1931-35	87
1936-40	86
1941-45	98
1946-50	92
1951-55	88
1956-60	106
1961-65	126
1966	133
1967	132
1968	131

Rye Milling - In 1973 there were 13 rye mills operating in the United States with a capacity, based on 24-hr production, of 10,999 cwt/day. Table 52 shows the geographical distribution of these mills.

Characteristics and Trends in Grain Milling

One of the major technological innovations in wheat milling in recent years was the development and adoption of fine grinding and air classification milling. This enables the mills to obtain closer tolerance in protein levels, particle size, and ash content of the flour. The fine grinding and air classification equipment, coupled with running analyses on protein, moisture, and ash content every few hours, enables larger plants to maintain strict control of the quality of their products.

Pneumatic mills are gradually replacing the conventional bucket elevator mill. Table 53 illustrates this transition for hard wheat flour milling plants.

Table 52. RYE FLOUR MILLING BY STATES (1973)[25]

State	Number	Capacity in Cwt
California	1	75
Illinois	1	144
Minnesota	3	6,200
New York	3	2,260
Ohio	2	1,900
Texas	1	30
Washington	1	150
Wisconsin	1	240[a]
TOTALS	13	10,999

a/ Inactive.

Table 53.[27/] TYPES OF MILLING UNITS IN OPERATION, BY TIME OF INSTALLATION, BY REGION[a/]

Region	1960 to 1965			1946 to 1959			Prior to 1946		
	Pneumatic	Conventional	Air Classification	Pneumatic	Conventional	Air Classification	Pneumatic	Conventional	Air Classification
North Central	14	0	2	3	3	1	0	26	0
Mountain	1	0	1	1	1	0	0	8	0
Pacific	3	0	0	3	0	0	0	8	0
South Central	2	0	1	0	1	0	0	13	0
Middle Atlantic	4	0	0	0	0	0	0	4	0
South Atlantic	1	0	0	0	0	0	0	3	0
Survey Total	25	0	4	7	5	1	0	62	0

a/ Based on responses by 97 hard wheat flour milling establishments. Some establishments reported more than one type of mill.

Wheat flour mills are often involved in a number of functions in addition to the milling of flour. Other operations that might be conducted at a wheat flour mill complex include corn milling, rye milling, oat milling, blending, and mixing. Table 54 summarizes data on functions other than milling wheat flour performed at plants during the 1964-65 marketing year.

The grain milling industry as a whole seems to be following a pattern of a decrease in number of mills with modest increases in capacity. The industry appears to be either a stable or declining industry. With the exception of two or three firms, there has not been much dramatic growth in individual firms. The growth of the exceptions was mainly by acquisition. In addition, some of the leading firms have had substantial declines in their value as a part of corporate strategy.

Most grain millers, because of the nature of their business, are automatically in the grain business. Similarly, the by-product of milling operations (mill feeds) puts them into the feed business.

COMMERCIAL RICE DRYING

Introduction

The rough rice drying and storage section of the rice industry is extremely important to rice producers, and a significant share of the marketing bill is spent for this service. An indication of the importance to rice growers and others of efficient, low-cost drying and storage of rough rice is reflected in the amount expended for these services. Of the $200 million received in 1966 for rough rice by growers in Louisiana and Texas, for example, an estimated $12 million or 6% of the value, was spent for artificial drying. The cost of storage, though not generally borne as directly by growers, probably amounted to another $5 million.[28/] The structure of the commercial rice drying industry is summarized in the following section.

Industry Structure

More than 400 firms were in operation with drying and storage facilities for rough rice in the continental U.S. in 1967.[29/] In Reference 29, both commercial and on-farm dryers were included. Commercial dryers are facilities available to the general public for the receiving, drying and storing of rough rice. On-farm dryers are privately owned facilities used primarily for drying and storing rice at points of production, and were not considered in this study. A complete survey of rice drying establishments has not been conducted since 1967, and the exact number of plants in operation in 1973 is not known. Reference 29 indicates that in 1967, Arkansas had over 125 firms

Table 54. FUNCTIONS OTHER THAN MILLING WHEAT FLOUR PERFORMED AT PLANT[27]
1964-65 MARKETING YEAR

Region	Total Number of Mills Reporting	Other Functions Performed[a]					
		Feed Milling	Corn Milling	Rye Milling	Blending[b]	Mixing[c]	Other
		Number of Plants Performing Functions					
North Central	47	10	1	2	10	10	7
Mountain	12	2	0	1	2	4	3
Pacific	13	3	1	3	1	4	4
South Central	15	4	6	0	3	3	2
Middle Atlantic	7	2	0	3	1	0	0
South Atlantic	4	2	3	0	2	1	1
Total	98	23	11	9	19	22	17
		Percent					
Proportion of Plants Performing Other Functions		23	11	9	19	22	17

a/ The number of functions other than milling wheat flour may be less than or exceed the number of mills reporting.
b/ Blending of purchased flour.
c/ Mixing department where ingredients other than flour are used.

engaged in drying and storing rice. The storage capacity for rough rice handled by these organizations ranged from about 19,000 cwt to over 1 million cwt. Cooperatives handled over 60% of the total drying and storing of rough rice in Arkansas. About 20 organizations supplied the off-farm drying and storage facilities for rice in California with the majority of them equipped to handle volume production. Storage capacity of these firms ranged from 47,500 cwt to over 3.3 million cwt of rice. Cooperative associations dried one-fourth of the total rice produced in California. In Louisiana and Texas, about 220 firms dried and stored rough rice. The number of firms was about equally divided between the two states with storage capacities ranging from about 16,000 to over 560,000 cwt of rough rice. Over 40% of the rice produced in these states was dried and stored by cooperative associations.

Reference 30 reports the results of a study by the Department of Agriculture to determine the costs of commercial drying, storing, and handling of rough rice for the 1965-66 period. The USDA identitied 279 commercial rice dryers in this study. Capacities ranged from less than 15,000 to over 3 million cwt. Most of the firms, however, had capacities of less than 250,000 cwt.

Characteristics of Plants

The study conducted by the USDA also acquired data on the operating characteristics of commercial rice dryers by sampling selected plants. A stratified, random sampling technique was utilized by USDA investigators to obtain data on the operational characteristics of the commerical rice drying units. Tables 55 to 59 summarize some of the results of the sampling.

Table 55 presents data on the number and total capacity of commercial rice dryers. Table 56 summarizes information on total plant capacity and utilization for rice handling and storing by regions. Other services such as handling of rice planting seed, other grains, seeds, fertilizers, and farm supplies were also provided by some commercial rice dryer operators. In Arkansas-Mississippi, joint use is generally made of rice drying and storing facilities with other grains, such as soybeans--a practice not observed to any extent in the other two regions. To provide for intraregional comparisons of average occupancy and capacity utilization rates, the total plant capacity data for Arkansas-Mississippi were reduced to the portion actually used for rice handling and storing during the 1965-66 season. As a result, there were 9,382,000 cwt less than the capacity used in sampling (Table 56). In Texas-Louisiana and California, similar adjustments were unnecessary.

Table 55. NUMBER AND TOTAL PLANT CAPACITY OF RICE DRYERS IN[30] UNIVERSE AND SAMPLE, BY REGION AND QUARTILE GROUPINGS, 1965-66[a]

Region and Quartile Grouping	Universe[b] Population No.	Universe[b] Capacity (000 cwt)	Sample Population No.	Sample Capacity (000 cwt)
Combined regions				
1	173	17,991	9	1,225
2	62	18,179	8	2,384
3	33	18,446	8	3,719
4	11	17,571	7	9,853
Total	279	72,187	32	17,181
Arkansas-Mississippi				
1	38	3,631	2	248
2	20	5,748	3	780
3	10	5,568	2	1,188
4	7	12,857	5	8,071
Total	75	27,804	12	10,287
Texas-Louisiana				
1	112	11,492	5	720
2	31	9,017	3	915
3	17	9,372	4	1,338
4	--	--	--	--
Total	160	29,881	12	2,973
California				
1	23	2,868	2	257
2	11	3,414	2	689
3	6	3,506	2	1,193
4	4	4,714	2	1,782
Total	44	14,502	8	3,921

a/ Includes both drying and storing facilities.
b/ All commercial dryers in Arkansas, Mississippi, Louisiana, Texas, and California.

Table 56. ESTIMATED TOTAL PLANT CAPACITY AND UTILIZATION[30/] FOR RICE HANDLING AND STORING BY REGIONS, 1965-66[a/]
(000 cwt)

Plant Capacity	Arkansas-Mississippi	Texas-Louisiana	California	Regions Combined
Total	27,804	29,881	14,502	72,187
Utilized for rice	18,422	29,881	14,502	62,805

a/ Sample dryers in each region statistically expanded to represent universe total.

Table 57. ESTIMATED VOLUMES OF ROUGH RICE HANDLED, AT COMMERCIAL RICE DRYERS, BY REGIONS,[30/] 1965-66[a/]
(000 cwt)

	Volume handled in--[b/]			
Handling Activity	Arkansas-Mississippi	Texas-Louisiana	California	Regions Combined
Received[c/]	20,512	39,534	16,023	76,069
Dried	20,000	36,236	14,024	70,260
Highest monthly inventory[d/]	13,410	21,236	10,617	45,263
Average occupancy[e/]	5,023	9,041	5,766	19,830
Loaded out[f/]	14,700	31,605	12,103	58,408

a/ Sample data statistically expanded to represent regional totals.
b/ All volumes adjusted to dry weight basis.
c/ Sample volumes expended to regional production totals.
d/ Maximum volume of rice in storage at end of peak month of year.
e/ Average volume of rice in storage during year.
f/ Excludes volume moved directly to mills by conveyor systems and that loaded out for shipment by barge.

Table 58. RECEIPTS OF ROUGH RICE BY MODE OF TRANSPORTATION COMPARED WITH TOTAL CAPACITIES, BY REGIONS, 1965-66[30]
(percent)

Volume Received	Arkansas-Mississippi	Texas-Louisiana	California	Regions Combined
In farm-owned trucks	99.8	70.3	60.0	75.2
In commercial trucks	0.2	29.7	40.0	24.8
Compared with total capacity[a]	111.3	132.3	110.5	121.1

a/ Based on portion actually used for rice handling and storing in 1965-66. In Arkansas-Mississippi, rice dryer-storage facilities were used jointly with other grains.

Table 59. COMPARISON OF VOLUMES OF ROUGH RICE DRIED TO VOLUMES RECEIVED AND TO TOTAL CAPACITIES, BY REGIONS, 1965-66[30]
(percent)

Item	Arkansas-Mississippi	Texas-Louisiana	California	Regions Combined
Volume dried compared with:				
Volume received	97.5	91.7	87.5	92.4
Total capacity[a]	108.6	121.3	96.7	111.9

a/ Based on portion actually utilized for rice handling and storing in 1965-66. In Arkansas-Mississippi, rice dryer-storage facilities were used jointly with other grains.

Volumes of rough rice handled are shown in Table 57, while Table 58 presents data on the mode of transportation of rough rice to commercial dryers. The data in Table 59 indicates that over 92% of total rice receipts at commercial dryers in 1965-66 for all regions combined were green and required drying. A considerable quantity of dried rough rice was transferred to mills or other storage facilities immediately after it was dried. Green rice passed through the drying-tempering cycle an average of 4.1 times in Arkansas-Mississippi, 5.2 times in California, and 5.4 times in Texas-Louisiana, averaging 4.9 times. Dryer passes ranged from 2 to 8, depending upon: volume and moisture content of the green rice, plant layout, and operating practices.

RICE MILLING

Introduction

United States rice production and milling is concentrated in relatively small areas of Arkansas, California, Louisiana, Mississippi, and Texas. Minor quantities are produced in several other states.

Rice processing, marketing, and distribution are important links between the concentrated domestic production and widely dispersed consumption areas in the United States. All the mills, except those in New Orleans and San Francisco, are located in or near the areas of concentrated rice production.

Raw Materials and Products

Rice is the only raw material processed in rice mills, and milled rice and various by-products are the products of the milling operations. Table 60 presents data on the supply and distribution of rough rice during the period 1949-71, while Table 61 summarizes similar data for milled rice during the 1949-70 period.

The quantity and value of shipments of products from rice mills in 1963 and 1967 are shown in Table 62, while Table 63 summarizes composite data for recent years.

Industry Structure

Approximately 50 rice mills in the United States handle the annual rice crop, but not all operate every year. The mills are located in the producing areas adjacent to the supply of rough rice. Table 64 shows the number of rice mills operating in 1971 in the major rice-producing states and the range in daily milling capacity.

Table 60. RICE, ROUGH· SUPPLY AND DISTRIBUTION, UNITED STATES, 1949-71[1]

Year Beginning August	Supply[a] Carryover Stocks Farm[b]	Mills	Ware-houses	Total	Production	Total	Distribution[a] Disappearance Seed	Milled	Exports	Residual[c]	Total	Ending Stocks
1949		455	756	1,211	40,769	41,980	1,832	37,122	696	365	40,015	1,965
1950		818	1,147	1,965	38,820	40,785	2,295	35,829	469	- 108	38,485	2,300
1951		1,195	1,105	2,300	46,089	48,389	2,340	43,611	471	1,186	47,608	781
1952		249	532	781	48,193	48,974	2,575	45,044	673	- 94	48,198	776
1953		485	291	776	52,834	53,610	3,103	46,660	846	- 426	50,183	3,427
1954		2,202	1,225	3,427	64,193	67,620	2,222	52,294	703	3,665	58,884	8,736
1955	16	3,975	4,745	8,736	55,902	64,638	1,988	42,078	1,188	1,090	46,344	18,294
1956	378	5,652	12,264	18,294	49,459	67,753	1,735	50,406	789	555	53,485	14,268
1957	373	4,878	9,017	14,268	42,935	57,203	1,849	43,657	280	890	46,676	10,527
1958	454	4,402	5,671	10,527	44,760	55,287	2,071	43,702	327	2,118	48,218	7,069
1959	218	3,645	3,206	7,069	53,647	60,716	2,092	49,525	385	901	52,903	7,813
1960	389	2,809	4,615	7,813	54,591	62,404	2,119	52,047	379	518	55,063	7,341
1961	85	2,940	4,316	7,341	54,198	61,539	2,350	55,387	79	583	58,399	3,140
1962	201	1,823	1,116	3,140	66,045	69,185	2,383	60,786	143	219	63,531	5,654
1963	167	2,343	3,144	5,654	70,269	75,923	2,458	68,264	105	- 91	70,736	5,187
1964	112	2,697	2,378	5,187	73,166	78,353	2,464	70,974	126	- 116	73,448	4,905
1965	141	2,402	2,362	4,905	76,281	81,186	2,702	70,595	169	2,240	75,706	5,480
1966	347	2,167	2,966	5,480	85,020	90,500	2,688	80,210	161	1,244	84,303	6,197
1967	226	2,869	3,102	6,197	89,379	95,576	3,235	88,116	205	561	92,117	3,459
1968	120	2,234	1,105	3,459	104,075	107,534	2,932	89,086	67	2,957	95,042	12,492
1969	331	4,295	7,866	12,492	90,838	103,330	2,510	86,544	193	868	90,115	13,215
1970[d]	242	4,955	8,018	13,215	83,754	96,969	2,510	77,326	140	2,105	82,081	14,888
1971[d]	199	4,520	10,169	14,888	84,315	99,203						

a/ 1,000 cwt.
b/ Farm stocks not reported separately prior to 1955.
c/ Includes feed, waste, loss, and shrinkage.
d/ Preliminary.

Table 61. RICE, MILLED: SUPPLY AND DISTRIBUTION, UNITED STATES, 1949-70[1/]

Year Beginning August	Supply[a/]				Distribution[a/]					
	Carry-Over Stocks	Production[b/]	Imports[c/]	Total	Exports[c/]	Shipments to Territories	Consumed at Breweries	Remaining for Domestic Food	Total	Ending Stocks
1949	767	25,727	42	26,536	10,718	3,954	3,276	7,613	25,561	975
1950	975	24,775	544	26,294	9,036	3,485	3,367	8,868	24,756	1,538
1951	1,538	31,286	389	33,213	16,933	3,610	3,395	8,370	32,308	905
1952	905	31,318	243	32,466	16,722	3,602	3,165	8,455	31,944	522
1953	522	31,821	290	32,633	15,198	3,256	3,170	8,561	30,185	2,448
1954	2,448	36,180	45	38,673	9,391	3,876	3,882	8,962	26,111	12,562
1955	12,562	28,289	135	40,986	12,056	3,677	4,176	9,739	29,648	11,338
1956	11,338	35,174	268	46,780	25,637	3,634	3,549	9,993	42,813	3,967
1957	3,967	30,523	165	34,655	12,609	3,732	3,348	9,623	29,312	5,343
1958	5,343	30,491	115	35,949	13,528	3,309	3,278	9,844	29,959	5,990
1959	5,990	34,896	550	41,436	20,327	3,630	3,488	10,939	38,384	3,052
1960	3,052	36,928	203	40,183	20,643	2,835	3,482	11,280	38,240	1,943
1961	1,943	39,688	274	41,905	20,835	2,551	3,361	13,586	40,333	1,572
1962	1,572	43,276	27	44,875	25,190	2,970	2,911	12,326	43,397	1,478
1963	1,478	49,146	13	50,637	30,020	2,798	2,767	13,360	48,945	1,692
1964	1,692	51,041	338	53,071	30,489	2,820	3,095	14,672	51,076	1,995
1965	1,995	50,942	482	53,419	31,135	2,752	3,391	14,150	51,428	1,991
1966	1,991	58,382	6	60,379	37,432	2,764	3,828	14,671	58,695	1,684
1967	1,684	64,080	5	65,769	41,215	2,605	3,952	15,579	63,351	2,418
1968	2,418	65,240	8	67,666	41,000[d/]	3,130	4,215	16,598	64,943	2,723
1969	2,723	62,349	159	65,231	40,820[d/]	3,324	5,089	13,670	62,903	2,328
1970	2,328	56,870	1,064	60,262	34,279[d/]	2,630	4,999	15,602	57,510	2,752

a/ 1,000 cwt.
b/ Production of heads, second heads, screenings, and brewers' rice.
c/ Compiled from reports of the U.S. Department of Commerce.
d/ Based on bills of lading.

Table 62. QUANTITY AND VALUE OF SHIPMENTS OF PRODUCTS FROM RICE MILLS[11]

Product	Total Shipments Including Interplant Transfers: 1967 Quantity (000,000 lb)	1967 Value ($000,000)	1963 Quantity (000,000 lb)	1963 Value ($000,000)
Milled rice and by-products:				
Head rice:				
Packed in 100 lb bags and over	4,342.7	365.7	3,071.3	272.7
Packed in 3 lb containers or less	398.1	53.6	420.4	48.7
Packed in other containers	564.2	56.2	318.8	33.6
Second heads	448.5	25.9	282.7	16.4
Screenings	150.8	8.9	145.3	7.2
Brewers' rice	258.4	12.1	261.3	12.4
Bran	453.3	8.8	506.5	8.9
All other milled rice and by-products	173.2	14.2	58.8	4.7
Milled rice products (for companies with 10 or more employees	18.2	1.5	31.8	2.5
Milled rice products (for companies with less than 10 employees	13.4	1.1		
Milled rice, total	6,820.8	548.0	5,097.1	407.1

Table 63. VALUE OF PRODUCT SHIPMENTS FROM RICE MILLS[16/]

Year	Value ($000,000)
1963	407.1
1967	548.0
1969	583.6
1970	553.4

Table 64. DISTRIBUTION OF RICE MILLS IN 1971[29/]

State	Number of Mills	Milling Capacity Range (10^6 lb, daily basis)
Texas	7	0.5-4.3
Arkansas	11	0.2-4
Louisiana	23	0.09-1.5
California	7	

Many of the rice mills are owned by cooperatives, and the importance of cooperatives in the structure of the rice milling industry varies among states. A relatively high percentage of rice is cooperatively milled in California (80-85%) and Arkansas (60-65%) as compared to Texas (20-25%) and Louisiana (6-8%). Table 65 outlines the general structure of the rice milling industry in recent years. Table 66 presents data on the value of shipments from the larger mills in the industry.

Very few new rough rice mills have been constructed in recent years. However, many mills have installed new milling equipment, improved both rough and clean rice handling facilities and made some renovation of the basic facilities during the past 5 to 10 years. Modernization of new equipment included bulk rice receiving, handling and storage facilities for both rough and clean rice, new conveyors, bulk loading and the installation of improved Japanese-made pearlers and rubber hullers. Some mills have also installed automatic processing controls and electronic sorting equipment. On

Table 65. GENERAL STRUCTURE OF RICE MILLING INDUSTRY[11]

Year	Number of Companies	Number of Mills	Employees (000)	Type of Operation		Legal Form of Organization		
				Multi Unit	Single Unit	Corporate	Individual and Partnership	Other
1967	54	68	4.2	27	41	42	4	13
1963	62	74	4.3	24	50	57	10	7
1958	61	72	3.8	23	49	54	8	10
% Change 1958-1967	-11.5	-5.5	+10.5					

Table 66. PERCENT OF VALUE OF SHIPMENTS ACCOUNTED FOR BY THE[16] LARGEST COMPANIES IN RICE MILLING INDUSTRY

Year	Companies (number)	Value of Industry Shipments				
			Percent Accounted for by			
		Total ($000,000)	4 Largest Companies	8 Largest Companies	20 Largest Companies	50 Largest Companies
1970	(NA)	550.8	50	73	(NA)	(NA)
1967	54	548.4	46	68	89	99+
1966	(NA)	457.6	45		(NA)	(NA)
1963	62	423.0	44	66	86	99+
1958	61	282.3	43	64	84	99
1954	65	266.9	41	60	81	(NA)
1947	75	224.7	33	48	72	(NA)
1935	(NA)	(NA)	38	52	(NA)	(NA)

the other hand, the rice parboiling process is relatively new in the U.S. and started in Texas on a commercial basis during World War II.

The attrition rate in rice mills has been rather heavy in recent years. The reduction in the number of mills resulted from: (1) the "folding up" of small, independent, family-owned and operated huller mills due mainly to increased competition for rough rice supplies and clean rice markets; and (2) the consolidation of milling facilities by large multimill firms by closing up their smaller, relatively inefficient mills in outlying areas and concentrating operations in the larger, centrally located, more efficient milling operations.

Total milling capacity has not been greatly affected by the reduction in the number of operating mills. The smaller mills usually are the ones that have ceased operating. The remaining mills have increased their average capacity as well as their total output during the past few years.

Characteristics of Mills

The typical mill in Louisiana normally operates only from August to early May. Louisiana mills usually operate 24 hr/day during the peak fall season but only if the clean rice is moving out every day. Lack of clean rice storage space is the limiting factor with several mills and forces most mills in Louisiana to move out the clean rice immediately after milling it.

During recent years, there has been a tendency in Louisiana mills to integrate their services and functions backward toward the producer. They have done this by erecting their own rough rice drying and storage facilities and engaging extensively in green rice purchasing and drying and storage operations for their own accounts. There are three basic reasons why mills have found this to their advantage. First, they can do their own blending and thus have better control over quality; second, there are cost savings in rough rice hauling and handling operations; and third, they can hedge on future price increase.

Texas mills normally operate year round with about half of them operating 24 hr a day and the remainder operating two shifts, or 16 hr a day. Likewise, half the mills operate 7 days/week and the others only 5 days. Texas rice mills have expanded or integrated their operations forward toward the consumer to a larger extent than has occurred in Louisiana. However, much of the output in Texas is still marketed in wholesale-type packages or in bulk. In Texas only two of the seven mills do not package milled rice in consumer size packages under their own brand names which they advertise in major rice markets.

SOYBEAN OIL PROCESSING

Introduction

Soybean milling involves the crushing of soybeans into a wide array of useful products. Processors convert a 60-lb bushel of soybeans into approximately 47 lb of high-protein meal and 11 lb of edible oil. Most of the meal ends up as livestock and poultry feed, while some goes into the manufacturing of soy protein products. The oil is used for margarine, shortening, salad oil, paint, plastics and cosmetics.

Today, soybeans provide the world with its largest source of vegetable oil and high-protein feed. Worldwide, more than 1.5 billion bushels of soybeans are produced annually, with the United States accounting for about 75% of the total production. Other major producers are Mainland China, Brazil, and the Soviet Union.

While soybean processing is one of the modern world's oldest industries, its growth in the U.S. has been most recent, dating from 1911, when the practice was brought to California from the Orient and used imported beans. The outbreak of World War I gave birth to a new industry in America and soybean processing grew in earnest in the United States East Coast. By 1922, it had spread to the Midwest with the opening of Illinois' first soybean processing plant.

In a little more than 40 years, the soybean has risen from the bottom of the U.S.'s agriculture crop ladder to its present position of being number two. Corn is still the number one crop in terms of cash value to the American farmer. Behind the growing importance of soybean growing and processing are two attributes of the soybean seed: (a) a high content of protein, and (b) a moderate content of oil useful for edible and industrial uses.

Today the U.S. soybean crop is produced on nearly 43 million acres in at least 30 states. It is the only major crop registering acreage increases during the last 20 years. Since 1949, over 30 million acres in the U.S. have been shifted from other crops (mainly corn, cotton, oats and wheat) into soybean production. The sharpest increases occurred during the 1960's.

Soybean Production

Soybeans have indeed found a place in American agriculture. In 1952, soybeans ranked fifth in acreage among the major crops, and sixth in dollar value and by 1971, ranked third in acreage and second in dollar value (Table 67). It is evident from these figures that soybean production and acreage has grown significantly since 1950. Acres harvested have increased

Table 67. COMPARISON OF MAJOR CROPS: ACREAGE AND DOLLAR VALUE[1/]

Crop	1952		1969		1971	
	1,000 Acres Planted	Dollar Value ($000,000)	1,000 Acres Planted	Dollar Value ($000,000)	1,000 Acres Planted	Dollar Value ($000,000)
Corn	82,200	5,200	64,400	5,850	74,100	5,890
Cotton	25,900	2,770	12,000	2,000	12,400	1,680
Wheat	78,600	2,730	54,300	1,915	54,600	2,168
Tobacco	1,800	1,125	930	1,140	840	1,342
Oats	42,300	950	23,300	545	22,000	538
Soybeans	14,400	765	43,000	2,400	43,200	3,465
Barley	9,200	310	10,400	450	11,100	443
Grain Sorghums	12,300	250	17,700	700	16,601	925

300% while value of production has risen 450%. Total 1971 U.S. harvested acreage was estimated at 42.4 million acres, while production was estimated at 1.1 billion bushels (Table 68). The United States soybean processing industry continues to anticipate the expanding of output of soybeans as the world's demand for soybean products increases.

Table 68. ACREAGE HARVESTED AND TOTAL PRODUCTION[31/] OF SOYBEANS FOR BEANS, 1950-71

Year	Acres Harvested for Beans (000 acres)	Total Production for Beans (000 bu)
1950	13,807	299,249
1955	18,620	373,682
1960	23,655	555,085
1965	34,449	845,608
1970	42,056	1,123,740
1971[a/]	42,409	1,169,361

a/ Preliminary.

The Corn Belt (Illinois, Iowa, Indiana, Ohio and Missouri) historically has been the main production area for soybeans because of the similar growing conditions required by both corn and soybeans. However, new varieties better suited to new production areas with improved oil content and yields have been developed widening the production area. In 1949, 70% of the soybean acreage was located in the five states comprising the Corn Belt. In 1971, this percentage had been reduced to 51%, even though acreage had risen from 9 to 22 million acres. The Delta States (Arkansas, Mississippi and Louisiana), the Lakes States (Minnesota, Wisconsin and Michigan) and the Atlantic States (North and South Carolina, Virginia, Maryland and Delaware) have all increased soybean acreage significantly.

The U.S. production of soybeans is expected to double again in the next decade as the world shortage of protein and fat becomes more acute with the anticipated increase in population and income levels. Researchers are developing new varieties and better weed, pest and disease control, and they are hoping to increase yields of soybeans in all production areas.

Characteristics of the Soybean Milling Industry

Number of Plants and Capacity - According to an ERS survey, there was an estimated 130 soybean mills operating in the U.S. in 1970 with an annual processing capacity of 825 million bushels (Table 69).[31/] Since 1960, a significant (57%) increase in processing capacity has been accomplished with only a 4% increase in the number of processing mills crushing soybeans. These figures differ somewhat from the Census of Manufacturers data issued in 1967 in that the ERS survey includes cottonseed and other oil seed mills that process significant quantities of soybeans. Thus, in 1967 the Census of Manufacturers identified 102 processing mills, while the ERS survey indicates 135 mills.

The soybean processing industry has historically had a record of a high rate of utilization of production capacity. In 1960, the ratio of utilized capacity to total capacity was approximately 77%, and in 1969 the average utilization rate per mill was close to 92%. Average processing capacity per mill in the U.S. has grown approximately 50% during the last decade, increasing from 4.2 million bushels to 6.3 million bushels. The dramatic increase in domestic processing capacity in recent years is a reflection of the industry's confidence that world demand for soybean oil and meal will continue to rise, and that U.S. soybean products will remain competitive in world markets. Thus, the soybean processing industry will accommodate further growth in demand for soybean products in the 1970's and increases in capacity are anticipated.

Location of Soybean Oil Mills - The expansion of soybean production areas is the main determinant of the location of the domestic soybean crushing industry. In 1958, about 58% of the soybean oil mills were located in the North Central Region, with the largest concentrations of plants located in Iowa and Illinois. By 1970, however, this share fell to about 42%. The Delta States (Arkansas, Mississippi and Louisiana) have increased their processing mills from 18 in 1958 to 30 in 1970 and now account for 30% of total. Table 70 shows the number of mills by state for selected years from 1951 to 1970. The leading U.S. processing center is Decatur, Illinois, where more than 180,000 bu of soybeans can be processed daily. Memphis, Tennessee, is second in crushing capacity, followed by Mankato, Minnesota.

Table 69. NUMBER OF SOYBEAN OIL MILLS AND PROCESSING CAPACITY IN THE UNITED STATES, 1960-70[31/]

Year Beginning September	Processing Mills a/	Annual Processing Capacity: Total b/	Annual Processing Capacity: Utilized c/	Annual Processing Capacity: Excess d/	Ratio of Utilized To Total	Average Per Mill: Processing Capacity	Average Per Mill: Capacity Utilized c/
	Number	(000,000 bu)	(000,000 bu)	(000,000 bu)	Percent	(000,000 bu)	(000,000 bu)
1960	125	525	406	119	77	4.2	3.2
1961	131	(535)	431	104	81	4.1	3.3
1962	130	550	473	77	86	4.2	3.6
1963	132	575	437	138	76	4.4	3.3
1964	125	585	479	106	82	4.7	3.8
1965	125	600	537	63	89	4.8	4.3
1966	129	650	559	91	86	5.0	4.3
1967	135	750	576	174	77	5.5	4.3
1968	134	750	606	144	81	5.6	4.5
1969	132	800	737	63	92	6.1	5.6
1970	130	875	760	115	87	6.1	5.8

a/ Estimates developed by ERS from Census data and trade directories. Includes cottonseed and other oilseed mills that process significant quantities of soybeans.

b/ Trade estimates 1958 to date (except 1961). Data in brackets are USDA interpolations.

c/ Soybeans actually crushed.

d/ Difference between total capacity and soybeans utilized (crushed).

Table 70. ESTIMATED NUMBER OF SOYBEAN OIL MILLS IN THE UNITED STATES[31/]
BY REGIONS AND STATES, 1951-1970[a/]

Region & State	1951	1970	Region & State	1951	1970
Corn Belt:			Atlantic:		
Illinois	31	12	North Carolina	13	7
Iowa	30	16	South Carolina	7	7
Indiana	10	5	Virginia	3	1
Ohio	14	4	Maryland	0	1
Missouri	9	3	Delaware	1	1
Total mills	94	40	Total Mills	24	17
% of U.S.	49%	31%	% of U.S.	13%	13%
Lake and Plains:			Other:		
Minnesota	7	7	Georgia	6	5
Kansas	6	4	Florida	1	0
Nebraska	3	3	Alabama	2	4
Total Mills	16	14	Tennessee	6	8
% of U.S.	8	11	Kentucky	4	2
Total Central States:	110	54	Oklahoma	5	2
% of U.S.	57%	42%	Texas	5	5
Delta:			California	4	3
Arkansas	10	11	Total Mills	33	29
Mississippi	13	15	% of U.S.	17%	22%
Louisiana	3	4	United States	193	130
Total Mills	26	30			
% of U.S.	13%	23%			

a/ Estimates developed mainly from Census data and trade directories. Includes cottonseed and other oilseed mills that process significant quantities of soybeans. The number of active mills fluctuates during any year due to new plants coming into operation, some mills becoming dormant (due to explosions, fires, strikes, etc.) and dismantling of older mills. The estimates shown here are approximations of the number of mills at the beginning of the marketing year.

Value of Products Shipped - The value of shipments of soybean oil mill producers has risen sharply during the last decade, growing more than 131.5% during the 1958-70 period (Table 71). Shipments of soybean cake or meal represented about 64.4% of the total value of shipments, and soybean oil 35.5%. During the 1958-70 period, the value of shipments of soybean cake grew more than 181.2%, while the value of shipments of soybean oil grew 77.7%. The growth in the volume of soybean cake and meal shipments has been predicated on the use of this commodity for domestic and foreign livestock and poultry feed. Feed manufacturers look to soybean meal as the basic protein source for modern livestock rations. The substantial growth in soybean oil shipments has been influenced by the expanding worldwide market for soybean oil as an economical vegetable oil, and by American industry for use in paints, waterproof cements, soaps, greases and lubricants, printing inks and fabric coatings, and the American public demand for a high polyunsaturated food for diet-conscious millions.

Quantities and Types of Products Shipped - A variety of products are shipped from soybean oil mills, but only two represent sizeable volumes, i.e., crude soybean oil and soybean cake or meal (Table 72). Crude soybean oil shipments in 1967 were 5.0 million pounds, a growth of nearly 46% during the 1958-67 period. Of the total crude shipments in 1967, 60.5% represented degummed soybean oil, while 39.5% was not degummed. Other soybean oil products shipped included once-refined soybean oil and soybean oil for inedible uses.

Table 71. VALUE OF SHIPMENTS SOYBEAN OIL MILL PRODUCTS[16/]
1958-70
($000,000)

Year	Soybean Oil	Soybean Cake	Soybean Oil Mill Products n.s.k.	Total
1970	756.9	1,370.7	1.2	2,128.8
1969	553.7	1,131.9	2.2	1,687.8
1967	594.3	1,143.4	3.1	1,640.8
1963	458.9	831.4	3.4	1,293.6
1958	425.9	487.4	6.4	919.7
Percent Change 1958-1970	77.7	181.2	-81.3	131.5

n.s.k. = not specified by kind

Table 72. PRODUCTION OF SOYBEAN OIL MILL PRODUCTS[11]
1958-67

Year	Soybean Oil					Soybean Meal and Other Products				
	Degummed (000,000 lb)	Crude Not Degummed (000,000 lb)	Total (000,000 lb)	Once Refined (000,000 lb)	Inedible Use (000,000 lb)	Cake and Meal (000 tons)	Soyflour and Grits (000,000 lb)	Lecithin (000,000 lb)	Millfeed (Hull Meal) (000 tons)	Other By-Products (000,000 lb)
1958	NA	NA	3,870	3,131	62	7,909	214	34	NA	NA
1963	NA	NA	4,959	3,915	21	10,463	326	44	NA	136
1967	3,891	2,119	6,011	4,975	a/	13,149	461	47	326	90
					VOLUME OF SOYBEAN OIL MILL PRODUCTS SHIPPED 1958-67					
1958	NA	NA	3,457	353	59	8,093	261	36	NA	NA
1963	NA	NA	4,296	590	24	10,668	363	44	NA	137
1967	3,046	1,992	5,038	603	a/	12,906	575	58	347	94

a/ Included with once-refined to avoid disclosing figures for individual companies.
NA = Not Available.

Soybean cake and meal shipments in 1967 totaled 12.9 million tons, up 59.4% from the 1958 total of 8.0 million tons. Shipments of cake and meal represented about 92% of the soybean mill products shipped. Among the other products are soyflour and grits, mill feed, lecithin, and other by-products which represent only 8% of the total shipment of soybean meal products.

Nearly 92% of the crude oil is further processed for human food products, such as vegetable cooking oil, margarine, shortening and salad oil. The remaining 8% is further refined for use in a wide variety of industrial products (Table 73).

No other protein meal can match that of the soybean for efficient livestock production. As a result, nearly 99% of the nation's soybean meal is fed to domestic livestock and poultry or exported for poultry and animal feed. The industry offers soybean meal as either 44% or 49% protein base, with few variations in between.

Competition with Other Protein Products - While at present, soybean meal is the giant of the animal and vegetable protein world, the U.S. soybean industry has other important competitors. Among the competitors are cottonseed meal, fish meal, gluten feed and meal, and tankage and meat scraps. During the past 10 years, domestic feed mill industry trends indicate a steady growth of soybean meal, a static use of cottonseed meal, an erratic growth of fish meal depending on fish catches, a consistent growth of gluten feed and meal paralleling growth of the corn wet milling industry, a consistent increase in meat scraps, in tankage usage, and the dramatic surge of urea from last to second place among the major sources of feed protein.

Despite the forays of urea, soybean meal has maintained just a little over one-half of the protein market. In the animal food area, soybean meal may have to compete in the near future with expanded use of urea, protein from petroleum and high-lysine corn.

On the other hand, some people see economic possibilities in using the vegetable proteins directly for human food instead of our present practice of feeding the vegetable protein to animals and then eating the animals.

Industry Concentration - The soybean processing industry has grown from a large number of relatively inefficient, small mills independently owned into today's modern industrial complex, mostly controlled by a small number of comparatively large companies. In terms of value of shipments, the larger firms are accounting for a growing share of the production. In 1958, the four largest soybean processors accounted for about 40% of the total value of shipments in the industry, and by 1970, the four largest processors accounted for 56% of the value of shipments (Table 74). The eight largest firms accounted for 73% in 1970, compared to 63% in 1958.

Table 73. SOYBEAN OIL UTILIZATION BY CLASSES OF PRODUCTS[31/]
UNITED STATES, 1958-70
(000,000 lb)

	Food Products				Nonfood Products					
Year	Margarine	Shortening	Other	Total	Soap	Paint Varnish	Other Drying Oil Products	Misc. Nonfood	Loss, Included Oil In foods	Total
1958	1,070	1,055	699	2,824	a/	101	57	30	139	328
1960	1,105	1,169	914	3,188	0	100	73	45	144	361
1965	1,112	1,471	1,599	4,182	0	96	112	48	165	421
1970	1,410	2,182	2,508	6,100	0	85	83	54	247	469

a/ Less than 500,000 lb.

Table 74. PERCENT OF VALUE SHIPMENTS ACCOUNTED FOR BY[16/] THE LARGEST COMPANIES IN SOYBEAN OIL MILLING 1958-70

Year	Companies (number)	Total ($000,000)	Value of Industry Shipments — Percent Accounted for By: 4 Largest Companies	8 Largest Companies	20 Largest Companies	50 Largest Companies
1958	66	999.2	40	63	86	99
1967	60	2,148.3	55	76	94	100
1970	NA	2,609.9	56	73	NA	NA

Integration - The large firms often own and operate several soybean mills (horizontally integrated) while others may extend their operation by vertical integration into vegetable oil refining and food and feed manufacturing. The increased integration is illustrated by the increase in multiplant operations from 68 in 1958 to 73 in 1967 and the significant decrease in single plants from 49 to 29 during the same period (Table 75). Several of the domestic soybean processors have their own terminal and country or subterminal elevators for the procurement of supplies and, in addition, have vertically integrated forward into oil refining and salad and cooking oils.

Corporate Structure - In 1967, the Census of Manufacturers indicated that of the 102 soybean mills listed, 76 were corporate-owned, while only 15 were operated on an individual or partnership basis. The 1967 Census listed 11 plants as neither corporate, individual nor partnership, but rather as farmer cooperatives. According to the Farmer Cooperative Service, USDA, there were 13 cooperative mills operating in 1968, and they accounted for 15% of the total soybeans crushed. An additional 10% of the soybean processing was accounted for by cooperative-corporate joint ventures. During the last 10 years, the trend has been toward greater corporate ownership of soybean mills, with corporations operating more than one mill.

Table 75. TRENDS IN CORPORATION STRUCTURE IN THE[11/] SOYBEAN MILLING INDUSTRY 1958-67

A. Type of Operation

Year	Total	Multi-Unit	Single Unit
1967	102	73	29
1963	102	68	34
1958	117	68	49

B. Legal Form of Operation

Year	Corporate	Individual & Partnership	Cooperatives
1967	76	15	11
1963	73	18	11
1958	94	12	11

CORN WET MILLING

Introduction

The history of the corn wet milling industry is one of consistent, substantial growth and development, accelerating as new uses are found for its diverse products. As present uses expand, new uses are also being devised, including: the further utilization of starch in the metallurgical industries; the use of starch as an integral part of paper, not only as sizing; the development of wood-like structural materials using starch; and the utilization of starch in insecticides and defoliating formulations. The industry has also continued to mechanize and experiment to meet the demands of customers for existing products and to cooperate with those interested in engaging in experimental projects.

Raw Materials and Products

The corn wet milling industry processed over 225 million bushels of corn in 1970 into a myriad of raw and finished products including starch, syrup, dextrose and corn oil, each of which has literally hundreds of food and industrial applications.

The corn refining industry is a year-round purchaser of corn, and an important contributor to the economies of the Corn Belt States, as reflected in Table 76 which was compiled by Dun and Bradstreet, Inc., for the Corn Refiners Association, Inc. This exclusive survey covers the member companies of the Association--the major manufacturers of corn starch, syrups and sugars, oil, gluten feed and meal and related products from corn in America.

Table 76. CORN PURCHASING PATTERNS FOR MAJOR FIRMS[32/] IN CORN WET MILLING INDUSTRY

A. Site of Purchase

Source	1967	1968	1969
Farms	6.0%	7.5%	8.2%
Country Elevators	79.1%	78.6%	81.0%
Terminal Elevators	14.4%	13.5%	10.5%
Government Stocks	0.5%	0.4%	0.3%

B. Percent Purchased by Selected States

State	1967	1968	1969
Illinois	50.7%	56.5%	49.1%
Iowa	32.7%	28.7%	34.3%
Indiana	9.6%	9.3%	12.6%
Nebraska	1.1%	1.4%	0.8%
Missouri	4.5%	3.2%	2.0%
Minnesota	0.8%	0.6%	0.8%
South Dakota	0.6%	0.3%	0.4%

Table 77 presents data on industry shipments for the period 1957-66. The data in Table 77 reflect only the activity of members of the Corn Refiners Association, Inc. Table 78 summarizes detailed data reported by the Bureau of Census on the quantity and value of shipments by all producers in 1963 and 1967, while Table 79 presents composite data for the value of shipments over the past 25 years.

Industry Structure

The domestic corn wet milling industry is comprised of some 17 plants. Of the 17 manufacturing facilities, nine were constructed in the early part of the century with an average age of over 60 years; two were constructed in the late 1940's and early 1950's and the other six were constructed within the last decade. The older plants are largest in size and represent over 77% of the industry processing capacity. The next oldest group has about 8% of the capacity, and the last group of six plants less than 15%. Originally, plants were located in rural areas, but today only one plant in the second group and two plants in the last group can be so classified--the others having become surrounded by metropolitan growth and development.

Table 80 presents general statistics from the Census of Manufacturers for all establishments under the Census of Manufacturers SIC code for starch manufacturing. This SIC code includes corn, wheat, rice, and potato starch processors. While the data in Table 80 do not represent only the corn wet milling industry, a comparison of the data in Tables 79 and 80 indicates that the corn wet milling industry has accounted for 85% to 90% of the value of shipments from starch processors in the last decade.

Characteristics of Plants

The corn wet milling industry dates to the early 1900's. Many of the older plants have undergone extensive modernization in recent years in order to increase production and expand product lines. Plants range in processing capacity from about 12,000 bu/day to over 100,000 bu/day. The 12,000 bu/day plant, one of the newer facilities, is considered minimum size for the U.S. A number of plants in the U.S. are in the 50,000-70,000 bu/day range, while a few are in the 30,000-40,000 bu/day range.

Two old facilities were shut down in the last few years. These were the Marschall Division Plant of Miles Laboratories in Granite City, Illinois, in early 1972, and the Anheuser-Busch, Inc., plant in St. Louis, Missouri, in December 1968. The combined annual capacity of these abandoned facilities was approximately 22 million bushels.

Table 77. SHIPMENTS BY CORN REFINING INDUSTRY OF PRODUCTS[32/] MANUFACTURED FROM CORN ANNUALLY, 1957-66
(000 lb)

Item	1957	1958	1959	1960	1961	1962	1963	1964	1965	1966
A. Shipments of Basic Products										
Domestic shipments										
Corn starch, all types	1,862,490	1,950,441	2,107,341	2,061,619	2,110,292	2,280,353	2,287,626	2,406,117	2,553,044	2,665,790
Corn syrup unmixed, all liquid types	1,633,113	1,770,709	1,874,638	1,968,256	2,098,202	2,338,258	2,502,430	2,779,979	2,834,487	2,935,171
Corn sugar, crude and refined	712,627	804,968	840,841	828,399	850,997	912,496	1,025,320	1,019,340	1,032,643	1,065,882
Export shipments										
Corn starch, all types	181,294	112,693	83,154	66,138	66,496	61,030	67,849	88,939	83,840	90,115
Corn syrup,unmixed, all liquid types	32,173	28,086	26,309	21,518	16,051	17,746	24,087	19,130	11,719	12,123
Corn sugar, crude and refined	32,217	29,460	26,410	41,652	19,269	14,730	26,052	29,675	18,459	14,660
Total domestic and export shipments										
Corn starch, all types	2,043,784	2,063,134	2,190,495	2,127,757	2,176,788	2,341,383	2,355,475	2,495,056	2,636,884	2,755,905
Corn syrup unmixed, all liquid types	1,665,286	1,798,795	1,900,947	1,989,774	2,114,253	2,356,004	2,526,517	2,799,109	2,846,206	2,947,294
Corn sugar, crude and refined	744,844	834,428	867,251	870,051	870,266	927,266	1,051,372	1,049,015	1,051,102	1,080,542
B. Total Shipments of Other Products										
Corn oil, crude and refined	270,703	265,675	282,791	280,531	310,131	303,174	320,443	366,755	358,476	351,348
Corn gluten feed and meal	1,953,080	2,004,318	3,106,018	2,188,492	2,207,219	2,438,370	2,533,304	2,698,747	2,832,872	2,911,883
Steepwater, 50% solids	74,046	80,773	64,423	53,256	43,197	46,363	54,609	68,455	56,757	94,479
Hydrol, commercial weights	190,053	237,843	251,390	272,800	270,801	275,962	326,775	350,779	312,754	270,472

Note. Shipments reflect activity of members of Corn Refiners Association, Inc., 1001 Connecticut Avenue, NW., Washington, D C. 20036.

Table 78. QUANTITY AND VALUE OF SHIPMENTS BY ALL PRODUCERS IN CORN WET MILLING INDUSTRY, 1967 AND 1963*[11/]

Product	1967 Quantity (000,000 lb)	1967 Value ($000,000)	1963 Quantity (000,000 lb)	1963 Value ($000,000)
WET CORN MILLING PRODUCTS, TOTAL	(X)	647.0	(X)	547.2
Corn syrup, unmixed:				
Low (28 to 37 dextrose equivalent)	210.5	10.5	89.4	4.5
Regular (38 to 47 dextrose equivalent)	1,423.0	66.6	1,200.5	60.1
Intermediate (48 to 57 dextrose equivalent)	175.0	8.3	128.4	6.4
High (58 to 67 dextrose equivalent)	908.8	43.2	843.0 (High and Extra High combined)	42.5
Extra High (68 and over dextrose equivalent)	60.6	2.8		
Corn sugar (crude and refined):				
Hydrous dextrose (including crude type); Anhydrous dextrose	1,227.9	81.6	1,093.6	71.5
Corn syrup solids (dried corn syrup)	127.1	10.4	110.4	8.8
Cornstarch, including milo:				
In packages larger than 5 pounds	3,119.0 (both package sizes combined)	199.5 (both package sizes combined)	2,498.3	169.2
In packages of 5 pounds or less			66.8	8.1
Other starches:				
Potato, Irish	121.3 (both starches combined)	11.0 (both starches combined)	132.6	8.7
Other starches (wheat, rice, etc.)			102.8	9.2
Dextrin (corn, tapioca, and other)	168.7	16.0	118.9	9.9
Crude corn oil; Refined corn oil	a/	76.4	a/	60.9
Wet process corn byproducts:				
Steepwater concentrate (50% solids basis)	78.0	1.5	42.7	1.0
Corn gluten feed	2,365.9	55.1	1,316.8	27.4
Corn gluten meal	875.2	36.6	1,078.2	33.3
Other wet process corn byproducts	341.4	16.9	(NA)	17.2
Other wet process corn byproducts, n.s.k.	(X)	10.3	(X)	8.6
Other wet process corn byproducts, n.s.k.	(X)	0.3	(X)	8.6

a/ Quantity data are withheld due to duplication arising from shipments between establishments in the same industry classification.

* Total shipments including interplant transfers.

Table 79. VALUE OF SHIPMENTS BY CORN WET MILLING[16/] PLANTS IN LAST 25 YEARS

Year	Value of Shipments ($000,000)
1947	422.0
1954	436.0
1958	482.6
1963	547.2
1964	546.5
1965	617.8
1966	654.8
1967	646.6
1969	697.9
1970	728.0

Table 80. GENERAL STATISTICS FOR STARCH PRODUCERS:11/
1958-67

	All Employees		Production Workers					
	Number (000)	Payroll (000,000)	Number (000)	Wages (000,000)	Cost of Materials (000,000)	Value Added by Manufacture ($000,000)	Value of Shipments (000,000)	Capital Expenditures New (000,000)
1967 Census	14.1	$116.2	9.8	$75.2	$401.7	$353.6	$751.4	$40.5
1966 ASM a/	13.9	106.6	9.9	73.6	417.7	346.6	755.2	43.7
1965 ASM a/	12.9	98.4	9.3	70.3	382.1	302.7	679.9	47.7
1964 ASM a/	12.5	95.3	9.2	66.0	345.1	291.8	629.5	47.9
1963 Census	13.2	89.7	9.8	65.3	335.8	290.9	622.4	26.1
1962 ASM a/	13.9	91.8	10.2	63.0	321.2	277.1	602.0	28.1
1961 ASM a/	13.9	87.4	10.3	60.2	307.7	282.3	584.7	33.9
1960 ASM a/	13.7	83.2	10.1	57.2	286.3	277.6	566.4	27.0
1959 ASM a/	13.3	79.5	7.9	55.6	293.6	262.2	557.8	25.0
1958 Census b/	13.8	78.8	10.4	56.3	282.0	249.4	528.5	18.1

a/ Based on a representative sample of establishments canvassed in the annual survey of manufacturers (ASM). These estimates may differ from the results of a complete canvass of all manufacturing establishments. The percentage standard errors of the 1966/1965 relatives for employment and value added were 1 and 1, respectively,

b/ Data prior to 1958 appear in Volume II, 1963 Census of Manufacturers, in Table 1 of the chapter devoted to this industry.

The processing capacity of the abandoned plants will be replaced by two new corn wet milling facilities recently constructed. Cargill, Inc., will complete construction of a plant at Dayton, Ohio, in 1973. The facility will have a daily processing capacity of 34,000 bu, equal to about 11 million bushels/year. A. E. Staley began operation of a plant in Morrisville, Pennsylvania, in 1972. The plant will process about 9 million bushels/year. The Staley plant is the first of its kind on the East Coast, and one of only a few located outside the Midwest.

CHAPTER 2

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CHAPTER 3

PROCESSES AND EMISSIONS

INTRODUCTION

Grain handling, milling, and processing include a variety of operations from the initial receipt of the grain at either a country or terminal elevator to the delivery of a finished product. Flour, livestock feed, soybean oil, and corn syrup are among the spectrum of products emanating from plants in the grain and feed industry.

There is a significant difference between atmospheric emissions arising from grain and feed industry operations and those of other industries; namely, the majority of emissions are due to raw material handling rather than raw material processing. Furthermore, some of the sources are of a "fugitive" type. That is, the emissions are those that become airborne because of ineffectual or nonexistent hooding or pollutant containment systems rather than those that penetrate an air pollution control device. Other characteristics of emissions from the grain and feed industry are the intermittent nature of many of the specific operations, and the day-to-day variability of emissions from a specific operation.

The myriad operations that comprise the individual plants in the grain and feed industry and the associated air pollution problems are presented in detail in the following sections of this chapter.

GRAIN ELEVATORS (GRAIN MARKETING OPERATIONS)

Grain sold from the farm generally proceeds through a series of grain storage facilities before it reaches the ultimate user. Grain elevators provide the storage space and serve as collection and transfer points.

There are three broad categories of grain elevators associated with grain marketing operations; country, subterminal, and terminal.[1/] The primary function of country grain elevators is to receive grain from the farms for future delivery to a secondary elevator or processor. Country elevators serve as the major outlet for grain sold from farms and are extremely important in the grain-producing regions of the United States.

In general, subterminal elevators are located away from metropolitan areas and are the only large grain-handling facilities in the immediate vicinity. They tend to be large, but their capacity is an incidental characteristic. Some subterminals are smaller than the largest country elevators, while others are larger than some terminal houses. Subterminal elevators rely on country elevators in their area to provide them with grain by either rail or truck. The subterminal generally has transit privileges for grain. The manager sells directly to terminal elevators, processors, and exporters instead of selling to interior dealers or commission merchants. Many subterminal elevators have facilities that were formerly available only in terminal elevators.

Terminal elevators are large elevators generally located at significant grain trade centers. The function of the terminal elevator is to store the grain without deterioration in quality and to blend it if necessary so as to conform to the needs of buyers. Grain-handling operations are similar at the country, subterminal, and terminal elevator, but the subterminal and terminal elevators are usually the first to thoroughly clean, dry, separate, and store the grain at proper temperature and humidity. Grain moving out from terminal elevators is ultimately used for food, feed, export, or industrial purposes. In the following sections, the discussion will consider only the country and terminal categories with the subterminal elevators being incorporated into the terminal elevator group.

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. There are approximately 10,000 such elevators in the U.S. representing a total storage capacity of about 2 billion bushels. In addition to storage, the country elevator sometimes includes facilities to clean the grain or to dry it or both.[1,2]

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 5. These elevators are usually 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 5. 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 5,000-7,500 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.

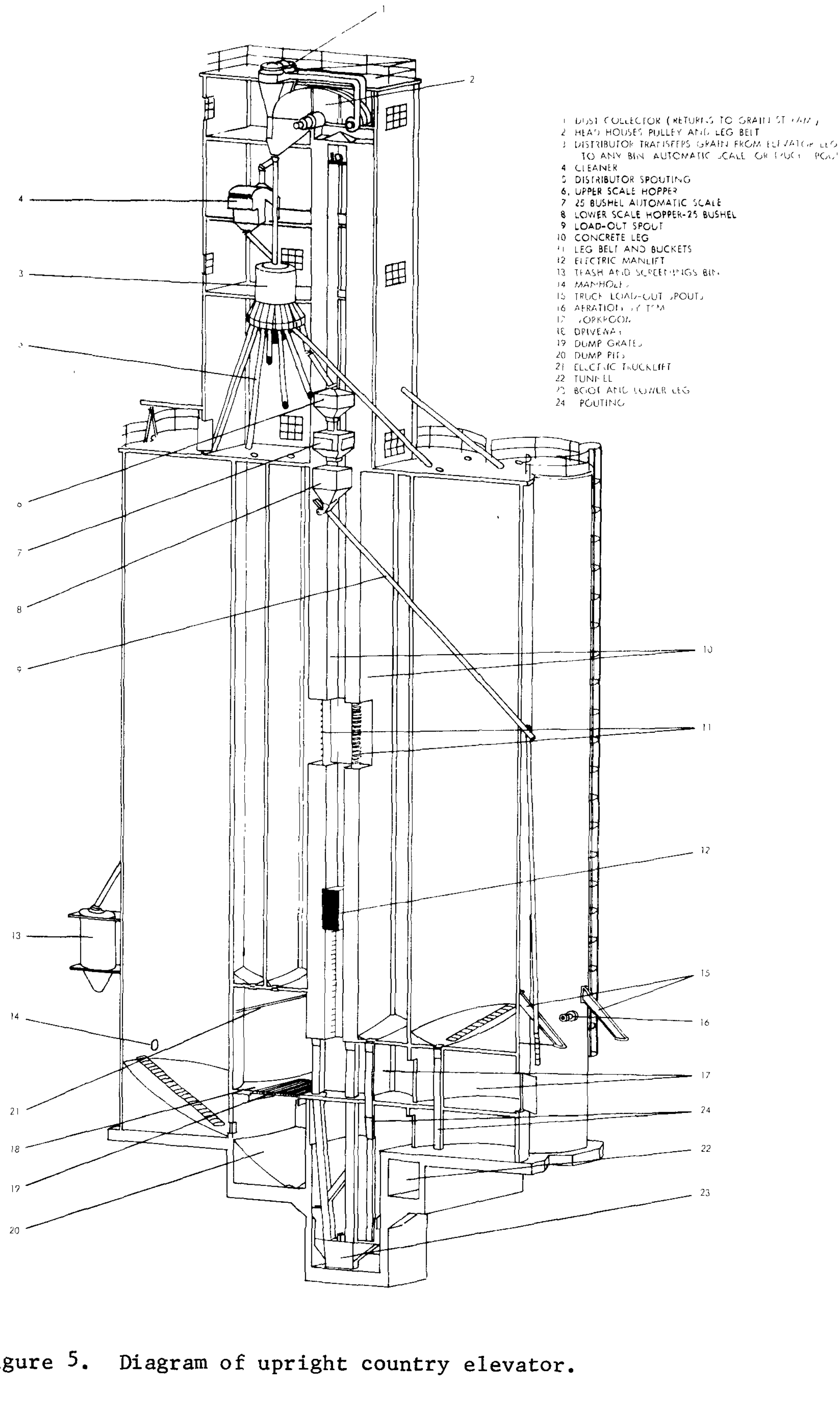


Figure 5. Diagram of upright country elevator.

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 cars and the interstice bins above the drive-through tunnel for trucks.

The design of many country elevators is similar to that shown in Figure 5, 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 6 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 railcars 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.

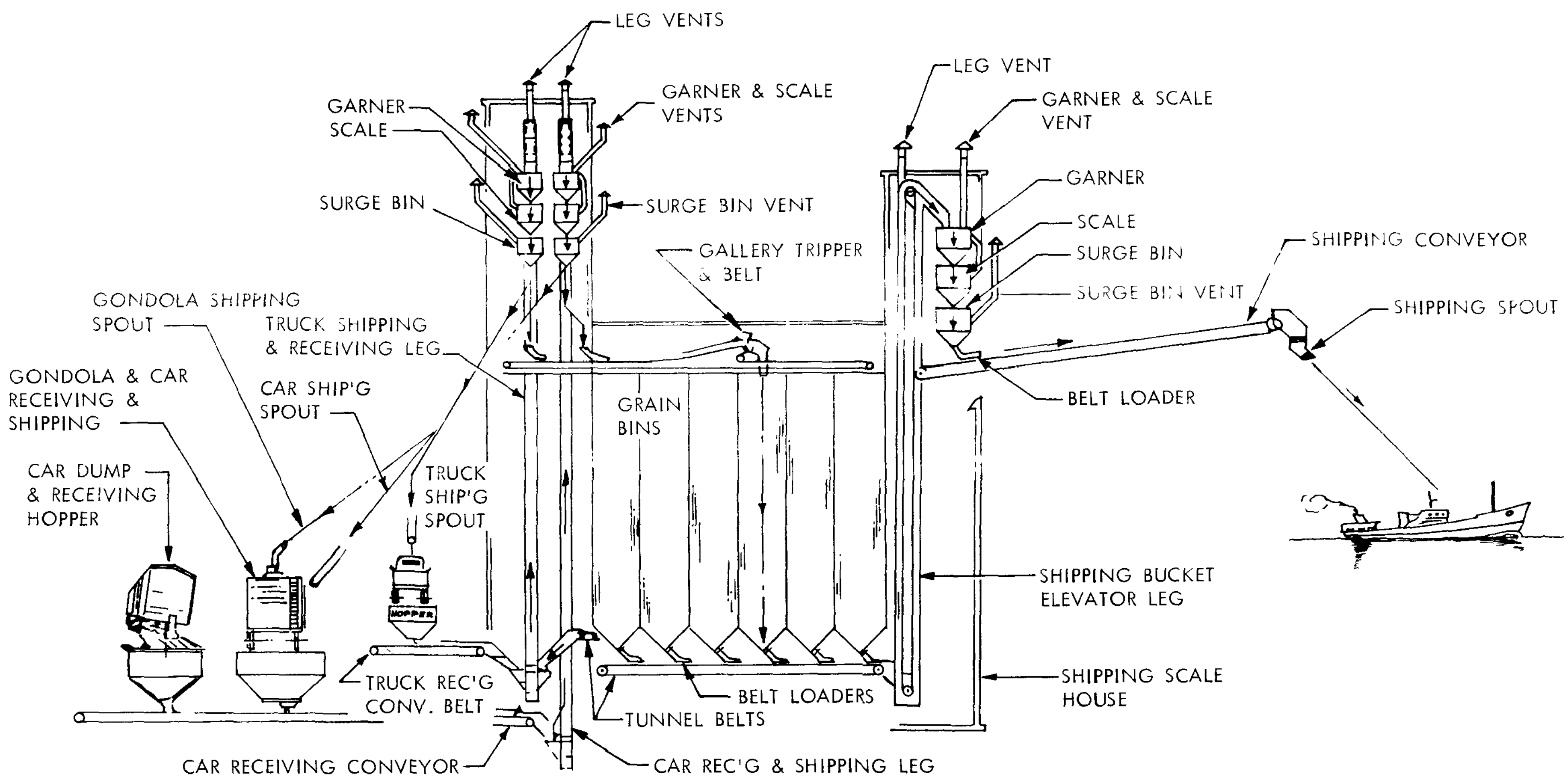


Figure 6. Flow diagram for terminal elevator.

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 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 system is large enough that the entire car can be unloaded without filling the receiving hopper. In other 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.

Air Pollution Sources, Emission Rates, and Effluent Properties

Except for barge and ship unloading and loading operations, the country elevator includes the same operations as a terminal elevator, only on a smaller scale and with a slower rate of grain movement. The air pollution problems of both types of elevators are similar and they will be discussed in this section.

The main particulate emission sources in grain elevators are:

1. Grain unloading
2. Grain loading
3. Grain dryers
4. Grain cleaning
5. Garner and scale bins
6. Elevator legs

7. Transfer points

8. Bin vents

Table 81 presents data on rates of emission of dust from grain-handling and processing operations at terminal and country elevators.[36,37] The emission rates shown in Table 81 are based on limited data and should be considered as indications of potential emissions and not absolute values.

Table 81. PARTICULATE EMISSIONS FROM GRAIN HANDLING AND PROCESSING (lb/ton of grain processed)

Emission Source	Lb/Ton Processed	Range of Emissions (lb/ton)
1. Terminal elevators		
Shipping or receiving		
Rail	1	(1 - 3)
Truck	1.4	(0.8 - 3.5)
Barge	1.2	(1 - 3.5)
Transferring, conveying, etc.	2.0	(2 - 2.5)
Screening and cleaning	5.0	(5 - 7)
Drying	5.5	(4 - 8)
2. Country elevators		
Shipping or receiving		
Rail	4	(3 - 8)
Truck	4.5	(2 - 8)
Barge	5.5	(3 - 8)
Transferring, conveying, etc.	3.5	(2 - 4)
Screening and cleaning	8.5	(7 - 10)
Drying	7.5	(4 - 8)

The amount of dust emitted during the various grain-handling operations depends upon the type of grain being handled, the quality or grade of the grain, the moisture content of the grain, the speed of the belt conveyors used to transport the grain and the extent and efficiency of dust contaminant systems (i.e., hoods, sheds, etc.) in use at an elevator. Many of these factors have not been studied in sufficient detail to permit the delineation of their relative importance to dust generation rates.

Part of the dust liberated during the handling of grain at elevators gets into the grain during the harvesting operation. This dust "follows" the grain to the country elevator and maybe to a terminal elevator or two and then to the final processing point. Appendix A presents a brief discussion of some modifications to harvesting techniques that could reduce the quantity of dust entering the grain during harvesting.

Grain dust emitted from these sources is composed of ~ 70% organic material, about 17% free silicon dioxide, and specific materials in the dust include particles of grain kernels, spores of smuts and molds, insect debris, pollens, herbicides, and field dust. Grain dust suspended in the air in the interior of grain elevators consists mostly of highly dispersed particles measuring < 5 μm in diameter.

Dust emitted from grain and feed industry operations may cause irritation of skin or eyes and respiratory ailments can be caused by inhalation of particulates of <5 μm in diameter.

At normal low ambient particulate concentrations (< 100 $\mu g/m^3$) no evidence exists for adverse effects to healthy people from grain and feed emissions. However, people having preexisting respiratory disorders may be affected or disabled by rapid increases above the seasonal mean concentration of particulate grain dust. Appendix B presents a review of current knowledge of the health effects of effluents from grain and feed industry operations.

It is a general practice in grain elevators to duct many of the individual dust sources to a common dust collector system. This is particularly true of dust sources in the headhouse. Thus, aspiration systems serving elevator legs, transfer points, bin vents, etc., may all be ducted to one collector in one elevator and to two or more individual systems in another. Because of the myriad possibilities for ducting, it is nearly impossible to characterize a "typical" grain elevator from the standpoint of delineating the exact number and types of air pollution sources.

Furthermore, many transfer points and bin vents do not emit dust externally to the elevator, but rather emit dust to the interior of the elevator. When the latter situation exists, the dust presents a housekeeping, working environment, or safety problem more than an air pollution problem.

However, it should not be inferred that a building can be considered as a suitable air pollution control system.

The many variations in elevator operating practices mean that only a generalized picture of potential emission sources can be presented. A specific elevator would require a survey of emission sources before its air pollution potential could be accurately described. Specific grain handling operations are discussed in the following sections. Each operation is treated as an individual source with no consideration of common ducting or external-internal venting options.

Grain Unloading - Elevators in the U.S. receive grain by truck, railroad hopper car, railroad boxcar and barge. The two principal factors that contribute to dust generation during bulk unloading are wind currents and dust generated when a falling stream of grain strikes the receiving pit. Falling or moving streams of grain inspirate a column of air moving in the same direction. When this moving mass of grain strikes an immovable object, the energy expended causes extreme air turbulence and a violent generation of dust occurs. This undesirable situation occurs when trucks and railcars are dumped into deep hoppers and also when railcars and the holds of ships are loaded.

Grain unloading is an intermittent source of dust occurring only when a truck or car is unloaded. It is a predominant source during the harvest season and declines sharply or is nonexistent during other parts of the year. Air pollution problems associated with each mode of grain unloading are discussed in the following sections.

Truck unloading - Trucks, except for the gondola (hopper) type, are generally unloaded by the use of some type of truck dumping platform. Gondola trucks discharge through the bottom of the trailer. Elevators are often designed with the truck unloading spot located in a drive-through tunnel. These drive-through areas are sometimes equipped with a roll-down door on one end, although, more commonly they are open at both ends so that the trucks can enter and leave as rapidly as possible. This drive-through access acts as a "wind-tunnel" so that the air is usually blowing through this tunnel at speeds greater than the wind in the open areas away from the elevator. The wind tunnel effect aggravates the dust problem and makes it more difficult to contain and capture the dust.

The unloading pit at a grain elevator generally consists of a heavy grate $\sim$ 10 ft x 10 ft through which the grain passes as it falls into the receiving hopper. This hopper will often be partially filled with grain as the truck unloads because the conveyor beneath the pit does not carry off the grain as fast as it enters.

The dust-laden air, which is emitted by the truck unloading operation, results from the displacement of air out of the hopper plus the aspiration of air caused by the falling stream of grain. The dust itself is comprised of field dirt and grain particles. The quantity of dust generated during unloading is largely a function of the type of grain and its moisture content; soybeans and milo being considerably more dusty than corn or wheat.

Table 82 presents recently obtained data on emission rates from grain receiving operations at grain elevators. All the data reported in Table 82 were obtained by various EPA contractors using EPA approved test methods for particulate emissions (EPA Methods 1 and 5).

At Elevator A which is a transfer or subterminal elevator, emissions were measured at the outlet of the control systems serving a truck dump pit and the associated receiving belt and leg boot. Corn was received in loads ranging from 13,000 lb to 56,000 lb each. Two receiving hoppers are enclosed by a common shed with bifold doors at the entrance to each receiving bay. Only one hopper was used during the testing program. The bifold doors were closed behind each truck before it was dumped. The grate over the hopper is about 14 ft x 16 ft with swinging baffles underneath to reduce the open area. The receiving belt system aspirates dust from the point where the hopper discharges grain onto the receiving belt and where the belt discharges into the boot of the truck receiving leg.

Emissions from a truck dump pit were also measured at Elevator B. Elevator B is a storage elevator associated with a soybean processing plant. The truck dump grating is covered by a building; however, there are no doors on either end. The hopper grate is baffled and 6,000 cfm of air is exhausted from each side of the hopper. During the dumping of the trucks, visible emissions were detectable in some instances from the lip of the truck bed as the beans were discharged into the receiving hopper. These emissions varied from 0 to 10-20% opacity depending on the dirtiness of the grain, the type of opening at the end of the truck where the beans were discharged, and the velocity of the wind through the dump building.

Table 83 presents the results of emission measurements conducted for a grain processing plant by an Ohio consulting firm. EPA approved test methods for particulate emissions were used for the measurements. Tests were conducted during periods of peak unloading of wheat in order to determine maximum emission rates.[3/] The truck unloading system is vented through Day Dual-Clone Cyclones which pick up dust from below the dump grates. These cyclones emitted a total of 2.6 lb/hr while unloading an average of 508,000 lb of grain per hour. This relatively low emission rate from the cyclones was partly due to the copious amounts of dust which escaped the dust collection system. This dust was generated near the tail gate of the truck during dumping, and was quickly blown away by the wind. Estimates of the quantity of this dust have been made by grain industry personnel and vary from 0.8-2 lb/ton of grain.

Table 82. MEASURED EMISSION RATES FOR GRAIN RECEIVING AND HANDLING OPERATIONS

Elevator	Source	Equipment Tested	Grain Handled	Process Rate (tons/hr)	Dust Loading At Inlet of Equipment (gr/scf)	Dust Loading At Inlet of Equipment (lb/ton)	Dust Loading At Outlet of Equipment (gr/scf)	Dust Loading At Outlet of Equipment (lb/ton)	Visible Emissions
A	Truck dump pit aspiration	Carter day 72 RJ 50 CD filter 55 H fan w/30 hp motor 13,270 cfm	Corn Average moisture content - 14.5% Average FM content - 1.4-1.8%	251 171 190	Not Measured "	Not Measured "	0.0055 0.0026 0.0022	0.0025 0.0017 0.0013	None
	Truck dump receiving belt and receiving leg boot	Carter day 24 RJ 72 CD filter 35 H fan w/15 hp motor 5,000 cfm	Corn Average moisture content - 13.9-14.5% Average FM content - 1.3-2.0%	240 290 339	"	"	0.0021 0.0017 0.0006	0.0005 0.00032 0.00008	None
B	Truck dump pit aspiration	Kice, model S100-10, reverse jet filter 30 hp fan	Soybeans Moisture content - 8.7-14.4% FM content - 0.2-4.5%	73 84	" "	" "	0.0090 0.0032	0.012 0.0032	None None

Table 83. EMISSIONS FROM GRAIN UNLOADING OPERATIONS, ELEVATOR C (WHEAT ONLY)3/

Emission Sources	Grain Unloaded Weight (1,000 lb/hr[a/])	Gas Flow scfm[b/]	Emissions (gr/scf)	Emissions (lb/hr)	Emission Factor (lb/ton)	Emission Factor (lb/bu)
I. Truck Unloading						
1. Cyclone exhaust (Unit No. 1)	-		0.019	1.4	0.01	$0.31x10^{-3}$
2. Cyclone exhaust (Unit No. 2)	508	17,890	0.016	1.2		
3. Fugitive dust	-	-	-	100[d/]	0.40	0.012
Total Truck Unloading	508			102.6	0.41	0.0123
II. Rail Car Unloading						
1. Cyclone exhaust (Unit No. 3)		7,421	0.059	3.7	0.012	$0.36x10^{-3}$
2. Cyclone exhaust (Unit No. 4)	623	7,137	0.057	3.5	0.011	$0.34x10^{-3}$
3. Cyclone exhaust (Unit No. 5)		9,774	0.335[c/]	28.3[c/]	0.091	$2.7x10^{-3}$
4. Fugitive Dust		-	-	15[d/]	0.048	$1.4x10^{-3}$
Total Rail Car Unloading	623			50.5	0.16	$4.8x10^{-3}$

a/ Based on 60 lb/bu.
b/ Standard cubic feet per minute corrected to 70°F and 14.7 psia.
c/ Calculated value after deducting 2.9 lb/hr attributed to turning grain only.
d/ Estimated emission - approximate values only.

Due to the relatively clean wheat handled at this operation and based on observation of the unloading process, an emission factor for the amount of fugitive dust escaping during unloading was selected which is somewhat lower than the published value; namely, 0.4 lb/ton. This is equivalent to ~ 100 lb/hr when unloading 508,000 lb/hr.[3]

Emissions from cyclones and an experimental filter (CAM-VAC) used to control emissions from other truck unloading stations are presented in Table 84. Information was not provided on the configuration of the receiving pits at these elevators. Particulate sampling trains utilizing Hi-Vol samplers were used to obtain the data shown in Table 84. At Elevator D, the tests were conducted in accordance with procedures as outlined in ASME Power Test Code 27. Two Rader Hi-Volume samplers were used to determine the simultaneous particulate loading to and from the cyclone. Extensions were added to the cyclone exhaust to provide a sampling location ~ 10 diameters downstream from bends and two diameters from the duct discharge.[38]

At Elevator E, a series of efficiency tests were conducted on an experimental filter system (CAM-VAC) installed downstream from a cyclone unit used to control dust emissions from the truck unloading station. The CAM-VAC filter is a high velocity fabric filter originally designed for use as a control system for grain dryers and the tests conducted at Elevator E were the first attempts to assess its capability in other dust control functions. Dirty air enters the plenum chamber of the CAM-VAC unit and is exhausted through a filter media backed by a screen. The filter media form a half circle having a perimeter of about 15 ft and is about 3 ft wide, which is equivalent to 45 ft^2 of filter surface. If the unit operates with one fan at 9,000 cfm, the air-to-cloth ratio would be 180 cfm/ft^2. The inside surface of the filter media is cleaned by a vacuum head which moves up and down the semi-circle of filter media. This vacuum head exhausts through a blower and cyclone.

The particulate sampling train used at Elevator E employed a Unico 500 Hi-Vol sampler. The nature of the test situation at the elevator did not allow complete adherence to any formally recognized test procedure. Inasmuch as actual dust loading could be maintained in the ducts only for a period of 1-2 min at a time, it was necessary to sample only at one traverse point location for each test.[38]

At Elevator F, particulate emission tests were performed on the exhaust gases of two CAM-VAC units in series. A 30-in. I.D. duct was extended to within 5 ft of the ground for these tests. Duplicate tests were performed with a sampling train using a Rader Hi-Volume sampler in accordance with ASME Test Code 27.[38]

Emission testing at Elevator G was conducted using procedures specified by ASME Test Code 27 and a regular particulate sampling train.[38]

Table 84. EMISSIONS FROM TRUCK UNLOADING STATIONS[38/]

Elevator	Source	Equipment Tested	Test Method	Test Location	Gas Flow (scfm) Inlet	Gas Flow (scfm) Outlet	Emissions Inlet (gr/scf)	Emissions Inlet (lb/hr)	Emissions Outlet (gr/scf)	Emissions Outlet (lb/hr)	Grain Unloaded (lb)	Emission Factor (lb/ton)
D	Truck dump pit	Cyclone	ASME Test Code 27, Hi-Volume samplers used to determine particulate loading.	Inlet and outlet	9,044	9,156	0.821	63.8	0.05	4.1	Corn (no weight given)	
				" " "	9,044	9,156	0.768	60.0	0.046	3.6		
E	Truck dump pit	Cyclone - CAM-VAC in series	ASME Test Code 27, Hi-Volume samplers used to determine particulate loading.	Cyclone inlet	8,376	--	2.23	160.0	--		Corn (no weight given)	
				CAM-VAC inlet and outlet	9,331	8,614	0.045	3.56	0.0046	0.34		
				CAM-VAC inlet and outlet	9,331	8,614	0.034	2.68	0.0017	0.12		
				CAM-VAC inlet and outlet	9,331	8,614	0.0078	0.62	0.004	0.30		
F	Truck dump pit	Double CAM-VAC unit	ASME Test Code 27, Hi-Volume samplers used to determine particulate loading.	CAM-VAC outlet		12,435			0.0167	1.77	98,520 (corn) 2% foreign material, 14-14.7% moisture	0.036
				CAM-VAC outlet		12,435			0.018	1.90	82,580 (corn) 1-2% foreign material, 14.2-15.9% moisture	0.046
G	Truck dump pit	Cyclone, Salina Model 5208-248 14,125 cfm	ASME Test Code 27, Hi-Volume samplers used to determine particulate loading.	Cyclone outlet		14,125			0.09	11.2	525,000 (corn) 178,000 (soybeans)	0.032

Table 85 presents limited emission data for a cyclone system serving a truck dump at another elevator.[7/] The data in Table 85 were provided by one elevator that responded to the emissions inventory questionnaire. The fan discharges to two identical parallel cyclones, but the emissions from only one cyclone were tested. Test procedures specified by ASME Test Code 27 were used. No information was provided regarding the grains handled, the configuration of the receiving pit, or the position of the dust pickup.

Table 86 summarizes the results of the emission testing reported in Tables 82 to 85. Inspection of the data in Table 86 shows that the standard fabric filter system is generally the most efficient control system. However, based on limited testing, a control system incorporating a cyclone and CAM-VAC in series appears to provide performance equivalent to the standard fabric filter.

Hopper car unloading - A hopper car can be unloaded with minimal dust generation if the material is allowed to form a cone around the receiving grate (i.e., choke feed to the receiving pit). This situation will occur when either the receiving pit or the conveying system serving the pit are undersized in comparison to the rate at which material can be unloaded from the hopper car. In such cases, dust is generated primarily during the initial stage of unloading, prior to establishment of the choked-feed conditions. Dust generated by wind currents can be minimized by the use of a shed enclosed on two sides with a manual or motorized door on one end.

Boxcar unloading - There are three methods used for unloading grain from boxcars and all present air pollution problems. The most common 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. This produces a surge of dust as each scoop is dumped out the car door into the receiving pits.

The other common boxcar unloading method, used mainly by terminal elevators, is a mechanical car dump which clamps the car to a movable section of track and rotates and tilts the car to dump the grain out of the car door into a receiving pit. This is a rapid method of unloading that creates a large surge of dust in a manner which makes it very difficult to efficiently capture the emissions.

Another boxcar unloading method, which is infrequently used, employs a movable screw conveyor which is inserted into the car to draw the grain out of the car door in a continuous stream.

Table 85. EMISSION DATA FOR CYCLONE SYSTEM SERVING A TRUCK DUMP

	Fan Inlet	Cyclone No. 1 Outlet
Grains/acf	0.438	0.0505
Grains/scf (dry)	0.465	0.0523
Grains/scf (wet)	0.454	0.0511
Material rate (lb/hr)	75.6	4.6
ACFM	20,100	10,600
SCFM dry	19,000	10,200
Temp °F	67	67
Cross section (ft^2)	5.95	7.06

Notes

Fan discharges to two identical parallel cyclones.

Cyclone No. 1 outlet tested concurrently with fan inlet.

Pitot traverses taken at both cyclone inlets.

Trucks being unloaded at maximum unloading rate. Various commodities were being unloaded.

Opacity of discharge varied over a range judged to be equal to Ringlemann 0 to 1-1/2 depending on commodity, truck unloading rate and material transfer rate.

Particle size of material collected at the fan inlet varied from 2 to 150 μm, with an abundance of fiberous material in the 100-150 μm size range.

Particle size of material collected at the cyclone discharge varied from 2 to 50 μm for nonagglomerated material. Most material observed (74%) had a micron size of 6 to 24 μm.

Table 86. SUMMARY OF EMISSION MEASUREMENTS ON TRUCK RECEIVING PITS AT GRAIN ELEVATORS

Control System	Test Method	Grain Handled	Range of Dust Loadings at Outlet of Control System (gr/scf)	(lb/ton)
Fabric filter	EPA Method 5	Corn, soybeans	0.002-0.009	0.001-0.01
Cyclone	EPA Method 5	Wheat	0.01-0.02	0.01
Cyclone	ASME Test Code 27	Corn, soybeans	0.05-0.09	0.03
Cyclone + CAM-VAC	--	Corn	0.002-0.005	--
Two CAM-VAC units in series	ASME Test Code 27	Corn	0.016-0.018	0.036-0.05

Table 83 presents data on emissions from cyclone dust collector systems handling railcar unloading operations. EPA Method 5 procedures were used to obtain the emission data. The enclosure around this operation was more effective than that at the truck dump area at the same elevator and reduced the amount of fugitive dust.[3] The greatest emission source was Cyclone No. 5 which vented the No. 1 elevator leg. This leg receives the unloaded grain from a conveyor belt. Cyclone No. 5 emitted 28.3 lb/hr from the unloading only. Cyclones Nos. 3 and 4 vented the car dump pit and emitted an average of 3.7 and 3.5 lb of dust per hour, respectively.[3]

Fugitive dust from railcar unloading was estimated using an emission rate of 0.8 lb/ton of grain. This is equivalent to 250 lb of dust for the 623,000 lb of grain unloaded in an hour. However, visual evaluation indicated that the dust collection system picked up most of this, and it was estimated that only 15 lb/hr of dust escaped from the car unloading.[3]

Barge and ship unloading - Dust emitted during barge and ship unloading is relatively small in quantity in comparison with railroad car and truck unloading. In most cases, the barges are unloaded by means of a retractable bucket type elevator that is lowered into the hold of the barge. There is some generation of dust in the hold as the grain is scooped out and also at the top of the leg where the grain is discharged onto the transfer belt. This latter source is more appropriately designated a transfer point.

A system used for unloading grain received by barge at an elevator on the Mississippi River was tested by an EPA contractor to determine dust emissions. The results of the tests are presented in Table 87. The data presented in Table 87 were obtained using EPA Method 5 procedures. At this elevator, barges are unloaded with a bucket elevator consisting of two belts of large buckets similar to those used in coal mining. The buckets move slowly compared with the typical link belt system used for grain handling. Approximately 25 tons of grain are removed from the barge per minute. The dust collector for the link belt system aspirated dust from the grain hopper, and from two conveyor belt transfer points. It appears that little dust was generated in the barge by the bucket elevator. Most of the dust was generated when the grain emptied from the buckets into the hopper bin and at the next conveyor belt transfer points. The total pickup efficiency of the dust aspiration system appeared to be 75%. Visible emissions of fugitive dust around the link belt were about 30% opaque.

Grain Loading - The loadout of grain from elevators into railcar, truck, barge or ship is another important source of particulate emissions and is difficult to control. Gravity forces are usually used to load grain with the grain being drawn from bins above the loading station or from the scale in the headhouse. The main causes of dust emission when loading bulk

Table 87. MEASURED EMISSION RATES FOR BARGE UNLOADING OPERATIONS (EPA Sampling Program)

Source	Equipment Tested	Grain Handled	Process Rate (tons/hr)	Dust Loading at Inlet of Equipment (gr/scf)	Dust Loading at Inlet of Equipment (lb/ton)	Dust Loading at Outlet of Equipment (gr/scf)	Dust Loading at Outlet of Equipment (lb/ton)	Visible Emissions
Link belt system, river barge unloading	Aerodyne 96 bag HPE filter, Model No. 41096.12 reverse jet cleaning 125 h.p. fan, 25,000 cfm	Corn	1,500	Not measured		0.0045	0.00055	75% pickup of dust, fugitive dust 30% opacity
Link belt system, river barge unloading	Aerodyne 96 bag HPE filter, Model No. 41096.12 reverse jet cleaning 125 h.p. fan, 25,000 cfm	Wheat	1,290	Not measured		0.0067	0.0009	75% pickup of dust, fugitive dust 30% opacity
	Aerodyne 96 bag HPE filter, Model No. 41096.12 reverse jet cleaning 125 h.p. fan, 25,000 cfm	Wheat	1,600	2.04	0.21	Not measured		

grain by gravity into trucks or railcars is the wind blowing through the loading sheds and dust generated when the falling stream of grain strikes the truck or railcar hopper. The grain leaving the loading spout is often traveling at relatively high velocity and generates a considerable amount of dust as the grain is deposited in the car or truck.

Most country elevators do not have any dust collection system installed on these sources and in many cases, the loading stations are not covered or enclosed except for the drive-through tunnel. The loading operations in terminal elevators are often enclosed for weather protection, but few have attempted to collect the emissions that occur during loading.

Dust emitted during loading of barges and ships can be quite significant but very difficult to control. The openings for the holds in these vessels are large, making it very hard to effectively capture the emissions. For this reason, most elevators have not as yet attempted to control this particular source.

Grain Dryers - When the grain received at the elevator has a moisture content higher than that at which grain can be safely stored, then it must be dried within a few days after receipt. Although many grains may require drying under certain conditions, corn is the grain that usually necessitates the use of the dryers. When corn is received, it may contain 20% moisture or more, and must be dried to 13-14% moisture to be suitable for storage.

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. Effluent from a corn dryer may consist of 25% beeswing, which has a specific gravity of about 0.70-1.2.

The rate of emission of particulates from grain dryers is primarily dependent upon the type of grain, the dustiness of the grain, and the dryer configuration (rack or column type). Field run soybeans usually create the greatest visible emission. However, during corn drying the characteristic "beeswing" is emitted along with normal grain dust. Essentially, all beeswing emissions are over 50 μm in diameter and the mass mean diameter is probably in the region of 150 μm. In addition to the beeswings, the dust discharge from grain dryers consists of hulls, cracked grain, weed seeds, and field dust. Approximately 95% of the grain dust is larger than 50 μm.

Rack or column type dryers are usually employed to dry grain at elevators. Figure 7 presents schematic diagrams of both types of units. A new type of column dryer, the recirculating unit, has recently been introduced to the market. In the recirculating unit, a portion of the air used to dry the grain is continuously recycled. Approximate air flow requirements for the dryers are:

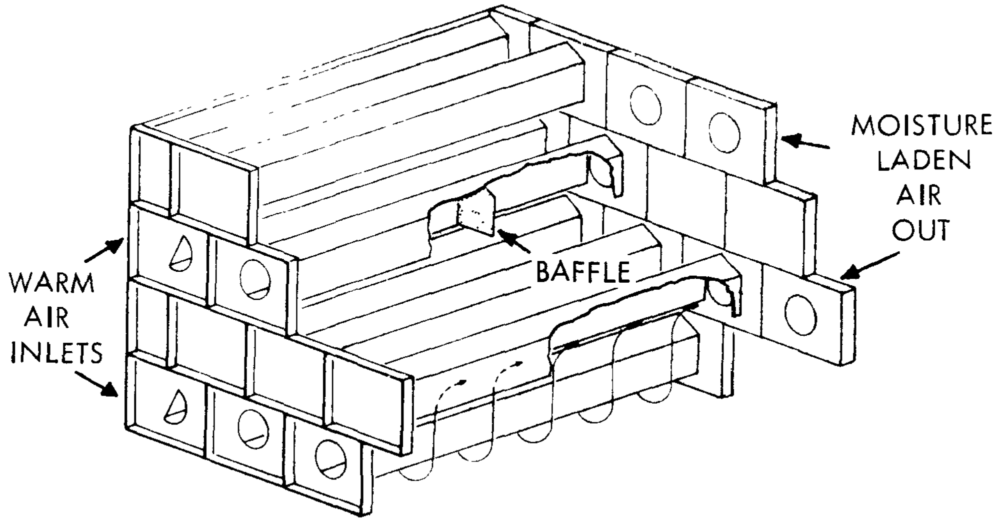
Column dryer - 100 acfm/bu/hr
Rack dryer - 70 acfm/bu/hr
Recirculating dryer (column) - 30 acfm/bu/hr

Column dryers have a lower emission rate than rack dryers since some of the dust is trapped by the column of grain. In order to control the dust which is emitted from the columns, it is necessary to build an enclosure. This enclosure also serves as a relatively inefficient settling chamber. In rack dryers, the emission rate is higher since the turning motion of the grain generates more beeswings and the design facilitates dust escape. The rack dryer is exhausted only from one or two points and is thus better suited for control device installation.

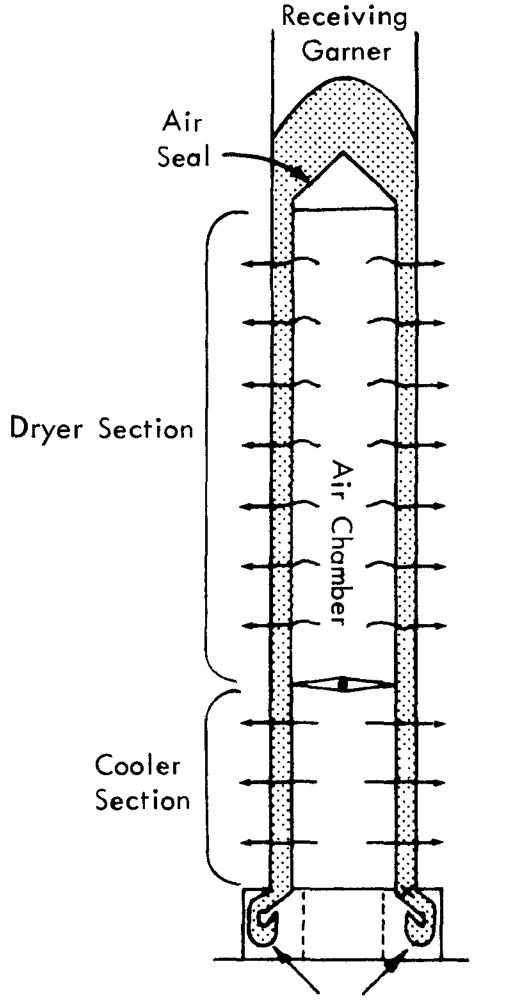
A quantitative assessment of emissions from grain dryers is difficult because of the absence of an acceptable test method. Available data on emissions from grain dryers are discussed in the following paragraphs. Because of the lack of an acceptable test method, the data available should be considered as indicative of probable emission levels and not absolute numbers.

The results of emission tests conducted by an EPA sampling team on a grain dryer in Colorado are summarized in Table 88. The equipment tested at the elevator was an Aeroglide rack dryer (Model 2010 CGLH) equipped with a Wiedenmann Screen Kleen control system. The Wiedenmann unit consists of a 14-ft diameter, metal, 34 mesh screen and its supporting framework. Chaff and beeswings collected by the Screen Kleen are vacuumed off the screen and recollected by a cyclone. Material that settles inside the screened enclosure is occasionally shoveled out onto the ground.

An Aeroglide Model 2010 CGLH rack dryer is designed to dry 1,000 bu/hr on a drying and cooling mode. The dryer was operated at 2,750 bu/hr during the tests. The 14-ft diameter exit was traversed in two directions 90 degrees apart and 12 points were sampled 5 min each. A total of 3-1 hr tests were run. The tests were performed with a 25.5 cfm hi-vol sampling train. Based on the average emission rate of 98.3 lb/hr and the drying rate of 2,750 bu/hr, a controlled emission factor of 1.3 lb/ton was calculated for this dryer.



(a) Rack Dryer



(b) Column Dryer

Figure 7. Schematic diagram of column and rack grain dryers.

Table 88. EMISSIONS FROM AEROGLIDE RACK DRYER CONTROLLED BY WIEDENMANN SCREEN KLEEN[39]

Test Run	Material Dried[a]	Drying Rate (bu/hr)	Natural Gas Use (ft^3/hr)	ACFM[a]	scfm	Isokinetic (%)	Emission gr/DSCF	Rate (lb/hr)
1	No. 4 yellow corn	2,750	52,000	80,990	63,740	98.9	0.223	116.5
2	No. 4 yellow corn	2,750	52,000	84,100	66,185	93.7	0.144	78.1
3	No. 4 yellow corn	2,750	52,000	84,100	66,185	90.1	0.185	100.3
			Average	83,000	65,400		0.184	98.3

a/ Corn dried from 19% moisture to 15% moisture.

Table 89 summarizes emission tests conducted by an EPA contractor and an EPA sampling team on a Hess rack dryer controlled with a DAY-VAC dust filter, Model 2-6, equipped with 12 (100 mesh) polyester screens. The DAY-VAC unit consists of twelve, 2 ft by 2 ft 100-mesh, polyester screens which filter particles from the air passing through it. A vacuum head travels up and down the face of the screen to suck off dust collected there. New screens were installed about 3 weeks prior to the emission tests.

Particulate emission measurements were performed using the EPA Method 5 sampling train and a 25.5 cfm hi-vol sampling system. The hi-vol train and one EPA Method 5 train were stationary and side by side. One EPA Method 5 train traversed the exit of the filter face.

As shown in Table 89, controlled emission factors for the series of tests ranged from 0.1 to 0.38 lb/ton of material dried.

The State of Illinois Institute for Environmental Quality has conducted a series of tests of particulate emissions from grain dryers using the UOP sampling train and the Joy Manufacturing Company--EPA sampling train.[41] Table 90 summarizes the results of the testing program.

At Elevator A, the Aeroglide rack dryer operated continuously during the testing, drying corn, at the rate of 1,033 bu/hr. Tests 1 and 2 were performed using UOP sampling units equipped with cloth fabric filter bags to catch the small particles and jars prior to the filter bags to catch the beeswings and larger particles. Test 3 was conducted with the Joy Manufacturing Company--EPA unit which was equipped with a heated filter assembly and an impinger train.

At Elevator B, an Aeroglide rack dryer equipped with a Wiedenmann Screen Kleen unit (50 mesh screen) was tested. The dryer operated smoothly during the testing periods except for one malfunction that required a shut-down during one test period. Corn was cleaned with two Scalperators in parallel and dried at the rate of 4,000 bu/hr. Tests 1 and 2 were performed with the UOP sampling train. The first test had to be aborted half way through due to a malfunction of the dryer equipment. The second test went very smoothly. Tests 3 and 4 were performed using a Joy Manufacturing Company--EPA sampling unit. Test No. 2 is believed to be the most reliable test giving an accurate indication of the emission rate. Test No. 1 was only a half of a complete traverse and the results had to be extrapolated.[41]

Two things are evident from the data in Table 90. First the Joy-EPA sampling unit consistently gives lower results than the UOP sampling units. Second, compared on the number of tons or bushels dryed per hour, the 50 mesh screen dryer installation has approximately 78% fewer emissions than the uncontrolled dryer installation.

Table 89. EMISSIONS FROM HESS RACK DRYER CONTROLLED BY DAY-VAC DUST FILTER[40]

Test[a,b,c] No.	Site	Material Dried[d]	Drying Rate (bu/hr)	Stack Gas Parameters: Velocity[e] (AFPM)	Stack Gas Parameters: Temperature (°F)	Stack Gas Parameters: Moisture (%)	Stack Gas Parameters: Volume (DSCFM)	Particulate Emissions: Concentration Gr/DSCF Front Half	Particulate Emissions: Concentration Gr/DSCF Total	Particulate Emissions: lb/hr Front Half	Particulate Emissions: lb/hr Total	Particulate Emissions: lb/ton Front Half	Particulate Emissions: lb/ton Total
1-A	Screen face	No. 2 white corn, 2.5% cracked corn	1,000	255.3	102.0	4.76	42,555	0.0214	0.0288	7.80	10.50	0.279	0.375
1-B	Screen face	and foreign material	1,000	255.0	105.2	2.93	43,074	0.0044	0.0226	1.62	8.34	0.0568	0.298
2-A	Screen face	No. 2 white corn, 2.5% cracked corn	1,000	251.3	89.6	2.46	43,875	0.0097	0.0171	3.65	6.43	0.130	0.230
2-B	Screen face	and foreign material	1,000	255.7	108.0	3.05	42,937	0.0049	0.0099	1.80	3.64	0.0643	0.130
3-A	Screen face	No. 2 white corn, 2.9% cracked corn	1,500-2,000	255.8	118.4	2.23	43,181	0.0049	0.0117	1.78	4.33	0.0424	0.103
3-B	Screen face	and foreign material	1,500-2,000	257.9	125.8	3.16	42,558	0.0052	0.0119	1.90	4.34	0.0443	0.103
Hi-Vol 1	Screen face	Same as 1-A and 1-B	Same as 1-A and 1-B	238.0	102.0	4.8	39,615	0.0011		0.38		0.0136	
Hi-Vol 2	Screen face	Same as 2-A and 2-B	Same as 2-A and 2-B	236.6	90.0	2.5	41,216	0.0033		1.22		0.0436	
Hi-Vol 3	Screen face	Same as 3-A and 3-B	Same as 3-A and 3-B	325.9	118.0	2.2	55,124	0.0044		2.09		0.0498	

a/ 1,2,3 - A - Stationary EPA Method 5 train.
b/ 1,2,3 - B - Traversing EPA Method 5 train.
c/ Hi-Vol tests were stationary.
d/ In Tests 1-A and 1-B corn was dried from 18% to 13% moisture; in Tests 2-A and 2-B corn was dried from 18% to 13% moisture; in Tests 3-A and 3-B corn was dried from 14.9% to 13% moisture.
e/ Hot wire anemometer readings indicated a range of 140 to 280 fpm across the control device exit, but it also indicated a wide variance (± 50 to 100%) at each individual point. For these and other reasons a constant sampling rate equivalent to a stack velocity of 250 fpm was employed during the test.

Table 90. SUMMARY OF GRAIN DRYER EMISSION TEST CONDUCTED FOR ILLINOIS INSTITUTE FOR ENVIRONMENTAL QUALITY[41]

Elevator	Dryer Type	Drying Rate (bu/hr)	Test Number	Test Method	Total Gas Flow (cfm)	Particulate Emissions gr/scf	lb/hr	lb/bu dried	lb/ton dried
A	Aeroglide rack dryer, no control system	1,033	1	UOP Sampling train	84,600	0.158	112	0.11	3.9
			2	UOP Sampling train	84,600	0.146	106	0.10	3.6
			3	Joy-EPA Sampling train	88,015	0.0415	29	0.028	1.0
B	Aeroglide rack dryer, Wiedenmann Screen Kleen unit, 50 mesh screen	4,000	1	UOP Sampling train	256,150	0.0444[a]	91[a]	0.023	0.82
			2	UOP Sampling train	256,150	0.0456	94	0.024	0.86
			3	Joy-EPA Sampling train	302,330	< 0.0019	< 4.5	0.0011	0.039
			4	Joy-EPA Sampling train	330,400	< 0.0019	< 4.9	0.0012	0.043

a/ Extrapolated from one-half test.

Evaluating the test results from both locations, it is evident that the Joy-EPA sampling train consistently gives lower results than the UOP train. A number of factors may contribute to this. The cross-sectional area of the nozzle and tube is constant from the nozzle through the tube to the cyclonic separating device in the UOP sampler, while in the Joy-EPA sampler, the nozzle area does not equal the cross sectional area of the probe. This means that there will be a velocity reduction in the probe of the Joy-EPA sampler and particulate matter may settle out to some degree. This is important because the Joy-EPA sampler probe is quite long and difficult to clean thoroughly.[41/]

Any loss of particulate catch is magnified by the fact that the Joy-EPA sampler is a low volume unit. It is designed to pull only about 1 cfm while the UOP samplers can pull much more than this, up to 5 to 10 cfm. The large sample volume capabilities of the UOP samplers reduce the chance and magnitude of errors that could be encountered with the small sample volumes that the Joy-EPA sampler is designed to handle. More sample volume means more particulates will be caught so that the loss of some particulate catch will produce an error of a much smaller magnitude than that produced when a smaller volume is sampled. For all these reasons, it is likely that the UOP sampler is better suited to the testing of grain dryers where large air flows are encountered and that the UOP sampler test results are more representative of the actual emission rates of the grain dryers tested.[41/]

Test results shown in Table 91, provided by the Aeroglide Corporation, indicate an uncontrolled emission rate of ~ 130 lb/hr or 2.3 lb/ton dried for a 2,000 bu/hr corn dryer.[4/] Details of the test procedure were not reported.

Table 92 summarizes results of determinations of emissions from a Zimmerman Continuous Flow Dryer, Model 8AP-1200, being used to dry corn. An emission rate of about 6.2 lb/hr was determined from these tests. The results of two particulate emission tests conducted on the exhaust gases of a Mathews Company Model 900 grain dryer (column dryer) are presented in Table 93. Corn was the grain being processed at the time of the tests. A Rader Hi-Volume Sampler was used to conduct the tests reported in both Tables 92 and 93. Sampling procedures of the ASME Power Test Code 27-1957 were followed during the tests.[5/]

Table 94 presents results of emission tests on a Berico Industries Turn-Flo Dryer.[6/] Soybeans were being dried during the time the emission tests were conducted. Details of the test procedures and characteristics of the grain (i.e., percent foreign matter, moisture) were not available.

Table 91.[4/] DUST EMISSION TEST ON 2,000 BU/HR AEROGLIDE RACK GRAIN DRYER

	Screen House Conditions
Gas temperature (dry) °F	92
Gas temperature (wet) °F	61
Gas density at conditions (lb/ft^3)	0.07184
Gas velocity (ft/min)	2,910
Gas volume (cfm)	81,481
Grain loading at actual conditions ($grains/ft^3$)	0.1896
Grain loading at 70°F ($grains/ft^3$)	0.1975
Dust loading (lb/1,000 lb gas)	0.3771
Dust emission (lb/min)	2.207
Dust emission (lb/hr)	132.5

Table 92. SUMMARY OF RESULTS OF EMISSION TESTS ON ZIMMERMAN CONTINUOUS FLOW GRAIN DRYER

	Test 1	Test 2
I. Corn Data		
Moisture content before drying (% by weight)	23.1	24.0
Foreign matter before drying (% by weight)	1.2	1.5
Grain temperature before drying, °F	50	38
Moisture content after drying (% by weight)	13.6	18.8
Foreign matter after drying (% by weight)	1.7	Not available
Grain temperature after drying, °F	44-46	46
Through put in dryer, lb/hr	54,200	61,500
Through put in dryer, bu/hr	968	1,098
II. Emissions at Standard Conditions (32°F, 29.92 in Hg)		
Grain loading, $grains/ft^3$	0.0124	0.0168
Emission rate, lb/min	0.0875	0.1188
Emission rate, lb/hr	5.25	7.12
Emission rate, lb/ton	0.19	0.23
Beeswing collected, $grains/ft^3$	0.00003	0.000027
Beeswing collected, lb/min	0.00021	0.00019
Beeswing collected, lb/hr	0.01	0.01

Table 93. SUMMARY OF RESULTS OF EMISSION TESTS ON MATHEWS COMPANY MODEL 900 GRAIN DRYER[5]

	Test 1	Test 2
Exhaust gas volume, scfm	46,904	46,890
Particulate output[a] concentration, grains/scf	0.00636	0.00623
Mass emission rate, lb/hr	2.56	2.50
Process weight, bu/hr	400	400
Pounds/Hour[b]	22,400	22,400
Emission factor, lb/bu	0.0064	0.0063
Emission factor, lb/ton	0.23	0.23

Corn data: At the time of the tests, the dryer was processing the following corn.

	Inlet Corn	Outlet Corn
Percent moisture	21	15
Percent foreign matter	1	3

a/ Standard conditions of 70°F and 29.92 in Hg.
b/ 56 lb/bu.

Table 94. SUMMARY OF RESULTS OF EMISSION TESTS ON BERICO INDUSTRIES TURN-FLO DRYER[6]

I. Dryer Data

Grain processed: Soybeans
Dryer capacity: 2,000 bu/hr (187,600 cfm)
Control equipment: 2 Weidemann Screen Kleen Units (93,800 cfm per unit)

II. Test Results

Collection duration: 210 min
Total mass collected: 2.2 g
Sampling rate: 41 cfm

Dust emitted per screen: $\frac{(2.2)\ (93,800)}{(210)(41)} = 23.97\ \frac{g}{min}$

Total dust emitted from dryer: $(2)\ (23.97) = 47.94\ \frac{g}{min}$

Emission rate: $(47.94\ \frac{g}{min})\ (60\ \frac{min}{hr})\ (\frac{1}{454}\ \frac{lb}{g}) = 6.33\ \frac{lb}{hr}$

$= 0.11\ \frac{lb}{ton}$

A summary of available data on emission tests on grain dryers is presented in Table 95. Examination of the data in Table 95 indicates that the emission rates vary with dryer type, grain dried, and sampling techniques utilized in the testing. Uncontrolled emission rates range from 0.2 to 3.8 lb/ton of grain dried, while controlled emission rates vary from 0.04 to 0.84 lb/ton of grain dried. Because of the significant dependence of the emission rates on the sampling procedures, the data in Table 95 should only be considered as indicative of the general level of emissions from grain dryers.

Grain Cleaning - Grain cleaners are used in many grain elevators especially at terminal facilities. Equipment used to clean grain varies from simple screening devices to aspiration type cleaners. The simple screening devices remove large sticks, rocks, tools, and other trash, while the aspirators remove chaff and other light impurities.

Emission test data from initial grain cleaning operations at storage elevators at two flour mills are presented in Tables 96 and 97.[3/] Wheat is the grain being cleaned in both instances. Since the wheat received at flour mills generally has come from a terminal elevator where the grain may have been cleaned also, the data in Tables 96 and 97 probably represent the lower ranges of dust emission rates that would be expected at a grain elevator where the grain undergoes its first cleaning.

At the processing facility represented in Table 96, the three aspirator cleaners were served by cyclones and processed a total of 10,000 bu/hr in approximately equal portions during the test period. Emissions ranged from 0.04 to 0.11 lb/ton. No reason is apparent for this difference in supposedly identical processes.[3/] The unequal air flows in the three vent systems indicate that the damper settings were not the same, and this in turn could affect the amount of dust picked up. A cyclone also controlled emissions from the scalper at this mill. This cyclone emitted 4.8 lb/hr or 0.008 lb/ton when processing about 20,000 bu/hr.[3/]

At the second elevator, a cyclone is also used to control emissions from a grain cleaner. As shown in Table 97, emissions from the cyclone were measured as 1.46 lb/hr or 0.185 lb/ton of grain handled by the Carter cleaner.[6/]

Garner and Scale Bins - Both country elevators and terminal elevators are usually equipped with garner and scale bins for weighing of grain. A country elevator may have only one garner bin and scale bin. However, a terminal elevator might have as many as four separate scale and garner bin systems, each with a capacity on the order of 1,200 to 2,500 bu to process 35,000 to 75,000 bu/hr.

Table 95. SUMMARY OF AVAILABLE EMISSION TESTS ON GRAIN DRYERS

Dryer Type	Control System	Grain Processed	Drying Rate (bu/hr)	Sampling Method	Emission Rate (lb/bu)	Emission Rate (lb/ton)
I. Uncontrolled						
a. Aeroglide rack dryer	None	Corn	1,033	UOP sampling train	0.10	3.75
				Joy-EPA sampling train	0.028	1.0
b. Aeroglide rack dryer	None	Corn	2,000	Not specified	0.066	2.4
c. Zimmerman continuous flow, Model 8AP-1200	None	Corn	1,033	Rader hi-vol sampling train	0.005	0.19
d. Mathews Company Model 900 (column dryer)	None	Corn	400	Rader hi-vol sampling train	0.0064	0.23
II. Controlled						
a. Aeroglide rack dryer (Model Z010G GLH)	Wiedenmann Screen Kleen with 34 mesh screen	Corn	2,750	EPA hi-vol sampling train (25.5 cfm)	0.036	1.3
b. Aeroglide rack dryer	Wiedenmann Screen Kleen with 50 mesh screen	Corn	4,000	UOP sampling train JOY - EPA sampling train	0.024 0.001	0.84 0.04
c. Hess rack dryer	DAY-VAC dust filter	Corn, dried from 18% to 13% moisture	1,000	EPA Method 5 train (stationary)	0.006-0.01	0.23-0.38
		Corn, dried from 14.9% to 13% moisture	1,500-2,000	EPA Method 5 train (stationary)	0.002	0.10
		Corn, dried from 18% to 13% moisture	1,000	EPA Method 5 train (traversing)	0.0036-0.0083	0.13-0.3
		Corn, dried from 14.9% to 13% moisture	1,500-2,000	EPA Method 5 train (traversing)	0.002	0.10
d. Berico Turn-Flo dryer	2 Wiedenmann Screen Kleen units	Soybeans	2,000	Not specified	0.003	0.11

Table 96. EMISSIONS FROM GRAIN CLEANING[3]

Emission Source	Process Weight 1,000 lb/hr[a]	Gas Flow scfm[b]	Emissions Grains/scf	lb/hr	Emission Factor lb/ton	lb/bu
Cyclone on aspirator[c] (Unit No. 1)	200	9,040	0.081	6.2	0.062	1.86×10^{-3}
Cyclone on aspirator (Unit No. 2)	200	6,860	0.071	4.2	0.042	1.26×10^{-3}
Cyclone on aspirator (Unit No. 3)	200	8,900	0.143	10.9	0.109	3.28×10^{-3}
Cyclone on scalper	1,200	5,740	0.098	4.8	0.008	0.24×10^{-3}

a/ Based on 60 lb/bu (wheat).

b/ Standard cubic feet per minute corrected to 70°F and 14.7 psia.

c/ All cyclones are Day Dual-Clone units.

Table 97. EMISSIONS FROM GRAIN CLEANING OPERATIONS[6]

Item	Inlet	Exhaust
Grain cleaning rate (bu/hr)[a]	500	500
Process weight rate (lb/hr)[b]	30,000	30,000
Source gas volume (scfm)	3,330	3,330
Duct static pressure (in H_2O)		
At Cyclone	+ 1.0	- 16.0
At Fan	- 16.0	+ 0.2
Fan speed (rpm)	1,200	1,200
Dust concentration (gr/scf)	0.098	0.051
Dust emission rate (lb/hr)	2.78	1.46[c]
Emission factor (lb/ton)	0.185	0.098

a/ Carter cleaner handling 500 bu/hr, wheat.

b/ Computed as the product of the cleaning rate and the average bulk density of No. 1 heavy dark northern spring wheat (60 lb/bu).

c/ Cyclone operating at 3,330 cfm which is 39% of designed capacity of 8,500 cfm. Unusually high pressure drop across cyclone (17.0 in H_2O) indicates a restriction or improperly set damper between the pressure taps.

Dust is emitted from both the scale bin and garner bin whenever grain is admitted. The incoming stream of grain displaces air from the bin, and the displaced air entrains dust. In some cases, the bins are completely open at the top while others are enclosed, but vented to the surroundings.

Table 98 presents recently obtained emission data for a scale system at a terminal elevator. The data were obtained by an EPA contractor using EPA Method 5 procedures. The scale system aspirates dust from the conveyor belt discharge point, the first garner bin, the scale, the second garner bin, and the head of the conveyor to the elevator leg.

Elevator Legs - The "leg" in a grain storage facility is commonly a bucket elevator that receives the grain and elevates it to the top of the headhouse, where it is discharged to a distributor system. Many country elevators have only one leg, which may range in size from 2,500 bu/hr up to 10,000 bu/hr. Legs in a terminal elevator may each handle 30,000 bu/hr or more.

The top of the legs is generally vented or aspirated in order to relieve the air pressure and remove dust created by the motion of the buckets and the grain flow. It is also done in some cases as part of insurance requirements. A variety of techniques is used to vent elevator legs. Many are aspirated to cyclones and some are vented directly to the atmosphere. Some are aspirated at both the top and the bottom. Some have installed ducting from the top to the bottom in order to equalize the pressure, sometimes including a small blower to serve this purpose. Others are operated completely closed without venting.

The leg can be an uncontrolled source of dust emissions if it is vented to atmosphere at the top of the leg, but more often the top of the leg is aspirated with a fan discharging to a cyclone. Table 99 presents results of emissions tests on a cyclone used to control emissions from an elevator leg. A particulate sampling train using two Rader Hi-Volume Samplers were used to determine simultaneous particulate loading to and from the cyclone. Extensions were added to the cyclone exhaust to provide a sampling location approximately 10 diameters downstream from bends and two diameters from the duct discharge. Tests were conducted in accordance with ASME Power Test Code 27. The grain handling rate was not reported.

Table 100 presents particle size distribution data for the cyclone inlet tests. The particle size distribution was obtained by 15 min Rotap screening and by microscopic methods (ASTM E-20). Inasmuch as the +200 and +325 Rotap fractions showed serious screen blinding, they were lightly disturbed with a camels hair brush to disperse agglomerates. The microscopic examination of the 325-mesh fraction showed very few agglomerates and no detectable milling of the particulate.

Table 98. MEASURED EMISSION RATES FOR SCALE SYSTEM

Source	Grain Handled	Equipment Tested	Process Rate (tons/hr)	Dust Loading at Outlet of Equipment Tested (gr/scf)	Dust Loading at Outlet of Equipment Tested (lb/ton)	Visible Emission
Scale system--grain handling and weighing	Corn	Aerodyne 84 bag HPE filter, Model No. 14084.8 reverse jet cleaning 40 h.p. fan, 14,100 cfm	1,070	0.0222	0.00236	10% opacity

Table 99. EMISSIONS FROM ELEVATOR LEG CONTROLLED BY CYCLONE COLLECTOR[5/]

Source	Control Device	Test Location	Gas Flow (scfm)	Emissions (gr/scf)	Emissions (lb/hr)
Elevator leg	Cyclone	Inlet	1,468	33.8	425
		Outlet	1,147	0.016	0.15
		Outlet	1,147	0.017	0.17
		Outlet	1,147	0.020	0.20

Table 100. PARTICLE SIZE DISTRIBUTION FOR LEG CYCLONE INLET TEST

(see Table 99)

US Sieve Mesh	Size Opening (microns)	Cumulative Weight (%)[a]
6	+3,327	0.5
7	+2,830	0.9
16	+1,190	7.6
20	+ 840	12.3
40	+ 420	21.0
60	+ 250	26.5
100	+ 149	32.7
170	+ 88	44.7
200	+ 74	48.7
325	+ 44	68.0
Microscopic	+ 20	91.0
Microscopic	+ 10	99.1
Microscopic	+ 5	99.9
Microscopic	+ 1	99.9[a]

a/ Greater than.

The -325 mesh fraction was dispersed in benzene and filtered on a 0.45 μ millipore pad. The pads were cleared with immersion oil. Multiple counts were made at 800X using a Unitron MPH phase contrast microscope under light field conditions. The particle frequency counts were converted to mass percentages by assuming spherical particles of homogeneous density.

Transfer Points - When grain is handled, the kernels scrape and strike against each other and the conveying medium. This action tends to rub off small particles of chaff and to fragment some kernels. In this manner, dust is continuously generated and the grain is never absolutely clean. Belt conveyors have less rubbing friction than either screw or drag conveyors, and generate less dust. Dust emissions usually occur at belt transfer points as materials fall onto or away from a belt. Belt speed has a strong effect on dust generation at transfer points. Examples of transfer points are the discharge from one belt conveyor onto another belt conveyor or the discharge from a leg onto a belt conveyor or the discharge from a bin onto a tunnel belt. If these transfer points are open to the atmosphere, an air pollution problem may result.

Every process in the elevator involves turning (or moving) the grain. Turning includes the operations of belt conveying, elevator transfer, turnhead operation, and bin dumping. Most of these same conveyors and elevators are also used during unloading operations and at times a control system may be serving multiple operations.

Measured emission data for grain handling operations at an elevator serving a flour mill are presented in Table 101. In Table 101, emissions from cyclone systems used at one storage elevator to control dust emissions from various equipment used to transfer grain are summarized.[3/] All the cyclones are Day Dual-Clone units. One cyclone vents the upper north and south conveyor belts and the storage tanks. This cyclone emitted 3.5 lb/hr or 5.85×10^{-3} lb/ton of grain handled. Another vents all the turnheads in addition to the dryer feed belt and the upper north belt. The emissions from this cyclone amounted to 17.8 lb/hr or 29.7×10^{-3} lb/ton of grain handled. Two cyclones are used to vent the lower belts and the elevator legs of the grain turning system. These units emitted 4.85×10^{-3} and 4×10^{-3} lb/ton of grain handled, respectively.[3/]

Table 102 presents dust emission data for the control system serving the tunnel belt aspiration system at a terminal elevator. The emission data were obtained by an EPA contractor using EPA Method 5 testing procedures. Except for Test No. 4 no significant differences were noted in the individual tests. Reasons for the significantly higher emissions rates observed in Test No. 4 were not discussed by the EPA contractor who performed the testing.

Table 101. EMISSIONS FROM GRAIN TURNING OPERATIONS CONTROLLED BY CYCLONES[3/]

Emission Source	Process Weight (1,000 lb/hr[a/])	Gas Flow (scfm[b/])	Emissions[c/] (gr/scf)	Emissions[c/] lb/hr	Emission Factor (lb/ton)	Emission Factor (lb/bu)
Cyclone venting two upper conveyor belts and storage bins	1,200; wheat	7,908	0.051	3.5	5.85×10^{-3}	0.35×10^{-3}
Cyclone venting all turnheads, dryer feed belt, and one upper conveyor belt	1,200; wheat	5,500	0.378	17.8	29.7×10^{-3}	1.8×10^{-3}
Two cyclones venting lower belts and elevator legs of grain turning system	1,200; wheat					
	Cyclone No. 1	9,774	0.035	2.9	4.85×10^{-3}	0.145×10^{-3}
	Cyclone No. 2	8,570	0.032	2.4	4×10^{-3}	0.12×10^{-3}

a/ Based on 60 lb/bu.
b/ Standard cubic feet per minute corrected to 70°F and 14.7 psia.
c/ EPA Method 5 sampling train used in all tests.

Table 102. EMISSIONS FROM TUNNEL BELT DUST CONTROL SYSTEM IN A TERMINAL ELEVATOR

Source	Control System	Test No.	Grain Handled	Grain Handling Rate (lb/min)	Emissions[a/] (lb/hr)	Emissions[a/] (lb/bu)	Emissions[a/] (lb/ton)
Tunnel belt conveyor aspiration system	Mikro D Pulsaire filter with reverse jet cleaning Serial No. 69H232 Type 100S 8.20 Air flow rate - 13,000 cfm Air/cloth ratio 14:1 Bags: polypropylene felt (Mikro style 17406)	1	No. 2 yellow milo, 5% FM, 13% moisture	13,000	0.131	$95.5x10^{-7}$	$33.5x10^{-5}$
		2	No. 2 yellow milo, 5% FM, 13% moisture	13,000	0.143	$105x10^{-7}$	$36.8x10^{-5}$
		3	No. 2 yellow milo, 5% FM, 13% moisture	13,500	0.059	$41.5x10^{-7}$	$14.5x10^{-5}$
		4	No. 2 yellow milo, 5% FM, 13% moisture	11,200	3.31	$276x10^{-6}$	$984x10^{-5}$
		5	Hard winter wheat, 0.2% FM, 12.5% moisture	12,200	0.076	$62x10^{-7}$	$20.6x10^{-5}$

a/ Emissions data obtained using EPA Method 5.

Figure 8 presents particle distribution data for dust entering the dust control unit for the tunnel belt aspiration system discussed in the preceding paragraph. The Brink Model B cascade impactor with a back up filter was used to obtain these data.

Table 103 presents dust emission data for a portion of the grain handling equipment at another elevator.[6] The testing procedures used to obtain the data in Table 103 were not reported.

Another series of emission tests on cyclones controlling dust emissions in various parts of an elevator is presented in Table 104. The tests were conducted in accordance with procedures of ASME Power Test Code 27. Particulate sampling trains using Rader Hi-Volume sampling systems were used in the tests. Extensions were added to the cyclone exhausts to provide a sampling location approximately 10 diameters from obstructions and bends. At this elevator, legs and all conveyor transfer points and drop points are equipped with suction hoods ducted to cyclones. One collection system and blower serves the basement area while another collection system and blower serves the headhouse area. The railcar loading station used a garner bin which was filled by means of a bridge conveyor from the elevator proper. This bridge conveyor was covered and was equipped at the head end with a suction fan discharging to a cyclone. Grain handling rates were not reported by the organization which conducted the tests summarized in Table 104. As a result, emission rates in terms of pounds per bushel or pounds per ton of grain handled could not be determined.

Bin Vents - Bin vents are small screen covered openings located at the top of the storage bins or silos, and they are used to vent air from the bins as the grain enters the bin. The grain flow into a bin induces a flow of air with the grain and the grain also displaces air out of the bin. The air pressure that would be created by these mechanisms is relieved through the bin vents. The flow of grain into the bin generates dust which may be carried out with the flow of air through the bin vents. The quantity of dust released through the vents increases as the level of the grain in the bin increases.

Bin vents are common to both country and terminal elevators, although the quantity of dust emitted is a function of the grain handling rate, which is considerably higher in terminal elevators. Few elevators are known to use anything other than direct venting to the atmosphere, but it would certainly be possible to aspirate the bins to an individual or a common dust collector. Small fabric filter units have been used for this purpose in some metropolitan areas. Some elevators exhaust the bins into the gallery or headhouse to prevent escape of the dust into the atmosphere.

No data on emission rates pertaining only to bin vents were found during this study.

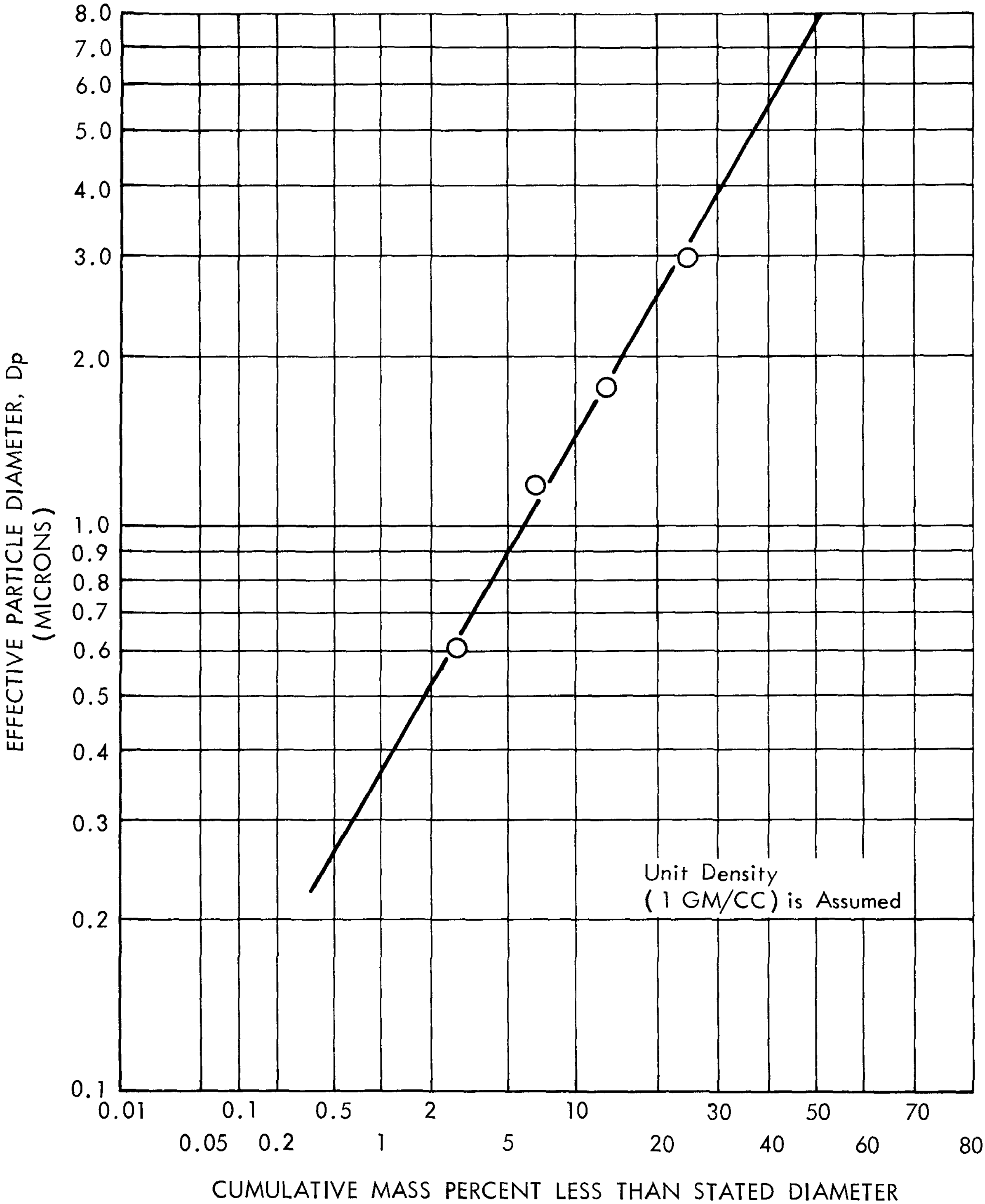


Figure 8. Particle size distribution of dust entering control system serving a tunnel belt aspiration system (grain elevator).

Table 103. DUST EMISSIONS FROM GRAIN HANDLING OPERATIONS[6]

Item	Inlet	Exhaust
Grain handling rate (bu/hr)[a]	9,000	9,000
Process weight rate (lb/hr)[b]	540,000	540,000
Source gas volume (scfm)	10,000	10,000
Duct static pressure (in. H_2O)		
At fan	- 3.9	+ 5.2
At cyclone	+ 5.1	+ 0.1
Dust concentration (gr/scf)	0.428	0.029
Dust emission rate (lb/hr)	36.68	2.48
Emission factor (lb/ton)	0.14	0.093

a/ Distributor head handling 4,500 bu/hr; front pit, back pit and legs handling 4,500 bu/hr.

b/ Computed as the product of the cleaning rate and the average bulk density of No. 1 heavy dark northern spring wheat (60 lb/bu).

Table 104. DUST EMISSIONS FROM GRAIN HANDLING OPERATIONS

Source	Control Device	Test Location	Gas Flow (scfm)	Emissions (gr/scf)	Emissions (lb/hr)
Conveyor transfer points, elevator legs	Cyclone, Carter-Day 45H	Outlet	11,013	0.09	8.5
Conveyor transfer points, elevator legs	Cyclone, Carter-Day 45H	Outlet	11,013	0.08	7.7
Conveyor transfer points, elevator legs	Cyclone, Carter-Day 45H	Outlet	9,620	0.05	4.2
Conveyor transfer points, elevator legs	Cyclone Carter-Day 45H	Outlet	9,620	0.065	5.4
Conveyor transfer point (load-out conveyor)	Cyclone, Carter-Day 20H	Outlet	1,755	0.004	0.058
Conveyor transfer point (load-out conveyor)	Cyclone, Carter-Day 20H	Outlet	1,755	0.0037	0.057

FEED MILLS

Processing of grains and other ingredients into mixed feed consists of converting the grains and other constituents into the form and size desired in the finished feed, adding other ingredients and mixing them with the grains, then forming a finished feed in the shape or consistency desired for feeding. The basic forms of finished feed are mash, pellets and crumbles. The latter are pellets which have been formed and then crushed or broken.

Feed milling uses two operations in the production of mash and four or more in the manufacture of pellets. Grinding and mixing are the two basic operations in feed milling. Pellet extrusion and pellet cooling are additional operations in the manufacture of pellets. If pellets are broken into "crumbles" or "granules," the crumbling operation and screening follow pelleting.

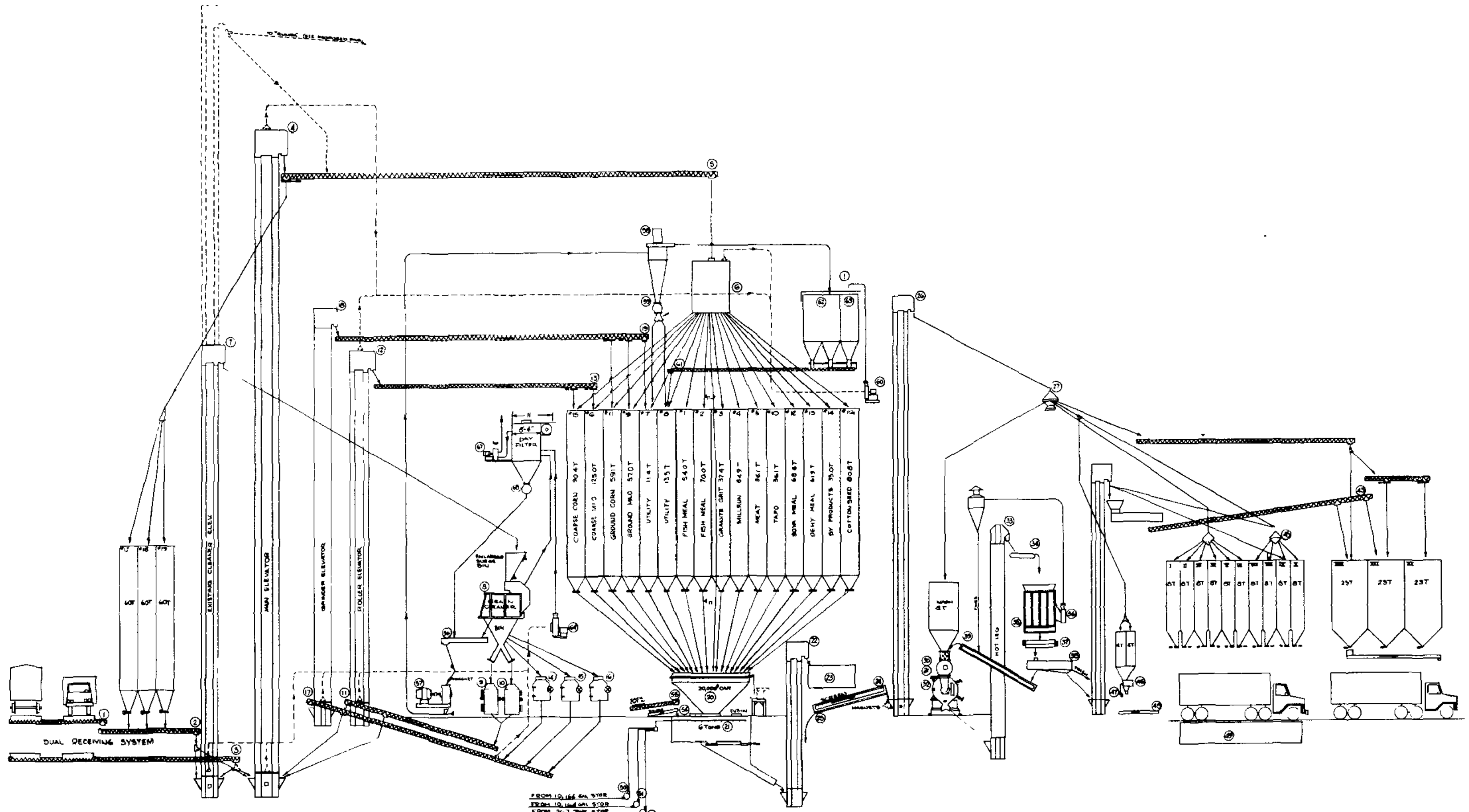
Feed Manufacturing Process

As shown in Figure 9, the manufacturer of feed begins with receiving of ingredients at the mill. Over 200 ingredients are used in feed manufacture. These include grain, scrap material such as meat scraps, bone meal, beet and tomato pulp, minerals which are used in very small portions, medicinals, and vitamins. Grain is usually received at the feed mill by truck, railroad, or in some cases, boat. Materials received in bulk, such as whole grains and soybean meal, are unloaded by gravity, air, or mechanical means. Frequently, power shovels are combined with hand labor to unload railroad boxcars. Bobcats are also used in many cases. Large feed mills sometimes employ boxcar unloaders. These machines lift the entire car, tilt it to one side, and then discharge the contents through the side doors.

Barges generally are unloaded by positive or negative air systems. Truck shipments usually are unloaded through the rear tailgate after elevating the truck body to 30 or 45 degrees. The cargo is dumped through a grate into an underground pit or onto an underground conveyor.

The actual movement of ingredients within the mill usually is done by gravity. First, however, the grain must be elevated above the highest processing machine before the gravity process can begin. This is accomplished through the use of bucket elevators.

For horizontal movement or slight elevation, a feed mill may use a screw-type conveyor, made of mild or stainless steel; a drag conveyor, in which single or double chains haul grain along a stainless steel chute; a continuous belt, with a V-trough in its center, or an air system, in which grain is carried along in a jet-like stream of compressed air.



EQUIPMENT SCHEDULE																PROPOSED INSTALLATIONS			
NO	DESCRIPTION	HP	REMARKS	NO	DESCRIPTION	HP	REMARKS	NO	DESCRIPTION	HP	REMARKS	NO	DESCRIPTION	HP	REMARKS	NO	DESCRIPTION	HP	REMARKS
1	14"ø SCREW CONVEYOR *	5		2	14"ø SCREW CONVEYOR	5	NEW INSTALLATION	37	8555 CRUMBLE ROLL	15		55	9"ø SACK SCREW	3	CUT IN TO MIXER	80	48x96 'RUMBA' SCALPER		
2	14"ø " " *	10		20	10T HOPPER SCALE W/DAM	~	WEIGHT D GRAFF	38	#23 ROTEX SHAKER	2		56	9"ø SCREW CONVEYOR	3	EXISTING REINSTALL	81	14"ø SCREW CONVEYOR		
3	14"ø " " *	5		21	MARION PADDLE MIXER 6T	100		39	DRAG CONVEYOR	1		57	G775 PRATER GRINDER	30	SCREENINGS	82	14"ø " "		
4	11x6 RECEIVING ELEV	15		22	14x7" MIXER ELEVATOR	15		40	PELLET ELEVATOR	3		58	HOLZINGER AIRLIFT	25	EXISTING REINSTALL	83	14"ø " "		
5	14"ø TUBULAR SCREW CONV	5		23	REEL TYPE SCALPER	3		41	FATS ROTO COATER	1		59	ROTARY AIRLOCK	3/4		84	11X6 ELEVATOR		
6	17 WAY 9"ø DISTRIBUTOR	1/3		24	24" BELT CONVEYOR	5		42	CI TALLOW PUMP	2		60	DUST CONTROL FAN	5					
7	11x6 CLEANER ELEV.	7½		25	CHAIN CLEAN OUT	~		43	9"ø SCREW CONVEYOR	5		61	6"ø SCREW CONV W/ROTARY V.	1½	COMMON DRIVE				
8	CLIPPER CLEANER	20	SUPER 2248D 2A	26	14x7" MASH ELEV	20		44	4 WAY VALVE TURNHEAD	–		62	SLY 'BAG HOUSE FILTER'	½	KNOCKER/SHAKER [illegible]				
9	"2 HIGH" ROLLER MILL	20		27	6-HOLE 14" DISTRIBUTOR	1/4		45	4 WAY VALVE TURNHEAD	–		63	" "	½					
10	" " "	20		28	14" SCREW CONVEYOR	5		46	G 17 BAGGING SCALE	–		64	#48 AMERICAN DUST CONTROL FAN	3					
11	12"ø SCREW CONVEYOR *	3		29	14" " "	3		47	SEWING MACHINE	1/4		65	DAY RJ FILTER	1/3	AUTOMATIC CLEANING				
12	9x5" ROLLED GRAIN ELEV	5		30	CPM PELLET MILL FEEDER	3/4		48	BAGGING BELT	½		66	#4A PRESSURE BLOWER	7½					
13	12"ø SCREW CONVEYOR	3		31	CPM PELLET MILL COND'T	10		49	50T TRUCK SCALE x 70'	–	TYPE REGISTERING BEAM	67	#45 TYPE 'H' EXHAUSTER FAN	20					
14	ORBIT GRINDERS	50		32	CPM PELLET MILL	100		50	TALLOW PUMP	3	STORAGE 10 164 GAL	68	ROTARY AIRLOCK (10"ø STYLE 'AH')	½					
15	" "	50		33	9x5" SS ELEVATOR	3		51	MOLASSES	5									
16	" "	50	OLD SCREENING GRINDER	34	14" BELT CONVEYOR	1		52	FISH SOLUBLES	5	267 TONS								
17	14"ø SCREW CONVEYOR	2	NEW INSTALLATION	35	2G5 CPM PELLET COOLER	3/4		53	CONTAINER LOADING SYS	3									
18	6x5" GRINDER ELEV	2	NEW DRIVE	36	CPM COOLER FAN	20		54	VITAMIN DRAG	½									

Figure 9. General flow diagram for a feed mill.

Most mills direct feed ingredients, especially grains, through cleaning equipment prior to storage. Cleaning equipment includes scalpers to remove coarse materials from the feed ingredients before they reach the mixer. Separators, which perform a similar function, often consist of reciprocating sieves which separate grains of different sizes and textures. Some mills employ these units to rough grade grain as to quality and weight.

Magnets are essential in the feed processing line. Most mills install them ahead of the grinders and at other critical locations in the mill system. They remove tramp iron, bits of wire, and other foreign metallic matter which could harm the machinery and contaminant the finished feed. Both permanent and electric magnets are used. Chute and rotary magnets are also commonly used.

From the cleaning operation, the ingredients are directed to storage. Bulk ingredients are stored in concrete silos, steel tanks or wooden bins. Wooden bins are generally found only in older feed mills.

Whole grains are ground prior to mixing with other feed components. The hammermill is the most widely used grinding device. The grinding chamber consists of rows of loosely mounted "swing" hammers or plates of hardened metal. These hammers pulverize the grain by striking it as they swing. The pulverized material is forced out of the mill chamber when it is ground finely enough to pass through the perforations in the screen which is a part of the mill. Several sizes of screen openings are used, depending on the fineness of the end product desired.

Mixing is the most important process in feed milling and is prevalently a batch process. Ingredients are weighed before mixing. Micro-ingredients, such as trace minerals and drugs are weighed on bench scales. Some of these are used in very small amounts--one, 8-oz/ton of feed.[8/] Ground grain and materials added in comparatively large amounts, such as wheat middlings and soybean meal, are weighed in a hopper scale with capacity corresponding to the capacity of the mixer--1 to 3 tons. In large mills, 200 tons/day and larger, ingredients are moved by conveyor from bins to the scale. In smaller mills (30 tons/day) a "weigh buggy," which is a hopper and scales on wheels, is generally used. A weigh buggy has a capacity of about 1,000 lb and is wheeled around under the bins from which ingredients are to be drawn for a given mix. After the ingredients are weighed into the buggy, it is wheeled to the mixer where it is unloaded. Liquids, such as vitamin feeding oils, fish solubles, molasses, and fat are included in the ingredients fed to the mixer.

Mixers may be either a vertical or a horizontal type. Vertical mixers utilize a screw to raise the ingredients from the bottom to the top of a mixing tank through an axial pipe from which the ingredients flow out, into and back to the bottom of the tank. Horizontal mixers move the ingredients in a horizontal direction with right- and left-hand, narrow helical ribbons or paddles attached to a shaft. The paddle-type mixer is more suitable when the molasses content of the formula is high (30-40%) or for continuous instead of batch mixing. Horizontal mixers have a higher mixing rate than vertical mixers and are used in large feed mills. Horizontal mixers are provided with a surge hopper underneath the mixing chamber so that the mixing process is not interrupted by conveying the mixed feed to storage. A mixer and its scale are sized to provide simultaneous weighing of the ingredients in the scale hopper, mixing the ingredients in the mixing chamber, and conveying the mixed feed from the surge hopper to storage.

The material from the mixer is a meal, or mash, and may be marketed in this form. If pellets are to be made, the meal is steamed prior to being pelleted.

Pellet making is an extrusion process in which steamed meal is forced through dies. Pellets are usually 1/8-3/4 in. in diameter and of similar length. Pellets must be cooled and dried after extrusion. This is accomplished in pellet coolers through which air at room temperature is drawn. Pellet coolers are of either horizontal or vertical types. Vertical coolers are less expensive with regard to both purchase and maintenance cost. Horizontal coolers may be used where space is not available for vertical coolers, and horizontal coolers are more satisfactory for feeds with high molasses content. Feeds with high molasses content are often dusted with bentonite or cottonseed meal to prevent caking. Cooling air is usually passed through cyclone dust collectors.

If pellets are to be reduced in size, which is necessary for such use as baby-chick feed, they are passed through a crumbler, or granulator. This machine is a roller mill with corrugated rolls. Crumbling is a more economical method of producing small pellets than using dies with the requisite-size holes because the use of small dies seriously restricts production. The roller mill is usually located directly below the cooler and is provided with a by-pass for use when pellets are sent to storage without crumbling. Crumbles must be screened to remove fines and oversize.

The product is sent to storage bins and pneumatic conveying may be used for this materials handling process. Finished feed is bagged by automatic bagging machines which are equipped with scales or is shipped in bulk in trucks and railroad cars.

Air Pollution Sources, Emission Rates, and Effluent Properties

Dust emissions in feed mills result from a variety of grain and ingredient handling and processing operations. Unloading of bulk ingredients is generally acknowledged to be one of the most troublesome dust sources in feed mills.[9] Centrifugal collectors used for product recovery and dust control represent the second largest emission source. Cyclones on pellet coolers and cyclones used as product collectors on pneumatic conveying systems are the most important sources in this category.[9] Pellet coolers can be operated without being notably dusty; however, where a powder, such as cottonseed meal, is being used to prevent caking of the pellets, dust emissions may be profuse. Dust emissions from storage bins depend upon the size of the bin, the rate at which it is filled, and the method of conveying the material to the bins. A large bin which is being filled slowly through a chute from a distributor can act as its own settling chamber. Bulk loading, particularly loading of meal, can be a significant source of dust. Loading through chutes into either railcars or trucks exposes the product to the action of the wind. Loading a boxcar with a flinger which throws feed from the door to the end of the car can be a very dusty operation.

Specific operations in feed mills are discussed in more detail in the following section. Each operation is treated as an individual source with no consideration of common ducting or external-internal venting options.

Ingredient Receiving - The ingredient receiving area represents the most serious dust emission problem in most feed mills. The truck and rail receiving stations present difficult dust control problems. The two principal factors that contribute to dust generation during bulk unloading are wind currents and dust generated when a falling stream of material strikes the receiving pit.

The ingredient receiving area can be broken into separate areas, each with a specific set of dust control problems. These areas are:

(a) Bulk unloading

1. Hopper car receiving
2. Boxcar receiving
3. Truck receiving

(b) Materials handling equipment

(c) Scales

(d) Cleaning and scalping equipment

The dust emission problems of the individual operations in each area parallel those discussed in the section, Air Pollution Sources, Emission Rates, and Effluent Properties, for the similar operations in grain elevators. However, in feed mills a slower rate of materials handling is usually employed and a much wider range of materials may be handled. Meager data are available on the rates of emission from the above operations in feed mills because little, if any, source testing has been done in feed mills. Table 105 presents estimates of emission rates from various sources in the ingredients receiving section of a feed mill.[10] These estimates were obtained from data submitted in response to the emission inventory questionnaires sent to selected feed mills. Since the data in Table 105 are only estimates and were provided by a limited number of feed mills, the emission rates should be used with caution and only as order-of-magnitude numbers.

Factors affecting emission rates from the ingredient receiving area of a feed mill include the type of grain and other ingredients handled, the methods used to unload the ingredients, and the configuration of the receiving pits. Emissions from the materials handling and cleaning equipment are dependent primarily upon the cleanliness of the received material and the type of equipment utilized.

Table 105. ESTIMATED EMISSION RATES FOR INGREDIENT RECEIVING OPERATIONS IN FEED MILLS

Source	Uncontrolled Emission (lb/hr)	Controlled Emission[a] (lb/hr)
Ingredient unloading by front end loader	32	3
Truck receiving pit	6.5	0.6
Receiving scale	3	0.15
Grain cleaner (milo)	750	60

a/ Cyclones used as the control device. Rate of material handled was not reported and emission factor in terms of pounds per ton could not be calculated.

Because of the wide variation in ingredients that can be and are used in the manufacture of feed, the nature of the emissions is also highly variable. This is especially true of the emissions from the ingredient unloading areas.

Grain Processing - Hammermills, roller mills, cutters, and granulators are often used in the grain processing section of a feed mill. Hammermills present a dust problem due primarily to their product conveying system.[11,12] Most hammermills are installed using a conventional attached or separate fan and cyclone collector as the finished product recovery system. The product recovery cyclone is the major dust source in the grain preparation operation.[11,12] Dust emissions will vary with the type of grinder (standard or full circle screens), products being ground, and the method of conveying finished product.

Standard type hammermills utilizing 180 degree screens will normally require minimum air flow through the screens in the range of 500-1,000 cfm per hammermill to maintain proper grinding action, eliminate back pressures in the mill and for heat removal.

The full circle or 360 degree screen hammermill may or may not require air for proper grinding action. Normally, on coarse grinding, no air will be required, however, on fine grinding applications, air may be required to control internal temperatures even where dustiness is not a problem, or it can be controlled by adding moisture during the grinding process.

Most grains being ground coarsely for mash type feeds do not present a particularly bad dusting problem. However, when fine-grinding alfalfa pellets and some grains (barley, wheat, milo) for pelleted type feeds, dustiness can become a much more severe problem.

As noted previously, the method of conveying the finished product has a major influence on dust emissions. Products from hammermills can be handled by:[9]

(a) Gravity system (direct flow to bin)

(b) Mechanical system (conveyors and elevators)

(c) Positive pressure pneumatic system (high pressure)

(d) Negative pressure pneumatic system

(e) Fan attached to mill shaft (negative and low positive pressure)

(f) Separate fan located at mill (negative and low positive pressure)

The gravity system will produce the least amount of dust emissions while the separate fan system will normally be the most "dusty" system.

Many of the older feed mills do not have provisions for controlling the dust emitted from the handling of the hammermill products. Older mills that use pneumatic conveying of the product are generally equipped only with a product recovery cyclone, and dust escaping from this cyclone is vented directly to the atmosphere.

Recently obtained data on emissions from various product recovery systems on hammer and attrition mills in feed mills are shown in Table 106. EPA contractors using EPA Method 5 and, in one case, a hi-vol sampler, obtained the data reported in Table 106. As shown in Table 106, emission rates determined by EPA Method 5 and the Rader Hi-Vol sampler are not in agreement. The Rader Hi-Vol sampler measured significantly lower emission rates. No explanation of the differences was offered by the EPA contractor performing the emission testing.

Storage Bins - Suction venting on storage bins is not a common practice in feed mills, except in newer mills. Most older plants vent storage bins to the atmosphere or to the interior of the mill.

Mixing Areas - Dust emissions in the mixing areas are normally not a problem. Primary means of dust control are through the use of fully enclosed systems, and providing for adequate interventing of displaced air due to rapid discharge of scales and multiple or drop bottom discharge mixers.[9/]

Pellet Mills and Pellet Coolers - The pellet mills do not present a significant source of dust emissions. However, the pellet coolers are a source of dust and they present control problems because of the moisture content of the air stream leaving the coolers. In a pellet cooler, the moisture content of the material is reduced from approximately 17% to 11%. The flow rate in older mills ranges from 6,000-14,000 cfm in the coolers while in newer plants 15,000-30,000 cfm are common. A rough rule-of-thumb for these units is 1,000 cfm/ton of pellets per hour.[12/]

Table 107 summarizes results of recent tests by EPA contractors on two types of pellet cooler. EPA Method 5 was used in all the emissions tests. At Plant A, two of the emissions tests were conducted while a beef cattle feed containing 5% molasses was being pelletized. The pellets were dusted with 500-550 lb of calcium carbonate applied at a steady rate. The high outlet grain loading and visible emissions are a direct result of the dusting operation.

Figure 10 presents particle size distribution data for the particulate emitted from the cyclone on the horizontal pellet cooler at Plant B (Table 107).

Table 106. MEASURED EMISSION RATES FROM TRANSFER SYSTEMS ON GRINDING EQUIPMENT IN FEED MILLS

Source or Process	Equipment Tested	Test Method	Material Ground	Process Rate (ton/hr)	Dust Loading at Outlet (gr/scf)	Dust Loading at Outlet (lb/ton)	Visible Emissions
Transfer of ground corn to storage	Product recovery cyclone	EPA Method 5, full sampling train	No. 2 yellow corn, 5% FM and 15% moisture	6.0	0.0037	0.0158	None
				6.0	0.0040	0.0175	
				6.0	0.0046	0.0158	
Transfer of ground grain to storage (corn, oats, barley, wheat)	Aerodyne, Vibrostream Filter Model 48.09 7-1/2 hp fan, 5,740 cfm. Two primary product recovery cyclones are ducted to this filter.	EPA Method 5, full sampling train	2 Tons of oats and 12 tons of barley;	7.8	0.0068	0.040	None
			6 Tons of oats, 9 tons of corn, and 2 tons of barley;	9.4	0.0022	0.011	
			6 Tons of oats, 5 tons of wheat, 7 tons of corn, and 1 ton of barley.	6.3	0.0023	0.015	
		Rader High-Vol sampler tests	Same sequence as above	7.8	0.0036	0.020	None
				9.4	0.0022	0.011	
				6.3	0.0012	0.009	
Transfer of ground corn to storage	2 Kice cyclones in series	EPA Method 5, full sampling train	No. 2 yellow corn, 2% FM	8.0	0.034	0.19	5% opacity
				8.0	0.025	0.15	
				8.0	0.021	0.14	

Table 107. MEASURED EMISSION RATES FROM PELLET COOLERS AT FEED MILLS

			Dust Loading				
			Inlet		Outlet		
Source or Process	Equipment Tested	Process Rate (ton/hr)	(gr/scf)	(lb/ton)	(gr/scf)	(lb/ton)	Visible Emissions
I. Plant A							
Horizontal pellet cooler (moving pan)	Cyclone, longhorn scroll type, 79 in. dia	7.6[a]	1.49	18.2	0.13	2.1	15-50% opacity
		6.1[a]	2.28	41.9	0.16	3.9	15-50%
		9.0	2.30	27.6	0.069	1.1	None
Column cooler	Cyclone, 48 in. dia	8.0	5.99	41.0	0.0048	0.052	None
		6.7	7.10	59.1	0.0092	0.108	None
		7.6	3.98	28.5	0.0048	0.057	None
II. Plant B							
Horizontal pellet cooler (double-pass)	Cyclone, 84 in. dia 16,200-16,300 scfm at outlet	9.13	0.36	5.1	0.025	0.36	None
		9.13	0.41	5.6	0.021	0.31	None
		10.8	0.51	5.9	0.017	0.22	None

a/ Pellets were dusted with calcium carbonate.

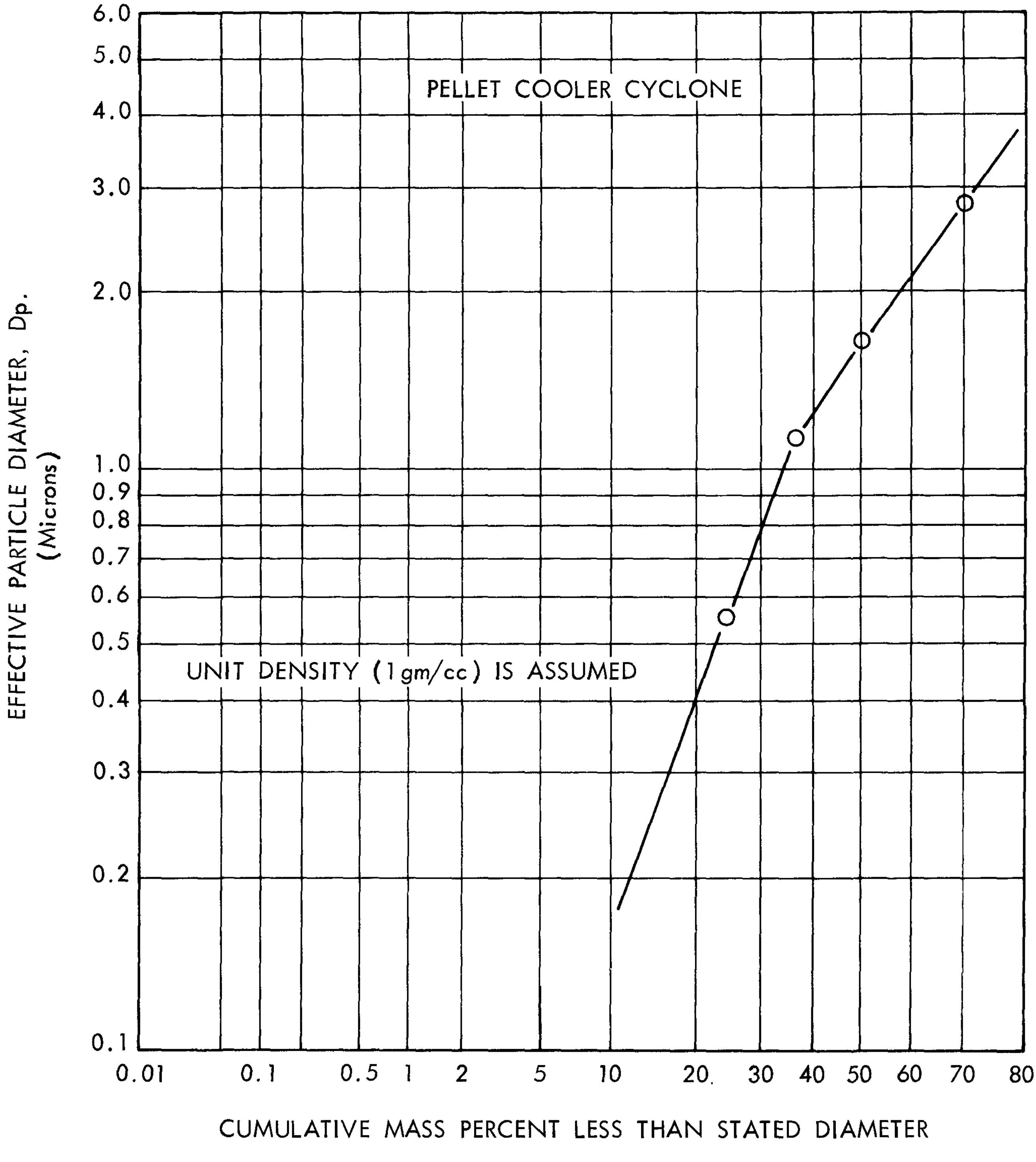


Figure 10. Size distribution of particulate emitted from cyclone controlling a horizontal pellet cooler (feed mill).

A Brink Model B cascade impactor with a back up filter was used to obtain the data. According to the data presented in Figure 10, the mass median diameter of the particle distribution is 1.6 μ.

Emission tests conducted on pellet coolers at a feed mill in Texas are summarized in Table 108. The sampling and analytical procedures used followed the procedures outlined in the "Compliance Sampling Manual," Texas State Department of Health, Air Pollution Control Services, January 1972. There are four horizontal coolers (screen conveyor type) at this feed mill. The emission rates in pounds/ton of product shown in Table 108 for the horizontal coolers are in general agreement with the data reported in Table 107 for the horizontal cooler at Plant B. However, the horizontal cooler at Plant A (Table 107) had a significantly higher emission rate even when a feed mix that did not require dusting with calcium carbonate was being processed.

The data in Tables 107 and 108 make it appear that emissions from cyclones on horizontal coolers exceed emissions from cyclones on vertical coolers. This result is at variance with the personal experience of many feed mill operators.[10,42] (See Table 109.) Operators of feed mills generally list the vertical cooler as a far more significant emission source than the horizontal cooler. Since only a limited amount of reliable emission testing has been conducted on cyclones on pellet coolers, definitive conclusions can not be reached regarding the relative importance of the two types of coolers.

Load-Out Operations - While the bulk load out of finished feed does not usually involve inherently dusty materials, load-out operations still present a major source of dust emissions at feed mills. Bulk loading of trucks and railcars is done in a number of ways all of which fall into two basic categories.

(1) Gravity filling--material is moved by pneumatic or mechanical conveyor systems or discharged from overhead bins or scale hopper dropping directly into car or truck by gravity through a suitable connection.

(2) Pneumatic filling--material is conveyed by air (positive pressure) directly to truck or car without use of a collector to separate air and material.

The main causes of dust emissions when loading bulk feed by gravity into trucks or railcars is the wind blowing through the loading sheds and dust generated when the falling stream of feed strikes the truck or railcar hopper. The wind velocity through load-out sheds and between bins is normally greater than that of the average wind velocity in open areas near the mill.

Loading of bulk feed into cars and trucks with a positive pressure system (pneumatic) requires a tightly closed system. Since the system must be tightly closed, the wind in the area has no effect at all on dust control.

Table 108. MEASURED EMISSION RATES FROM HORIZONTAL PELLET COOLERS AT TEXAS FEED MILL

Source or Process	Equipment Tested	Test Number	Process Rate (ton/hr)	Dust Loading Outlet (gr/scf)	Dust Loading Outlet (lb/ton)
Pellet cooler No. 1, processing poultry feed	Cyclone	1	12.5	0.036	0.32
		2	15.0	0.10	0.69
		3	14.4	0.066	0.50
Pellet cooler No. 2, processing poultry feed	Cyclone	1	14.0	0.042	0.32
		2	14.0	0.038	0.29
		3	15.0	0.03	0.22
Pellet cooler No. 3, processing beef feed	Cyclone[a]	1	12.0	0.048[a]	0.39[a]
		2	12.5	0.045[a]	0.35[a]
		3	13.5	0.032[a]	0.21[a]
Pellet cooler No. 4, processing beef feed	Cyclone[a]	1	14.0	0.063[a]	0.57[a]
		2	13.5	0.050[a]	0.44[a]
		3	15.0	0.055[a]	0.46[a]

a/ Each cyclone on the pellet coolers producing beef feed had two discharge points. The emission rate shown is the sum of the emissions from each point.

Table 109. ESTIMATED EMISSIONS FROM PELLET COOLER CYCLONE SYSTEMS[10/]

System	Gas Flow to Cyclone(s) (cfm)	Mass Loading to Cyclone(s) (lb/hr)	Emission from Cyclone(s) (lb/hr)
A. Vertical cooler			
(a) single cooler --single cyclone	13,000	56	6
	22,000	100	8
	11,425	49	5
	22,000	95	10
	28,000	400	40
	16,000	100	5
	10,000	50	10
	19,000	200	10
(b) single cooler --5 cyclones	36,000	155	16
B. Horizontal cooler with single cyclone	6,600	30	3

ALFALFA DEHYDRATION PLANTS

Alfalfa dehydration is a relatively new industry as the dehydration of alfalfa did not begin to be of commercial importance until the 1930's. Alfalfa dehydration plants are relatively small operations that receive fresh cut alfalfa from the fields and dehydrate it in a rotary drum that is usually gas fired. Harvested alfalfa can also be processed by sun-curing but the sun-cured product generally contains only about 14% protein whereas the dehydrated product contains 15% to 20% protein and also retains more Vitamin A. Generally, sun-cured hay is lower in protein because it is usually harvested at a more mature stage and more leaves are lost in the sun-curing process than in dehydration.

Alfalfa Dehydration Process

The first step in the alfalfa dehydration process is the field operation of harvesting. At harvest time the standing alfalfa is mowed and chopped in the field and transferred to a dump truck. The truck carries the "chops" to the dehydration plant (usually less than 10 miles away) where they are dumped onto a self feeder which carries the chopped alfalfa into the drying drum.

The drying drum is a slowly rotating drum that is fired with natural gas or oil. Combustion air flows into the drum by the induced draft fan (primary blower) as shown on the generalized process flow sheet (Figure 11). The temperature at the drum inlet is about 1800°F and the outlet is approximately 275°F. Drums may be single pass or triple pass. Subjecting the alfalfa to the hot gases in the drum evaporates the water to dehydrate the alfalfa from its original moisture content of about 80% down to 8 to 10%. The exhaust gases have a high moisture content (30%) and also entrain the finer particles of alfalfa. The effluent may also contain odors from volatile matter driven off the alfalfa in the drying process.

The high moisture gases and dry product from the drum enter the primary cyclone which separates the product from the gases. The moisture laden gases discharged to the atmosphere represent the first, and perhaps the largest source of particulate emissions. In some plants, the fan or blower is between the drying drum and the primary cooling cyclone (referred to as a positive pressure system). In other plants the blower may be located in the outlet line from the primary cooling cyclone (negative pressure system).

The material separated in the primary cyclone next enters the grinding machine, normally a hammermill. The grinder reduces the dehydrated chops to a powder referred to as "meal." From the grinder the meal enters the negative pneumatic conveyor that discharges into the meal collection cyclone. The cyclone is intended to separate the meal from the conveying air and to accumulate the meal in the meal bin feeding the pelletizing system. In some plants,

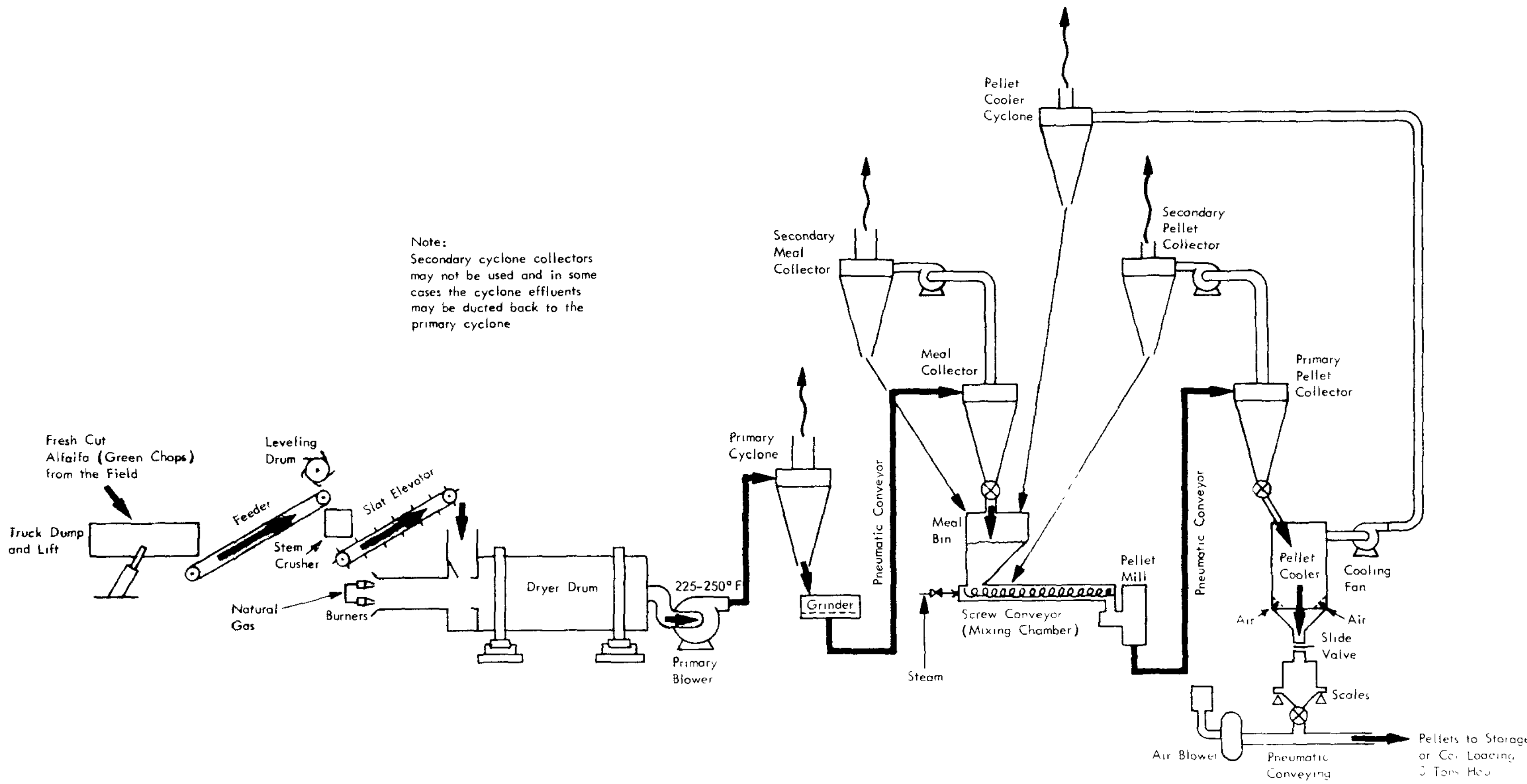


Figure 11. Generalized flow diagram for alfalfa dehydration plant.

the air from the meal collection cyclone is drawn through a fan and discharged into the secondary meal collection cyclone in an attempt to recover meal that escapes the first meal collector.

The meal accumulated in the meal bin is fed through a steam conditioner prior to entering the pellet mill. The pellets from the mill are pneumatically conveyed to the primary pellet collection cyclone from which they are fed into the pellet cooler. The air exhaust from the primary pellet collection cyclone enters a fan and may be discharged through a secondary pellet collection cyclone.

In the pellet cooler a flow of ambient air is drawn through a downward moving column of pellets to cool the pellets prior to bagging or transport to bulk storage or bulk loading. The air from the pellet cooler picks up some moisture and heat from the pellets. This air is discharged through a fan to a pellet cooler cyclone.

The process flow described above and depicted in Figure 11 is a general example for an alfalfa dehydrating plant. However, there are several variations in the process scheme that are used. For example, the pellets from the pellet mill may be mechanically conveyed to the pellet cooler, thereby eliminating the pellet collection cyclones. As another example, some plants duct all the cyclone effluents back to the primary cyclone so the only discharge point is from this primary cyclone. Another process variation included in some plants is the addition of vegetable oil or animal fat to the alfalfa meal at the hammermill. This oil helps to minimize the dust produced in subsequent handling and storage operations.

Air Pollution Sources, Emission Rates, and Effluent Properties

Emissions from alfalfa dehydrating plants include dust from the various cyclone separators, and odors from the volatile matter driven off the alfalfa.

In comparison to the other segments of the grain and feed industry, a significant amount of source testing has been done to characterize the emissions from dehydration plants.[13,14] Midwest Research Institute has recently completed two source testing programs for the Alfalfa Dehydrators Association (ADA). References 13 and 14 present the results of the testing programs in detail and a summary is given in the following paragraphs.

Reference 13 describes the field testing program conducted by MRI for the ADA during the summer of 1971 at four plants which had been selected by ADA as representative of this industry. Particulate emissions and process conditions were measured at the four alfalfa dehydrating mills for both normal and extreme process operating conditions. The general characteristics of the four plants are shown in the simplified flow diagrams presented in Figures 12 to 15.

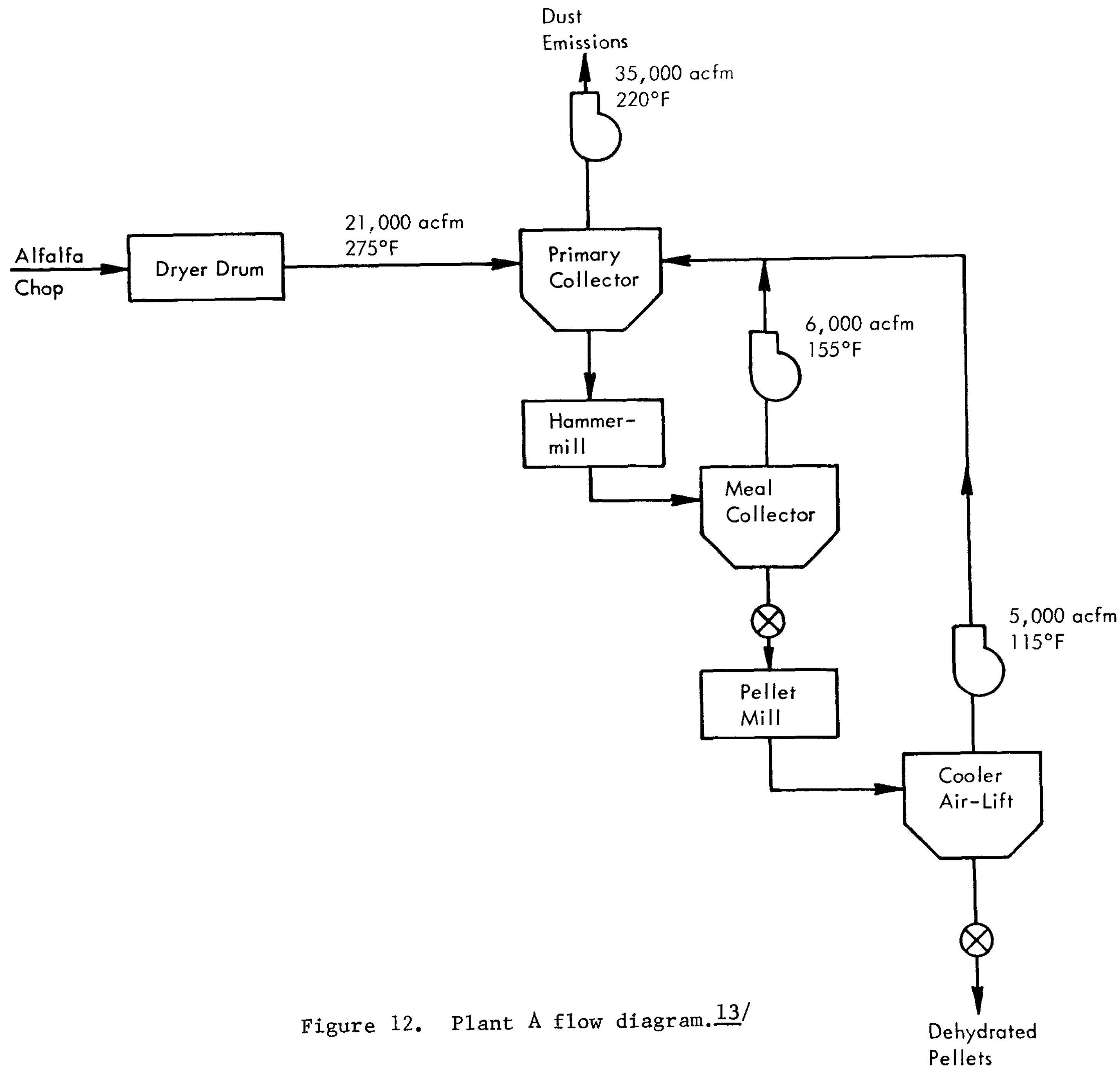


Figure 12. Plant A flow diagram.13/

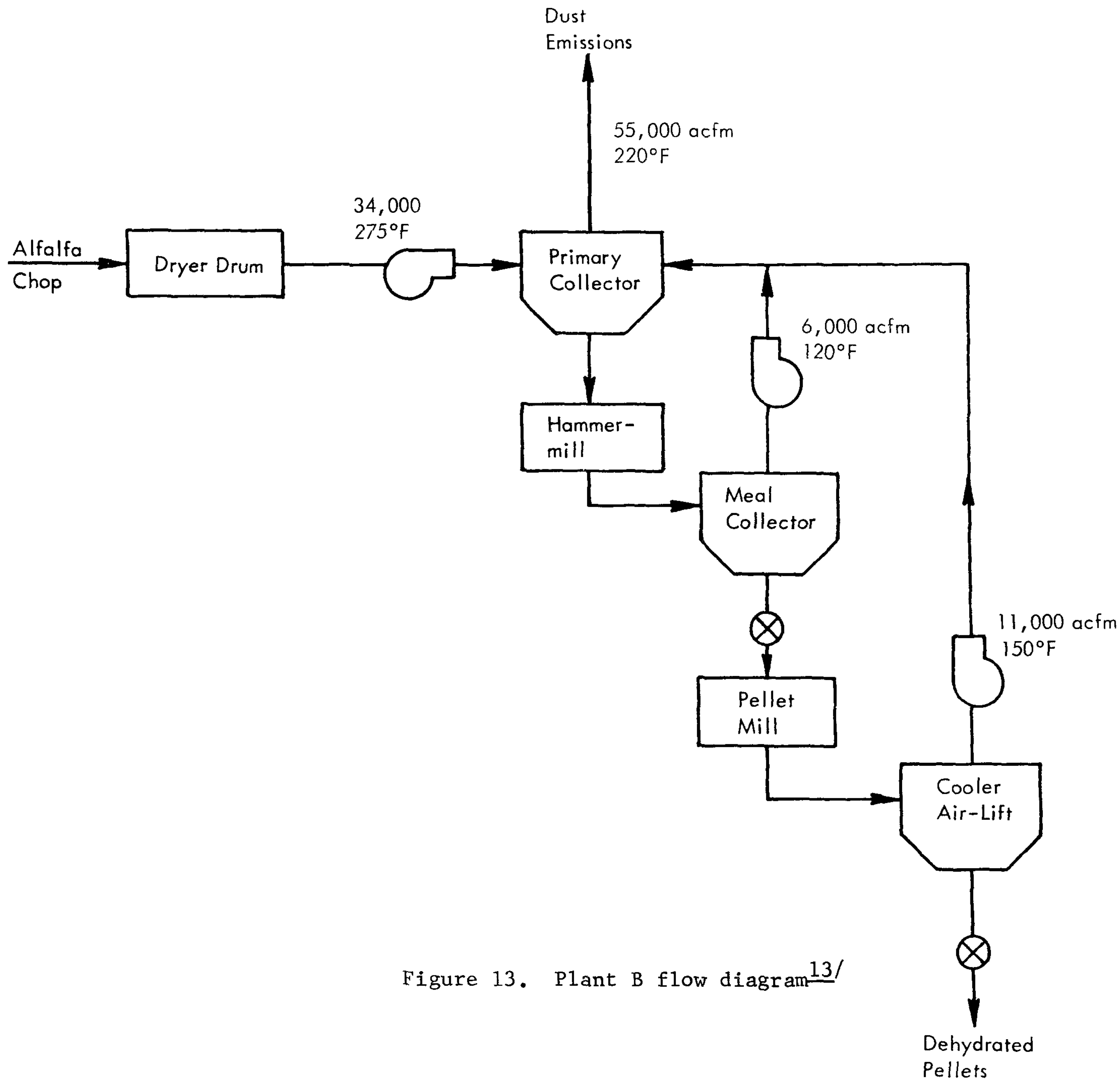


Figure 13. Plant B flow diagram[13/]

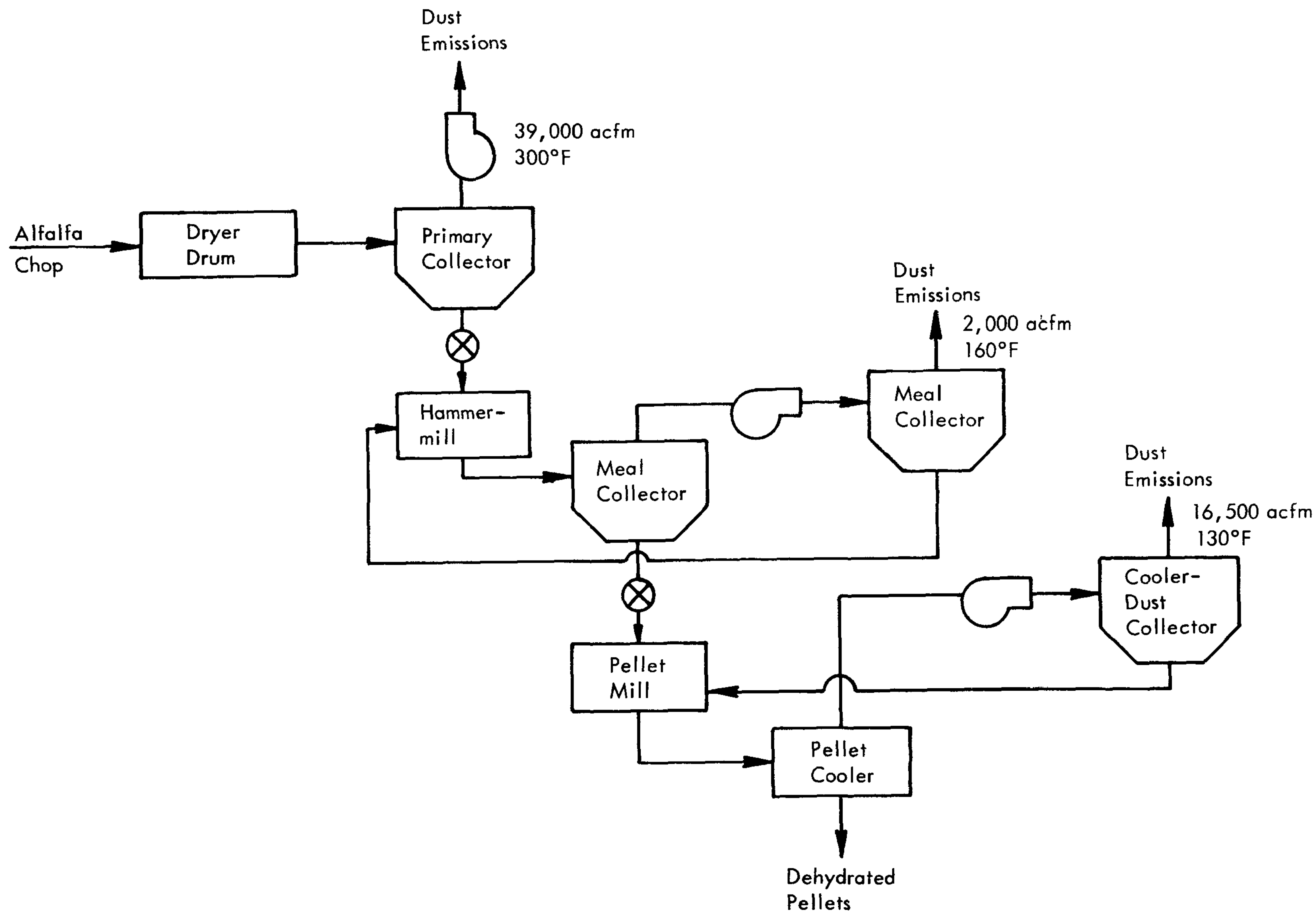


Figure 14. Plant C flow diagram[13/]

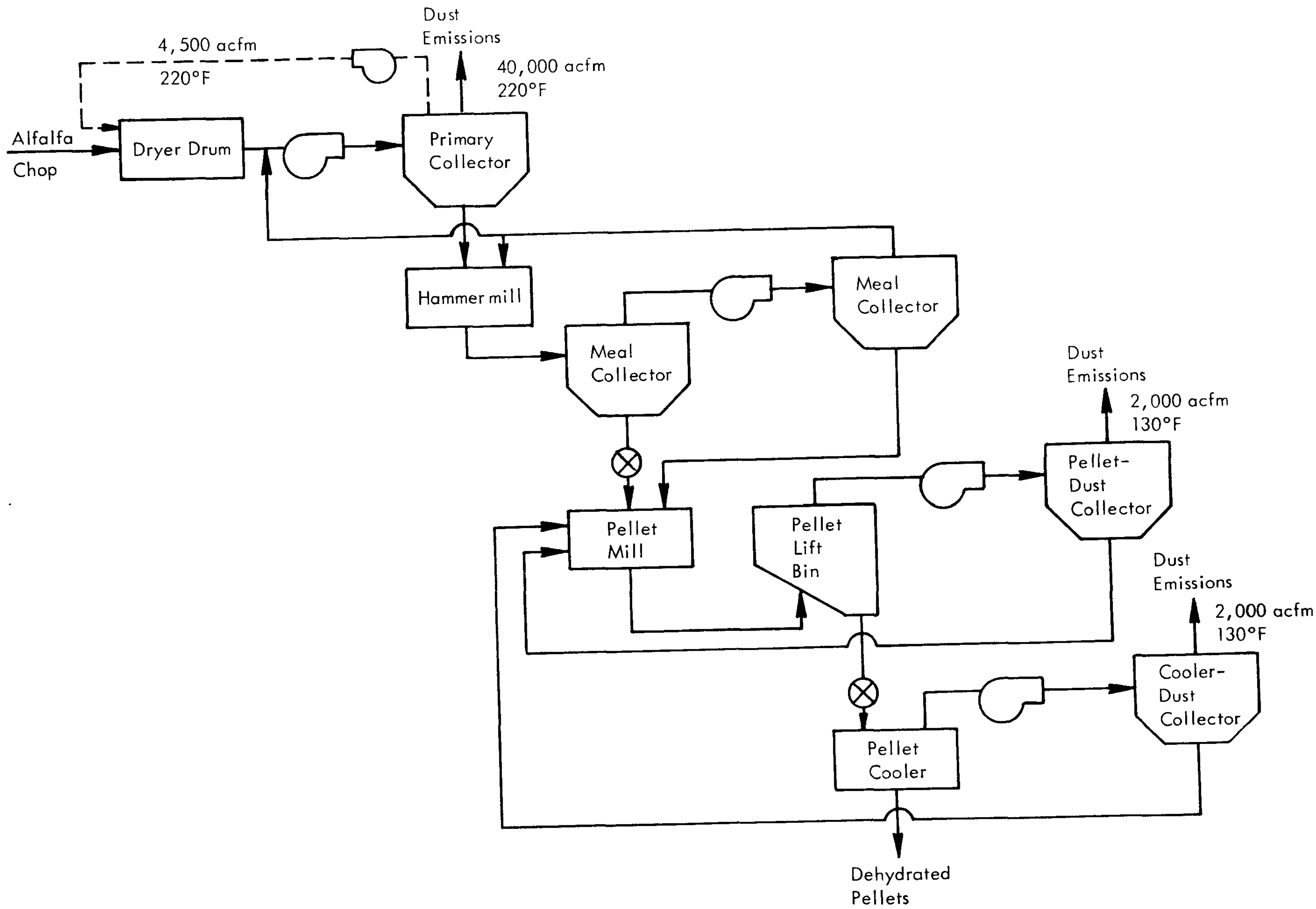


Figure 15. Plant D flow diagram[13/]

Two types of source tests were performed to determine, respectively, (1) the particulate emission rate from a given source, and (2) the particle size distribution of the dust emission. The emission-rate test consisted of the measurement of effluent flow rate and temperature, dust loading, and carrier gas composition (moisture and Orsat analysis). For these measurements, EPA Method 5 and the Research Appliance Company Model 2343 "Staksamplr" equipment were used. Integrated particulate samples representative of the entire duct cross section were collected by sampling for equal amounts of time over a network of properly distributed points. For each test the duration of sampling ranged from 30 to 60 min so that short-term fluctuations in emissions were averaged out.

For the dust sizing tests, an Andersen in-stack impactor was mounted on the end of the sampling probe. The Andersen impactor measures size distribution in situ thereby eliminating particle agglomeration problems encountered when dust samples must be collected and transferred before sizing analysis.

Table 110 indicates the process parameters that were measured during testing and the method of measurement. These parameters have been classified into three groups: (1) raw materials, (2) product (pellets), and (3) process operating conditions relating to drying, grinding and pelleting of the alfalfa. These quantities were measured periodically during testing.

Tables 111 to 115 present the results of the emission rate tests for the four plants. Plant A, as shown in Table 111 was tested under normal operating conditions with the full plant in operation (Test 101), and with the pellet mill shut off (Test 102). At Plant B, tests were conducted to determine the effect of changes in certain process conditions on the dust emission rate--namely, the effects of overdrying the hay (Tests 201 and 203), varying the process weight rate (Tests 202 and 209), and operating water spray systems (Tests 204 and 211). The size distribution of dust emitted under normal operating conditions (Tests 205A and 210A) and the mass flow rate of dust in the two major recycle streams (Tests 206 and 207) were also measured. In one test (208), the dust emission rate was measured with only the dryer operating but with the other air flows maintained. The results of these tests are given in Tables 112 and 113 and Figure 16.

Table 114 and Figure 17 present the results of tests conducted at Plant C. Tests were conducted to determine the emission rate (Tests 302, 305, and 307) and size distribution (Tests 301A, 303A, and 308A) of dust from each of the sources under normal operating conditions. The effect of overdrying was also measured (Tests 304 and 306).

At Plant D, tests were conducted to determine the emission rate and size distribution from the three sources shown in Figure 15. Test resuts from Plant D are presented in Table 115 and Figure 18.

Table 110. PROCESS PARAMETERS FOR ALFALFA DEHYDRATION PLANTS[11/]

Parameter	Units	Measurement Method
I. Raw materials		
A. Hay (green chops)		
1. Moisture content	Percent by weight	Cenco balance
2. Feed rate	ton/hr	Truck weights
	in/min	Feed travel
B. Fuel consumption rate	scfm	Meter reading
C. Make-up air flow rate	scfm	Duct velocity profile
II. Product (pellets)		
A. Protein content	Percent by weight	Lab. determination
B. Moisture content	Percent by weight	Cenco balance
C. Production rate	ton/hr	Scale dumps
III. Operating conditions - internal		
A. Dryer conditions		
1. Furnace temperature	°F	Optical pyrometer
2. Outlet temperature	°F	Mercurial thermometer
3. Excess air	Percent	Orsat analysis
B. Moisture in hammermill feed (dry chops)	Percent by weight	Cenco balance
C. Hammermill current	Percent rated amps	Meter reading
D. Pellet mill current	Percent rated amps	Meter reading
E. Recycle flow rates	acfm	Duct velocity profile

Table 111. ALFALFA DEHYDRATION, PLANT A EMISSIONS[a/]

Test	Source Operation	PWR[b/] (lb/hr)	Protein (%)	Chops Moisture (%) Green	Chops Moisture (%) Dry	Effluent Rate (acfm)	Dust Loading (gr/acf)	Emission Rate (lb/hr)
101	Total	21,600	--	73.5	14.0	34,600	0.183	54.1
102	D + HM[c/]	21,800	16.0	74.5	14.0	34,300	0.183	53.7

a/ Plant A has one emission point--the top discharge from the primary cyclone collector.
b/ PWR - Process Weight Rate (i.e., lb/hr of green chops entering the dryer).
c/ D - dryer
HM - hammermill

Table 112. ALFALFA DEHYDRATION, PLANT B EMISSIONS[a/]

Test	Source Operation	PWR (lb/hr)	Protein (%)	Chops Moisture (%) Green	Chops Moisture (%) Dry	Effluent Rate (acfm)	Dust Loading (gr/acf)	Emission Rate (lb/hr)
201	Total	21,800		74.5	5.0	54,400	0.187	87.1
202	Total	22,700	16.0	75.0	18.0	58,100	0.118	58.9
203	Total	22,800		72.5	5.0	62,300	0.131	69.9
204[b/]	Total	26,000	16.4	71.0	15.5	55,300	0.166	78.7
205A	Total	21,700		(70.0)	(20.0)	-	-	-
208	D only[c/]	-	15.7	-	-	59,800	0.105	53.7
209	Total	27,400		74.0	26.0	53,600	0.158	72.4
210A	Total	21,800	15.6	75.0	31.0	-	-	-
211[d/]	Total	25,600		74.5	22.0	55,100	0.166	78.1

a/ Plant B has one emission point--the top discharge from the primary cyclone.
b/ Test conducted with water spray in feeder.
c/ Dryer.
d/ Test conducted with controlled water scrubbing of dryer effluent.

Table 114. ALFALFA DEHYDRATION, PLANT C EMISSIONS

Test	Source Operation/ Emission Point	PWR (lb/hr)	Protein (%)	Chops Moisture (%) Green	Chops Moisture (%) Dry	Effluent Rate (acfm)	Dust Loading (gr/acf)	Emissions (lb/hr)
301A	PM (cooler/cooler-dust collector	34,500	17.4	77.5	14.0	--	--	--
302	PM (cooler/cooler-dust collector	39,300	18.1	77.5	12.0	16,600	0.089	12.7
303A	D/primary collector	30,500	19.0	80.0	11.5	--	--	--
304	D/primary collector	31,300	17.6	76.5	11.5[a]	39,300	0.572	192.7
305	HM/secondary meal collector	33,400	--	77.5	13.5	2,000	0.585	10.1
306	HM/secondary meal collector	29,400	17.3	78.0	8.5	1,700	1.623	24.1
307	D/primary collector	29,700	17.2	79.0	14.5	38,000	0.298	97.3
308A	HM/secondary meal collector	30,200	17.5	78.0	11.0	--	--	--

a/ At the start of test, moisture was 7.8%; at end of test, 15.6%. It is believed that the low initial moisture caused the substantial increase in emissions.

D - dryer
HM - hammermill
PM - pellet mill

Table 115. ALFALFA DEHYDRATION, PLANT D EMISSIONS

Test	Source Operation/ Emission Point	PWR (lb/hr)	Protein (%)	Chops Moisture (%) Green	Dry	Effluent Rate (acfm)	Dust Loading (gr/acf)	Emissions Rate (lb/hr)
401A	PM (lift)/pellet-dust collector	19,700	19.7	72.5	9.0	--	--	--
402	PM (lift)/pellet-dust collector	20,000	19.4	73.0	10.0	1,800	0.045	0.69
403	PM (cooler)/cooler-dust collector	25,200	17.5	72.5	8.0	2,000	0.242	4.1
404A	PM (cooler)/cooler-dust collector	28,700	17.8	74.5	9.0	--	--	--
405	D + HM/primary collector	22,600	17.0	76.0	7.0	41,800	0.083	29.9
406	D + HM/primary collector	25,200	16.6	78.5	5.5	42,800	0.099	36.5
407A	D + HM/primary collector	24,100	16.2	77.0	7.5	--	--	--
408[a]	D + HM/primary collector	21,500	16.0	76.0	7.5	37,300	0.086	27.4
409A	D + HM/primary collector	29,500	15.3	75.0	7.5	--	--	--
410	D + HM/primary collector	21,000	17.8	80.0	8.0	36,000	0.057	17.7

a/ Test conducted with skimmer recycle system in operation.
D - dryer
HM - hammermill
PM - pellet mill

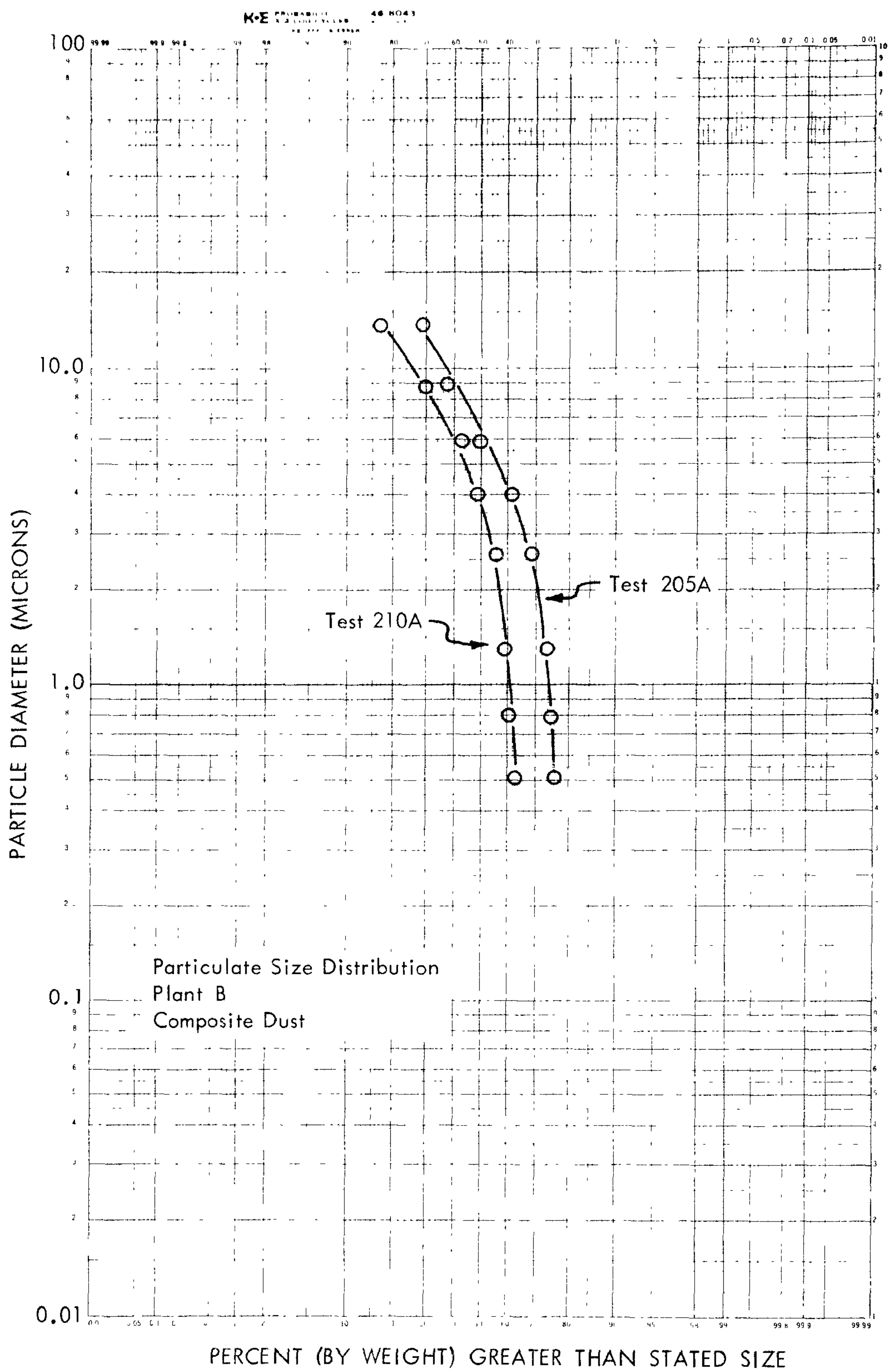


Figure 16. Particulate size distribution, alfalfa dehydration, Plant B.

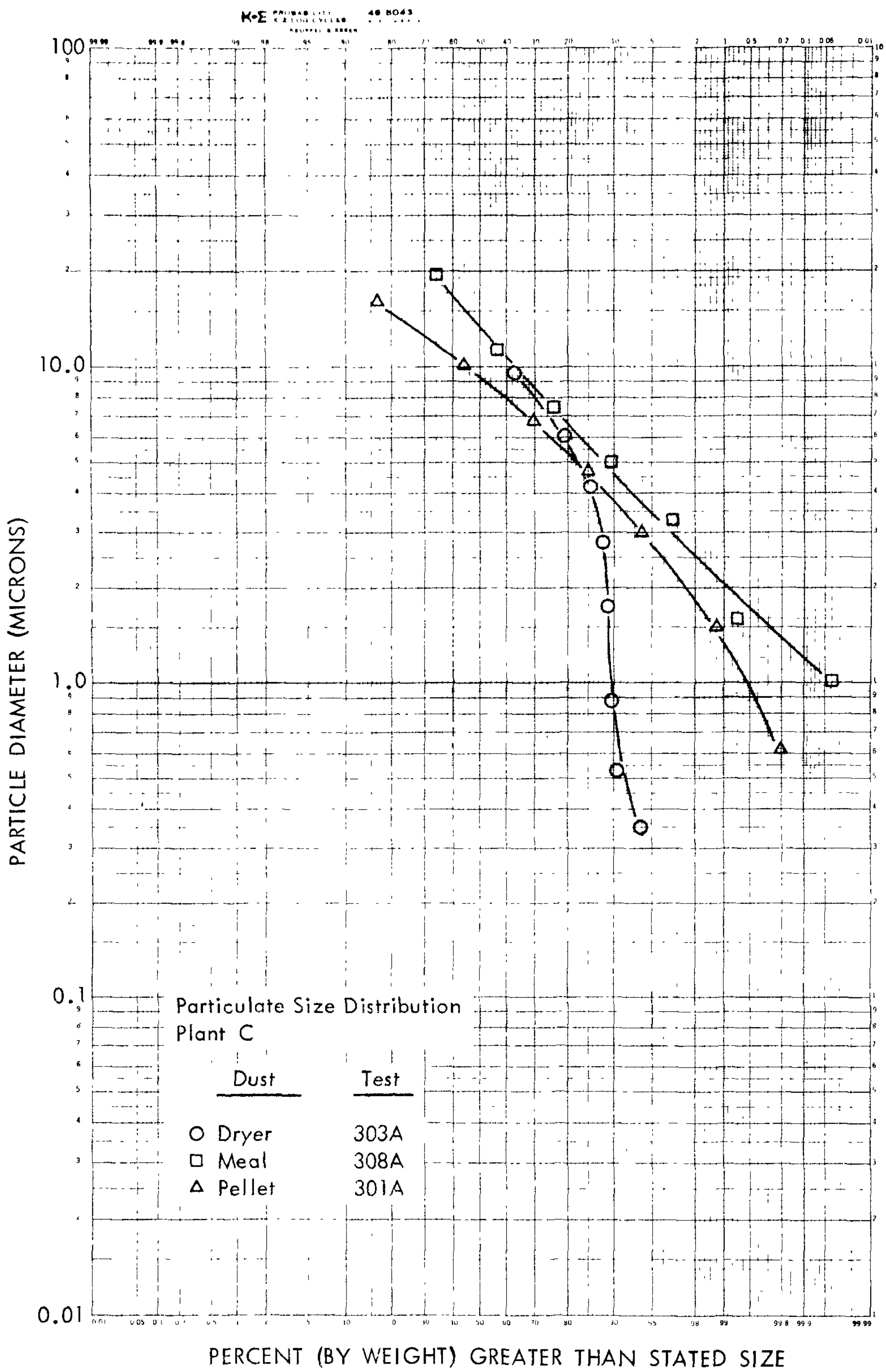


Figure 17. Particulate size distribution, alfalfa dehydration, Plant C.

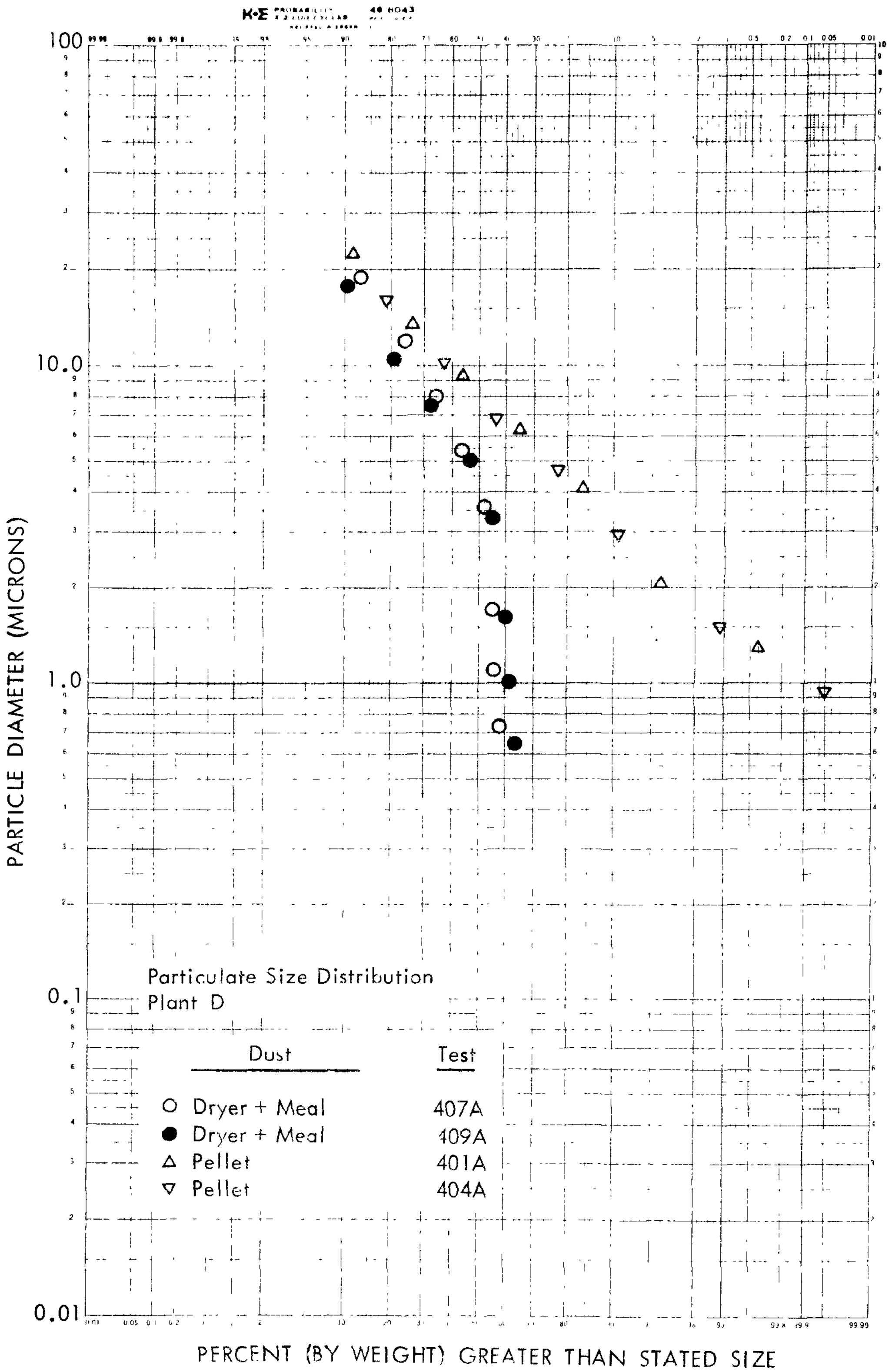


Figure 18. Particulate size distribution, alfalfa dehydration, Plant D.

The effects of changes in process weight rate were measured (Tests 405, 406, and 410), and a skimmer system (Tests 408 and 409A) which recycled dust from the outlet of the primary collector back to the dryer furnace was also tested.

The test results summarized in the preceding paragraphs show that emissions from the drying operation comprise more than 75% of the total emissions, and are the most difficult to control. Dryer emissions vary with process-weight-rate, hay quality, dryer operations, and cyclone collector efficiency. The effect of over drying is to increase substantially emissions from the drying and grinding operations.

Reference 14 presents the results of another field testing program conducted by MRI for the ADA during the summer of 1972. In this second testing program, benchmark performance data were obtained on two pilot-scale and three full-scale wet scrubbers and on two full-scale control systems which recycle effluent from the primary cyclone. More complete information about these devices/systems and the testing results are contained in Reference 14. The test results are shown in Tables 116 through 122. The test results presented in Tables 116 to 122 indicate that medium efficiency wet scrubbers have the potential to bring alfalfa dryer emissions into compliance with process-weight-rate standards, although problems of water clarification and sludge disposal remain to be solved. The results also indicate that the partial recycle of primary cyclone effluent back to the dryer furnace holds promise for the significant reduction of particulate emissions.

The test data reported in References 13 and 14 can be utilized to calculate emission factors. Tables 123 and 124 present emission factors derived from the test programs conducted by MRI. Table 125 presents emission factors derived from data presented in a separate study reported in Reference 15. The emission factors shown in Tables 123 and 124 are expressed in pounds of dust emitted from the collection cyclones per ton of alfalfa chops entering the process. Emission factors for alfalfa dehydrating plants may also be reported as pounds of dust emitted per ton of meal produced. To convert from one basis (lb/ton of chops) to the other (lb/ton of meal) the following approximate relationship can be used:

$$\frac{\text{Pounds Dust}}{\text{Ton of Chops}} \times 4 \approx \frac{\text{Pound Dust}}{\text{Ton of Meal}}$$

The multiplier of four (4) was used on the basis that the chops usually contain about 77% water, while the meal contains only about 8% water. Thus, 100 lb of chops will yield about 25 lb of meal. Actual moisture contents of the chops and meal should be used, if available.

Table 116. ALFALFA DEHYDRATION, TEST RESULTS CONTROL DEVICE/SYSTEM - A[a]
(Pilot-Scale Wet Scrubber)

DRYER CONDITIONS

Test	Process Weight Rate (lb/hr)	Protein (%)	Chop Moistures (%) Green	Chop Moistures (%) Dry	Back-End Temp. (°F)	Excess Air (%)	Evaporation Rate (lb/hr)
1	20,600	18.5	74.3[b]	10.8[b]	270	202	14,600
3	22,000	18.5	77.9[b]	11.1[b]	258	182	16,500
6	19,300	-	71.2	6.9	250	512	13,300

CARRIER GAS CONDITIONS

Test	Temp. (°F)	Moisture (% by vol.)	Avg. Vel. (fpm)	Flow Rate (acfm)	Flow Rate (dscfm)	Particulate Loading (gr/acf)	Particulate Loading (gr/dscf)
1-I	208	32.7	1,734	850	445	0.0631	0.1203
1-O	164	31.7	1,205	590	332	0.0546	0.0919
3-I	206	37.3	1,517	743	366	0.0836	0.1699
3-O	166	31.0	1,304	639	364	0.0561	0.0985
6-I	182	24.1	1,366	672	407	0.0497	0.0822
6-O	217	16.4	1,525	750	491	0.0183	0.0280

CONTROL PERFORMANCE

Test	Pellet Prod. Rate (tons/hr)	Moisture Flow (lb/hr)	Pressure Drop (in. H_2O)	Water Usage (gpm)	Avg. Particle Size (μ)	Particulate Rate (lb/hr)	Collection Efficiency (%)
1-I	2.85	605	12	4.4	0.55	0.46	39.1
1-O		430			-	0.28	
3-I	2.62	608	11.7	3.1	0.55	0.53	41.5
3-O		458			-	0.31	
6-I	3.00	361	9.5	3.7	0.60	0.29	58.6
6-O		269			-	0.12	

a/ Primary cyclone effluent is dryer plus hammermill.
b/ Laboratory result.

Table 117. ALFALFA DEHYDRATION TEST RESULTS CONTROL DEVICE/SYSTEM - B[a]
(Pilot-Scale Wet Scrubber)

DRYER CONDITIONS

Test	Process Weight Rate (lb/hr)	Protein (%)	Chop Moistures (%) Green	Dry	Back-End Temp. (°F)	Excess Air (%)	Evaporation Rate (lb/hr)
2	22,700	21.8	76.8[b]	6.5[b]	275	353	17,100
3	16,800	18.9	77.3[b]	4.0[b]	290	353	12,900
4	16,100	19.9	73.8[b]	5.2[b]	285	353	11,600

CARRIER GAS CONDITIONS

Test	Temp. (°F)	Moisture (% by vol.)	Avg. Vel. (fpm)	Flow Rate (acfm)	Flow Rate (dscfm)	Particulate Loading (gr/acf)	Particulate Loading (gr/dscf)
2-I	216	32.1	4,376	2,210	1,170	0.0890	0.1690
2-O	154	33.1	4,498	2,270	1,260	0.0389	0.0705
3-I	193	32.0	3,950	2,000	1,090	0.1180	0.2170
3-O	153	32.2	3,965	2,000	1,120	0.0385	0.0692
4-I	218	32.9	4,126	2,080	1,070	0.1700	0.3300
4-O	155	33.2	4,000	2,020	1,100	0.0606	0.1110

CONTROL PERFORMANCE

Test	Pellet Prod. Rate (tons/hr)	Moisture Flow (lb/hr)	Pressure Drop (in. H_2O)	Water Usage (gpm)	Avg. Particle Size (μ)	Particulate Rate (lb/hr)	Collection Efficiency (%)
2-I	2.75	1,540	6.0		17.0	1.69	55.0
2-O		1,740			0.45	0.76	
3-I	1.95	1,430	7.1		-	2.02	67.3
3-O		1,480			-	0.66	
4-I	2.15	1,470	7.8		-	3.03	65.3
4-O		1,530			-	1.05	

a/ Primary cyclone effluent is dryer plus hammermill.
b/ Laboratory results.

Table 118. ALFALFA DEHYDRATION TEST RESULTS CONTROL DEVICE/SYSTEM - C[a]
(Recycle System)

	DRYER CONDITIONS						
Test	Process Weight Rate (lb/hr)	Protein (%)	Chop Moistures (%) Green	Chop Moistures (%) Dry	Back-End Temp. (°F)	Excess Air (%)	Evaporation Rate (lb/hr)
1	24,300	17.0	73.0	4.8[b]	280[c]	224	17,400
3	32,800	16.5	73.0	8.5[b]	275	189	23,100
5	35,500	-	76.0	8.9[b]	278	165	26,200
6	36,500	18.5	76.6	9.4[b]	279	165	27,100
8	33,200	18.6	76.0	4.3[b]	294	132	24,900
9	32,800	19.3	77.7	8.3[b]	310	216	24,800
10	31,800	21.6	78.5[b]	5.8[b]	320	183	24,500
11[d]	33,700	21.4	76.2[b]	5.8[b]	325	240	25,200
12	20,800	20.0	74.9[b]	7.2[b]	330	271	15,200

Table 118. (Continued)

GAS CARRIER CONDITIONS

Test	Sampling Location	Temp. (°F)	Moisture (% by vol.)	Avg. Vel. (fpm)	Flow Rate (acfm)	Flow Rate (dscfm)	Particulate Loading (gr/acf)	Particulate Loading (gr/dscf)
1-1	Inlet	213	43.0	5,645	44,500	19,100	0.136	0.318
1-2	Stack	209	34.1	3,071	32,000	12,300	0.114	0.225
3-1	Inlet	224	38.7	5,565	43,800	19,900	0.328	0.722
3-2	Stack	206	42.9	3,694	29,100	12,800	0.470	1.065
5-6	Recycle to: Primary cyclone	211	40.6	7,121	3,150	1,430	0.681	1.499
5-7	Drum	199	42.2	2,139	2,620	1,190	0.448	0.990
5-8	Furnace	188	41.8	3,547	6,470	3,220	0.314	0.681
6-1	Inlet	222	43.1	5,430	42,800	18,100	0.278	0.657
6-2	Stack	213	28.9	4,128	32,500	17,700	0.299	0.5[illegible]9
8-1	Inlet	223	45.3	5,323	41,900	17,100	0.211	0.519
8-2	Stack	204	44.7	4,619	36,400	15,600	0.157	0.336
9-1	Inlet	223	42.8	5,181	40,800	17,500	0.166	0.372
9-2	Stack	215	41.5	4,528	35,700	16,100	0.082	0.183
10-1	Inlet	223	42.2	5,221	41,100	17,800	0.101	0.235
10-2	Stack	209	41.1	4,591	36,200	16,500	0.068	0.149
11-1 d/	Inlet	226	37.2	5,235	41,200	19,200	0.148	0.319
11-2 d/	Stack	228	36.0	5,352	42,200	20,200	0.137	0.284
12-2	Stack	229	38.3	4,420	34,800	16,100	0.066	0.142
12-6	Recycle to: Primary cyclone	236	38.8	6,130	2,700	1,220	0.135	0.299
12-8	Furnace	245	37.3	2,540	5,000	2,290	0.052	0.113

Table 118. (Concluded)

	CONTROL PERFORMANCE					
Test	Pellet Prod. Rate (tons/hr)	Moisture Flow (lb/hr)	Water Usage (gpm) Feeder	Water Usage (gpm) Venturi	Avg. Particle Size (μ)	Particulate Rate (lb/hr)
1-1	3.45	40,200	e/	0	-	50.2
1-2		23,500			-	33.5
3-1	4.63	35,100	0	0	-	123.0
3-2		27,000			7.1	117.0
5-6	4.48	2,730	-		-	18.4
5-7		2,420	4.8	0	-	10.1
5-8		6,470			-	18.8
6-1	4.43	38,400	0	0	-	102.0
6-2		20,100			-	83.2
8-1	4.18	39,500	12.0	1.9 f/	-	75.7
8-2		35,300			-	48.9
9-1	3.85	36,500	2.4	2 f/	-	55.6
9-2		31,800			-	25.1
10-1	3.65	36,300	5.4	2 f/	-	35.8
10-2		32,200			-	21.1
11-1 d/	4.25	31,800	0	0	-	52.4
11-2 d/		31,800			-	49.3
12-2	2.76	27,900	5.8	2 f/	-	19.5
12-6		2,160			-	3.1
12-8		3,800			-	2.2

a/ Primary cyclone effluent is dryer plus all other sources.
b/ Laboratory result.
c/ Estimated value.
d/ Without recycle.
e/ Volume of water not measured.
f/ Volume estimated.

Table 119. ALFALFA DEHYDRATION TEST RESULTS CONTROL DEVICE/SYSTEM - D[a]
(Recycle System)

DRYER CONDITIONS

Test	Process Weight Rate (lb/hr)	Protein (%)	Chop Moistures (%) Green	Chop Moistures (%) Dry	Back-End Temp. (°F)	Fuel Rate (scfh)	Excess Air (%)	Evaporation Rate (lb/hr)
1	38,100	19.1	74.0	13.2	290	43,900	-	26,700
2[b]	35,800	19.0[c]	74.7	11.5	278	52,100	268	25,600
3	35,300	18.8	74.7	11.5	295	-	-	25,600
4[b]	39,600	-	74.2	8.8	-	34,800	168	28,400
5[b]	42,200	-	74.0	10.6	-	51,000	103	29,900
7	35,500	-	73.1	8.3	-	44,500	84	25,100
9	40,600	-	74.6	6.8	-	48,000[c]	42	29,500

CARRIER GAS CONDITIONS

Test	Sampling Location	Temp. (°F)	Moisture (% by vol.)	Avg. Vel. (fpm)	Flow Rate (acfm)	Flow Rate (dscfm)	Particulate Loading (gr/acf)	Particulate Loading (gr/dscf)
1-0	Outlet	225	50.9	1,609	31,000	11,000	0.105	0.297
2-0[b]	Outlet	225	39.9	2,838	54,800	23,800	0.122	0.281
3-0	Outlet	226	53.5	2,081	40,200	13,500	0.138	0.412
3-R	Recycle to: furnace	238	54.5	3,400	21,500	6,930	0.543	1.683
4-0[b]	Outlet	231	37.5	2,416	46,600	22,400	0.283	0.589
5-0[b]	Outlet	214	42.9	2,523	48,700	21,100	0.304	0.703
7-0	Outlet	233	49.9	1,887	36,400	13,200	0.101	0.281
7-R	Recycle to: furnace	254	50.1	3,335	21,000	7,350	0.125	0.359
9-0	Outlet	243	51.5	1,867	36,100	12,300	0.116	0.339
9-R	Recycle to: furnace	239	51.8	3,330	21,000	7,160	0.218	0.639

Table 119. (Concluded)

CONTROL PERFORMANCE

Test	Pellet Prod. Rate (tons/hr)	Moisture Flow (lb/hr)	Avg. Particle Size (μ)	Particulate Rate (lb/hr)	Emission Factor (lb/ton)
1-0	5.35	32,000	-	28.0	
2-0 b/	4.83	44,200	-	57.4	3.21
3-0	4.83	43,400	-	47.7	
3-R		23,200	-	99.9	
4-0 b/	5.49	37,600	-	113.2	5.72
5-0 b/	5.93	44,300	4.5	127.1	6.03
7-0	5.22	36,600	-	31.6	
7-R		20,600	-	22.6	
9-0	5.65	36,500	< 0.5	35.7	
9-R		21,500	11.0	39.2	

a/ Primary cyclone effluent is dryer only.
b/ Without recycle.
c/ Estimated value

Table 120. ALFALFA DEHYDRATION, TEST RESULTS CONTROL DEVICE/SYSTEM - E[a/]
(Full-Scale Wet Scrubber)

DRYER CONDITIONS

Test	Process Weight Rate (lb/hr)	Protein (%)	Chop Moistures (%) Green	Chop Moistures (%) Dry	Back-End Temp. (°F)	Excess Air (%)	Evaporation Rate (lb/hr)
1	29,400	18.3	74.6[b/]	6.1[b/]	301	306	21,500
2	29,400	-	71.9	4.6[b/]	316	90	20,700
4	27,400	20.1	76.4[b/]	8.2[b/]	280	152	20,400
6[c/]	19,600	18.6	59.3[b/]	8.1[b/]	326	907	10,900

CARRIER GAS CONDITIONS

Test	Temp. (°F)	Moisture (% by vol.)	Avg. Vel. (fpm)	Flow Rate (acfm)	Flow Rate (dscfm)	Particulate Loading (gr/acf)	Particulate Loading (gr/dscf)
1-I	225	45.7	4,443	31,400	12,600	0.1029	0.256
1-0	158	45.0	4,163	29,400	13,000	0.0869	0.196
2-I	242	47.0	4,587	32,400	12,400	0.1122	0.293
2-0	150	47.3	4,132	29,200	12,600	0.0936	0.218
4-I	210	39.6	4,746	33,500	15,300	0.0703	0.154
4-0	147	41.1	4,166	29,400	14,200	0.0497	0.103
6-I[c/]	226	17.1	5,843	41,300	25,600	0.0377	0.061

Table 120. (Concluded)

CONTROL PERFORMANCE

Test	Pellet Prod. Rate (tons/hr)	Moisture Flow (lb/hr)	Pressure Drop (in. H_2O)	Water Usage (gpm)	Avg. Particle Size (μ)	Particulate Rate (lb/hr)	Emission Factor (lb/ton)	Collection Efficiency (%)
1-I	3.94	29,800	6-9[e]	175[d]	-	27.7	1.89	
1-0		29,800			-	21.9		20.9
2-I	4.31	31,000	6-9[e]	175[d]	-	31.2	2.12	
2-0		31,600			-	23.4		24.9
4-I	3.46	28,200	6-9[e]	175[d]	< 0.7	20.2	1.48	
4-0		27,700			< 0.7	12.5		38.0
6-I[c]	4.22	14,800	6-9[e]	175[d]	3.4	13.4	1.37	

a/ Primary cyclone effluent is dryer only.
b/ Laboratory result.
c/ Koch unit disconnected.
d/ Estimated recirculation rate; estimated make-up rate = 2.5 gpm.
e/ Estimated value.

Table 121. ALFALFA DEHYDRATION, TEST RESULTS CONTROL DEVICE/SYSTEM - F[a]
(Full-Scale Wet Scrubber)

DRYER CONDITIONS

Test	Process Weight Rate (lb/hr)	Protein (%)	Chop Moistures (%) Green	Chop Moistures (%) Dry	Back-End Temp. (°F)	Excess Air (%)	Evaporation Rate (lb/hr)
1	19,200	20.9	80.3[b]	8.4[b]	232	313	15,100
3	14,500	18.3	81.0[b]	7.4[b]	232	193	11,500

CARRIER GAS CONDITIONS

Test	Temp. (°F)	Moisture (% by Vol.)	Avg. Vel. (fpm)	Flow Rate (acfm)	Flow Rate (dscfm)	Particulate Loading (gr/acf)	Particulate Loading (gr/dscf)
1-I	207	44.8	2,516	19,300	8,120	0.0780	0.1854
1-0	160	35.1	221	17,000	8,980	0.0337	0.0637
3-I	219	41.8	2,458	18,600	8,340	0.0673	0.1523
3-0	158	33.7	219	16,700	9,210	0.0360	0.0654

CONTROL PERFORMANCE

Test	Pellet Prod. Rate (tons/hr)	Moisture Flow (lb/hr)	Pressure Drop (in. H_2O)	Water Usage (gpm)	Avg. Particle Size (μ)	Particulate Rate (lb/hr)	Collection Efficiency (%)	Emission Factor (lb/ton)
1-I	2.07	18,400	2.8	125[c]	8.4	12.9	62.0	1.34
1-0		13,600			0.5	4.9		
3-I	1.49	16,700	2.9	125[c]	-	10.9	52.6	1.50
3-0		13,100			-	5.2		

a/ Primary cyclone effluent is dryer only.
b/ Laboratory result.
c/ Estimated recirculation rate; estimated make-up rate = 2 gpm.

Table 122. ALFALFA DEHYDRATION TEST RESULTS CONTROL DEVICE/SYSTEM - G[a]
(Full-Scale Wet Scrubber)

DRYER CONDITIONS

Test	Process Weight Rate (lb/hr)	Protein (%)	Chop Moistures (%) Green	Chop Moistures (%) Dry	Back-End Temp. (°F)	Excess Air (%)	Evaporation Rate (lb/hr)
2	19,200	24.3	76.3[b]	5.7[b]	290[c]	229	14,400
3	22,500	24.5	82.3[b]	7.2[b]	290[c]	229	18,200
4	22,500	24.5	82.3[b]	7.2[b]	290[c]	229	18,200

CARRIER GAS CONDITIONS

Test	Temp. (°F)	Moisture (% by vol.)	Avg. Vel. (fpm)	Flow Rate (acfm)	Flow Rate (dscfm)	Particulate Loading (gr/acf)	Particulate Loading (gr/dscf)
2-I	246	37.2	4,382	29,300	14,600	0.1434	0.2877
2-0	118	13.8	3,914	26,500	22,000	0.0431	0.0519
3-I	236	26.2	4,821	32,200	19,100	0.0926	0.1570
3-0	103	9.4	3,091	20,900	18,700	0.0372	0.0418
4-I	232	30.6	4,918	32,900	18,300	0.1331	0.2388
4-0	108	6.7	2,962	20,100	18,300	0.0185	0.0203

CONTROL PERFORMANCE

Test	Pellet Prod. Rate (tons/hr)	Moisture Flow (lb/hr)	Pressure Drop (in. H_2O)	Water Usage (gpm)	Avg. Particle Size (μ)	Particulate Rate (lb/hr)	Collection Efficiency (%)	Emission Factor (lb/ton)
2-I, 2-0	2.35	24,200; 9,860	-	400-800[b]; 400-800[b]	7.0; 0.6	36.0; 9.8	72.8	3.75
3-I, 3-0	1.95	18,800; 5,420	-	400-800[b]; 400-800[b]	-; -	25.6; 6.7	73.8	2.28
4-I, 4-0	2.15	22,600; 3,670	1.5	400-800[b]; 400-800[b]	-; -	37.5; 3.2	91.5	3.34

a/ Primary cyclone effluent is dryer only.
b/ Laboratory result.
c/ Value estimated.

Table 123. ALFALFA DEHYDRATION PLANT EMISSION FACTORS[a]

Plant	PWR[b] (lb/hr)	Pollutant Source(s)	Carrier Gas Flow, acfm	Carrier Gas Temp. °F	Grain Loading (grains/acf)	Emissions (lb/hr)	Emission Factor[c] (lb/ton)
A[d]	21,700	Primary cyclone and meal collection cyclone and pellet cooler cyclone	35,000	220	0.20	50	4.6
A[c]	21,700	Primary cyclone and meal collection cyclone	35,000	220	0.20	50	4.6
B[c]	23,000	Primary cyclone	Not available		0.10	50	4.4
B[c]	23,000	Primary cyclone and meal collection cyclone and pellet cooler cyclone	55,000	220	0.15	60	5.2
C	31,000	Primary cyclone	40,000	300	0.30	100	6.5
C	31,000	Meal collection cyclone	2,000	160	0.60	10	0.65
C	31,000	Pellet cooler cyclone	16,500	130	0.10	10	0.65
D[e]	23,000	Primary cyclone and meal collection cyclone	40,000	220	0.10	30	2.6
D	23,000	Pellet collector cyclone	2,000	Not available	0.05	1	0.09
D	23,000	Pellet cooler cyclone	2,000	130	0.25	5	0.44

a/ Emissions factors calculated from data in Reference 13.
b/ PWR is Process Weight Rate expressed as pounds per hour green chops.
c/ Emission Factor expressed as pounds emitted per ton of green chops.
d/ All sources discharge through primary cyclone.
e/ Meal collector cyclone discharges through primary cyclone.

Table 124. ALFALFA DEHYDRATION PLANT EMISSION FACTORS

Emission Source	Uncontrolled[a/] Emission Factors (lb/ton)	Average Uncontrolled Emission Factor (lb/ton)
Primary cyclone (Plant C)[b/]	3.03	3.03
Primary cyclone (Plant D)[c/]	3.21, 5.72, 6.03	4.99
Primary cyclone (Plant E)[c/]	1.89, 2.12, 1.48, 1.37	1.72
Primary cyclone (Plant F)[c/]	1.34, 1.50	1.42
Primary cyclone (Plant G)[c/]	3.75, 2.28, 3.34	3.12
	Average	2.86

a/ Emission factors are in pounds/ton of green chop. Emission factors derived from data in Reference 14.

b/ All sources ducted to primary cyclone.

c/ Primary cyclone effluent was from dryer only.

A comparison of available emission factor data, for the particulate sources in the dehydrating process, is shown in Table 126. There are considerable differences in the data from the different information sources. The emission factors for the primary cyclone (which include other significant sources in some cases) are highest for the data in Reference 13, and show a range of 2.6-6.5 lb/ton chops and an average of 4.65 lb/ton chops. However, emissions from the other sources are lower in Reference 13 than Reference 15, especially from the meal collection cyclone. These variations may be due to differences in control equipment, measurement techniques or plant operating conditions. Data in Reference 13, for emissions from the meal collector, were taken at the outlet of the secondary cyclone that is in series with the primary cyclone which should help to reduce the emissions. The emissions from the primary cyclone reported in References 13 and 14 also include, in some cases, the effluents from other sources that are ducted to the primary cyclone. This would add to the effluent from the primary cyclone, but the total emissions may be less than they would be if the effluent from other sources were allowed to vent to atmosphere.

Although the data reported in References 13 and 14 represent relatively well controlled plants, the measurement techniques are significantly different than those used in References 15 and 16. Measurements in References 13 and 14 were according to EPA Method 5 and included duct extensions for the cyclone outlets. At least part of the sampling reported in Reference 15 was performed right at the cyclone outlet which makes it difficult to obtain accurate results. While differences in the emission factors may be partly caused by the type of primary cyclone and the measurement techniques, it is also known that emissions from these plants can vary widely due to quality of the alfalfa (moisture and protein content) and operating conditions (over drying or under drying), etc.).

Examination of the available data plus many plant visits and discussions with plant operators and others knowledgeable in the field have lead to the conclusion that the greatest portion of the dust emission from an alfalfa dehydrating plant comes from the drying operation (i.e., the primary cyclone). The data in Table 126 show that the average emission factor for the primary cyclone varies from 2.0 to 4.65 lb/ton. The data reported in References 13 and 14 were obtained using EPA Method 5 procedures so these are probably the most accurate values available. The average of these two values (2.86 and 4.65) indicate that the overall average would be 3.75 lb/ton of green chops. This is approximately equivalent to 15.0 lb/ton of meal, which is much lower than the emission factor of 60 lb/ton of meal specified in Reference 17. The Duprey factor was apparently based on data from Reference 15. These data were obtained prior to 1960, using techniques that are not as accurate as the recent EPA procedures. It is therefore felt that the emission factor of 15 lb/ton of meal is more representative for the primary cyclone and that the total plant emission factor probably does not exceed 20 lb/ton of meal.

Table 126. COMPARISON OF ALFALFA DEHYDRATION PLANT EMISSION FACTOR DATA (lb/ton)[a]

PRIMARY CYCLONE

Reference 13	Reference 14	Reference 15	Reference 16
4.6[b]	3.03[c]	2.25	4.8[b]
4.6[d]	4.99	3.25	1.9[b]
5.2[b]	1.72		1.0[b]
4.4	1.42		0.8[b]
6.5	3.12		1.6[b]
2.6[d]			2.7[b]
			3.0[d]
Average 4.65	Average 2.86	Average 2.75	1.2
			0.6[d]
			Average 2.0

SECONDARY COOLING CYCLONE

Reference 15
1.25
0.72
Average 1.0

MEAL COLLECTION CYCLONE(S)

Reference 13	Reference 15
0.65	2.25
	12.0
	Average 7.1

PELLET COOLER CYCLONE

Reference 13	Reference 15
0.65	0.25
0.53[e]	1.5
Average 0.8	

PELLET REGRIND

Reference 13	Reference 15
2.0	0.5

a/ All emission data expressed as pounds per ton of green chops.
b/ Includes discharge from meal collector cyclone and pellet cooler cyclone.
c/ All sources ducted to primary cyclone.
d/ Includes discharge from meal collector cyclone.
e/ Sum of pellet collector and pellet cooler cyclone discharges.

WHEAT MILLING

Flour and products made from flour have been used by man for centuries. Flour milling has been transformed during the last 50 to 60 years from a semi-agricultural operation into a complex industry. Milling processes have undergone dramatic changes, as have also the transportation, distribution, and usage of the product.

Modern flour mills are steel and concrete structures flanked by wheat storage elevators. They draw wheat from wide regions, often from a quarter of the nation, and the destination of the product is even wider in scope.

The Milling of Wheat

The wheat milling process consists of five main parts. They are:[18/]

1. Reception and storage of wheat,

2. Cleaning of the wheat,

3. Tempering or conditioning,

4. Milling of wheat into flour and into its by-products, and

5. Storage and/or shipment of finished product.

Figure 19 presents a simplified diagram of a flour mill.[19/] Operations performed in each of these areas are discussed in the following sections.

Reception and Storage of Wheat - Wheat arrives at mill elevators by truck, rail, barge or ship. Truck and rail shipments are unloaded at receiving pits while marine conveying systems are used for barge or ship unloading. Following unloading the grain is transferred by conveyors to the elevator headhouse. The wheat received at a mill generally contains impurities and foreign material such as sticks, stones, and bits of cloth or paper. These are removed in a preliminary cleaning operation prior to storage of the wheat. From the cleaning equipment, the wheat is conveyed to storage tanks.

Cleaning House - As grain is needed for milling, it is withdrawn from the storage elevator and conveyed to the mill area. The first step is to send the wheat through a cleaning operation prior to the actual milling. This section of a mill is called the cleaning house. The techniques used in the cleaning house must be refined in order to remove dust and smaller pieces of foreign matter. The impurities usually differ from wheat by one or several of the following characteristics: (1) size, (2) specific gravity,

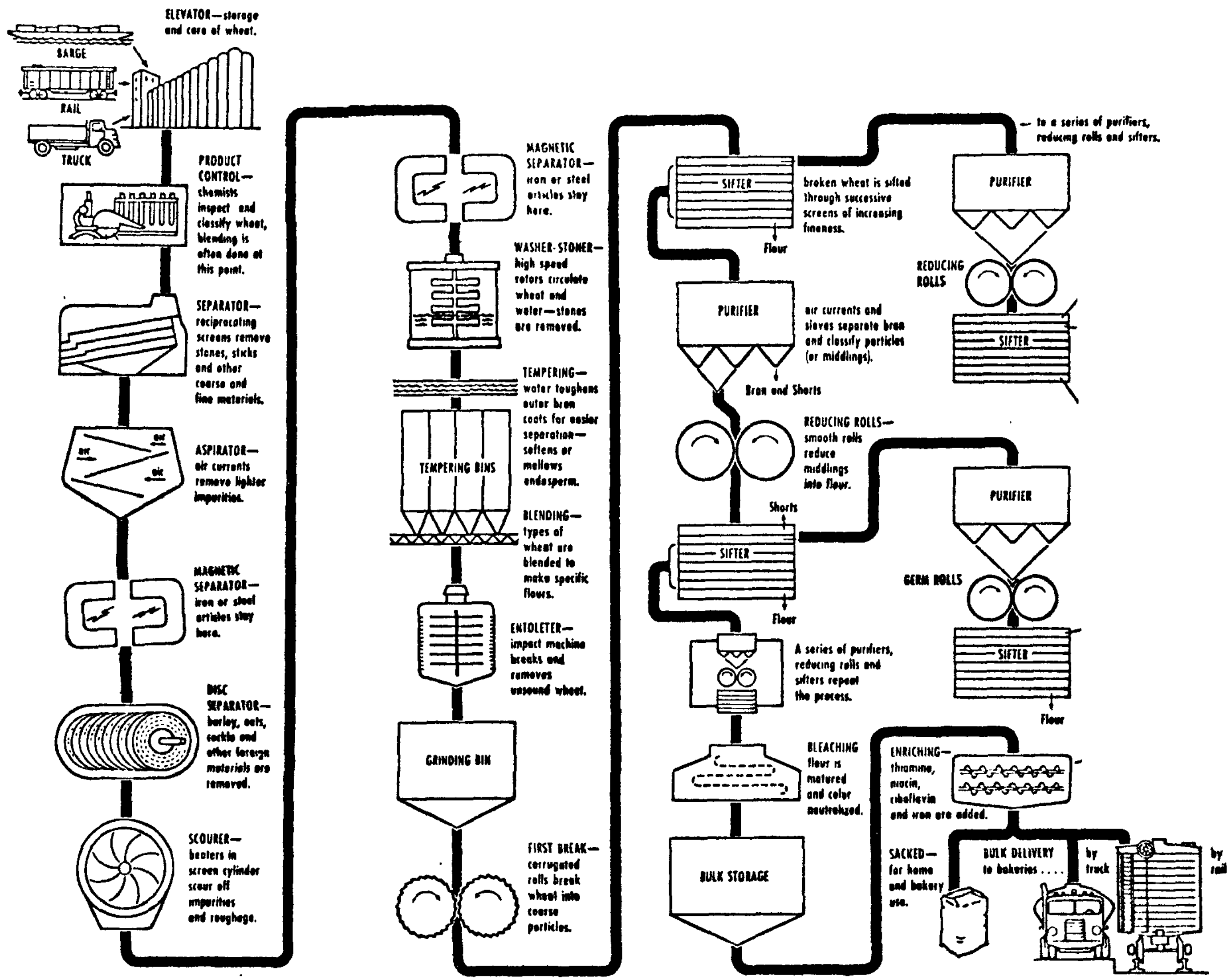


Figure 19. Simplified flow diagram of a flour mill.19/

(3) shape, (4) air resistance, and (5) inherently different material (e.g., metal, stone). Equipment used to clean the wheat utilizes one or more of these differences to accomplish the cleaning.[20]

While placement and sequence of equipment varies from mill to mill, the general flow scheme shown in Figure 19 will be used for subsequent discussion. The wheat first enters a separator, where it passes through a vibrating screen which removes bits of straw and other foreign matter, then over a second screen through which drop small foreign materials like seeds.

Next, an aspirator lifts off lighter impurities in the wheat. The stream of grain is directed across screens while air sucks off the dust and lighter particles. The stream of wheat next passes over a magnetic separator that pulls out iron and steel particles. The magnetic separator acts as a safeguard against nuts, bolts, rivets, or other pieces of metal which may break loose from machinery. Magnetic separators are used at many different points in a mill, especially in the feed to any machine applying friction, where the risk of damage or fire is greatest.

From the magnetic separator, the wheat enters a disc separator which consists of discs revolving on a horizontal axis. The surface of the discs are indented to catch individual grains of wheat but reject larger or smaller material. The blades also act to push the wheat from one end of the machine to the other. The revolving discs discharge the wheat into a hopper, or into the continuing stream. The wheat is then directed through another magnet to a stoner for removal of stones, sand, flints, and balls of caked earth or mud which may be so nearly the same size as the wheat grains that they cannot be sifted out. Both wet and dry stoners are used for this purpose.[19]

The wheat then moves into a scourer--a machine in which beaters attached to a central shaft throw the wheat violently against a surrounding drum--buffing each kernal and breaking off the beard. These machines remove a great deal of dust and loose bran--skin adhering to the wheat grains. Scourers may either be horizontal or upright, with or without brushes, and adjusted for mild, medium or hard scouring. Air currents carry off the dust and loosened particles of bran coating. Following the scouring step, the grain is sent to a surge bin which acts as a storage/supply point between the cleaning house and the tempering bins or tanks.

<u>Tempering or Conditioning</u> - Modern milling practice utilizes conditioning or tempering before the start of grinding. Tempering, as it is practiced in the United States, involves adding water to grain to raise the moisture to 15% to 19% for hard wheats and 14.5% to 17% for soft wheats and allowing the wheat to lie in tempering bins (with little or no temperature control) for periods of 8 up to 72 hr. During this time, the water enters the bran

and diffuses inward causing the bran to lose its friable characteristic and to become leathery in texture. The percentage of moisture, length of soaking time, and temperature are the three important factors in tempering, with different requirements for soft, medium, and hard wheats. Usually, tempering is done in successive steps since it is impractical to add more than a few percent of water to wheat at one time.

When the moisture content is properly dispersed in the wheat for efficient milling, the grain is passed over a magnet and then through an Entoleter - Scourer - Aspirator as a final step in cleaning. Discs revolving at high speed in the scourer-aspirator hurl the wheat against finger-like pins. The impact cracks any unsound kernels which are rejected. From the Entoleter machines the wheat flows to a grinding bin or hopper from which it is fed in a continuous metered stream into the mill itself.

Milling - The purpose of flour milling is to first separate the endosperm from bran and germ in as large chunks as possible and then reduce the size of the endosperm chunks to flour-sized particles through a series of milling steps. The milling of wheat is done between pairs of rolls. These rolls, which rotate in opposite directions at different rates of speed, do not mill the wheat primarily by crushing. Rather, the reduction of the wheat is by shearing forces which, because of the set of the rolls, are relatively gentle.

The roller milling area is divided into two sections, the break section and the reduction section. In the first, the kernel is broken open and the endosperm is milled away. This system quite often involves four or more sets of rolls each taking stock from the preceding one. After each break, the mixture of free bran, free endosperm, free germ, and bran containing adhering endosperm is sifted. The bran having endosperm still attached goes to the next break roll, and the process is repeated until as much endosperm has been separated from the bran as is possible.[18/]

The sifting system is a combination of sieving operation (plansifters) and air aspiration (purifiers). A plansifter has flat sieves piled in tiers, one above the other. The action of the sifter is rotary in a plane parallel with the floor. As the sifter moves in about a 3.5-in. circle, the small-sized particles spill through the sieve below while the oversized particles travel across the sieve to a collecting trough and are removed. As many as 12 sieves can be piled one on top of the other and there are four separate compartments in one plansifter.[18/]

The flour and endosperm chunks (middlings) from the plansifter still contain minute size bran particles which are removed by sending the product through a purifier where air currents carry the bran away. A purifier is essentially a long oscillating sieve, inclined downwards and becoming coarser from head to tail. Air currents pass upward through the sieve causing the flour to stratify into endosperm chunks of different size. Aspirated materials go to millfeed.

The reduction system comprises two parts, roll mills and sifting machines. The major difference from the break system is that the surface of the reduction mills is smooth rather than grooved. The purpose of reduction rolls is to reduce endosperm middlings to flour size and facilitate the removal of the last remaining particles of bran and germ.

Plansifters are used behind the reduction rolls and their purpose is to divide the stock into coarse middlings, fine middlings, and flour. The coarse middlings are returned to the coarse (or sizing) rolls, and the fine middlings are returned to the fine roll, while the flour is removed from the milling system.

Purifiers are often used behind the coarse reduction rolls. The purpose in this case is size grading rather than purification, and purifiers are sometimes superior to plansifters for these separation requirements.

Flour stock is transported from machine to machine by gravity or air conveying. Older mills depend upon gravity with the wheat and flour being moved to the top of the mill by bucket elevators and the flour flows by spouts to the rolls and to the sifters. Bucket elevators have two serious disadvantages: they are dusty, and they provide a place for insects to grow. Consequently, flour mills are converting to the air conveying of flour and are abandoning bucket elevators and gravity spouts.[18/]

Storage and Shipment of Finished Product - Bulk handling of flour is generally done by pneumatic conveying systems. Bulk storage capacity varies widely but most mills have bulk flour storage for from 2 to 4 days of production. Special railroad cars and trucks are used to transport bulk flour.

Air Pollution Sources, Emission Rates, and Effluent Properties

The sources of air pollution in a flour mill complex can be grouped into three main categories: (1) grain receiving and handling operations; (2) grain cleaning (cleaning house); and (3) milling operations. Table 127 presents some of the more significant potential sources of air pollution in each category.

Dust emission sources associated with grain receiving are similar to those already discussed for grain elevators in the section on page 120. Nearly all the operations associated with grain receiving and subsequent transfer to storage are potential sources of dust. The grain unloading and cleaning steps are generally considered to be the main sources in this part of the mill complex.

Grain dust, dirt, seeds, and chaff are all emitted from the equipment used in the cleaning house. The separator, aspirator, and scouring equipment are the principal sources of emissions in the cleaning house.

In the milling house, the product recovery systems associated with the various pieces of milling equipment are potential sources of emission. Bran and flour would be the principal materials emitted from these sources.

Flour shipping operations are not a significant dust source because efforts are made to minimize loss of the valuable final product. Loading of by-products can be a significant dust source depending upon the loading procedures used at specific mills.

Data on rates of emissions from flour mill operations are not extensive because only limited source testing has been conducted in flour mills. Available source test data for emissions from flour mill operations are summarized in the following sections.

Table 127. POTENTIAL SOURCES OF AIR POLLUTANTS IN A FLOUR MILL COMPLEX

I. Grain Receiving and Storage

1. Grain unloading
2. Elevator boots and heads
3. Garner and scale vents
4. Grain cleaner
5. Conveyor transfer points

II. Cleaning House

1. Separator
2. Aspirator
3. Disc separator
4. Scourer

III. Mill House

1. Break rolls
2. Purifiers

IV. By-Products

1. Hammermill

V. Shipping

1. Bulk loading
    a. Flour
    b. By-products
2. Packing station

Grain Receiving and Storage - Measured emissions from cyclone dust collector systems serving railcar and truck unloading operations at one mill are summarized in Table 82, p. 122. Tests were conducted during periods of peak unloading activity in order to determine maximum emission rates.

Preliminary Grain Cleaning - Data on emissions from grain cleaning operations performed at two storage elevators are summarized in Tables 96 and 97, pp. 143 and 144.

Grain Turning or Handling Operations - Every process in the storage elevator involves turning (or moving) the grain. Turning includes the operations of belt conveying, elevator transfer, turnhead operation, and bin dumping. Most of these same conveyors and elevators are also used during unloading operations and at times a control system may be serving multiple operations. Emission data for grain handling operations at two flour mills are presented in Tables 101 and 103, pp. 149 and 153.

Cleaning House - All the equipment in a cleaning house can be a source of dust emissions. The limited data available from one mill are presented in Table 128.[3/] In this mill, two cyclones are used to vent a Eureka Separator and one cyclone vents the disc separator and all the conveyor belts and legs.[3/] EPA Method 5 source testing procedures were utilized to obtain the data summarized in Table 128.

Mill House - Particulate emissions from the various machines used to mill the wheat vary with type of equipment used and the physical properties of the wheat. Table 129 presents some test data on grain loadings in the air flowing in the ducts of flour mill suction systems. The data reported in Table 129 were obtained as part of a study conducted in four flour mills to establish the relative efficiencies of cyclone collection systems.

Reference 23 indicates that the dust generated by roller mills ranges from 1.6 to 3.3 lb/bu milled with an average of 2.1 lb/bu milled.

Tables 130 and 131 present some estimated emission rates from control systems on various sources in a flour mill complex.[21/] The data in Tables 130 and 131 were calculated from measured air volumes and the quantity of dust collected by the control device. These measured quantities, combined with assumed efficiencies for the control devices, were used to calculate the inlet and outlet grain loadings as well as quantity emitted from the control device. Because accurate source testing procedures were not used, the emission rates shown in these tables should only be used as general indications of emission levels.

Table 128. DUST EMISSIONS FROM CLEANING HOUSE PROCESSES AT A WHEAT FLOUR MILL[3/]

Emission Source	Process Weight 1,000 lb/hr[a/]	Gas Flow (scfm)[b/]	Emissions (gr/scf)	(lb/hr)	Emission Factor[c/] (lb/ton)	(lb/bu)
Cyclones Venting - Cyclone 1	600	4,720	0.027	1.1	0.0037	0.11×10^{-3}
Eureka Separator - Cyclone 2		4,910	0.036	1.5	0.005	0.15×10^{-3}
Cyclone Venting Disc Separator and Conveyor Belts and Legs	600	5,740	0.098	4.8	0.016	0.48×10^{-3}

a/ Based on 60 lb/bu.
b/ Standard cubic feet per minute corrected to 70°F and 14.7 psia.
c/ EPA Method 5 procedures were used in the sampling activity.

Table 129. GRAIN LOADINGS IN DUCTS OF FLOUR MILL SUCTION SYSTEMS[22]

Mill	Suction System	Grain On Mill	Grain Loading in Air to Collector[a]	Dust in Air Leaving Collector[a]
1	Smooth roll	HRS	7.00	0.045
2	Entoleter	SRW & W	4.00	0.175
3	Hammermill	RYE	35.00	0.182
4	All rolls	SRW & W	12.00	0.053
4	All rolls	HRW	16.80	0.036

a/ Grains per cubic foot, cyclones used as control device.

Table 130. ESTIMATED EMISSIONS FROM VARIOUS OPERATIONS IN FLOUR MILLS[21/]

Source	Control Device	Air Volume (cfm)	Dust Load to Control Device (gr/scf)	Dust Load to Control Device (lb/hr)	Emissions from Control Device (gr/scf)	Emissions from Control Device (lb/hr)
Truck unloading pit belt hoods	Fabric filter	3,000	1.65	42.4	0.15	3.9
Railroad pit belt hoods	Cyclone	3,000	1.23	31.7	0.11	2.9
Railroad pit belt hoods	Cyclone	2,500	2.10	45.2	0.21	4.6
Millerator	Cyclone	3,200	0.91	25.0	0.19	5.0
Flour dryer	Cyclone	3,000	0.29	7.5	0.06	1.5
Scalper	2 Cyclones	3,860	1.1	37.3	0.11	4.1
Scalper	Cyclone	2,950	3.2	81.0	0.35	8.9
Gallery belt hoods	Cyclone	6,700	1.7	100.0	0.19	10.9
Hammermill	Cyclone	1,150	92.4	1,200.0	0.97	12.6
Scourer	Cyclone	2,350	9.9	200.0	-	-
Wet ESA Suction	Cyclone	1,800	9.0	140.0	-	-
Dry ESA Suction	Cyclone	2,000	8.7	150.0	-	-
Wheat cleaning separator	Fabric filter	8,000	1.45	100.0	-	-
Wheat cleaning aspirator	Fabric filter	5,000	2.32	100.0	-	-
Stoner	Cyclone	8,500	2.0	150.0	-	-
Germ table	Fabric filter	2,000	5.8	100.0	-	-
ESA Filter	Fabric filter	12,000	9.78	1,000.0	-	-
Stoner	Cyclone	8,000	4.7	300.0	-	-
Chippewa screener	Cyclone	3,000	0.76	20.0	0.076	2.0
Stoner	2 Cyclones	4,000	0.87	30.0	0.06	2.0

Table 131. ESTIMATED EMISSIONS FROM CYCLONE DUST CONTROL SYSTEMS AT A FLOUR MILL[21/]

Source	Control Device	Air Volume (cfm)	Emission Rate (gr/scf)	Emission Rate (lb/hr)
Elevator house suction	Cyclone	6,000	0.327	16.8
Elevator house suction	Cyclone	6,000	0.327	16.8
Whole wheat house suction	Cyclone	1,660	0.096	1.37
Whole wheat house suction	Cyclone	1,660	0.0205	0.29
Destoner	Cyclone	2,640	0.0144	0.33
Destoner	Cyclone	2,640	0.0267	0.60
Whole wheat millerator	Cyclone	1,200	0.076	0.78
Whole wheat millerator	Cyclone	1,200	0.076	0.78
Flour millerator	Cyclone	7,300	0.075	4.69
Whole wheat grinder	Cyclone	1,820	0.615	0.96
Bran grinder	Cyclone	1,150	0.260	2.56
Whole wheat roll grinder suction	Cyclone	1,540	0.0257	0.34
House suction	Cyclone	8,120	0.560	39.0
Germ table	Cyclone	1,630	0.042	0.59
Germ table	Cyclone	1,900	0.042	0.68
Entoleters	Cyclone	3,080	0.044	1.16
Purifiers	Cyclone	2,510	0.015	0.32
Purifiers	Cyclone	2,510	0.015	0.32
Purifiers	Cyclone	3,040	0.015	0.39
Purifiers	Cyclone	3,040	0.015	0.39

DURUM WHEAT MILLING

Durum Milling Process

The method of milling durum is similar to the milling of wheat, but the purpose is quite different. In the milling of wheat, flour is the desired end product. In the milling of durum, middlings are wanted. Consequently, in durum milling, the break system, where middlings are formed, is emphasized, and the part of the reduction system where flour is formed is de-emphasized.

The processing of durum wheat into durum products consists of the following steps:

1. Reception and storage of wheat

2. Cleaning of wheat

3. Tempering of wheat

4. Milling of durum wheat into products

5. Storage and/or shipment of finished product

Operations performed in the various parts of the mill are discussed in the following sections.

Reception and Storage of Wheat - The operations involved in the reception and storage of durum wheat are similar to those described for wheat in the section on p. 203. Following unloading the grain is transferred to the storage elevator by conveyors. Preliminary cleaning of the durum wheat is usually performed prior to storage.

Cleaning House - Durum goes through normal cleaning house operations used for wheat. The function and placement of equipment in a durum mill cleaning house is similar to that discussed for wheat.

Tempering or Conditioning - The tempering of durum uses the same equipment as wheat but the holding times are shorter than for wheat. This is because of the desire for middlings without flour production. Excessive times in temper soften the endosperm making it easier to make flour. Short times maintain the hard structure of endosperm which encourages the production of endosperm chunks.

Milling House - The break system in a durum mill generally has at least five breaks and provides for the very gradual reduction of the stock necessary for good middlings production while still avoiding large amounts of break flour.

The rolls in a reduction system are used as sizing rolls only. None is used to produce flour. They function the same as the sizing rolls in a flour mill reducing the coarse middling to a uniform particle size. In a flour mill, the sizing is done to produce a uniform product for further grinding on the reduction rolls. In a durum mill, however, sizing is done to make a uniform product for sale.

The sifting system of a durum mill differs from a flour mill by the heavy reliance on purifiers. Actually, plansifters are used little. Rather conventional sieves are much more in evidence. These are used to make rough separations ahead of the purifiers.[26/]

Storage and Shipment of Products - The methods used to transfer, store, and ship the products of a durum mill are similar to those discussed for wheat milling.

Air Pollution Sources, Emission Rates, and Effluent Properties

The sources of air pollution in a durum mill parallel those of a flour mill and can be grouped into three main categories: (1) grain receiving and handling operations; (2) grain cleaning (cleaning house); and (3) milling operations.

Dust emission sources associated with grain receiving are similar to those already discussed for wheat on p. 207. Nearly all the operations associated with grain receiving and subsequent transfer to storage are potential sources of dust. The grain unloading and cleaning steps are generally considered to be the main sources in this part of the mill complex.

Grain dust, dirt, seeds, and chaff are all emitted from the equipment used in the cleaning house. The separator, aspirator, and scouring equipment are the principal sources of emissions in the cleaning house.

In the milling house, the product recovery systems associated with the various pieces of milling equipment are potential sources of emission.

Shipping operations are not a major dust source because efforts are made to minimize loss of the valuable final product. Loading of by-products can be a significant dust source depending upon the loading procedures used at specific mills.

Data on rates of emission from durum mill operations are limited. Since the processing operations are similar to those of a flour mill, the rates of emission are expected to be similar.

CORN DRY MILLING

Corn is dry milled by two general systems--degerming or nondegerming. The nondegerming system grinds corn, preferably a white dent, into a meal with little, if any, removal of germ. Near the turn of the 20th Century, the Beall corn degerminator was introduced to the dry corn milling industry. The development of degerming equipment resulted in a milling system that removes from the kernel practically all the hull, germ, and tip cap for the production of corn grits, meal, flour, hominy feed, and oil. This system, as used in the United States, will be used to discuss the various processes in a corn dry milling plant.

The Dry Milling of Corn

The conventional degerming system involves the following steps after receipt of the grain:[26,27]

1. Dry cleaning and, if necessary, wet cleaning of the corn.

2. Tempering of the corn by controlled addition of moisture.

3. Separation of hull, germ, and tip cap from the endosperm in a degermer.

4. Drying and cooling of product from degermer.

5. Multistep milling of degermer product through a series of roller mills, sifters, aspirators, and purifiers.

6. Further drying of products, if necessary.

7. Processing of germ fraction for recovery of crude corn oil.

8. Packaging and shipping of products.

Figure 20 presents a general flow diagram of a corn dry milling facility. The individual steps in the milling process are discussed in the following sections.

Grain Receiving - Grain is transported to a mill by truck, rail or barge. Truck and rail shipments are unloaded at receiving pits while marine conveying systems are used for barge unloading. Following unloading, the grain is transferred by conveyors to a storage elevator. Preliminary cleaning of the grain, using scalpers, etc., to remove gross impurities may be performed prior to storage.

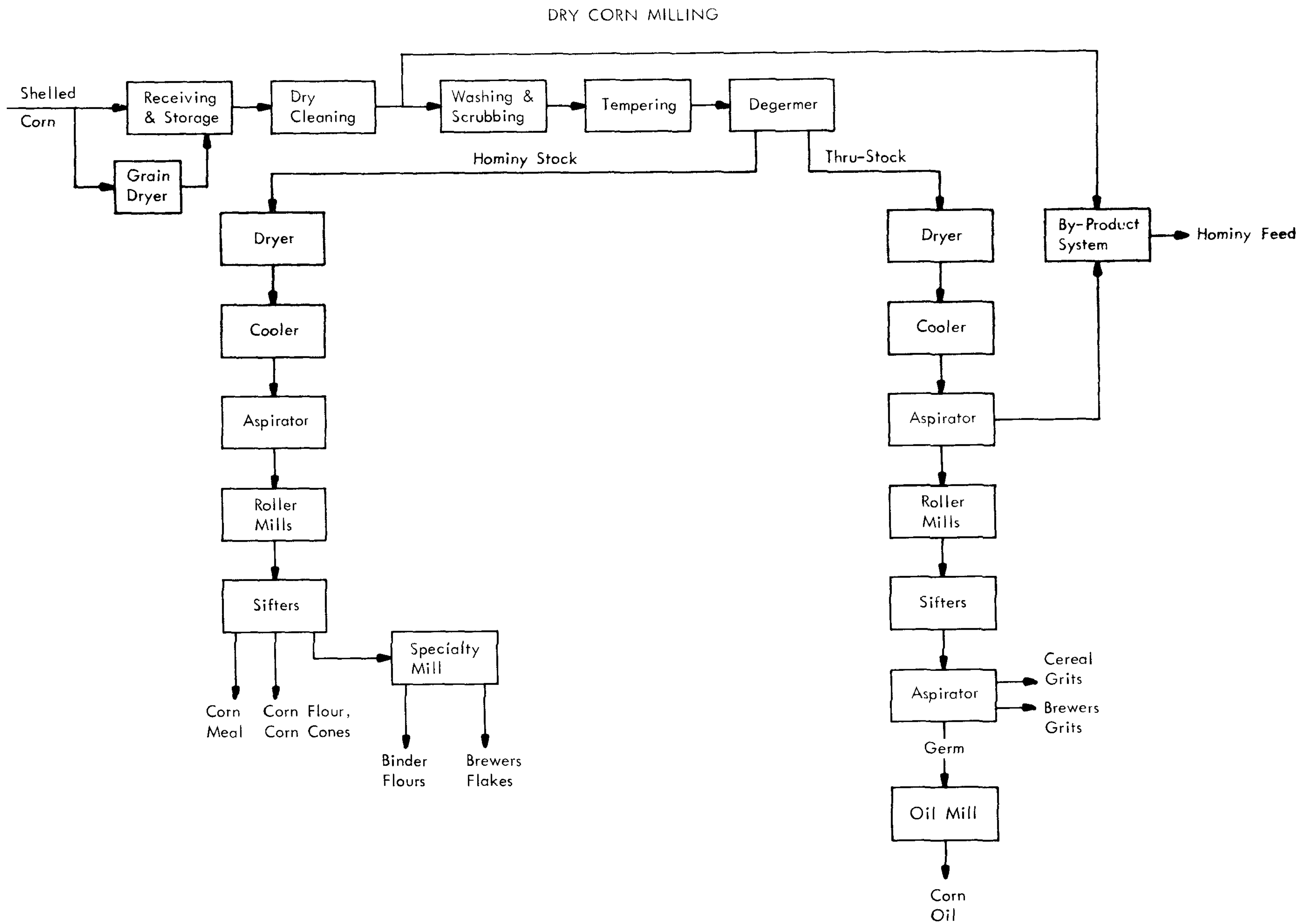


Figure 20. General flow diagram of a corn dry milling plant.

Grain Cleaning - The cleaning step is one of the most important operations in a dry corn mill. Ferrous metals are removed by a magnetic separator. Dry cleaning devices such as milling separators, scourers, disc separators, electrostatic separators, aspirators, vibrating screens, and destoners are used to remove impurities. Surface dirt and spores of microorganisms can best be removed by wet cleaning rather than dry. Conventional wet cleaning equipment consists of a washing-destoning unit followed by a mechanical-type dewatering unit, usually referred to as a whizzer.

Suspended solids are removed from the wash water effluent by a dewatering screen, settling tank, or similar means and are added to the hominy feed. The effluent usually is further processed in a waste treatment plant to reduce the BOD level before discharge from the mill.

Tempering - After cleaning, the corn is sent through a tempering or conditioning step. Normally, the moisture content of the corn is raised to about 21-25% rather than the 17% used for wheat milling.[26,27] This is done because the germ of the corn tends to be more friable than the germ of the wheat and if it is too dry, it will break into small flour sized pieces during degerming. If enough water is added, not only the bran is toughened but so is the germ.

Degerming - Degerming follows the conditioning or tempering step. The Beall degermer and corn huller are used in over 90% of the degerming mills in the U.S. The Beall degermer is essentially an attrition device built in the form of a cone mill. It consists of a cast-iron, cone-shaped rotor mounted on a rotating, horizontal shaft in a conical cage. Part of the cage is fitted with perforated screens and the remainder with plates having conical protrusions on their inner surface. The cone has similar protrusions over most of its surface. Also, the small or feed end of the cone has spiral corrugations to move the corn forward; attached to the large end is a short cylinder corrugated in an opposing direction to retard the flow. The product leaves in two streams. Through stock, normally about 60-75% of the degermer stock, is discharged through the perforated screens and contains a major portion of the released germ, hull, and degermer fines, as well as some of the grits. Tail stock, in which large grits predominate, escapes through an opening in an end plate facing the large end of the cone. A hinged gate with an adjustable weight restricts flow of this stock stream.

Entoleters, granulators, disc mills and roller mills are also used as degermers.

Drying and Cooling of Degermer Stock - The moisture content of the degermer product must be in the 15-18% range for proper milling. Rotary steam-tube dryers with air drawn through the dryer to carry off the vaporized moisture are often used to dry the degermer products.

Coolers may be counter-flow or cross-flow rotary, vertical gravity louver, or fluid bed. In the rotary types, lifting flights rotating inside a horizontal shell shower material through an air stream and move the stock towards the outlet. In the vertical cooler, solids flow by gravity down through a column containing louvers for alternately introducing and withdrawing cooling air. Air is drawn through the coolers either by a fan or a natural draft tower. Temperature of the stock is lowered to 90°-100°F in the cooler and the cooling step removes about 0.5% moisture.

Milling Operation - The milling section in a dry corn mill consists of sifting, classifying, milling, purifying, aspirating and possible final drying operations. After drying and cooling the degermer stock is sifted or classified by particle size and enters into the conventional milling system. The feed to each pair of rolls consists of selected mill streams produced during the steps of sifting, aspirating, roller milling and gravity table separating in preceding stages of the process. Detailed data on the milling section are presented in References 27 and 28.

For the production of specific products, various streams would be withdrawn at appropriate points in the milling process. A number of process streams often are blended to produce a specific product. The finished products are stored temporarily in working bins, dried and cooled if necessary, and rebolted before packaging or shipping in bulk.

Recovery of Crude Corn Oil - Oil is recovered from the germ fraction either by mechanical screw presses or by a combination of screw presses and solvent extraction.

Air Pollution Sources, Emission Rates and Effluent Properties

Table 132 presents some of the more significant potential sources of air pollution in a dry corn mill. The dust, small corn particles, spillage, etc., are collected as part of the processing operation and saved for animal feed in most corn mills. For this reason, control devices are considered as an integral part of the process equipment, and, strictly speaking, the control systems, rather than the milling equipment, are the emission sources. As is the case in many of the operations in the grain and feed industry, it is usual practice to duct several individual dust sources to a common control device.

Nearly all the operations associated with grain receiving and subsequent transfer to storage are potential sources of emission. The grain unloading, cleaning and drying steps are generally considered to be the main sources of air pollutants in this part of the mill complex.

Table 132. POTENTIAL SOURCES OF AIR POLLUTANTS IN A DRY CORN MILL

I. Grain Receiving, Cleaning, and Storage

1. Grain unloading
2. Elevator leg vents
3. Garner and scale vents
4. Trippers, conveyor transfer points
5. Grain cleaner
6. Grain dryer

II. Cleaning Section

1. Separator
2. Aspirator
3. Disc separator
4. Scourer

III. Degerming Section

1. Degermer
2. Degermer product dryers and cooler
3. Aspirators

IV. Milling Section

1. Break rolls
2. Purifiers
3. Aspirators
4. Product dryers and coolers

V. By-Products

1. Hammermill for extracted flakes and hulls

VI. Shipping

1. Bulk loading
2. Packing station

Grain dust, dirt, seeds and chaff are all emitted from the equipment used in the cleaning section. The separator, aspirator, and scouring equipment are the principal sources of emissions in the cleaning house.

In the degerming section of the mill, the product dryer and cooler exhaust streams may contain particulates. The aspiration system used to separate the dried degermed product can also emit particulates.

In the milling section, the product recovery systems associated with the various pieces of milling and aspiration equipment are potential sources of emission. Bran and flour would be the principal materials emitted from these sources.

Shipping operations involving the main products are not a major dust source because efforts are made to minimize loss of the valuable final product. Loading of by-products can be a significant dust source depending on the loading procedures used at specific mills.

Limited data are available on the rates of emission from individual or combined sources in dry corn mills. Table 133 presents data on measured emission rates from selected sources controlled by fabric filter systems. The data in Table 133, obtained with a UOP flue gas sampler, were reported by one of the corn mills that submitted data in response to the emissions inventory questionnaire. The mill has a daily production capacity of 17,500 bu and operates on a 24-hr day. A production rate of 730 bu/hr was used to calculate the emission factors shown in Table 133.

Table 134 summarizes estimated emission rates from another dry corn mill which responded to the emissions inventory questionnaire. The daily production capacity of this mill was listed as 55,500 bu based on a 24-hr day.

RYE MILLING

There is much more similarity between the milling of rye and the milling of wheat than there are differences. In either case, the object is to produce a powdery or granular material from a cereal grain by careful pulverizing of the seed. In both instances, the purpose is to make the flour substantially free of bran and germ. The same basic type of machinery is employed.

Rye Milling Process

The milling of rye consists of the same five processing steps as for wheat milling, namely;[26]

Table 133. MEASURED EMISSION RATES FROM CONTROLLED SOURCES IN A DRY CORN MILL[a/]

Source	Control System	Gas Flow (cfm)	Dust Load From Control System (gr/scf)	Dust Load From Control System (lb/hr)	Emission Factor (lb/bu processed)
Cleaning house	Fabric filter	7,500	0.02	1.16	0.0015
Pneumatic separator	Fabric filter	5,500	0.008	0.36	0.0004
Grits aspirator	Fabric filter	2,400	0.009	0.18	0.0002
Gravity tables (2)	Fabric filter	6,600	0.01	0.68	0.0009
Gravity tables (2)	Fabric filter	7,200	0.005	0.3	0.0004
Gravity tables (2)	Fabric filter	7,200	0.005	0.3	0.0004
Centridyne	Fabric filter	5,400	0.003	0.14	0.0001
Purifiers	Fabric filter	5,200	0.004	0.2	0.0002

a/ Data obtained with UOP Flue Gas Sampler.

Table 134. ESTIMATED EMISSION RATES FROM VARIOUS SOURCES IN A DRY CORN MILL

Source	Control Device	Gas Flow (cfm)	Dust Load to Device (gr/ft^3)	Dust Load to Device (lb/hr)	Emission from Device (gr/ft^3)	Emission from Device (lb/hr)	Emission Factor (lb/bu processed)
Through stock dryer and coolers	Scrubber	18,000	0.016	2.5	0.0016	0.25	0.0001
Gravity tables and aspirators	Cyclone	2,600	10.3	230	0.54	12	0.005
Grits dryer	None	2,000	0.41	7	0.41	7	0.003
Grits cooler, meal and grits dryer	None	8,000	0.15	100	0.15	100	0.04
Sifters	Cyclone	3,100	5.3	140	0.26	7	0.003
Aspirators (5th), hominy receiver	Cyclone	2,000	14.6	250	0.76	13	0.0056
Elevator heads	Cyclone	3,100	5.65	150	0.30	8	0.0035
Germ dryer	None	3,000	2.72	70	2.72	70	0.03
Hammermill	Cyclone	1,100	42.4	400	2.12	20	0.0086
Hammermill	Cyclone	1,000	58	500	1.17	10	0.004
Hammermill screenings	Cyclone	900	64.8	500	3.24	25	0.01
Hominy dryer	None	1,900	0.18	3	0.18	3	0.001
Hominy cooler	None	1,980		4	0.24	4	0.0017
Aspirators	Cyclone	3,000	1.75	45	0.078	2	0.00086
Gravity table	Cyclone	3,000	3.5	90	0.078	2	0.00086

1. Receiving and storage of grain

2. Cleaning of the grain

3. Tempering

4. Milling of rye into flour and its by-products

5. Storage and/or shipment of finished product

Receiving and Storage - The grain receiving and storage operations at a rye flour mill parallel those at a wheat flour mill.

Cleaning and Tempering - The flow through the cleaning and tempering portions of a rye mill is essentially the same as the flow used in a wheat flour mill. Conventional machinery, such as a receiving separator, disc machines, Entoleter Scourer-Aspirators, and a stoner, can be used. However, because it is more difficult to clean rye than wheat, this cleaning operation must be more carefully controlled. The special problem with rye is occasioned by the fact that rye grain, in contrast to wheat, varies more in size. It is because of this that rye is graded for size as well as dockage and moisture. Because of the size differences, in the cleaning house of a rye mill gravity tables may be used to separate according to weight differences. Pocket sizes in the disc machinery are also slightly different because the shape of the rye kernel is different than the wheat kernel. The average rye kernel is thinner and slightly longer than the average wheat kernel.

Rye Milling - After the rye mix has been cleaned, the proper amount of tempering water added, and allowed to rest in the temper bins the length of time desired, it is ready for milling.

In contrast to milling of wheat which is a process of gradual reduction with purification and classification, rye milling is different in that it does not employ gradual reduction. Both the break roller mills and reduction roller mills in a rye mill are corrugated. Smooth rolls would flake the stocks so that they either scalp off to tailings or to the next reduction system and on out the tail of the mill to feed.

Following grinding, the screening systems employ plansifters just as are found in a wheat flour mill. However, there is little evidence of purifiers that are commonly used in wheat flour mills. This is the first major difference between rye and wheat flour milling. The lack of purifiers is important since it immediately indicates that there is not a premium on the production of middlings on the break rolls of a rye mill.

This brings up a second and very basic difference between wheat flour milling and rye flour milling. In wheat flour milling, the point is to make as much middlings and as little flour as possible on the break rolls. In rye milling, one tries to make as much rye flour and as little middlings as is possible on the break rolls. Essentially, this is done by applying more pressure on the rolls although the type of surface on the break rolls--that is the corrugations--also plays a part. As a consequence, there are more break rolls in proportion to reduction rolls in a rye mill than in a wheat flour mill.

Air Pollution Sources, Emission Rates and Effluent Properties

Air pollution sources in a rye flour mill parallel those in a wheat flour mill. Table 135 presents some of the more significant potential sources of air pollution in a rye flour mill. Data on emission rates from the sources shown in Table 135 are meager. Estimates of emissions from a few of the sources were provided by one mill that responded to the emissions inventory questionnaire. Table 136 presents the estimates. The mill for which the data are applicable has a production capacity of 2,500 hundred weight (cwt) of flour per day and operated on a 24 hr/day basis. Using the yield factor of 2.15 bu/cwt of flour, a processing rate of 224 bu/hr was obtained for the mill. This processing rate was used to calculate the emission factors shown in the last column of Table 136.

Table 135. POTENTIAL SOURCES OF AIR POLLUTANTS IN A RYE MILL COMPLEX

I. Grain Receiving and Storage
   1. Grain unloading
   2. Elevator boots and heads
   3. Garner and scale vents
   4. Grain cleaner
   5. Conveyor transfer points

II. Cleaning House
   1. Millerator
   2. Aspirator
   3. Disc separator
   4. Entoleter scourer aspirator

III. Mill House
   1. Roller mills
   2. Sifters

IV. By-Products
   1. Hammermill

V. Shipping
   1. Bulk loading
      a. Flour
      b. By-Products
   2. Packing station

Table 136. ESTIMATED EMISSION RATES FROM VARIOUS SOURCES IN A RYE FLOUR MILL

Source	Control Device	Gas Flow (cfm)	Dust Load to Control Device (gr/ft^3)	Dust Load to Control Device (lb/hr)	Emission from Control Device (gr/ft^3)	Emission from Control Device (lb/hr)	Emission Factor (lb/bu processed)
Entoleter	Cyclone	1,660	2.2	31	0.24	3.4	0.015
Aspirator	Cyclone	600	0.35	1.8	0.04	0.2	0.0009
Scourer	Cyclone	1,750	0.85	12.7	0.09	1.4	0.006
Millerator	Cyclone (2)	1,725	0.55	8.2	0.06	0.9	0.004
Millerator	Cyclone	1,250	0.25	2.7	0.03	0.3	0.001

OAT MILLING

The processing of oats for hot cereals accounts for only about 10% of the total bushels harvested each year. The milling of oats has the objective of producing two primary products; regular oats and quick oats. The longer oats are separated from shorter oats in the processing and are used to produce regular oats. The shorter oats are further reduced in size in a cutting plant and are used to produce the quick oats.

The Milling of Oats

The milling process for oats consists of the following segments.[29/]

1. Reception, storage and mixing of oats
2. Cleaning
3. Drying
4. Grading, hulling, and finishing
5. Cutting and flaking.

Figures 21, 22, and 23 present a simplified diagram of the oat milling process. Operations performed in each part of this process are discussed in the following sections.

Reception, Storage, and Mixing of Oats - Operations involved in the reception and storage of oats parallel those used in wheat milling. The mixing of oats for milling is also similar to the practice of blending of different grades of wheat in the elevator operations.

Cleaning House - The initial step in the milling flow is the cleaning house. The foreign materials removed during cleaning are sticks, corn, seeds, soybeans, barley, wheat, and dust. These contaminants usually become mixed with the oats in the field and the various elevators through which the oats may have passed prior to arrival at the processing mill.

The first machine in the cleaning flow usually is a closed circuit aspirator to remove dust, hulls, light trash and poor oats with no groat inside. Most cleaning house flows include a receiving separator which makes a high volume separation by thickness, width and further aspiration.

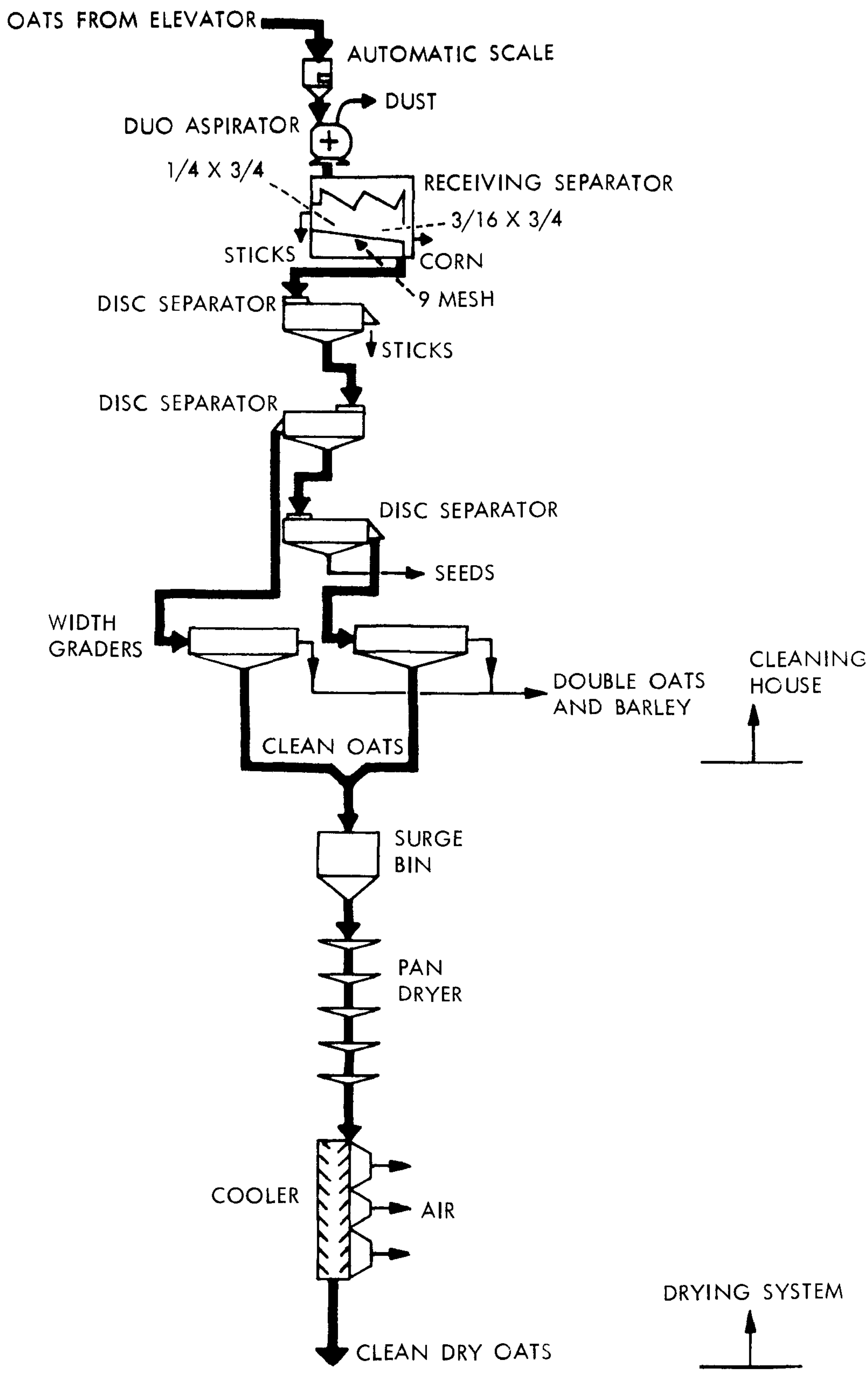


Figure 21. Flow diagram for oat mill (cleaning house and drying system).

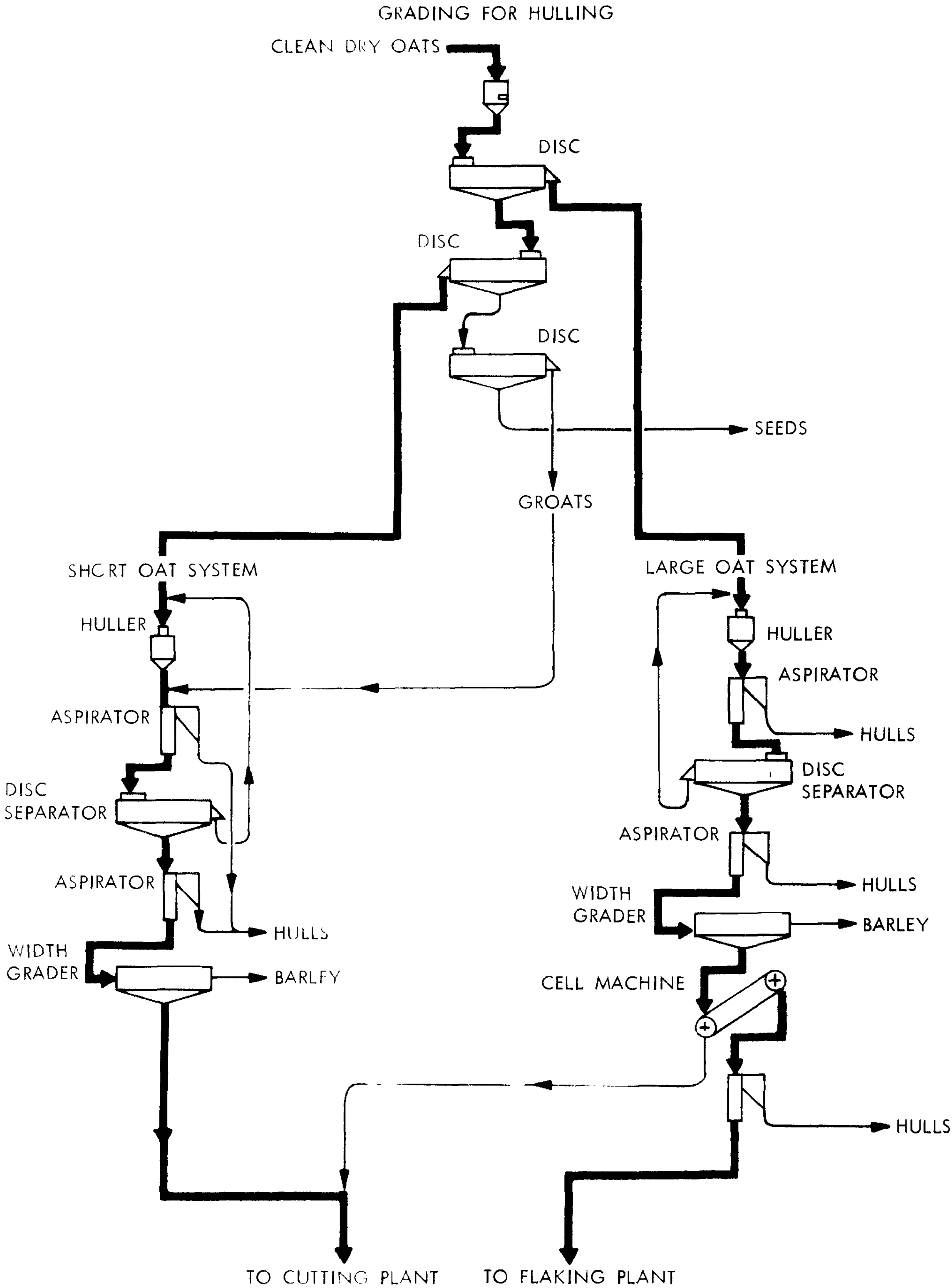


Figure 22. Flow diagram for oat mill (grading, hulling and finishing).

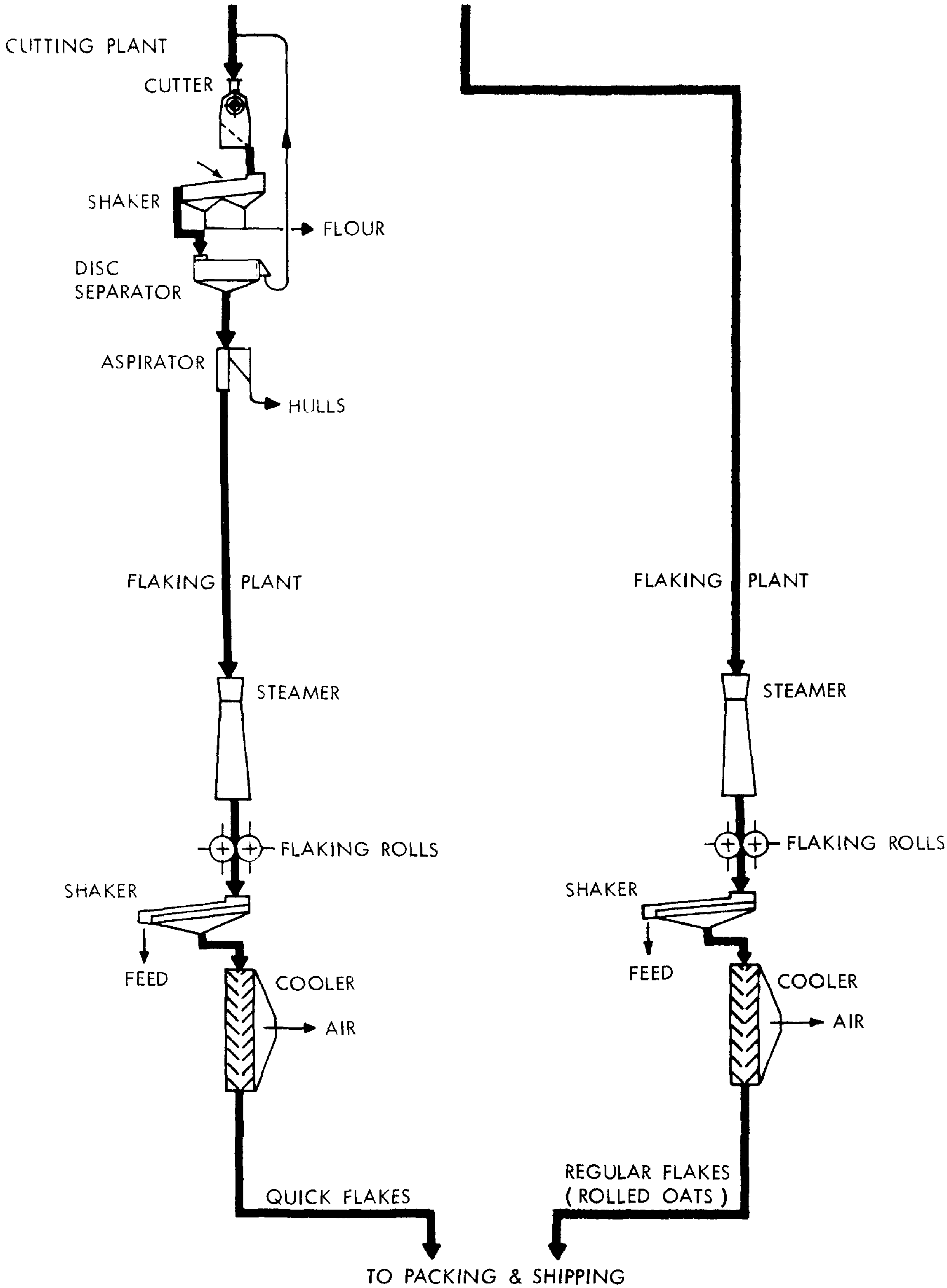


Figure 23. Flow diagram for oat mill (cutting and flaking plant).

The oats then flow to a series of disc separators where sticks, seeds, small oats, small wheat, barley and groats are removed. The main-stream of grain then passes to a width grader. Though commonly called a width grader, these units are really thickness graders as a slotted screen is used.

These short oats then go to a separate width grader. Normally most of the barley and wheat pass over the slots. However, it is not necessary to attempt removal of all contamination at this point since after hulling the differential between the width of the wheat and barley as compared with the groat will be greater so a width grading step in the mill will complete the job. At times a thin slot at the head of the grader is necessary to remove thin flat seeds, such as flax. The small oats are then recombined with the large for drying.

<u>Drying</u> - The next major step in oat milling is drying. Most oats are dried using pan driers, which are normally 10-12 ft in diameter and placed one above the other in stacks of 7-14. Each pan is steam jacketed and open on the top. The oats take at least 1 hr to gradually pass down the stack and are moved from inside to outside by slowly moving sweeps. Oats then drop from the outside to the inside of the pan below. Smaller mills use the rotary steam tube dryer, but generally the flavor development is considered to be lower than in the pan dryers. Some mills are now hulling oats with no drying or conditioning, then drying the groats separately to develop the desired toasted flavor.

<u>Grading, Hulling, and Finishing</u> - After drying and cooling, the oats are ready for hulling. The primary purpose of the huller, as the name implies is to separate the hulls from the groats; the hulling efficiency can be improved by prior grading or sizing of the oats.

The impact huller, which is in almost universal use today, produces a better yield and requires much less horsepower than the old stone huller. The oats enter the center of a high speed rotor with fins which throw the oats against a rubber liner fixed to the housing of the machine. This liner, which reduces the breakage during impact, also assists in efficient separation of the hull from the groat. The huller produces a mixture of free groats, free hulls, groat chips, fines, unhulled oats and some hulled barley.

The large and short hulled oats remain separated through the last stages of milling which includes removal of the hulls and the final grading steps to extract unhulled kernels, wheat, and barley.

The free hulls are "light" enough that aspirators remove them quite effectively. However, small groats and chips can be lost with the hulls so the air on the aspirators must be carefully adjusted particularly in the short oat system.

The sizing of the grain prior to hulling also assists the oat and groat separation after hulling. The groats are sufficiently shorter than oats so that a practical separation can be made by length using disc machines. However, this separation is made less effective by some oats whose groats are as long as the oat and by the huller damaging the tips of many oats that are not hulled on the first pass. The oat stream separated in this step for return hulling always contains some groats.

After most of the unhulled kernels have been separated, the groats are sent to a width grader for additional barley removal. This separation has become more difficult due to the increase in the size of the new oat varieties and the contamination with thin barley.

Generally the final step in the large oat system is the separation of the totally oat free groats. These groats are separated by cell machines and will by-pass the cutting operation.

The cell machine consists of rectangular plates with indents similar to a disc machine moving up a 30 degree incline. The groats drop onto the moving plates near the center of the machine. The clean groats are carried over the top and directed to storage prior to flaking. The rejects of the cell machine, which will contain a few unhulled oats, are sent to the cutting plant for processing into Quick Cooking Oat Flakes (1 min). Cell machines for groat finishing are gradually being replaced by the more efficient gravity tables.

Cutting and Flaking - Those groats which are to be processed in the cutting plant for Quick Cooking Oat Flakes are usually not milled completely free of oats and oat hulls. The cutting plant is designed to remove these contaminants.

The purpose of cutting is to convert the groats into uniform pieces, two to four per groat, with a minimum of fine granules or flour. Cutting is accomplished with rotary granulators. These consist of rotating round hole perforated drums, through which the groats align themselves endwise and fall against stationary knives that are arranged around the bottom and outside surface of the drum.

The cutting fines (oat middlings) are then removed by a shaker equipped with a 22-mesh tin mill screen, though various meshes are used in different plants. The cutting flour is generally used as a high quality animal feed.

Next the cut groats are separated from the uncut groats, oats, and long hulls by a cylinder separator or disc machine. The pickups of the disc are aspirated by a closed circuit or multilouver type machine which removes loose hulls or slivers that may be present in the cut groats.

The cut material is now ready for the flaking plant. Conditioning the groats for flaking is accomplished by steaming them with live steam at atmospheric pressure just prior to flaking. The steaming softens the groats and permits flaking with a minimum of breakage. Also enzyme systems which could cause rancidity and undesirable flavors in oatmeal are inactivated.

The steamed groats pass directly into the rolls from the steamer. The cut groats are rolled into relatively thick flakes for quick cooking oatmeal. The uncut groats are flaked about 50% thicker. The rolls are adjusted to produce flakes of uniform quality, which is determined by thickness or density measurement of the flakes.

The shakers under the rolls remove fines produced in the flaking process. Also, over-cooked pieces which are generally agglomerates of several flakes, are scalped off. The flakes also generally pass through a multilouver or terminal velocity type cooler. Hull slivers are removed with the cooling air. The moisture content and temperature are quickly reduced to insure acceptable shelf life.

The cooled flakes are then conveyed to the packaging system. Since quick flakes are easily broken, the flaking system is often located above and near the packaging equipment. Conveying equipment causing a minimum of abrasion is used.

Because of a wide density variation in the flakes, packaging must include weighing the contents of each container. The poor flowing characteristics make the filling somewhat difficult. Generally a plunger is used to gently compress the flakes into each package.

Air Pollution Sources, Emission Rates, and Effluent Properties

The operations and equipment in an oat mill that are main sources of air pollutants are shown in Table 137. Dust emission sources associated with grain receiving and storage are essentially the same as those in other grain elevator operations. The handling of oats is reported to be dustier than many other grains but no data have been located that would allow a quantitative comparison.

The separation requirements in an oat mill, unlike wheat milling, necessitates extensive use of aspirators and it is expected that these would represent a significant portion of the potential emissions from the oat milling process.

Table 137. POTENTIAL SOURCES OF AIR POLLUTANTS IN AN OAT MILL

I. Receiving, Storage and Mixing

1. Grain unloading
2. Elevator boots and heads
3. Garner and scale
4. Transfer points

II. Cleaning

1. Duo aspirator
2. Receiving separator
3. Disc separators

III. Drying

1. Pan dryer
2. Cooler

IV. Grading, Hulling, and Finishing

1. Disc separators
2. Hullers and aspirators
3. Cell machines or gravity tables

V. Cutting and Flaking

1. Shaker
2. Disc separator
3. Aspirators
4. Steamers
5. Groat conditioners
6. Shakers
7. Coolers

VI. Packing and Shipping

1. Packing
2. Bulk loading

VII. By-Product System

1. Hammermills

Oat milling also includes coolers in the drying and flaking operations. Cooling is accomplished by direct contact with a stream of forced air which could also represent a significant source of dust emissions.

The pan dryer in the dryer section and the steamer in the flaking section may not be significant sources of dust emission but they may be potential sources of odors.

In some oat mills, the hulls are ground in hammermills and this could also represent a significant source of emissions.

Because nearly all the grain dust and by-products collected in an oat mill are used in animal feed or other products, control devices are generally considered as an integral part of the process equipment. Therefore, the control devices actually represent the emission sources. Limited data are available on emissions from the various operations in oat mills.

Table 138 summarizes measured emission rates reported by one mill that responded to the emission inventory questionnaire. The mill for which the data are applicable has a production capacity of 1,250 bu/hr. The emission factors shown in the last column of Table 138 were calculated using this production rate.

RICE MILLING

Nearly all rice consumed as food undergoes some type of milling operation during its preparation. Rice milling differs considerably from the milling of other grains because the preferred form of rice is the whole grain rather than a flour or meal. Pulverized forms of rice are used to a limited extent in sauces and the like. Fairly large amounts of broken kernels and small pieces are sold for manufacturing purposes, as for brewing and the manufacture of breakfast cereals or snacks. However, the demand for whole cereal rice far exceeds that for smaller piece sizes, and the market value of the former is correspondingly greater.

Rice Milling Process

Both conventional and parboil rice mills are used in the U.S. with the former accounting for about 85% of the national rice crop. There are three distinct stages in each of these mills: (1) rough rice receiving, cleaning, drying and storage; (2) milling; and (3) milled rice and by-product bagging, packaging, and shipping.

Rough Rice Receiving, Cleaning, Drying, and Storage - The rough rice receiving, cleaning, drying, and storage operations are the same for both types of rice mills. Grain is received primarily by truck and rail at rice mills. Rough rice is delivered to the mill containing various kinds of debris, such as straw, loose hulls, bran, weed seeds, pebbles, and granules of dirt. The rough rice is first cleaned using combinations of scalpers, screens, and aspiration. If the rice was not purchased from a commercial dryer, the rice is then sent to drying equipment to reduce moisture content to a level suitable for storage. Since rice is marketed as a whole grain product, it is important that the grains not be fractured or otherwise damaged before or during the drying process. Large column-type, continuous-flow dryers using heated air as well as batch-type units have been widely used.

Following drying of the grain, the rice is transported by conveyors and elevators to storage facilities. In some rice mills, the grain is given an additional cleaning when it is transferred from storage to the milling section of the plant. Figure 24 presents a flow diagram for a rough rice receiving department in a rice mill while Figure 25 shows the general sequence of operations in a combined white rice and parboil plant.

Table 138. MEASURED EMISSION RATES FROM CONTROLLED SOURCES IN AN OAT MILL COMPLEX
(UOP Flue Gas Sampler Used for Measurements)

Source	Control Device	Gas Flow (cfm)	Emission From Control Device (gr/ft^3)	Emission From Control Device (lb/hr)	Emission Factor (lb/bu processed)
I. Storage Elevator					
1. Basement belts and bin floor belts	Fabric filter	15,000	0.056	7.2	0.0058
2. Bin floor transfer belts	Fabric filter	15,000	0.035	4.5	0.0036
3. Basement and bin floor belts	Fabric filter	15,000	0.056	7.2	0.0058
4. Conveyor belt	Fabric filter	1,000	0.013	0.11	0.00009
II. Mill Complex					
Cleaning house equipment	Fabric filter	7,500	0.018	1.16	0.0009
Cleaning house equipment	Fabric filter	7,200	0.018	1.11	0.0009
Mill equipment	Fabric filter	4,000	0.026	0.89	0.0007
Mill equipment	Fabric filter	4,000	0.026	0.86	0.0007
Mill equipment	Fabric filter	3,800	0.012	0.39	0.0003
Cutting plant	Fabric filter	5,600	0.025	1.2	0.001
Cutting plant	Fabric filter	3,000	0.017	0.44	0.0004
Gravity tables	Fabric filter	6,600	-	-	
Gravity tables	Fabric filter	7,800	-	-	
Brush machines	Fabric filter	6,800	0.036	2.10	0.0017
Drying and cooling equipment	Cyclone	7,500	0.04	2.57	0.002
Drying and cooling equipment	Cyclone	7,500	0.06	3.73	0.003
Drying and cooling equipment	Cyclone	7,500	0.08	5.08	0.0041
Oat rolls and screeners	Cyclone	4,800	0.007	0.29	0.0002
Cooling towers	Cyclone	6,500	0.026	1.45	0.001
Cooling towers	Cyclone	6,800		4.84	0.004
Screenings system	Cyclone	1,800	0.083	0.37	0.0003
Hull grinder	Cyclone	2,000	0.002	0.032	0.000026
Hull grinder	Cyclone	2,600	0.11	2.36	0.0019
Hull grinder	Cyclone	2,400	0.13	2.66	0.002

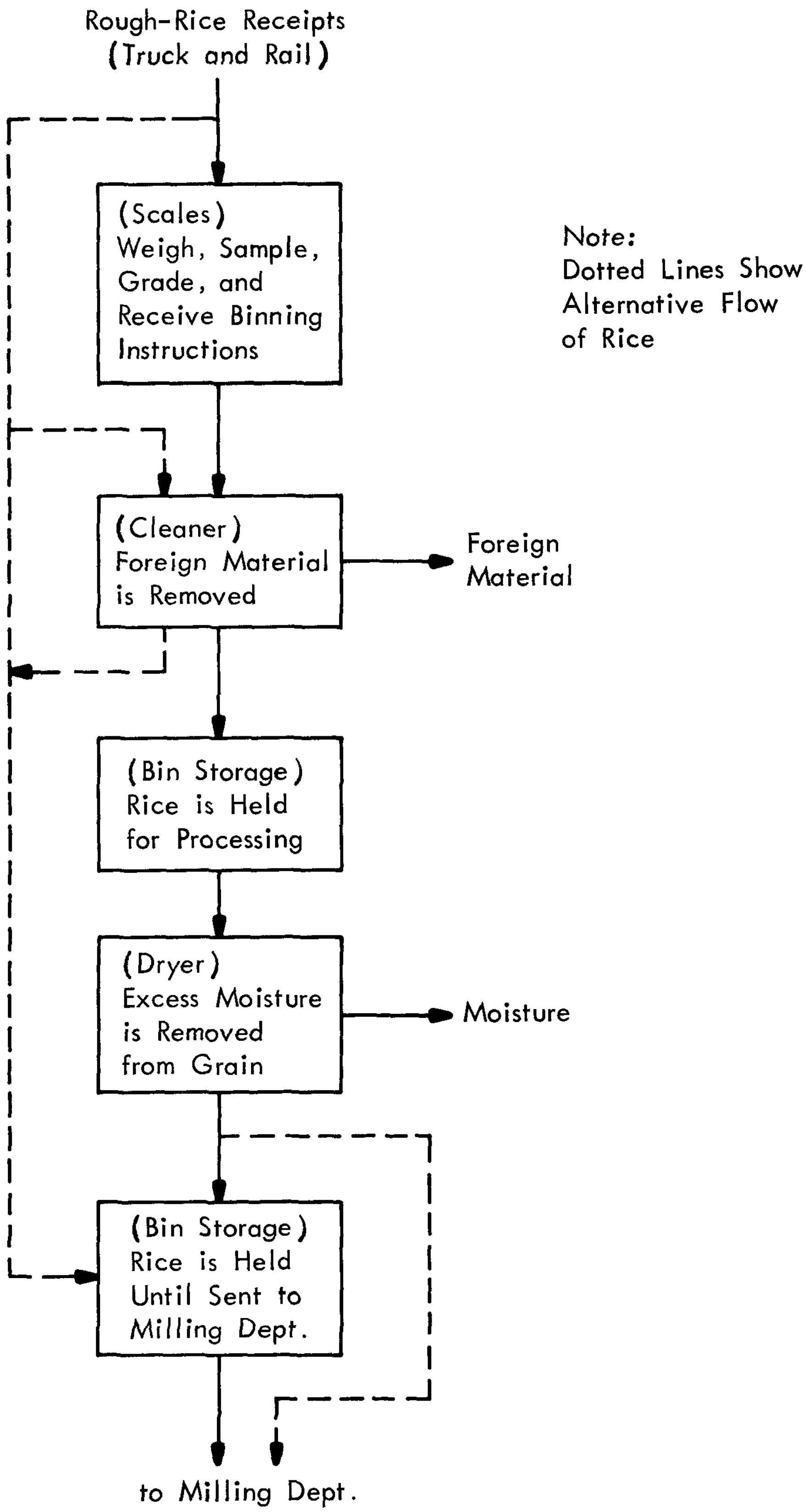


Figure 24. Flow diagram for rough rice receiving section of a rice mill.

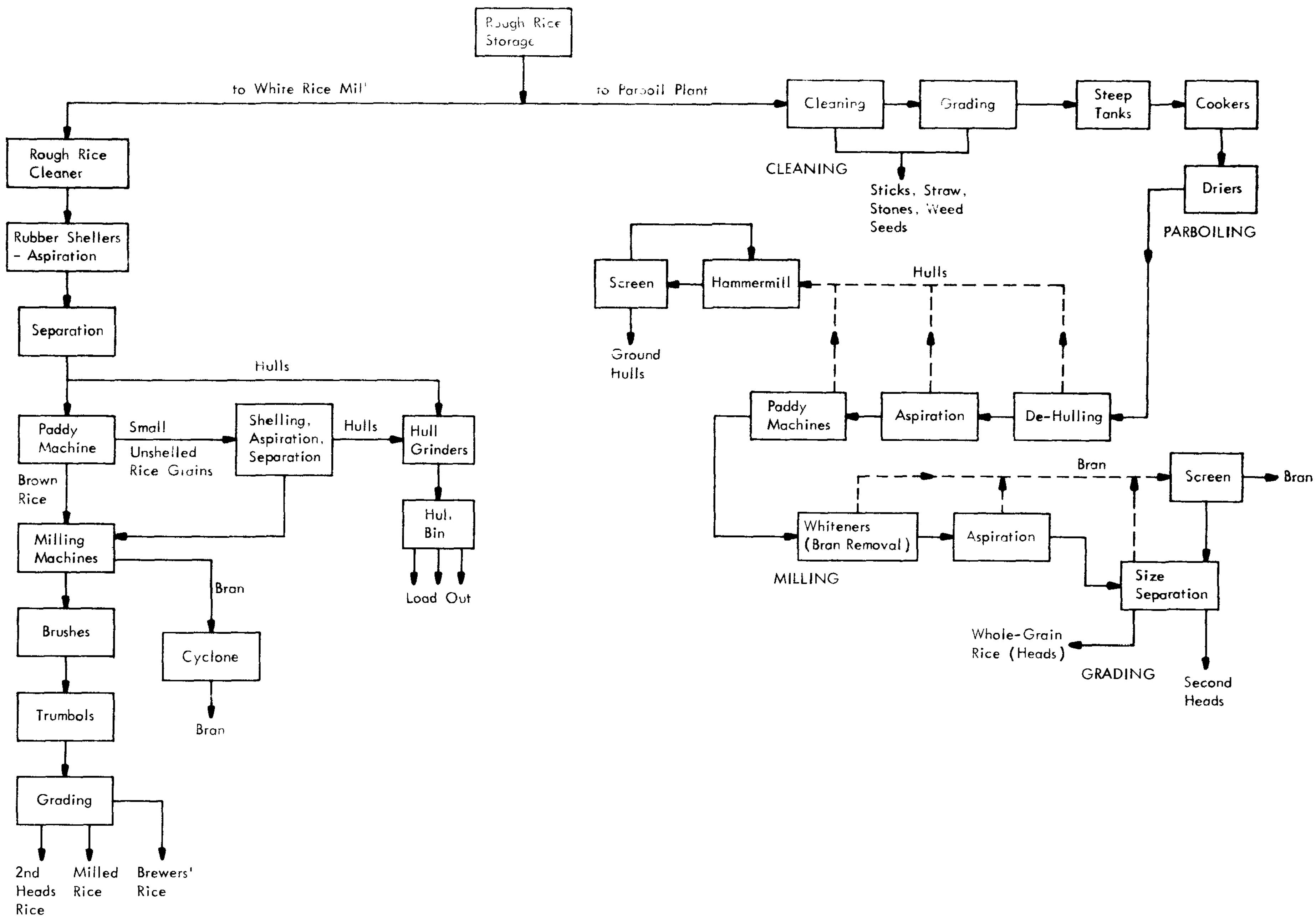


Figure 25. General flow diagram in a combined white rice and parboil rice mill.

Milling Section

White Rice Milling - The milling of rough rice to produce white rice is the major milling operation conducted at U.S. rice mills. Cleaned rice is first transported to a shelling device where the rice is dehulled. Stone and rubber shellers are used for this operation. The hulls that are produced are relatively light and are readily removed from the shelled grains when the mixture is aspirated. The hulls are collected by passing the aspiration air through a product recovery device, usually a cyclone.

Brown rice produced in the shelling process contains some unshelled rice grains which must be separated. This operation is performed in a device known as a paddy separator, which consists of flat cars divided into three tiers of irregular compartments. The cars are tilted in such a way that when they are rapidly shuttled, the lighter, bulkier, rough rice (commonly called paddy) is concentrated at the raised side, while the heavier brown rice migrates to the lower opposite side. The process is continuous, and streams of brown and rough rice are removed simultaneously. The unshelled paddy is then fed into another pair of shellers set closer together than the first set, and the above process of shelling, aspiration, and separation is repeated.

From the paddy machines, the rice is conveyed to the hullers or milling machines which scour off the outer bran coats and germ from the rice kernels. Milling may be accomplished in one or two "breaks" that is, by a single pass through a mill or by consecutive passages through two mills, depending on plant practice. In some plants, as many as four breaks have been used.

After the rice is milled, it consists of almost white whole kernels mixed with broken kernels of different sizes. It is now ready for the brush, a device for removing the white inner bran layers and the proteinaceous aleurone layer. The brush is essentially a large vertical stationary cylindrical screen inside of which rotates a drum to which is attached overlapping leather flaps. The rice enters at the top of the machine and, as it progresses toward the bottom, is rubbed against the screen by the leather flaps. The white flour mixture of fine bran and aleurone layer removed by abrasive action is forced through the screen and is collected and sacked. The collected "polishings" is usually sold as a by-product for animal feed.

At this stage the rice kernel consists of the white, starchy endosperm, together with fragments of the aleurone layer. Rice may be sold in this form as polished uncoated rice or it may be conveyed to machines known as trumbels, in which it is coated with talc and glucose. This inert, harmless coating is used to give the rice a gloss.

Even with care, some of the kernels are broken during milling. A series of machines or classifiers separate the different size kernels. The whole and three-quarter kernels are screened into a fraction and designated as "head" rice; the one-third to three-quarter rice grains are classed as "second-heads." The one-quarter to one-third length of grains are known as "screenings;" and the still smaller fragments are termed "brewers" since they form a useful brewing adjunct.

Parboiled Rice - A limited number of mills in the United States produce parboiled rice. In some cases mills produce both white and parboiled rice. The mills are similar in that all involve soaking rough rice following cleaning, steaming, drying, and milling. Pressure vessels are utilized for the steaming step and steam tube dryers are employed to dry the rice to 11-13% moisture. Following the drying step, the rice is milled in conventional equipment to remove hull, bran, and germ. The better head yields obtained in the milling of parboiled rice than in the milling of raw rice defrays to a considerable degree the cost of parboiling so that parboiled rice sells for little more than white rice.

Air Pollution Sources, Emission Rates, and Effluent Properties

In rice mills air pollutants result primarily from: (1) grain receiving, cleaning, and storage operations; and (2) rice milling equipment, and by-product processing and loading operations. Table 139 presents some of the more significant potential sources of air pollution in rice mills.

Emission sources associated with the grain receiving, cleaning, and storage operations are similar to those involved with all grain processing. For those mills that dry rice, the rice dryers present a very troublesome source of emissions. Combine harvested rice is cut at a relatively high moisture content and must be dried before it can be stored. Since rice is marketed as a whole grain product, it is important that grains not be fractured or otherwise damaged before or during the drying process. Large column-type, continuous-flow dryers are widely used for rice drying. It usually requires two or more passes through the dryers to bring the moisture content down to 12.0 to 13.5% which is usually considered satisfactory for safe storage. Air volumes of 120 cfm/bu of rice are commonly used. Rice drying is reported to generate a considerable amount of dust.[30,31]

Preliminary cleaning of rice is sometimes done prior to drying. This preliminary cleaning can produce a significant reduction in dust emissions during the drying step.

Finished rice, marketed as U.S. No. 1 grade, contains no dust. To achieve this grade, aspiration is used extensively in rice mills to remove dust as it is generated in the various milling steps (i.e., dust is not conveyed from one machine to another). As a result, all machinery in a rice

Table 139. POTENTIAL SOURCES OF AIR POLLUTANTS IN RICE MILLS

I. Grain Receiving, Cleaning, and Storage

1. Grain unloading
2. Elevator leg vents
3. Garner and scale vents
4. Trippers, conveyor transfer points
5. Grain cleaners
6. Grain dryer

II. Cleaning House

1. Scalpers
2. Screens
3. Disc separators

III. Mill House

1. Shellers
2. Paddy separator
3. Milling machines (hullers)
4. Brushes
5. Hull grinders

IV. Load-Out

1. Hull loading

mill is a pollution source to some extent. The most significant sources of dust are the scalpers, screens, sieves, disc separators, and shellers involved in the cleaning and handling of rough rice. The milling machines, pearlers, and brushes create a bran dust; however, this is collected rather carefully because of its value as a by-product.

Finished rice is free of dust, and its handling poses no problem in air pollution. However, handling of the by-product hulls, especially loading, generates considerable dust.

Table 140 presents actual measurements of emission rates from some operations in a rice mill located in the State of California. All testing was conducted with the mill running at normal operation. Testing was conducted in accordance with the San Francisco Bay Air Pollution Control District Regulation 2 procedure.

In addition to these tests, visual observations were also made at the truck and railcar unloading facilities. All of these facilities are "under cover." Particulate losses from these facilities were observed to be minimal and were not judged to contribute in any gross amount to overall losses from the mill to atmosphere, even under the high wind conditions which existed during a majority of the observation periods.

Table 140. PARTICULATE EMISSIONS FROM SELECTED OPERATIONS IN A RICE MILL

Test No.	Location	Flow (SCFM-dry)	Loading (Gr/SCF-dry)	Loss (Lb/Hr)
1	Hull conveyor cyclone	22,700	0.0529	10.3
2	Hull conveyor cyclone	22,700	0.0625	12.2
3	Bran airlift (75 hp)	15,400	0.0037	0.5
4	Bran airlift (75 hp)	15,300	0.0063	0.8
5	Dustex filter outlet[a]	81,000	0.0450	31.3
6	Dustex filter outlet[a]	81,000	0.0581	40.3
7	Dustex filter outlet[a]	81,000	0.0486	33.8
8	Bran airlift (60 hp)	19,100	0.0012	0.2
9	Bran airlift (60 hp)	19,300	0.0003	0.04
10	Brewers airlift	2,500	0.0003	0.01
11	Brewers airlift	2,500	0.0026	0.05

a/ Integrated system for cleaning and milling section of complex.

COMMERCIAL RICE DRYING

A distinctive feature of the rice harvesting, marketing, processing cycle is the use of commercial rice drying and storage facilities. Commercial rice dryers operate as a distinct industry in the rice growing areas of the United States. Commercial rice dryers provide drying and storage services for rough rice on a custom basis and are either private or cooperative in financial organization.

Commercial Rice Drying Facilities

Rice is normally harvested with moisture levels ranging from 18-26%. Since it cannot be safely held for long periods at these levels, the moisture content is generally reduced to about 12-14% before storing. At commercial dryers, this is accomplished artificially by use of aeration and heat. Although much of the moisture can be removed by aeration alone, use of heated air greatly reduces drying time, making it possible to handle larger volumes of rice in shorter periods.

A commercial rice drying facility has four basic operations: receiving, drying, storing, and shipping. A rice drying facility, therefore, operates in essentially the same manner as a grain elevator with emphasis placed on the drying operation. Figure 26 shows the flow pattern at a rice drying installation. The receiving operations parallel those described for grain elevators in the section on Grain Elevators (Grain Marketing Operations) on p. 110. Trucks generally transport harvested rice (green rice) to dryers. Methods of receiving at dryers vary, depending upon such factors as location, age, and size of plant. The most common procedure is to weigh, sample, and grade at the scale house. After weighing, the truck is directed to the dump pit where it is unloaded mechanically by hydraulic hoist, dragboard, or other means.

Green rice is usually conveyed from the receiving pit to the receiving leg by auger or belt conveyor. It is then elevated to the top of the head-house where it can be diverted either to the dryer or scalper-type cleaners, or dropped onto a gallery conveyor and moved to storage tanks to await drying. Relatively clean, properly aerated green rice may be held in storage several days before or during the drying process.

Green rice is normally dried gently several times to avoid cracking and checking the kernels. Large column-type, continuous-flow dryers using heated air are widely used for rice drying. Aeration is also used as a supplemental drying method at some facilities. On each pass through the dryer column, the forced heated air evaporates the moisture, which gradually migrates to the surface of the kernels during the 6-24 hr between passes.

After the moisture content is reduced to about 12-14%, the rice is ready for storage. Both upright and flat storage is used for rice with upright facilities being the most common on a capacity basis.

Rice is loaded out by several methods, depending mainly upon type of storage facility and mode of shipment used. Gravity is generally used when loading out for truck shipment from upright storage. Various types of equipment are used to load rice directly from flat storage into trucks. In some situations, part or all of the rice in flat storage is moved to upright storage before loading out. This better utilizes labor, increases loadout rate, allows several trucks to load out at once, or allows weighing through a dump scale before loading out into railcars. Rough rice is shipped domestically almost entirely by truck or rail.

Air Pollution Sources, Emission Rates, and Effluent Properties

At a rice drying facility, emission of air pollutants result from the rice handling and drying operations. Receiving pits, conveyors, elevator legs, transfer points and vents are all potential sources of emission of grain dust, chaff, and dust. The cleaning step, if accomplished by

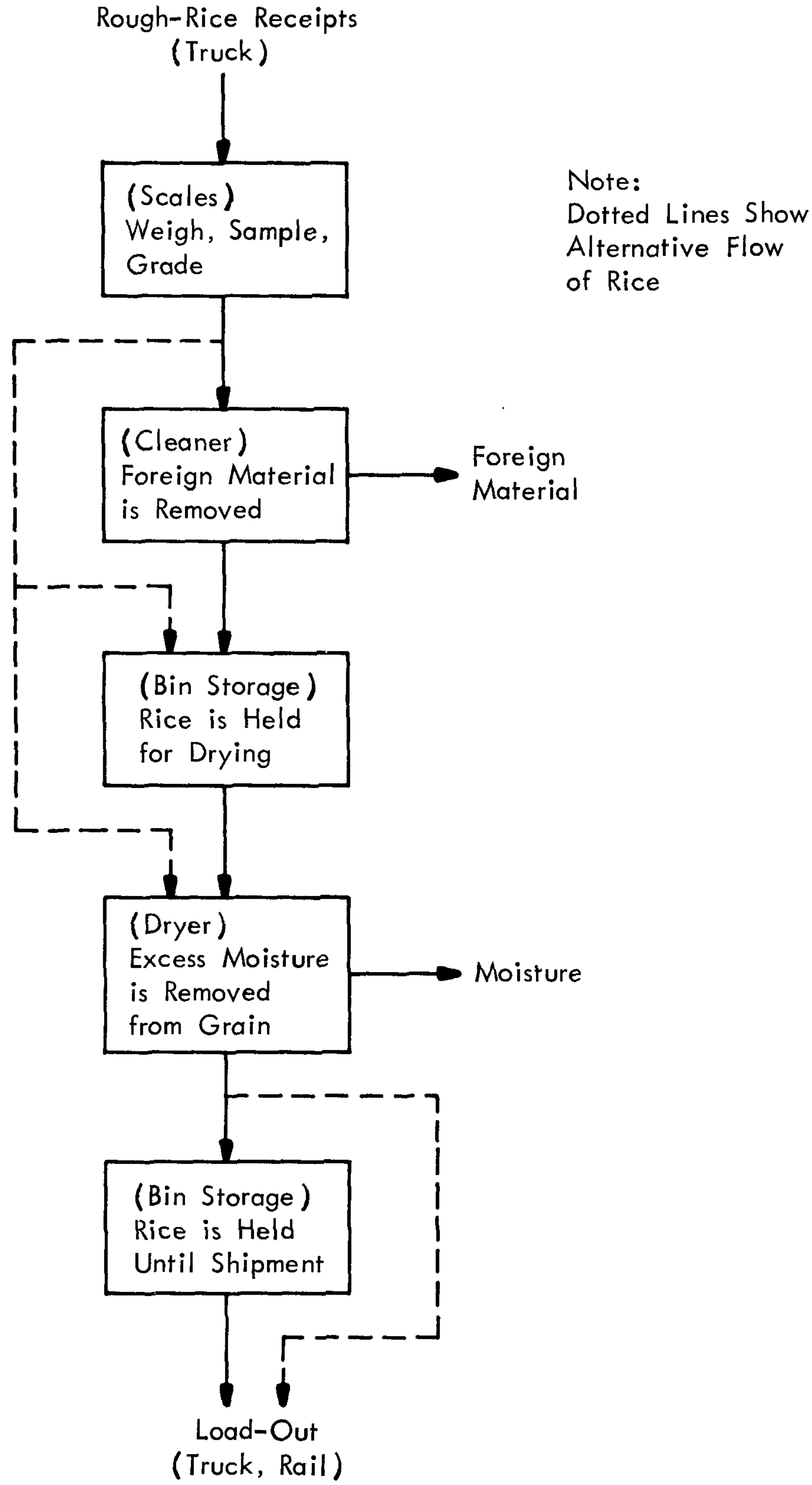


Figure 26. Flow diagram for rice drying facility.

aspiration, is a major source of dust. The grain dryer is the other major emission source. Rice loading operations can also be a dust source.

Neither measured nor estimated emission rates for any of the operations at a rice drying facility were reported by companies responding to the emissions inventory questionnaire.

SOYBEAN PROCESSING

The soybean has risen from the bottom of the U.S. agricultural crop ladder over the past 40 years to its position today of being number two. Only corn is still ahead of the soybean in cash value to the American farmer. Behind this unprecedented growth of an agricultural crop were two attributes of the soybean seed: a high content of excellent protein and a moderate content of oil useful for edible and industrial purposes. Exploitation of the attributes of the soybean resulted in the development of a worldwide marketing and processing technology covering the seeds and its two main products. Today, soybean and its products are the most exported agricultural goods reaching, from the U.S. alone, the billion dollar level in recent years. So important has the soybean become to the American scene that it receives the active attention of almost every facet of private and public agribusiness.[32/]

Soybean Plant Operations

Each bushel (60 lb) of soybeans yields ~ 11 lb of oil and 47 lb of soybean meal with 2 lb normally lost in processing. Oil is extracted from the beans by (1) expeller or rotary screw pressing, (2) batch type hydraulic pressing, and (3) solvent extraction. Since most U.S. soybeans are processed by the solvent method, using hexane as the solvent in a continuous extraction process, subsequent discussion will be focused on this process.

Figure 27 presents a schematic of the overall features of a soybean processing plant using solvent extraction. Not all plants produce the complete spectrum of products depicted in Figure 27. A majority of the plants produce only the soybean meal and soybean oil. The industry generally offers soybean meal as either 44 or 49% protein base, with few variations in between.

Soybeans are shipped to the processing facility by rail, truck or barge. Upon arrival at the plant, the beans are dumped into hoppers at unloading stations and conveyed to the storage facility. Prior to entering the processing portion of the plant, the beans are cleaned and dried. Since the process requires beans between 10.5 and 11% moisture, and beans from the field contain 10 to 16% moisture, most, if not all plants, utilize grain dryers to reduce the moisture content to the requisite level.

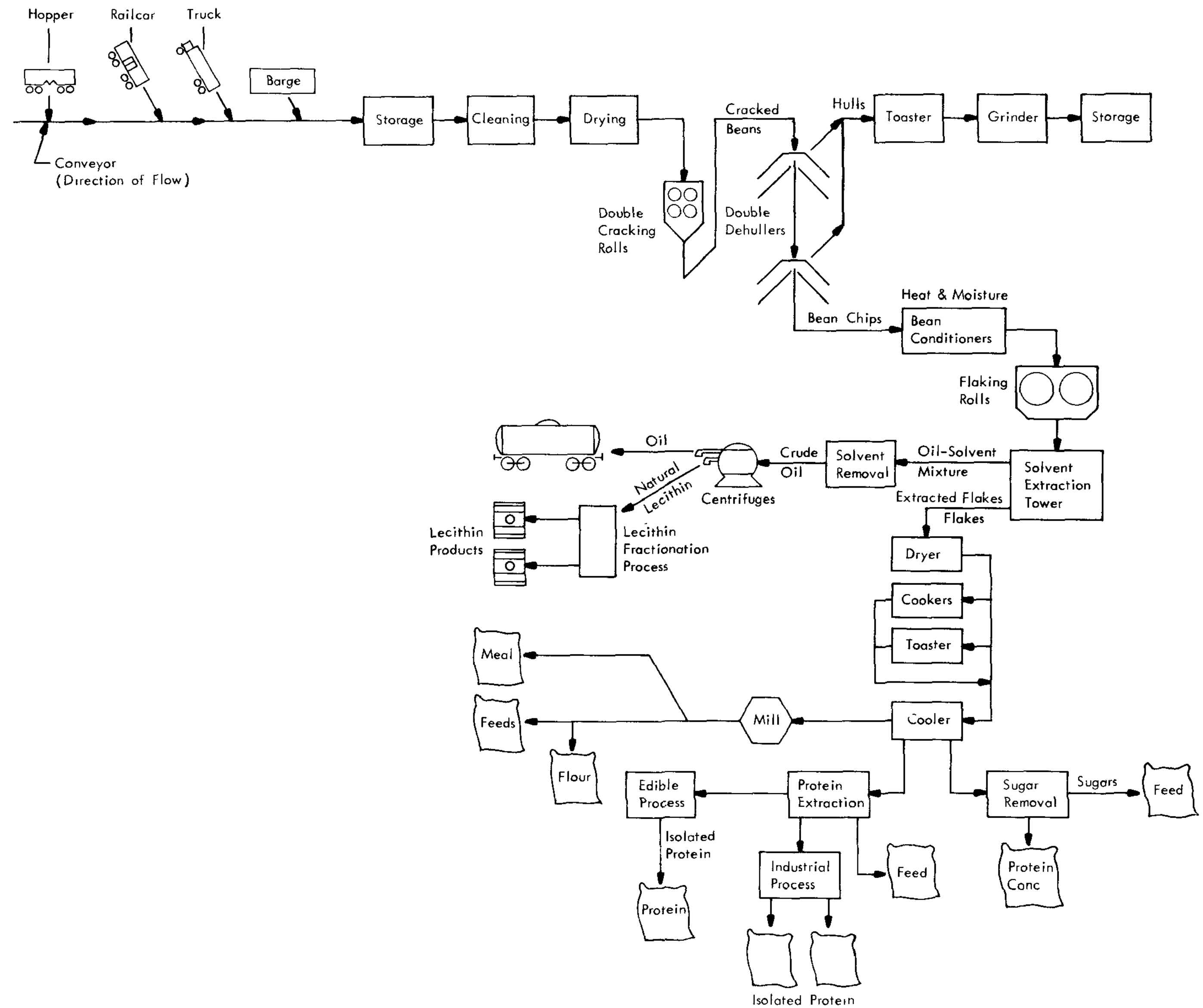


Figure 27. General flow diagram of a soybean processing plant.

After the cleaning and drying steps, the beans are conveying to the flake preparation portion of the plant. Flake preparation consists of cracking, dehulling, and conditioning. The beans are first passed through cracking mills or rolls where each bean is broken into four to eight parts. The hulls and meat are then separated in dehulling equipment which may utilize a combination of screens, aspiration, and gravity tables. The hulls, which were separated from the meat, are collected by a cyclone and/or fabric filters, and then sent through a grinding step prior to being conveyed to storage. Some plants toast the hulls prior to grinding. The meat is transferred from the dehulling-separation equipment to the conditioning equipment. The conditioner is typically a rotary steam tube unit that heats the meat to 160-170°F. Proper conditioning yields bean pieces which are sufficiently plastic that good flakes can be formed.

From the conditioning equipment, the meat is conveyed to the flaking rolls. Properly prepared flakes are essential for consistently good extraction. Normally, soybeans are flaked to 0.01 to 0.012 in. in thickness before extraction.

Following the flaking operation, the beans enter the solvent extraction part of the plant. There are several different types of extractors. In one of the common types (Hansa-Muhle System, Bollman System and French Oil Mill System) the bean flakes, in sieve baskets attached to an endless chain constantly moving in bucket elevator fashion, are soaked with sprayed solvent which drains and is recirculated.

The "Rotocel" unit (Blaw-Know Company) carries the flakes in compartments horizontally around a central axis as they are sprayed with solvent.

Another type of extractor (Hildebrandt System) is a U-tube shaped tower through which the flakes move by screw conveyor with the solvent circulating in a counter current direction.

The Allis Chalmer System and Anderson System consist of a vertical column, similar in size to the sieve basket type, but containing slotted horizontal plates spaced several feet apart. The flakes fall downward from one plate to another after being carried around the circumference of each plate by a scraper arm. Solvent is introduced at the bottom and the miscella (about 20% oil and 80% solvent) flows out at the top.

Extractors are operated at about 125°F and at nearly atmospheric pressures. Bean flake and oil-extracted-meal seals at the extractors may be either choke arrangements with screw conveyor flights removed, rotary valves, or automatically operated double valve seals. Fresh solvent or reclaimed solvent is added as needed, usually through preheaters or heat exchangers.

The following refining processes, depicted in Figure 28, are typical although they may differ in detail at various plants. Miscella from the extractor generally flows to a working storage tank and thence to filters, flash or pre-evaporators, and finally to stripping columns or stills usually operated under partial vacuum. Steam is used for necessary heating and heat exchangers are utilized where practical. Solvent vapors are condensed and returned to a solvent working tank after removal of water by decantation. Maximum operating temperatures usually do not exceed 250°F. Desolventized oil may be pumped to storage or further refined depending on plant facilities. It is customary to vent the extraction and solvent recovery equipment through condensers, which are equipped with mineral oil absorption towers for the recovery of any traces of solvent vapors.

Spent flakes from the extractor are carried by closed screw or drag conveyor through a desolventizer. Four types of desolventizers are in use: (1) desolventizer-toaster system, (2) steam-jacketed conveyor, (3) flash desolventizer, and (4) vapor-desolventizer-deodorizer system. Solvent vapors released in this operation are condensed and returned to the solvent working tank.

From a desolventizer-toaster system, the meal is dried first in a rotary steam tube dryer and it is then cooled by air before being sent to a grinder and storage. Meal from a steam jacket, flash dryer and vapor desolventizer-deodorizer systems does not need to be dried.

Some U.S. soybean processors take the meal a step further. They send the toasted soybean meal through a protein extraction process that prepares soy protein for human food use. Much of this protein is currently used as meat extenders and for soy flours.

Air Pollution Sources, Emission Rates, and Effluent Properties

The sources of air pollution in a soybean processing plant can be grouped into three broad categories: (1) soybean receiving, handling, and drying operations; (2) soybean processing operations; and (3) soybean meal load-out operations. Table 141 presents some of the more significant potential sources in each category.

Emission sources associated with the grain receiving and handling operations are similar to those involved in all grain handling storage operations. The grain unloading, grain cleaning, and grain drying operations are the most significant emission sources in this part of a soybean processing facility.

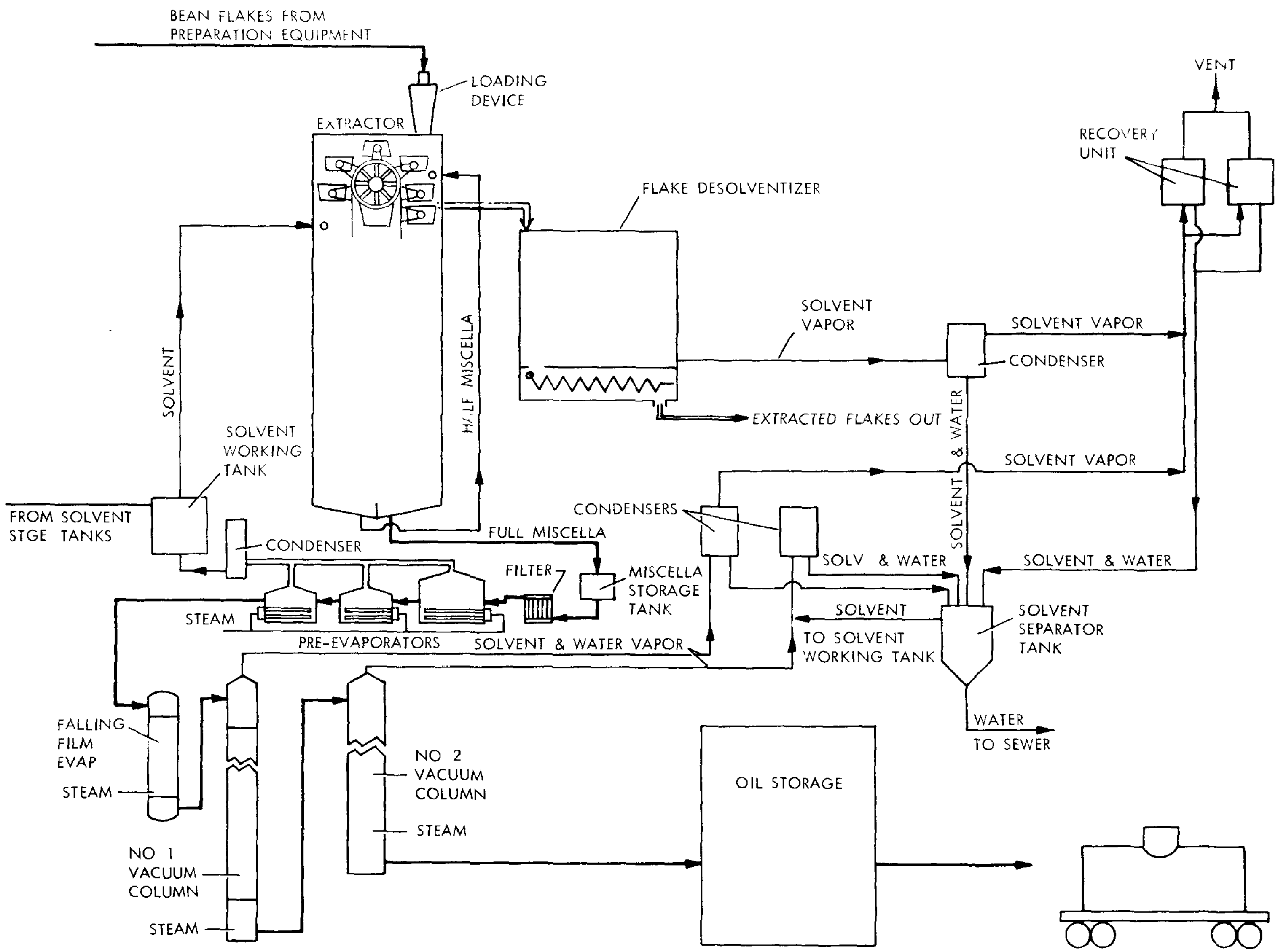


Figure 28. General flow diagram for oil refining section of a soybean processing plant.

Table 141. POTENTIAL SOURCES OF AIR POLLUTANTS IN SOYBEAN PROCESSING PLANTS

I. Grain Receiving, Cleaning, Drying and Storage

1. Grain unloading
2. Elevator leg vents
3. Garner and scale vents
4. Trippers, conveyor transfer points
5. Grain cleaner
6. Grain dryer

II. Soybean Processing

1. Cracking rolls
2. Dehulling system
3. Hull toaster
4. Hull grinding
5. Bean conditioner
6. Flaking mills
7. Desolventizer-toaster
8. Meal dryer
9. Meal cooler
10. Meal grinder
11. Solvent vapor recovery system

III. Product Shipping

1. Meal loadout

The major emission sources in the soybean processing section of the plant are the product recovery systems used on the dehulling equipment and the hull grinders and the meal dryers and coolers.

Loading of the finished meal into trucks or railcars can present a source of dust emissions depending on the configuration of the loading shed.

Tables 142, 143, and 144 summarize available information on measured emission rates from various sources in soybean processing plants. The data for a truck dump pit shown in Table 142 were obtained by an EPA contractor using the latest testing methods (Test Method EPA-5). The data in Table 143 were obtained with a Universal Oil Products stack sampler (UOP Sampler No. 13-16). This unit employs a cyclonic separator for coarse particles ahead of the filter bag of $\sim$1-1/4 ft^2 of area. The pressure drop is measured across the cyclonic separator and continually monitored during the tests by leads attached to a Dwyer Magnehelic gauge. A glass jar collects the material spun out in the cyclonic separator. The sum of this weight of material collected in the glass jar plus the weight of material collected in the bag constitutes the particulate emissions in the measured air volume of the air sampled.

Table 142. MEASURED EMISSION RATES FROM TRUCK DUMP PIT ASPIRATION SYSTEM AT A SOYBEAN PLANT[a/]

Source	Control Equipment	Process Rate (tons/hr)	Dust Loading Leaving Control Equipment (gr/scf)	Emission Factor (lb/ton processed)
Truck dump pit aspiration system	Fabric filter	73	0.009	0.0119
	reverse jet cleaning	54	0.0247	0.04
	30 hp fan, 11,250 cfm	84	0.0032	0.0032

a/ EPA Method 5 sampling procedures were used to obtain data.

Table 143. MEASURED EMISSION RATES FROM SELECTED SOURCES AT A SOYBEAN PROCESSING PLANT

Source	Control Equipment	Gas Volume (cfm)	Process Rate (lb/hr)	Emission Rate (lb/hr)	Emission Factor (lb/ton processed)
Forsberg screen system	Cyclone	2,680	10,500	0.11	0.021
White flakes cooling system	Cyclone	12,500	12,000	5.7	0.95

Table 144. MEASURED EMISSION RATES FROM SELECTED SOURCES AT A SOYBEAN PROCESSING PLANT

Source	Control Equipment	Gas Volume (cfm)	Plant Process Rate (bu/day)	Emission Rate (lb/day)	Emission Factor (lb/bu)
Hull toaster	Cyclone	8,629	37,500	92.4	0.0025
Flake roll aspiration	Cyclone	12,204	37,500	144.2	0.0038
Primary dehulling	Cyclone	19,646	37,500	351.5	0.0095
Hull screens and conveyor	Cyclone	6,506	37,500	23.6	0.00063
Meal cooler	Cyclone (2)	22,608	37,500	209.5	0.0056
Meal dryer	Cyclone	9,050	37,500	11.7	0.00031

A Carter-Day ISO-KINETIC dust sampler was used to obtain the samples for the data reported in Table 144.

Some estimates of emission rates from soybean processing plants are presented in Tables 145 to 147.[43] The estimates were provided by various soybean processing plants which responded to the emissions inventory questionnaire.

CORN WET MILLING

The corn refining or wet-milling industry has grown in its 120-130 years existence into the most diversified of the grain processing industries. As the outflow of its integrated operations, the corn refining industry produces hundreds of products and by-products. The industry's products have so many diverse and multiple applications that they cut across defense, civilian, health and national interest uses.

Corn Wet-Milling Process

In the corn wet-milling process, the corn kernel is separated into four principal parts: (1) the outer skin, called the bran or hull; (2) the germ (containing most of the oil); (3) gluten, a high-protein component; and (4) starch. From a 56-lb bushel of corn, approximately 32 lb of starch are produced, about 14-1/2 lb of feed and feed products, about 2 lb of oil, and the remainder is water.

The overall corn wet-milling process, as illustrated in Figure 29, consists of several distinct segments: (1) the separation process, which divides and isolates the components of the corn kernel to obtain starch as the principal end product and steepwater, oil, and feeds as by-products; (2) the hydrolysis process, which converts some of the starch to syrup or dextrose; and (3) the starch modification process which changes starch characteristics by physical or chemical treatment.

Grain Receiving - Shelled corn is delivered to the wet-milling plant primarily by rail and truck and unloaded into a receiving pit. The corn is then elevated to temporary storage bins, then to scale hoppers for weighing and sampling. The corn then passes through mechanical cleaners designed to separate unwanted substances such as pieces of cobs, sticks, and husks, as well as metal and stones. The cleaners agitate the kernels over a series of perforated metal sheets; the smaller foreign materials drop through the perforations while a blast of air blows away chaff and dust, and electromagnets draw out nails and bits of metal. Coming out of storage bins, the corn is given a second cleaning before going into "steep" tanks.

Table 145. ESTIMATED DUST EMISSION RATES FROM GRAIN RECEIVING, HANDLING, AND CLEANING OPERATIONS AT VARIOUS SOYBEAN PROCESSING PLANTS[43]

Source	Control Device	Gas Volume (cfm)	Dust Load to Control Device (gr/scf)	Dust Load to Control Device (lb/hr)	Emission Rate From Dust Control Device (gr/scf)	Emission Rate From Dust Control Device (lb/hr)
Truck dump receiving pit and transfer conveyor	Fabric filter	17,000	0.82	120	0.0008	0.12
Truck dump receiving pit and transfer conveyor	Fabric filter	17,200	3.1	450	-	-
Truck dump receiving pit	Cyclone	7,000	5.0	300	-	-
Garner and scale vents	Cyclone	5,000	2.3	100	-	-
Scalper	Cyclone	3,000	5.8	150	-	-
Primary cleaner	Cyclone	5,000	2.33	100	0.12	5
Primary cleaner	Fabric filter	13,300	0.88	100	-	-
Tripper system	Cyclone	4,500	3.1	120	-	-
Conveyors and elevator legs	Fabric filter	14,500	5.6	700	-	-
Conveyors and elevator legs	Fabric filter	8,100	5.8	400	-	-
Conveyors and elevator legs	Fabric filter	26,800	1.0	230	-	-
Conveyors and elevator legs	Fabric filter	31,800	0.99	270	-	-

Table 146. ESTIMATED DUST EMISSION RATES FROM SOYBEAN GRAIN DRYERS AT VARIOUS SOYBEAN PROCESSING PLANTS[43]

Source	Control Device	Gas Volume (cfm)	Dust Load to Control Device (gr/scf)	Dust Load to Control Device (lb/hr)	Emission From Dust Control Device (gr/scf)	Emission From Dust Control Device (lb/hr)	Processing Rate (bu/day)	Emission Factor (lb/bu processed)
Soybean dryer	Carter-Day Day-Vac	308,000	1.51	4,000	0.0075	20	38,500	0.0124
Soybean dryer	Screen house	186,000	0.33	526	0.022	35	60,000	0.014
Soybean dryer	Screen house	300,000	0.194	500	0.035	90	37,500	0.058
Soybean dryer	Screen house	125,000	0.19	200	0.056	60	37,500	0.038

Table 147. ESTIMATED DUST EMISSION RATES FROM PROCESSING EQUIPMENT AT VARIOUS SOYBEAN PROCESSING PLANTS

Source	Control Device	Gas Volume (cfm)	Dust Load to Control Device (gr/scf)	Dust Load to Control Device (lb/hr)	Emission Rate From Dust Control Device (gr/scf)	Emission Rate From Dust Control Device (lb/hr)	Processing Rate (bu/day)	Emission Factor (lb/bu processed)
Cracking rolls	Cyclone	5,330	1.31	60	0.4	1.8	36,630	0.0012
Primary dehulling aspirator	Cyclone	13,000	134.6	15,000	0.09	10	37,500	0.0064
	Cyclone	16,000	60	8,230	0.25	34	60,000	0.014
Secondary dehulling aspirator	Cyclone	6,500	125.6	7,000	0.017	1	37,500	0.0006
	Cyclone	7,000	125	7,500	0.033	2	37,500	0.0012
Bean conditioner	Settling chamber	3,000	0.39	10	0.16	4	38,500	0.0024
	Cyclone	3,000	0.78	20	0.019	0.5	36,630	0.0003
Hull grinder	Cyclone	5,780	40	2,000	0.16	8	36,630	0.0052
	Cyclone	7,500	104	6,690	0.093	6	60,000	0.0024
	Cyclone	6,000	152	7,800	0.31	16	37,500	0.01
Flaking rolls	Cyclone	5,000	0.38	16.2	0.047	2	38,500	0.0012
	Cyclone	6,800	0.68	40	0.021	1.2	36,630	0.0007
	Cyclone	3,550	0.98	30	0.0135	2	37,500	0.0013
Meal dryer	Cyclone	6,200	0.56	30	0.056	3	38,500	0.0018
	Cyclone	13,500	0.96	112	0.06	7	38,500	0.0043
	Cyclone	12,500	5.6	600	0.11	12	36,630	0.0078
	Cyclone	9,000	2.6	200	0.26	20	37,500	0.0128
	Cyclone	9,000	0.26	20	0.0064	0.5	37,500	0.0003
	Settling chamber	2,000	5.1	87.3	0.12	2	60,000	0.0008
Meal grinder	Cyclone	6,600	10.6	600	0.32	18	36,630	0.012
	Cyclone	10,200	5.15	450	0.15	13.5	36,630	0.0088

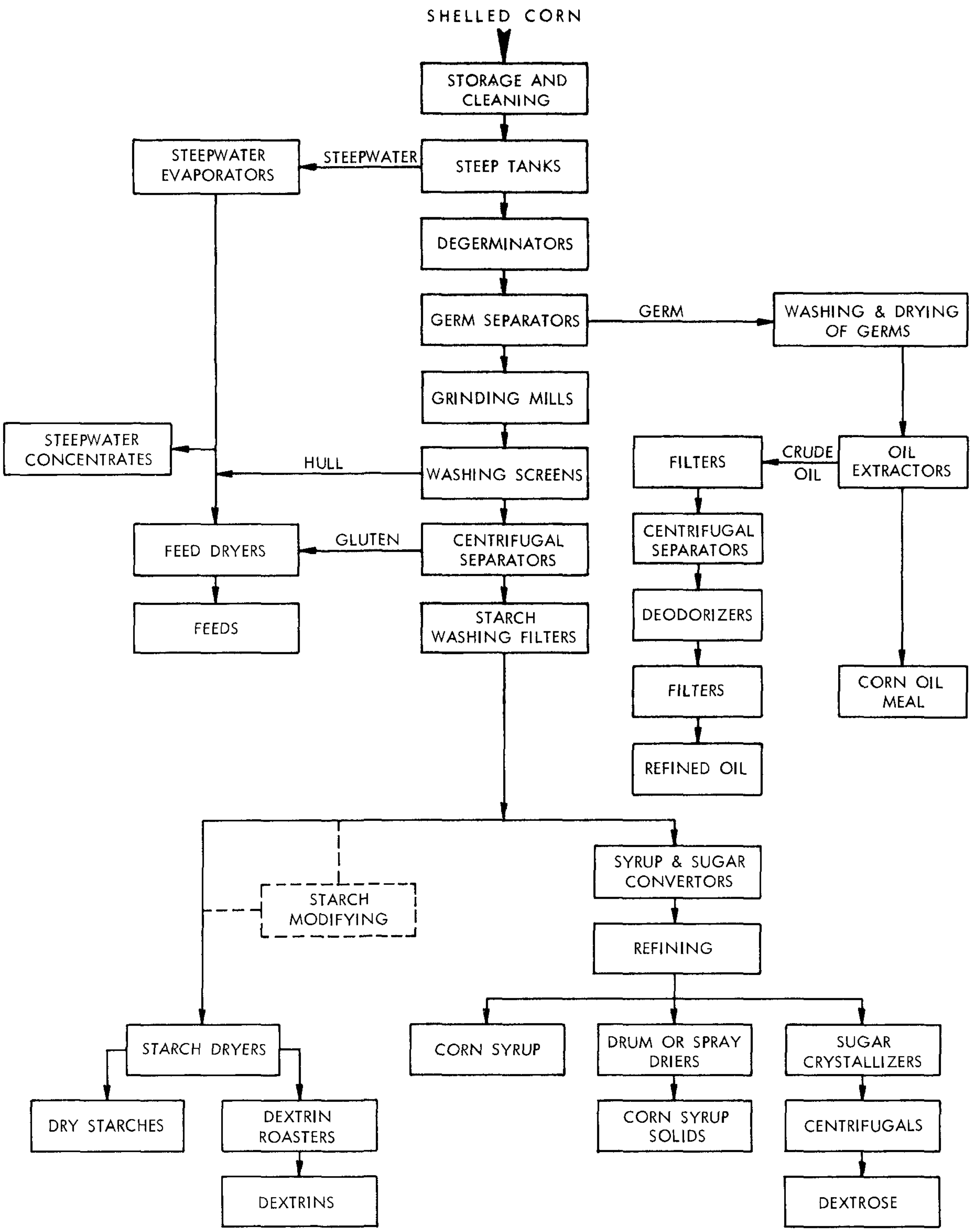


Figure 29. General flow diagram for corn wet milling plant.

Steeping - Steeping, the first step in the process, conditions the grain for subsequent milling and recovery of corn constituents. This process softens the kernel for milling, helps break down the protein holding the starch particles, and removes certain soluble constituents.

The steeping process consists of a series of tanks, usually referred to as steeps, and might be termed a batch-continuous operation. Each steep holds about 2,000 to 6,000 bu of corn, which is submerged in continuously recirculating hot water (about 50°C). Sulfur dioxide in the form of sulfurous acid is added to the incoming water to aid in the steeping process.

As a fully-steeped tank of corn is discharged for further processing, fresh corn is added to that steep tank. Incoming water to the total steeping system is derived from recycled waters from other operations at the mill, and is first introduced into the tank with the oldest corn (in terms of steep time) and passes through the series of steeps to the newest batch of corn. Total steeping time ranges from 28 to 48 hr.

Steepwater Evaporation - Water drained from the newest corn steep is discharged to evaporators as so-called light steepwater containing about 6% of the original dry weight of the grain. On a dry weight basis, the solids in the steepwater contain 35 to 45% protein and are worth recovering for addition to feeds. Such recovery is effected by concentrating the steepwater to 30 to 55% solids in triple-effect evaporators. The resulting steeping liquor, or heavy steepwater, is usually added to the fibrous milling residue which is sold as animal feed. Some steepwater may also be sold for use as a nutrient in fermentation processes.

Milling - The steeped corn then passes through degerminating mills which tear the kernel apart to free the germ and about half of the starch and gluten. The resultant pulpy material is pumped through liquid cyclones or flotation separators to extract the germ from the mixture of pulp, starch, and gluten. The germ is subsequently washed, dewatered, dried, the oil extracted, and the spent germ then sold as corn oil meal.

The product slurry passes through a series of washing, grinding, and screening operations to separate the starch and gluten from the fibrous material. The hulls are discharged to the feed house where they are dried and used in animal feeds.

At this point, the main product stream contains starch, gluten, and soluble organic materials. The lower density gluten is then separated from the starch by centrifugation, generally in two stages. A high quality gluten of 60 to 70% protein and 1.0 to 1.5% solids, is then centrifuged, dewatered, dried, and added to the animal feed. The centrifuge underflow containing the starch passes to starch washing filters to remove any residual gluten and solubles.

Starch Production - The pure starch slurry can now be directed into one of three basic finishing operations, namely ordinary dry starch, modified starches, and corn syrup and sugar. In the production of ordinary pearl starch, the starch slurry is dewatered using vacuum filters or basket centrifuges. The discharged starch cake has a moisture content of 35 to 42% and is further thermally dewatered by one of several different types of dryers. The dry starch is then packaged or shipped in bulk, or a portion may be used to make dextrine.

Modified starches are manufactured for various food and trade industries for special uses for which unmodified starches are not suitable. For example, large quantities of modified starches go into the manufacture of paper products, serving as binding for the fiber. Modifying is accomplished by treating the starch slurry with selected chemicals such as hydrochloric acid to produce acid-modified, sodium hypochlorite to produce oxidized, and ethylene oxide to produce hydroxyethyl starches. The treated starch is then washed, dried, and packaged for distribution. Since most chemical treatments result in a more water soluble product, wastewaters from the washing of modified starches may contain a large concentration of BOD. In addition, because of the presence of residual chemicals, these wastewaters often cannot be reused and must be discharged to the sewer.

Syrup and Sugar - In most corn wet mills, about 40 to 70% of the starch slurry is diverted to the corn syrup and sugar finishing department. Syrups and sugars are formed by hydrolyzing the starch, partial hydrolysis resulting in corn syrup and complete hydrolysis producing corn sugar. The hydrolysis step can be accomplished using mineral acids or enzymes, or a combination of both. The hydrolyzed product is then refined, a process which consists of decolorization with activated carbon and removal of inorganic salt impurities with ion exchange resins. The refined syrup is concentrated to the desired level in evaporators and cooled for storage and shipping.

The production of dextrose is quite similar to that of corn syrup, the major difference being that the hydrolysis process is allowed to go to completion. The hydrolyzed liquor is refined with activated carbon and ion exchange resins to remove color and inorganic salts, and the product stream is concentrated to the 70 to 75% solids range by evaporation. After cooling, the liquor is transferred to crystallizing vessels where it is seeded with sugar crystals from a previous batch. The solution is held for several days while the contents are further cooled and the dextrose crystallizes. After about 60% of the dextrose solids have crystallized, they are removed from the liquid by centrifuges, dried, and packed for shipment.

A smaller portion of the syrup refinery is devoted to the production of corn syrup solids. In this operation, refined corn syrup is drum- or spray-dried to generate corn syrup solids, which are somewhat more convenient to use than the liquid syrup.

Air Pollution Sources, Emission Rates and Effluent Properties

The diversity of operations in a corn wet milling plant results in numerous and varied potential sources of air pollution. It has been reported that the number of process emission points number well over 100 at a typical plant. Table 148 presents some of the potential sources of air pollution in corn wet milling plants.

Emission sources associated with the grain receiving, cleaning, and storage are similar in character to those involved in all grain elevator operations.

Table 148. POTENTIAL SOURCES OF AIR POLLUTANTS IN CORN WET MILLING PLANTS

I. Grain Receiving, Cleaning and Storage

1. Grain unloading
2. Elevator leg vents
3. Garner and scale vents
4. Trippers, conveyor transfer points
5. Grain cleaner

II. Separation Process

1. SO_2 absorption tower
2. Steep tanks
3. Germ drying
4. Gluten drying
5. Feed drying
6. Feed pellet mill (if used)
7. Pellet cooler (if used)
8. Starch drying
9. Starch milling

III. Conversion Process

1. Dextrose drying
2. Corn syrup solids drying
3. Spent carbon regenerator

Table 82, p. 122 presents recently obtained emission rate data for corn receiving and handling operations.

The various drying operations performed in the separation process are major sources of particulate and odor emissions. Several different types of dryers such as ring, flash, rotary, belt, and steam tube are used to dry feed, gluten, germ, and starch. Since a product recovery system (e.g., cyclone collector) is used in conjunction with the dryers, the actual source of emissions is the product recovery cyclone. Discussions with plant managers have indicated that the feed drying operation is the most difficult source of air pollution to control.[33,34] The feed drying operation is also considered the worst fire hazard followed by the gluten and starch drying processes.[33,34] The starch drying process also presents an explosion hazard.[34]

Dextrose and corn syrup solids drying are also emission sources. As with the other drying operations, the actual emission point is the product recovery unit. Spray dryers used for the drying of corn syrup solids are reported to emit particulates that are difficult to collect.[34] Regeneration of the granular carbon used in dextrose and syrup refining may also result in the emission of particulates.[33]

The emission rates from the drying operations will vary with the type of dryer and product recovery system utilized. Table 149 presents some data on measured emission rates from drying operations in various corn wet milling plants. The data for Plants A and B were obtained with Western Precipitation Sampling equipment, while RAC equipment was used at the other plants.

Table 150 summarizes the results of emission testing activity conducted by one company using emission testing equipment and procedures which they believe are applicable for use on exhaust streams of high moisture content. The exact test procedures are not known and the validity of the data in Table 150 cannot be assessed.

Table 151 presents data on the properties of effluent streams from cyclone product collection systems on various dryers in corn refining plants. The data in Table 151 on moisture content in the gas stream were obtained by material balances around the dryer units. The outlet temperatures and gas volumes were obtained from discussions with individual plant managers and emission inventory questionnaires.

Table 149. MEASURED EMISSION RATES FROM DRYING OPERATIONS AT CORN WET MILLING PLANTS[1/]

Plant Designation	Source	Product Recovery Device	Gas Volume (cfm)	Emission Rate from Product Recovery Device (gr/scf)	Emission Rate from Product Recovery Device (lb/hr)	Secondary Dust Control Device On Product Recovery Device or Process Equipment	Emission Rates from Secondary Dust Control Device: Inlet Dust Load (lb/hr)	Emission Rates from Secondary Dust Control Device: Outlet Dust Load (lb/hr)
Plant A[a/]	Gluten meal dryer	Cyclone	37,500	0.076	24.4			
	2 gluten feed dryers	8 cyclones per dryer	46,000 per dryer	0.05	20.4			
	Proctor and Schwartz starch dryer	--	27,700	0.012	2.8[b/]			
	Proctor and Schwartz starch dryer	--	9,600	0.024	1.96[b/]			
	Flash starch dryer	2 cyclones	43,000	0.019	7.0			
	Flash starch dryer	2 cyclones	43,000	0.019	7.1			
	Syrup spray dryer	Cyclone	23,700		--	Wet scrubber	216	66
	Syrup spray dryer	Cyclone	32,600		--	2 cyclones		92
	Germ dryer	Not applicable	20,500		--	Dry rotoclone		25.5
	Feed conveying	2 cyclones (Aerodyne Type S)	25,100	0.02	4.2			

Table 149. (continued)

Plant Designation	Source	Product Recovery Device	Gas Volume (cfm)	Emission Rate from Product Recovery Device		Secondary Dust Control Device On Product Recovery Device or Process Equipment	Emission Rates from Secondary Dust Control Device	
				(gr/scf)	(lb/hr)		Inlet Dust Load (lb/hr)	Outlet Dust Load (lb/hr)
Plant B[a]	Feed dryer (Raymond flash, regular feed)	Cyclone	44,400	0.12	44.0			
	Feed dryer (Raymond flash, regular feed)	Cyclone	45,400	0.06	23.0			
	Feed dryer (Raymond flash, hominy feed)	Cyclone	40,100	0.11	37.0			
	Feed dryer (Heil rotary dryer, regular feed, finish drying)	Cyclone	45,000	0.038	14.6			
	Gluten dryer (Barr-Murphy dryer, gluten, single pass)	Cyclone	72,600	0.061	38.0			
	Starch dryer (belt dryer)	Not applicable	32,800	0.26	73.5[b]			
	Dextrose dryer (rotary dryer)	Cyclone	9,300			Rotoclone		0.6
Plant C[c]	Feed dryer	Cyclones	29,500	0.04	11.25			
	Gluten dryer	Cyclones	16,300	0.07	9.65			
Plant D[c]	Gluten dryer (Barr-Murphy dryer)	6 cyclones in parallel	17,600	0.026-0.077	8.0[d]			
	Distillers, dark grains dryer (rotary dryer)	Cyclone	31,000	0.03	8.7[d]			

Table 149. (Concluded)

Plant Designation	Source	Product Recovery Device	Gas Volume (cfm)	Emission Rate from Product Recovery Device (gr/scf)	Emission Rate from Product Recovery Device (lb/hr)	Secondary Dust Control Device On Product Recovery Device or Process Equipment	Emission Rates from Secondary Dust Control Device: Inlet Dust Load (lb/hr)	Emission Rates from Secondary Dust Control Device: Outlet Dust Load (lb/hr)
Plant F[c/]	Feed dryer (Raymond flash)	Cyclone	27,000	0.024	5.55			
	Feed dryer (Raymond flash)	Cyclone	27,000	0.028	6.58			
	Feed dryer (Heil, rotary finish drying)	Cyclone	13,000	0.045	5.01			
	Gluten dryer (Barr-Murphy Dryer)	8 cyclones	55,000	0.034	16.3			
Plant F[c/]	Starch dryer (Intensa flash dryer)	Cyclones	45,000			Wet scrubber		17.3

a/ Western Precipitation sampling equipment used for source testing.
b/ No product recovery device or dust control device installed on belt dryer.
c/ RAC sampling equipment used for source testing.
d/ Average of several individual tests.

Table 150. MEASURED EMISSION DATA FOR SPECIFIC CORN REFINING PLANTS

Source	Input to Process Unit (lb/hr)[a]	Emission Rate (lb/hr)[b]	Concentration (gr/scf)[c]	Emission Factor (lb/ton)[d]
Plant A				
Product recovery cyclone on feed dryer	60,000	9.6	0.046	0.32
Product recovery cyclones on feed coolers (4 cyclones in parallel	96,000	17.4-32	0.056-0.105	0.36-0.67
Product recovery cyclones on feed transport system (2 cyclones in series)	96,000	9.9-10.8	0.27-0.29	0.2-0.23
Product recovery cyclone on gluten dryer	31,500	6.1-18.2	0.12-0.38	0.39-1.2
Plant B				
Product recovery cyclone on rotary feed dryer	-	11.25	0.045	-
Product recovery cyclone on rotary gluten dryer	-	9.65	0.069	-

a/ Input to dryer or cooler.
b/ Emission rate from cyclone.
c/ Cyclone exhaust stream.
d/ Based on input to dryer or cooler.

Table 151. CHEMICAL AND PHYSICAL PROPERTIES OF EFFLUENTS FROM PRODUCT COLLECTION SYSTEMS (CYCLONES) ON DRYER EXHAUSTS (CORN WET MILLING PLANT)

Source	Specific Gravity of Dust (g/cc)	Outlet Temperature of Gas - °F	Flow Rate (scfm)	Moisture Content of Gas Stream (lb H_2O/scf)
Plant A.				
I. Feed Drying				
a. primary rotary flash dryer - single cyclone collector	0.5	225	48,000	0.0079
II. Gluten Drying				
a. rotary flash dryer - single cyclone collector	0.9	200	40,000	0.0046
Plant B.				
I. Feed Drying				
a. secondary rotary dryer - single cyclone collector	0.5	200	29,500	0.012
II. Gluten Drying				
a. rotary gluten dryer - single cyclone collector	0.9	156	16,300	0.0077
Plant C.				
I. Feed Drying				
a. primary flash dryer - single cyclone collector	0.5	160-315	40,000	0.0063
b. secondary rotary dryer - single cyclone collector	0.5		14,000	0.009
II. Gluten Drying				
a. 3 pass rotary dryer - single cyclone collector	0.9	140-170	14,000	0.006-0.007
b. rotary flash dryer - single cyclone collector	0.9	200	40,000	0.0036
III. Starch Drying				
a. flash dryer - single cyclone collector	1.5	--	40,000	0.002
b. Barr-Murphy ring dryer - fabric filter collector	1.5	--	60,000	--
IV. Corn Syrup Solids Drying				
a. flash dryer - single cyclone collector		--	25,000	0.003

The Corn Refiners Association has contracted studies to identify the nature of gaseous emissions from feed dryers.[35] Condensable organic constituents in stack effluents from 13 different dryers in five plants were sampled. Analysis of the samples indicated that the dryer exhausts all contained the same group of organic compounds from a qualitative standpoint. Ten low-molecular-weight acids, 10 aldehydes, and an amine were identified by a combination of mass spectrometry and gas chromatography. Table 152 summarizes the data for the acids and aldehydes.

Table 152. VOLATILE ORGANIC COMPONENTS IN FEED DRYER EXHAUST STREAM (CORN WET MILLING PLANT)

	PPM in Aqueous Condensate													
Dryer	1	2	3	4	5	6	6A	7	8	9	10	11	12	13
Acids														
Acetic	0.4	3.0	1.0	0.3	0.1	2.0	8.0	1.0	4.0	1.0	0.04	2.0	2.0	0.5
Propionic	0.3	0.3	0.2	0.04	0.05	0.4	0.4	0.2	0.4	0.5	0.01	0.4	0.5	0.2
Isobutyric	0.1	0.1	0.1	0.02	0.05	0.3	0.4	0.1	0.3	0.3	0.02	0.2	0.1	0.1
n-Butyric	0.5	1.0	1.0	0.1	0.3	0.8	1.0	1.0	2.0	2.0	0.1	2.0	3.0	0.8
Isovaleric	2.0	0.4	0.6	0.2	0.3	0.8	1.0	0.4	2.0	2.0	0.2	1.0	0.5	0.5
n-Valeric	0.5	1.0	1.0	0.04	0.3	0.5	0.4	1.0	9.0	3.0	0.04	1.0	1.0	1.0
Isocaproic	0.5	0.4	0.3	0.4	0.05	0.4	0.2	0.08	0.4	0.1	0.04	0.1	0.01	0.1
n-Caproic	1.0	3.0	3.0	0.4	1.0	1.0	1.0	3.0	5.0	3.0	1.0	3.0	3.0	3.0
Benzoic	0.5	0.4	0.3	0.2	0.05	0.3	0.1	0.3	0.3	0.2	0.2	0.5	1.0	0.8
Phenylacetic	0.5	0.5	0.4	0.2	0.5	0.2	1.0	0.3	1.0	0.5	0.02	0.5	0.2	0.2
TOTAL	6.3	10.1	8.0	1.9	2.7	6.7	13.5	7.4	24.4	12.6	1.7	10.7	11.3	7.2
Aldehydes														
Acetaldehye	25.0	2.0	15.0	7.0	0.6	7.0	2.0	1.0	0.7	3.0	3.0	1.0	1.0	3.0
Propionaldehyde	0.6	0.2	0.3	0.7	0.3	0.3	0.2	0.6	0.08	0.7	0.6	0.8	0.8	0.4
Isobutyraldehyde	2.0	0.3	0.7	1.0	> 0.01	1.0	1.0	0.02	0.05	0.1	> 0.01	0.05	0.05	0.1
Isovaleraldehyde	8.0	1.0	3.0	2.0	> 0.01	6.0	4.0	0.01	0.04	0.4	> 0.01	0.3	0.3	1.0
n-Valeraldehyde	1.0	0.1	0.6	0.7	> 0.01	0.7	0.6	0.1	0.02	0.5	> 0.01	0.05	> 0.01	0.05
Furfural	7.0	0.1	12.0	3.0	> 0.01	10.0	15.0	0.4	0.3	0.1	> 0.01	1.0	3.0	7.0
Octyl aldehyde	3.0	2.0	5.0	4.0	> 0.01	10.0	6.0	0.3	3.0	0.3	> 0.01	0.1	0.3	7.0
Pyruvaldehyde	10.0	1.0	20.0	6.0	0.4	0.4	0.2	2.0	2.0	0.8	0.1	0.1	0.7	2.0
Benzaldehyde	1.0	0.1	3.0	0.4	> 0.01	0.7	1.0	0.5	0.1	0.05	> 0.01	0.05	0.05	0.2
Phenylacetaldehyde	9.0	6.0	15.0	4.0	0.3	10.0	10.0	5.0	12.0	2.0	0.4	2.0	2.0	9.0
TOTAL	66.6	12.8	74.6	28.8	1.6	46.1	40.0	9.9	18.3	8.0	4.1	5.4	8.2	29.8

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CHAPTER 4

TECHNICAL AND ECONOMIC ASPECTS OF DUST CONTROL SYSTEMS

INTRODUCTION

Systems for the control of dust emissions from grain and feed operations consist of either extensive hooding and aspiration systems leading to a dust collector or methods for eliminating emissions at the source. These latter methods can be as simple as interventing the head and boot of a bucket elevator or use of enclosed conveyors in pressurized elevators. The incentives for controlling emissions, in addition to complying with air pollution regulations, include recovery of valuable materials, sanitation, and reducing the fire and explosion hazards.

Where practical, techniques which eliminate the sources of dust emission or which retain it in the process are the most effective. Enclosures or covers on bins, tanks, and hoppers, and the replacement of worn-out parts can help eliminate sources of dust emissions. Emissions can also be eliminated by minimizing the number and size of openings, and maintaining the system's internal pressure below the external pressure; thus air flows into, rather than out of, the openings. Such systems are in use in the basements of elevators where the conveyors are completely enclosed and the basement is slightly pressurized.

When methods for eliminating the sources of dust emission are not practical, control systems must be used which capture the dust as it is entrained or suspended in the air, and convey it to a dust collection device.

Thus, eliminating dust at the source and capturing the entrained dust, followed by separation in a collection device, are both important methods for controlling emissions. Although a number of facilities have taken steps to eliminate dust emissions at the source, the majority have installed an aspiration system using one of the common collection devices such as cyclones or fabric filters. The estimated effectiveness of these practices in the major segments of the grain and feed industry is listed in Table 153.[1/]

Table 153. ADEQUACY OF TYPICAL DUST CONTROL SYSTEMS - CURRENT STATUS, 1972[a/][1/]

Industry Segment	Retention[b/] Adequacy of Typical Practice	Capture[c/] Adequacy of Typical Systems	Separation[d/] Filters (%)	Cyclones (%)
Flour mills - milling process	8	9	50	50
Flour mills - cleaning house	7	8	10	90
Flour mills - grain storage	5	5	10	90
Soybean (dry) processing	6	6	25	75
Corn mills - entire plant	6	6	40	60
Rice mills - entire plant	6	6	5	95
Feed mills - entire plant	5	5	5	95
Terminal elevators	4	4	3	97
Country elevators	2	2	1	99
Alfalfa mills	3	3	1	99

a/ Opinion regarding the adequacy of dust retention efforts and collection systems (Column 2) is presented by a scale from 0 to 10, in which 0 indicates complete inadequacy and 10 indicates complete adequacy.

b/ Effectiveness of practices which reduce or eliminate dust emissions at the source.

c/ Effectiveness of methods which capture the dust entrained in air at the source.

d/ Approximate percent usage, industry average, of fabric filter and cyclone devices by industry category.

Technical and economic factors associated with dust control systems suitable for use in the grain and feed industry are discussed in general terms in the following section. Dust control practices for specific segments of the grain and feed industry are presented in the section on p. 292 (Currently Used Control Systems).

DUST CONTROL SYSTEMS

Control of emissions requires proper design of both the dust pick-up and the contaminant removal system to adequately collect the contaminants at the emission source, remove the contaminant from the carrier gas stream and then exhaust the cleaned gas to either the atmosphere or back into the building. Thus, the design of the hoods, ducts, fans, and vents, plus the design of the contaminant removal device must be carefully specified to insure an effective emission control system. It is especially important that this system be designed as an integrated unit with adequate capacity for current and planned production.

Dust Capture Systems

Adequate design of the emission dust capture system is vital for effective air pollution control and in most cases the system must be individually tailored for each process. Grain unloading, loading, and drying operations represent some of the more difficult sources for proper dust pick-up whereas for most other sources, the design of the emission comtainment system is essentially straightforward. Air flow in the ducts must be high enough to prevent the dust from settling out and plugging the duct. The air velocity at the inlet or dust pick-up points must be high enough to capture the dust, but not so high as to pick up grain or other products from the belts, transfer points, etc. Duct velocities are usually above 3,000 ft/min and inlet air velocities at openings range from 75 ft/min to as high as 2,000 ft/min. Table 154 presents some data on design parameters for dust control systems in grain and feed plants.[2/] Additional information regarding design of hooding and exhaust systems in grain handling operations is given in Reference 2.

Types of Air Pollution Control Devices

Cyclone collectors, fabric filters and wet scrubbers are used to control emissions from the various grain handling and processing sources. Wet scrubbers have not found wide application because of the associated water pollution potential and because they do not permit direct recycling of the collected material. Due to tightening emission control regulations, fabric filters are now being used on many sources which were formerly controlled by only low efficiency

Table 154. DESIGN PARAMETERS FOR DUST CONTROL SYSTEMS IN GRAIN ELEVATORS, FEED MILLS, AND FLOUR MILLS[2]

Operation	Hood Design[a]	Air Volume
Bag loading	VS 301, 302 Booth VS-303	As shown 100 cfm/ft^2 open face area
Belt discharge	To belt--VS-306 To bin--VS-304 To elevator--VS-305, 306	150 cfm/ft of belt width up to 200 fpm belt speed 250 cfm/ft of belt width over 200 fpm belt speed Increase 1/3 if material drop is over 10 ft
Bins	Direct exhaust. Use taper.	550 cfm/bin
Bucket elevator	VS-305	100 cfm/ft^2 cross-section
Cleaning machines	Consult manufacturer	
Distributors	Enclose discharge 200 fpm in-draft through enclosure openings.	Exhaust cfm — Diameter of Spouts No. of Spouts: 6 in. / 7 in. / 8 in. / 9 in. 0-6: 550 / 675 / 950 / 1,250 6-12: 950 / 1,250 / 1,500 / 1,900 12-24: 1,500 / 1,900 / 2,250 / 2,750
Feed grinders	Consult manufacturer	
Floor dump	Booth	200 cfm/ft^2 open face area
Floor sweep		950 cfm in 4 in. x 8 in. opening
Garner bin	Direct exhaust. Use taper.	cfm = 1.25 x bu/min
Mixers	Ventilated cover	Mixer Capacity — Exhaust, cfm Up to 1/2 ton — 300 1/2 ton - 1-1/2 ton — 675 Over 1-1/2 tons — 950
Hammermill		18-20 cfm/hp if separate pneumatic system 36-40 cfm/hp with hammermill fan

Table 154 (Concluded)

Operation	Hood Design a/	Air Volume	
Percentage feeders	Enclosed conveyor	200 cfm at each feeder	
Purifiers	Enclosure	30-40 cfm/ft^2 screen area	
Roll stands	Enclosure	60 cfm/lineal ft	
Scales	Enclosure	Scale Capacity, bu	Exhaust, cfm
		Up to 5	250
		6 to 10	400
		Over 11	600
Scale hopper	Direct exhaust. Use taper.	cfm = 1.25 x bu/min	
Screw conveyor	Direct exhaust. Use taper.	200 cfm - ducts on 30 ft centers	
Sifters	Enclosure	200 cfm/compartment	
Dump pit	Direct exhaust from hopper. Use taper.	100 cfm/ft^2 grate area	
Tripper car	Belt discharge. FS-304, 305, 306. Spout ends - tapered connection. Spillage - exhaust under head pulley.	See "Belt Discharge" above. 200 cfm/ft^2 spout cross-section 90 cfm/ft belt width	

a/ See Reference 2 for specific hood design descriptions.

mechanical collectors. High efficiency mechanical collectors are being used on several processes, where the high moisture content of the effluent streams or other process requirements precludes the use of fabric filters. The fairly dry nature of the dust, the low temperature involved (ambient) and the relatively large particle size make cyclone collectors and fabric filters effective. A variety of these devices has been installed, ranging from single large diameter cyclones to reverse-air fabric filters. Screens have also been used for such unique applications as reducing the emission of large sized particles (beeswing) from grain drying operations.

In the following sections, the technical characteristics of the various types of control devices suitable for use on emission sources in grain processing operations are discussed. In the section on p. 292 (Currently Used Control Systems), the specific devices and process modifications suitable for reducing emissions are reviewed for each emission source.

Inertial Separators - Collectors which rely upon particle inertia to separate particulate matter from the carrier gas stream range from simple settling chambers to relatively sophisticated cyclones. Because of the large mass mean diameter of grain dust, these units are capable of medium to high collection efficiencies. However, even the most efficient units normally operate with at least some visible emissions.

Inertial collectors can be grouped into three board categories: settling chambers; cyclones; and impeller collectors. These units, and their operating and design characteristics, are described in the following sections.

Settling chambers - Settling chambers rely solely upon gravitational force to separate the particles from the carrier gas stream. Figure 30 is a schematic of a typical expansion chamber. Particles are removed from the carrier gas stream when their settling velocities are high enough (i.e., the particles have sufficient mass) such that they settle out of the gas stream in a period of time less than the residence time of the carrier gas in the settling chamber. The carrier gas velocity must be low enough to achieve the desired particle settling and also to prevent reentrainment of the settled particles. These velocities are usually in the range of 1 to 10 ft/sec.[3] Physical limitations on the size of the settling chamber set the lower limits on this velocity. Most units are designed such that the collection efficiency declines rapidly for particles smaller than 50 μm in diameter. Overall collection efficiency is, of course, dependent upon the particle size distribution.

In the grain and feed industry, settling chambers are often used as "grain traps" to remove the kernels of grain and large grain particles entrained at various dust pick-up points. These grain traps are located close to the dust pick-up points so the recovered product can be returned to the process and to minimize duct wear by reducing erosion. Settling chambers are generally not used for air pollution control.

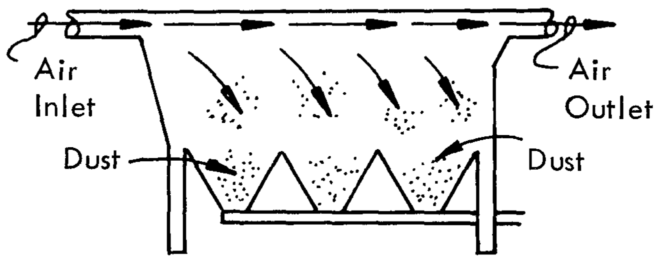


Figure 30. Settling chamber.

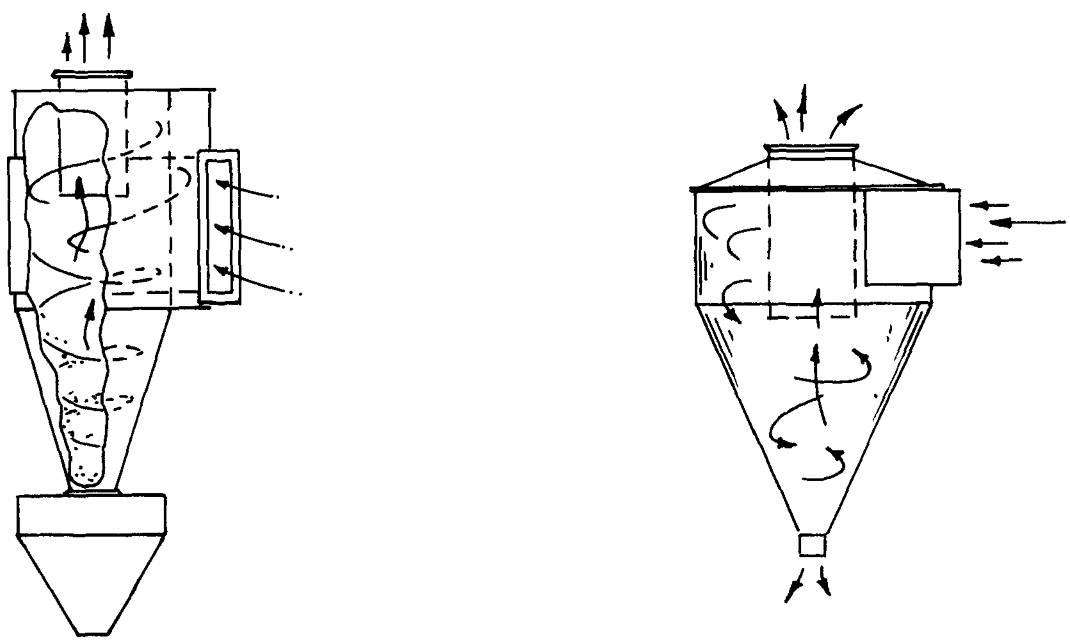
Cyclones - Cyclones have been used extensively for controlling emissions in the grain and feed industry. In the last 5 to 10 years, however, many companies have been installing fabric filters on new sources which were formally controlled only by cyclones and replacing existing cyclones with fabric filters.

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 155.

Table 155. CYCLONE DESIGN PARAMETER AND ITS EFFECT ON EFFICIENCY[4]

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 31 illustrates the geometrical relationships for these types of cyclones. Pressure drop through the low efficiency 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.[5]



High Efficiency Design High Throughput Design

Figure 31. 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.[6] With the exception of flour mill systems, the units can normally operate with minimum visible emissions; however, significant visible emissions can occur if a dusty load of grain is received.

Figure 32 shows the typical collection efficiency for both the high throughput and high efficiency cyclones for various particle diameters.[7] 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.

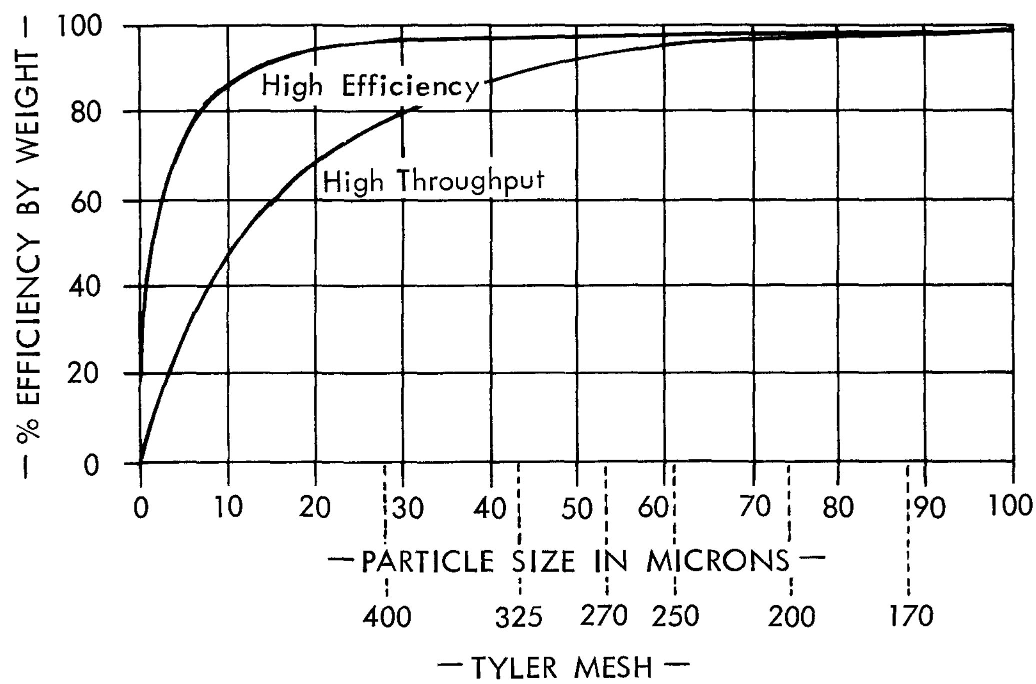


Figure 32. Typical collection efficiency curves for high throughput and high efficiency cyclones.

A modification of the conventional high efficiency cyclone, shown in Figure 33, 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.[8] 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.

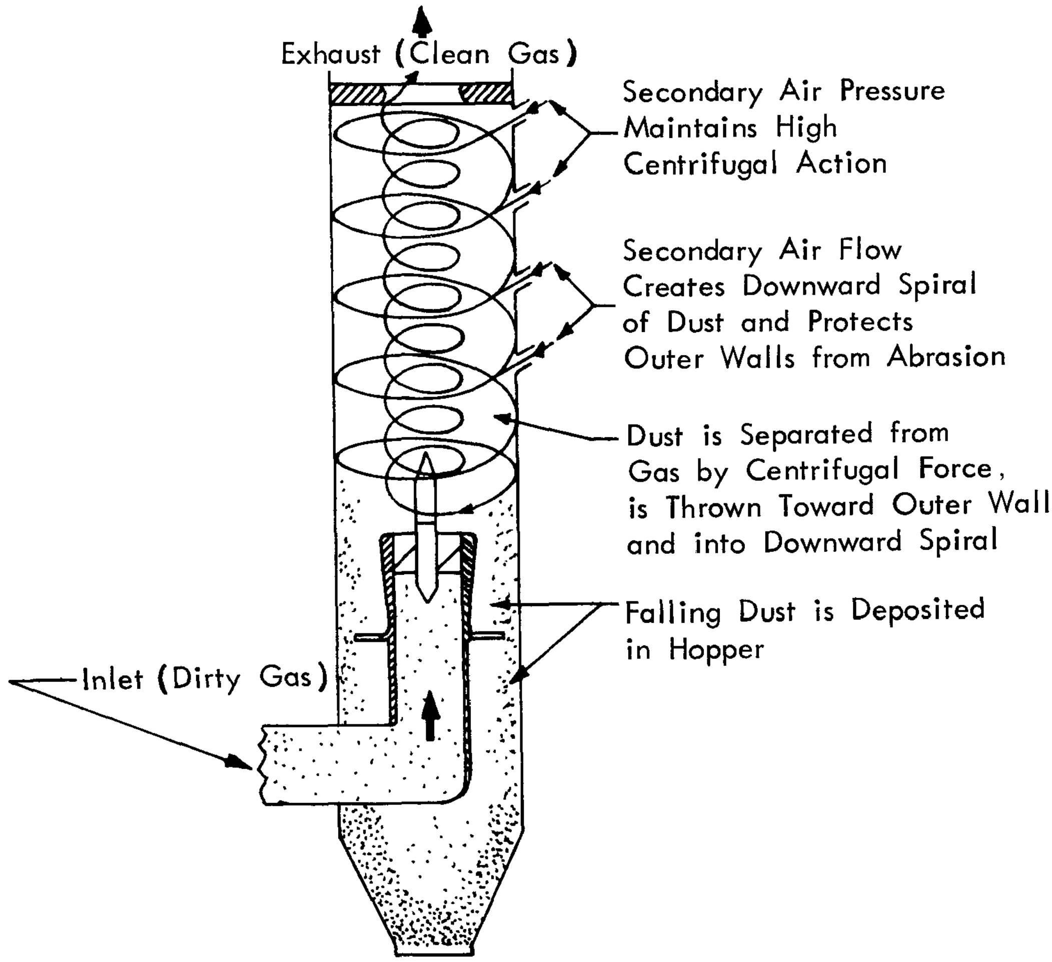


Figure 33. Recirculating cyclonic collector.[8]

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.

Impeller collector - Figure 34 illustrates the impeller collector.[4/] The advantage of this unit is that it combines the functions of the exhauster (blower) and the dust collector. The dust laden gas stream enters at the central part of the impeller, and the centrifugal force imparted to the particles forces them into the collection hopper below the unit.

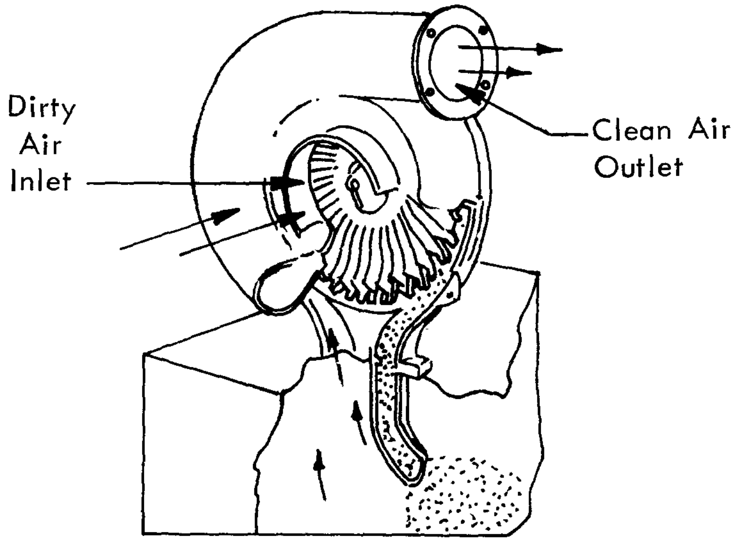


Figure 34. Impeller collector.

These units are used to a limited extent on both grain handling and process sources. Properly operated units are estimated to have collection efficiencies of approximately 95% although definitive test data are not available. The units operating on emission sources involving grain handling usually have a visible discharge.

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 sources 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.

Cloth fabric filters - 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.[9] 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 35 illustrates these basic shapes and the possible configurations of air flow through the filter.[9]

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 to 20 ft/min (typically around 10 ft/min for grain dust).[9]

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.[9] One common system uses a blower to provide the reverse air for cleaning one bank of filter tubes 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

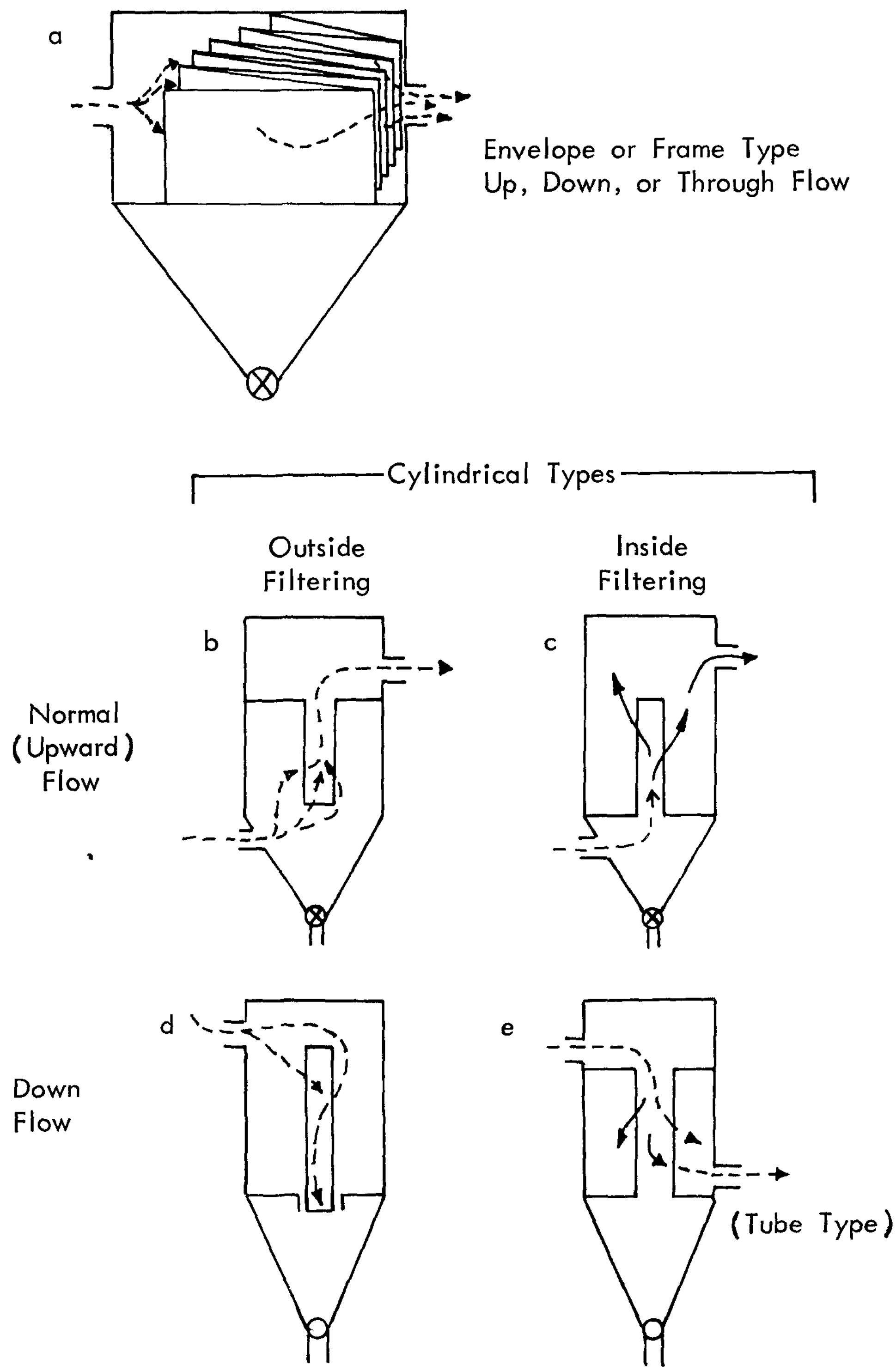


Figure 35. Fabric filter configurations.

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.[9] 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.

Bag life is on the order of 18 to 36 months, and varies with the type of cleaning cycle. A complete cleaning of the bags (i.e., dry cleaning) is sometimes required to restore their original efficiency and operating characteristics. Complete cleaning of the bags would occur about once or twice a year in a plant with a good preventive maintenance program.

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

Glass mat filters - A fabric filtration device with a high pressure drop has recently been introduced for controlling sticky particulate matter. The operation of this device is illustrated in Figure 36.[10] Although this device is not currently used for grain and feed emission sources, it might be suitable for controlling emissions from such difficult sources as feed dryers in wet corn milling.

Solid and liquid particulate matter is removed from the gas stream as they pass through the blanket of glass fiber material. The glass fiber mat uncoils from a spool, passes over a metal perforated drum, returns to a rewind spool and is then disposed of. The filter mat can be manually advanced or automatically advanced at a predetermined rate.

The filter mat can vary between 0.03 in. and 1.5 in. in thickness with densities between 0.6 and 8 lb/ft^3. The glass fiber mats are bonded with a phenol formaldehyde resin. Other fiber materials can also be used. Filtering velocities are generally in the range of 200 to 700 ft/min with pressure drops between 6 and 25 in. of water. Collection efficiency increases with filtering velocity, and hence pressure drop. Tests on nongrain industry sources have indicated efficiencies in the 96% to 98% range.[10]

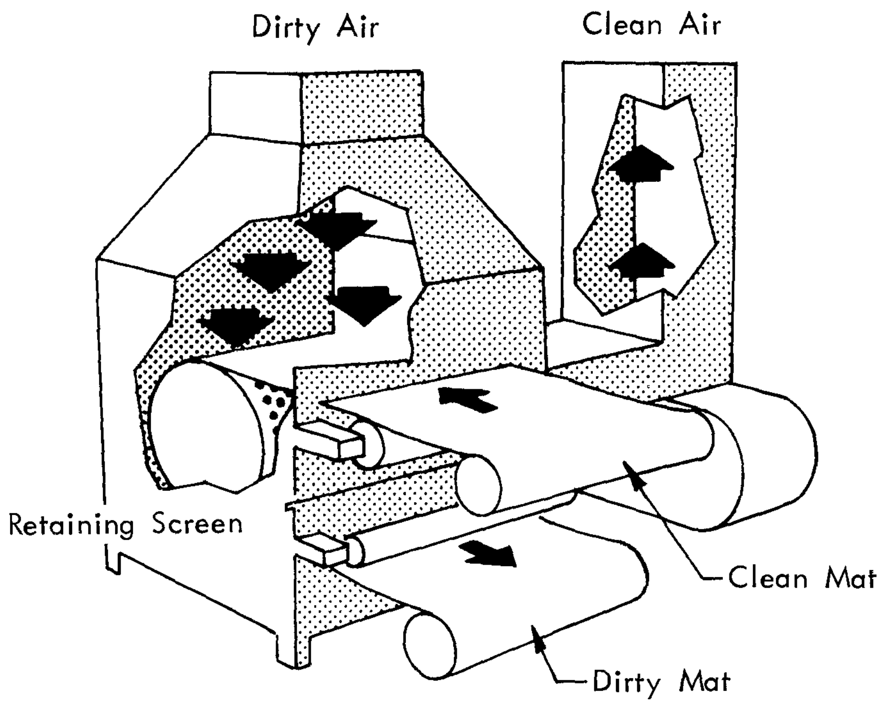


Figure 36. Glass mat filter.10/

High velocity filters - Another type of high velocity fabric filter recently introduced is illustrated in Figure 37. This unit has been evaluated for use on controlling truck dumps and is recommended by one grain dryer manufacturer for use on their grain dryer. Recommended filter velocities generally range from 400 to 500 ft/min. Pressure drops vary between 0.3 and 0.9 (clean media) to 0.5 and 1.5 in. of water during routine operation depending upon the type of media and filter velocity. Typical media are 230 mesh woven nylon, nonwoven polyester and nonwoven rayon felt. Test efficiency data are not available but the manufacturer states that it is about 85% to 97% efficient depending upon the particle size distribution, type of media and filtration velocity.

The exhaust stream from the vacuum head is about 3% to 5% of the total effluent, and the stream can be exhausted through a small fabric filter or cyclone, or in the case of a grain dryer, through the dryer.

Screen filters - Screen systems are used to control beeswings and other particulate matter from grain dryers. The collection mechanisms and operating principles are essentially the same as for fabric filtration, but the larger mesh size enables high moisture content streams to be handled without fabric blinding. Because of this larger mesh, however, screen systems are suitable only for particulate emission streams which have large mass mean diameter.

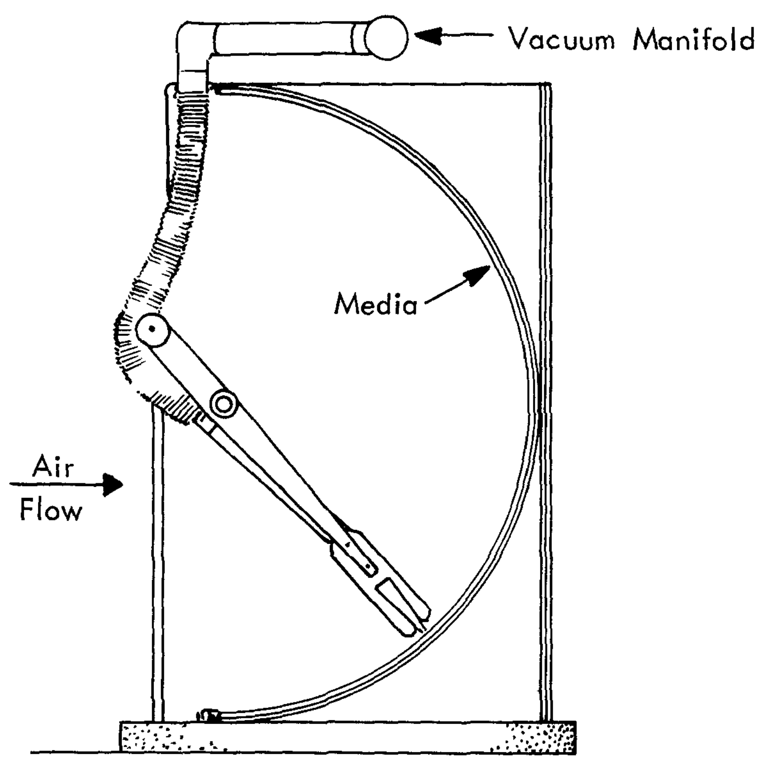


Figure 37. High velocity filter.

There are three basic types of screen systems, namely screen houses, rotary self-cleaning screens and sliding bar self-cleaning screens. These units vary in physical configuration which in turn affects the filtering velocity, and the method of removing the collected particulate matter. The mesh size and material also vary for the different types.

There are two types of screen houses, settling and concentrating. In the concentrating unit, an attempt is made to induce a flow pattern which will concentrate the beeswings and other particulate matter into a selected cleaning area where a vacuum head will remove the material. The vacuum system capacity is about 10% of the total dryer discharge. The beeswings concentrated in this system are collected in a higher efficiency cyclone or filtered back through the dryer. These units are hard to design and outside wind currents can disrupt the flow patterns.

Settling screen houses are cleaned manually. Thus, although they have low initial capital requirements, the operating labor costs may be relatively high. The wire mesh size is typically 24, 35, or 50 mesh. Pressure drops through the screen house are nominal.

Outlet loadings are hard to measure, at best, and vary due to the variable characteristics of the grain. Also, if the grain is cleaned before being dried, visible emission from the screen house will be reduced.

The rotary screen control systems can be either located at ground level or elevated. Emissions from the dryer are vented through circular screens between 5 and 14 ft in diameter. The screen is continuously vacuumed by a rotary unit whose capacity equals about 10% of the dryer discharge air. The beeswings collected in this 10% stream can be recovered in a high efficiency cyclone.

The wire screen is usually 34 to 100 mesh. Pressure drops are less than 1 in. of water during operation. Filtering velocities range up to 1,000 ft/min but about 650 ft/min is usually the recommended value since the higher filtering velocities can lead to blinding and higher pressure drops. In order to eliminate blinding, some installations have increased the distance between the rotary cleaning arm and the screen, but this has usually led to increased and unacceptable screen maintenance.

In the sliding bar self-cleaning screen, the dryer emissions are vented through screens mounted on long vertical panels. The unit is attached to the dryer exhaust. The screens are cleaned by a vacuum head which traverses the screen surface. The vacuum stream, which is about 10% of the total dryer discharge, is exhausted through a high efficiency cyclone or recycled back through the dryer.

The screen is usually made of 100 mesh dacron. As with the other screen units, high moisture content does not impair operation because the cleaning bar vacuum causes the dacron to "pucker" thereby effecting the higher degree of cleaning needed for the finer mesh screen.

The pressure drop across the unit is about 0.5 in. of water. Filtering velocities are between about 250 and 300 ft/min. Since these units are mounted on the dryer discharge, the high efficiency cyclone used for removing the collected beeswings and particulate matter is located between the dryer discharge and the filtering surface. Placement of cyclone between the dryer discharge and the filtering surface, helps to minimize problems with rotary lock freezing on the cyclones, which can occur during cold weather. The unit is guaranteed to remove 95% of all particles greater than 50 μm in diameter and normally operates without visible emissions.

Wet Scrubber - Wet scrubbers have been used to control sulfur dioxide emissions from corn wet steeping, odor control in feed manufacture, and control of particulates from high moisture content discharge streams. Their use has been limited to such special applications for the following reasons:

- Particulates are the only emissions of concern from most sources. If a level of control higher than that attainable by a cyclone is required, a fabric filter can usually be used;

- The material collected by a wet scrubber is rarely suited for reuse in the process; and

- Use of a wet scrubber requires treatment of the scrubbing liquor effluent to prevent water pollution and sanitation problems.

The wet scrubbers used on grain processing emission sources can be broadly categorized according to the following types:

- Spray chambers

- Venturi

- Packed tower (included fluidized and turbulent bed)

Spray chambers - Spray chambers are simply a cylinder with sprays located at the top of the unit. The gas flow can be either countercurrent or cocurrent with liquid flow. Pressure drops are in the range of 2 to 5 in. of water with the usual scrubbing liquor consumption of about 4 gal/1,000 ft^3. This type of device is rarely used solely for gaseous control because of its relatively low efficiency but occasionally is used for simultaneous gas and particulate removal.

Venturi scrubbers - There are two general types of venturi scrubbers. The first utilizes a high velocity gas stream in the throat of a venturi to disintegrate the liquid and expose it to contact with the gas stream. The other type, referred to as an ejector venturi, relies on a high velocity liquid stream to provide the required mixing power. Because of the limited contact time in these units, the unit is not efficient for gaseous pollutant removal. The unit is effective for particulate removal although relatively high power inputs are required. Pressure drops of 15 to 40 in. of water are not uncommon with this unit. Liquid requirements range from 5 to 7 gal/1,000 ft^3 of gas treated.[11/]

Venturi scrubbers are rarely used for control of grain handling emission sources because control devices with lower overall costs operate satisfactorily and do not have the attendant water pollution problems. However, for some grain processing sources where fine particulates are emitted in a high moisture content gas stream such as feed dryers in wet corn milling, this device may be suitable.

Packed bed scrubbers - Packed bed scrubbers are used to provide sufficient contact between the scrubbing liquor and effluent gas stream to effect gaseous pollutant removal. There are three basic types of packed towers, namely fixed, fluidized, and turbulent bed. The selection of a particular type of packed tower depends upon the characteristics of the emission stream. Because of the potential for plugging the scrubber, fixed bed scrubbers are normally used strictly for gaseous pollutant removal where there is only a very light particulate loading. The fluid bed scrubbers, which use high density spheres for packing material, have only found limited use.

Turbulent bed scrubbers, which use low density spheres, are not susceptible to plugging because of the intense motion of the packing media. The packing media move freely between the upper and lower retaining grids. Under the influence of countercurrent gas and liquid flow the spheres are forced upward in a random, turbulent motion, creating an area of intimate mixing between gas and liquid. This type of scrubber is especially useful when particulate matter is also present in the gas stream, since the turbulent motion of the spheres prevents plugging. Typical liquid-to-gas ratios are 2 to 4 gal. of water per 1,000 ft^3 with pressure drops in the range of 6 to 8 in. of water. This unit operates with particulate collection efficiencies of about 99% for particles with a mass mean diameter larger than 2 μm.

Afterburners - Afterburners can be used for control of combustible particulates and odors. Although they have been identified as suitable for use on such sources as feed dryers in wet corn milling and in animal feed manufacture, there is only one known installation in use. The known afterburner installation is on a suspension dryer at the St. Lawrence Starch Company at Port Credit, Ontario.

There are two basic types of afterburners, thermal and catalytic. The thermal afterburners use direct flame incineration and operate at higher temperatures than do the catalytic units. Thus, they require more fuel.

Minimum required temperatures and residence times are usually specified for thermal afterburners to effectively oxidize the pollutants. They are usually in the range of 1200-1800°F and 0.3-0.6 sec depending upon the characteristics of the emissions.

The main advantages of the thermal afterburner are the high degree of removal efficiency for submicron sized combustible particulates, the ability to control both gaseous and combustible particulate pollutants and the low maintenance requirements. The primary disadvantage is, of course, the high fuel requirements which mean high operating costs. Heat recovery is usually necessary to have acceptable operating costs. Furthermore, afterburners will only remove combustible particulate, not mineral particulate. Thus, it may be necessary to use the afterburner in conjunction with some type of high energy mechanical collector or other particulate control device.

There are processes where direct flame incineration can be accomplished by using the effluent from a process as combustion air. An example of such an application is using the exhaust from a feed dryer as part of the combustion air. Careful consideration must be given in the design of such systems to avoid possible explosions or complications with the combustion process.

CURRENTLY USED CONTROL SYSTEMS

The section on p. 275 Dust Control Systems, described the general types of control equipment either in use or suitable for use on grain handling and processing sources. In this section, additional information on those systems, or process modifications to reduce emissions, which was not relevant to the previous general discussion, is presented.

Table 156 lists the types of devices which are applicable to the various emission sources, their approximate collection efficiencies, and outlet grain loading. Only those devices which are either currently used or appear suitable for use are listed. Devices which may be capable of attaining equivalent collection efficiencies but which have definite limitations (e.g., water pollution potential) with respect to other devices capable of satisfactorily controlling emissions for that source are not discussed. The collection efficiency and outlet grain loading data are primarily based upon the source test results described in Chapter 3. However, for many sources it was not possible to quantitatively describe collection efficiency due to the general lack of test data. In such cases, collection efficiencies have been estimated based upon the performance of these control systems on similar emission sources. Some of the more important dust sources and control methods used on the sources in various segments of the grain and feed industry are discussed in the following sections.

Grain Handling Operations

Many grain handling operations can be modified to contain the dust which is normally emitted. Examples of these modifications are listed in Table 157.

Cyclones and fabric filters are used almost exclusively to control emissions from grain handling operations. The use of cyclones has been declining because of tightening environmental regulations, especially with regard to visible emission regulations since properly designed cyclones can usually meet existing process weight type regulations.

Because of product value, cyclones on pneumatic conveying operations generally operate with efficiencies in excess of 99%. These units can operate with essentially zero visible emission except when handling very dusty materials. In some cases, product recovery cyclones are followed by fabric filters for emission control purposes.

Table 156. AIR POLLUTION CONTROL DEVICES USED IN THE GRAIN PROCESSING INDUSTRY

	Operation	Control Device	Applicable Control Devices: Collection Efficiency Range	Applicable Control Devices: Typical Outlet Loading Range (gr/scf)
1.0	ELEVATORS			
1.1	Grain receiving	Cyclone	85-95	0.02-0.09
		High energy, recirculating cyclone	97-99	--
		High velocity filter	95-99	0.005
		Fabric filter	99 +	0.002-0.006
1.2	Grain drying	Screen house		
		Rotary screen - self cleaning		
		Vertical screen - self cleaning		
1.3	Transfer operations	Same as grain receiving		
1.4	Shipping	Same as grain receiving		
2.0	FEED MILLS			
2.1	Receiving	See grain receiving operations for elevators.		
2.2	Grinding system	Product recovery cyclone (Pneumatic conveying from grinder)	99	0.01-0.02[a]
		Fabric filter	99 +	0.002-0.01[a]
2.3	Pellet cooler	Cyclone		
		low energy	88-96[a]	0.02-0.7[a]
		medium to high energy	98-99[a]	0.06-0.1[a]
2.4	Shipping	See shipping operations for elevators		
3.0	ALFALFA DEHYDRATING			
3.1	Dryer	Cyclone	85-98	0.10-0.30[a]
		Wet scrubber	21-92[a]	0.02-0.09[a]
3.2	Hammermill	Cyclone	85-98	0.60-1.6[a]
		Fabric filter	99 +	
3.3	Pellet mill	Cyclone	85-98	
		Fabric filter	99+	
3.4	Pellet cooler	Cyclone	85-98	0.09-0.24[a]
		Fabric filter	99+	
4.0	MILLING			
4.1	Receiving	See grain receiving operation for elevators		
4.2	Cleaning house	Cyclones	88-99[a]	0.03-0.1[a]
		Fabric filter	99 + [a]	0.005-0.02[a]
4.3	Mill house	Cyclone	96-99[a]	0.04-0.2
		Fabric filter	99 + [a]	0.005-0.01[a]
4.4	By-Products Hammermill	Cyclone	95-99[a]	0.1-2.0

Table 156. (Continued)

		Applicable Control Devices	
Operation	Control Device	Collection Efficiency Range	Typical Outlet Loading Range (gr/scf)
4.5 Shipping by-products	Cyclone	99+	
	Fabric filter	99+	
Flour	Fabric filter	99+	
5.0 <u>SOYBEAN PROCESSING</u>			
5.1 Receiving	See grain receiving operations for elevators		
5.2 Drying	Screen house	--	0.02-0.05[a]
	Vertical self-cleaning screen	--	0.008[a]
5.3 Processing			
. Cracking mills	Fabric filter	99+	
	Cyclone	95-99[a]	
. Dehulling, conditioning, flaking, cooling, and toasting	Cyclone	88.7-99	
	Wet scrubber		
. Meal drying		99+	
. Meal grinding	Fabric filter	99+	
	Cyclone	98-99[a]	
5.4 Shipping	See shipping operations for elevators		
6.0 <u>WET CORN MILLING</u>			
6.1 Receiving	See grain receiving operations for elevators		
6.2 Drying	See drying operations for elevators		
6.3 Steeping	Packed bed scrubbers	90-99+ for SO_2 control	
6.4 Germ and gluten Drying and cooling and feed and pellet cooling	Medium energy cyclones	80-95	0.145[a]
	High energy cyclones	95-98	
6.5 Feed drying	High energy cyclone	95-98	
	High energy scrubber	98-99	
	Afterburner	99+	
6.6 Feed house aspiration; transfer of germ, gluten, feed, and starch; and starch drying	Low to high energy cyclone	85-98	
	Fabric filter	99+	
	Wet scrubber (starch drying only)	95-99	
6.7 Carbon regeneration furnace	Afterburner	99+	0.145[a]
6.8 Corn syrup solids drying	Low to high energy cyclone	85-98	
	Wet scrubber	99+	
6.9 Product loading	See grain loading operations for elevators		

Table 156. (Concluded)

Operation	Control Device	Applicable Control Devices: Collection Efficiency Range	Typical Outlet Loading Range (gr/scf)
7.0 RICE MILLING			
7.1 Receiving	See grain receiving operations for elevators		
7.2 Drying	See drying operations for elevators		
7.3 Shellers, paddy separators, hullers brushes, and hull grinders	Cyclone	85-98	
	Fabric filter	99+	
7.4 Loading	See grain loading operations for elevators		

a/ From actual stack test data, EPA Method 5.

Table 157. PROCESS MODIFICATIONS USED TO REDUCE DUST EMISSIONS FROM GRAIN HANDLING OPERATIONS

1. Close at least one door in unloading areas (three sides closed). An air suction across or through the grating is necessary.

2. For loading hopper cars or bulk trucks and ships, a secondary pipe may be installed next to the feed discharge pipe to pick up the airborne dust. Minimize the area of opening by use of tarps or other covers.

3. Telescoping loading spouts to reduce free fall distance of grain.

4. Use closed mechanical conveyors and processing systems.

5. Intervent the scale hopper, mixer and surge hopper.

6. Intervent the up and down leg of the bucket elevator.

7. Pressurize the processing building to contain dust inside the conveying and processing equipment (usually economical only if included in initial design).

8. Seal the materials handling system as tightly as possible; apply a slight vacuum to entire system with suction air routed to a collector.

9. Intervent two or more storage bins. (Insurance companies may not permit interventing all storage bins).

10. Utilize choke unloading of hopper cars.

11. Install louvers under grating of unloading operations which open when grain falls on the louver. This reduces the volume of air which must be aspirated through the grating.

12. Utilize drag conveyors in place of belt conveyors where feasible.

Cyclones which are used purely for air pollution control are usually designed for much lower efficiencies. The general lack of maintenance given many of these units further degrades their performance. Typical efficiencies for such units are between 85% and 95%. Visible emissions can range up to 30% or 40% equivalent opacity, again depending upon the nature and type of material being transferred or handled.

High energy recycling cyclones have also been used to a limited extent to control emissions from truck dumps. Although the weight percent collection efficiency is high, visible emissions occur when grain with large amounts of field dust are received.

Fabric filters are the most efficient devices for controlling emissions from these sources, operating with collection efficiencies in excess of 99% and with no visible emissions. Air to cloth ratios on filters for most grain handling emission sources are usually between 10 and 15 cfm/ft^2 of cloth, with the higher ratios used in dry climates and on intermittent operations where there is less chance of fabric blinding. Newer systems with more effective fabric cleaning are purported to be operating with air to cloth ratios of 20 to 30.[16/]

Spokesmen for the grain and feed industry have indicated that operational problems occur with fabric filter systems on grain receiving pits when wet grain is unloaded. Corn with a high moisture content poses a distinct problem. Blinding of the fabric filter by the wet dust has created numerous cases of equipment malfunctions.

Specific dust control systems for various grain handling operations are discussed in more detail in the following sections.

Grain Receiving and Shipping - The grain receiving and shipping areas represent a difficult dust control problem. The two principal factors that contribute to dust generation during bulk unloading and loading are wind currents and dust generated when a falling stream of grain strikes the receiving pit. Capture or containment of the dust is the most difficult problem encountered in receiving and shipping operations.

Truck unloading - Effective control of the dust emitted during truck unloading operations generally requires the use of undergrate aspiration and a suitable enclosure or shed over the receiving pit. The undergrate aspiration prevents the upflow of air out of the grate and the enclosure minimizes the influence of wind currents. The aspirated air is directed to a control device--generally a cyclone or fabric filter.

The undergrate aspiration system is often designed on the basis of a minimum of 100 ft/min face velocity/ft^2 through the grate.* Therefore, a

* Some consultants recommend that a minimum of 200 ft/min be used.

grate having dimensions of 10 ft x 10 ft would contain 100 ft^2, requiring an airflow of 10,000 cfm. Considering the wind velocity that often exists in the drive-through tunnel or a shed with no rear door, the face velocity of 100 ft/min may not provide sufficient capture of the emissions. However, the capture can be improved without increasing the airflow rate. Improved capture is accomplished by installing louvres underneath the grate. These louvres restrict the flow of air but swing open under the weight of the grain and allow it to pass through into the receiving hopper. This configuration results in maximum airflow at higher velocities near the grain stream which, in turn, provides improved capture of the dust.

A different type of truck unloading dust control system was reported in Reference 12. The system was installed on a 600-bu truck dump pit, and utilized a swing-away hood at one end of the pit behind the truck. The hood covered the last 2 ft across the width of the grating and exhausted 16,500 cfm to a fabric filter. A capture efficiency of 95% to 97% was reported.

Boxcar unloading - 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 movable section of track and rotates and tilts the car to dump the grain out of the car door into a receiving pit. This is a rapid unloading method that creates a large surge of dust in a manner which makes it difficult to efficiently capture the emissions.

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. Aspiration from the belt loading below the hopper would be 800 to 1,000 cfm and at the belt discharge it would be about 1,000 to 2,000 cfm.

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 38. This can be reasonably effective even when the unloading area is not enclosed.

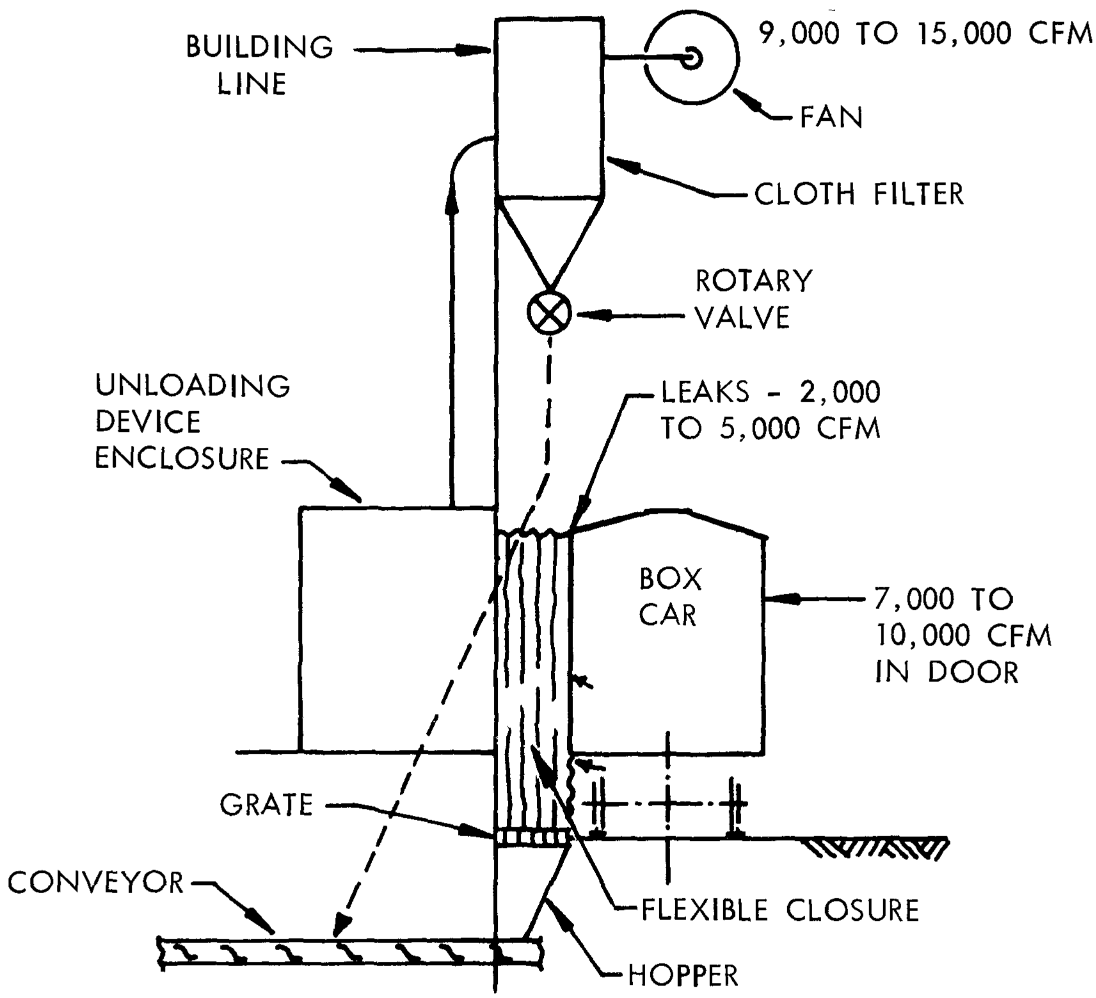


Figure 38. Boxcar unloading dust control system.

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.

Hopper car unloading - Control of dust emissions during unloading of hopper cars has been accomplished by using two methods. The first of these uses undergrate aspiration similar to that for truck unloading, except that the grate area is usually smaller and therefore requires correspondingly smaller airflow. The second control method is based on the use of a small receiving hopper to effect choke unloading. With this method, there is a momentary surge of dust as the receiving hopper fills, but very little dust is generated during the remainder of the unloading operation. This unloading method does eliminate the need for air aspiration and a collector, but there would be some expense involved in modifying an existing unloading facility.

Truck loading - Most truck loading operations involve the free-fall of grain into the truck with considerable emission of dust. The quantity of dust is less when using choke loading, by means of a telescoping spout or when a slide valve or other flow control mechanism is used to restrict the flow of grain to reduce the velocity at which it leaves the spout.

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.

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.

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.

It would be possible, of course, to use doors at both ends of the unloading 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.

Boxcar loading - 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 39.

Hopper car loading - 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 40. 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.

Barge and ship loading - Barge or ship loading presents a difficult dust control problem. The grain usually falls a considerable distance into the holds which results in a cloud of dust. Containment of the dust without interference with the loading process presents a challenge. The ship loader consists of a belt conveyor discharging to a vertical duct that extends into the ship's hold. The loading duct may vary from one installation to another. Some installations have a telescoping loader that can displace laterally only, others provide full traverse; some raise the entry loading gantry; some use an inclined loading boom that is emplaced after the ship is moored. The telescoping feature allows for variation in tide, height of the ship, and depth of material in the hold.[13/]

Most installations employ a slinger (trimmer) at the lower end of the loading spout to insure proper distribution of the load and maximum utilization of the cargo space. A trimmer is essentially a short (4 ft to 6 ft) belt conveyor running at high speed (3,000 to 6,000 ft/min) whose function is to "throw" the bulk material being loaded to those areas of the hold distant from the loading spout (up to 60 ft).[13/]

The fall of bulk material through a vertical loading spout acts as a kind of linear fan inducing a flow of air into the hold. The volume of this induced air may be substantially greater than the air volume displaced by

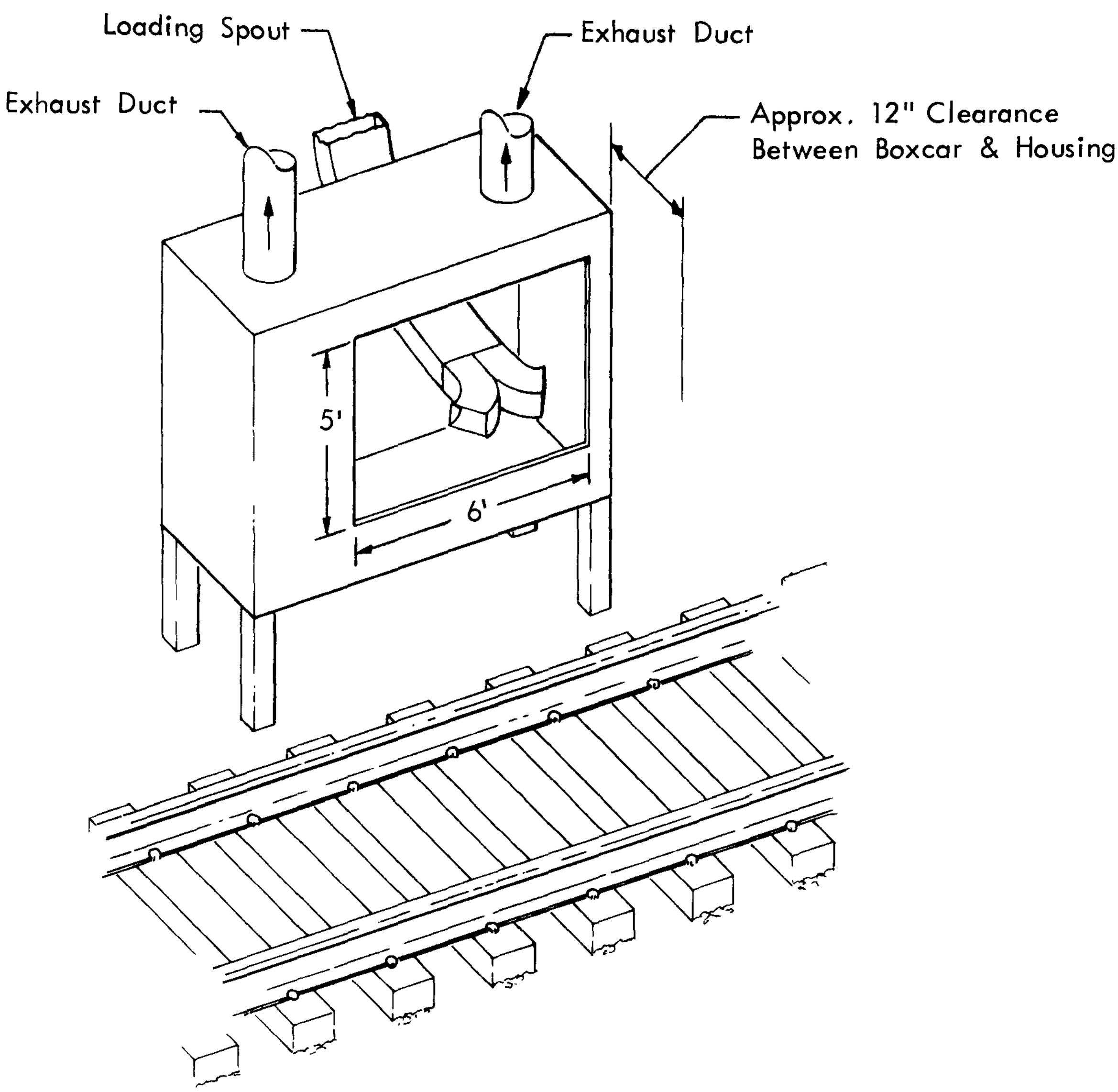


Figure 39. Dust control system for boxcar loading.

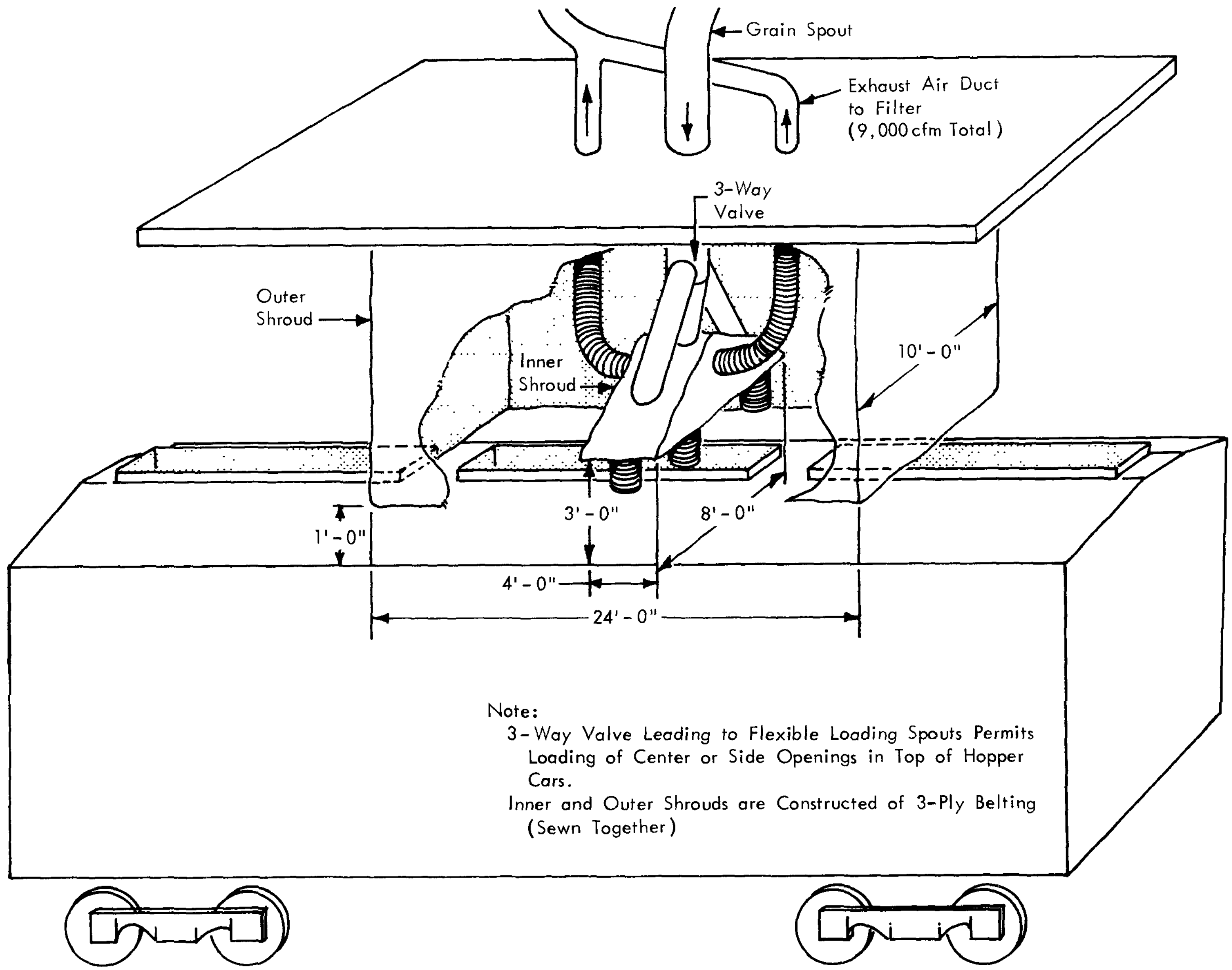


Figure 40. Hopper car loading dust control system.

the bulk material delivered into the hold. The high velocity "throw" of the slinger at the bottom of the loading spout produces a "rooster tail" of particles that are readily entrained in the induced and displaced air. Voluminous clouds of dust escape from the ship's hold as the loading operation proceeds. Additionally, the vertically falling material hitting the high speed horizontal belt of the slinger causes a bounce-back of particles up the loading spout. This results in a boil-out of dust at the joints of the telescoping loading spout. Some of this dust falls back into the hold while the remaining portion adds to the dust cloud from the hold.

As in any problem of air pollution control, capture or containment of the emission to be controlled is the first prerequisite to its removal. It is this capture that is the most difficult problem encountered in bulk loading of ships. Unlike a normal industrial operation, a bulk loading installation must serve ships of widely varying length, beam and hatch opening dimensions. The ship's rigging and loading booms interfere with the free space above the holds. The level of the deck rises and falls as the height of the tide varies and as the loading changes the ship's trim.

The problem of ship loading dust control is compounded by the necessity of developing techniques and methods for three basic and different ship configurations: bulk carriers, tankers and 'tween deckers.[14/]

The bulk carrier is an empty hull compartmented by a series of vertical bulkheads. Each hold seldom has any internal structures, i.e., wing decks, or center bulkheads and thus no encumbrances are normally found which can slow the loading operation (Figure 41). Hatch openings are generally large; access to all parts of the hold is relatively easy.

The tankers used in grain transport are designed for movement of liquid bulk. As such, the openings into any particular compartment or tank are relatively small. Two types of hatches are common to tankers, the larger "hard hat," about 3 ft in diameter, for major filling, and the smaller Butterworth (normally 11 to 12 in. in diameter) used for filling the voids (Figure 42). Occasionally "bulk carriers" have side or wing tanks with Butterworths that are loaded in a similar manner.

'Tween deckers generally tend to be smaller and older than either tankers or bulk carriers. Basically, the hold is similar to a bulk carrier with the addition of usually two horizontal cargo decks. These have a large opening in the center which may or may not be divided by crossbeams, (Figure 43). In loading these ships, care must be taken to adequately stow the grain under the intermediate decks. If all spaces are not properly filled, i.e., trimmed, a shift in cargo could cause the ship to list or capsize. Some of the newer type 'tween deckers have grates located in the bulkheads that allow the grain to flow through and fill the void.

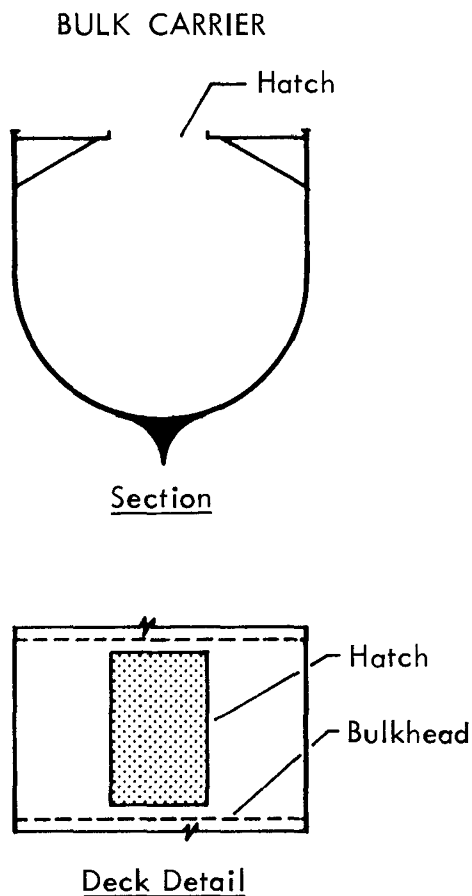


Figure 41. Diagrammatic representation of a bulk carrier hold.

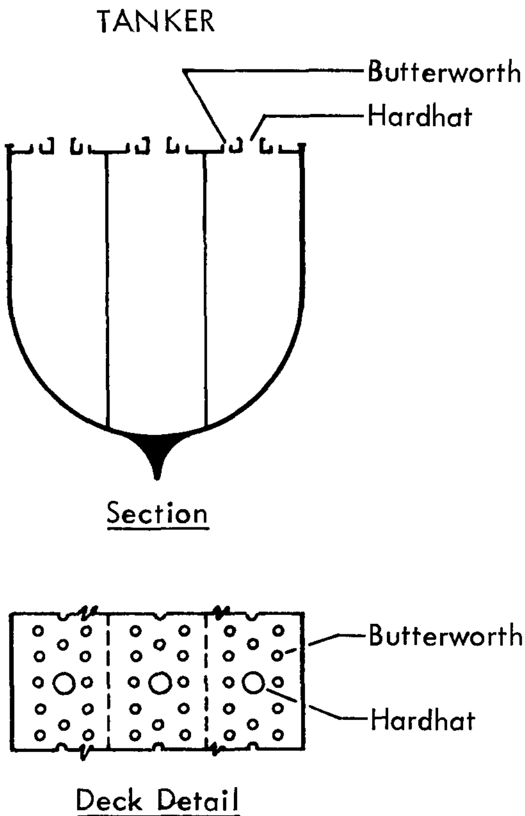


Figure 42. Diagrammatic representation of a tanker.

'TWEEN DECKER

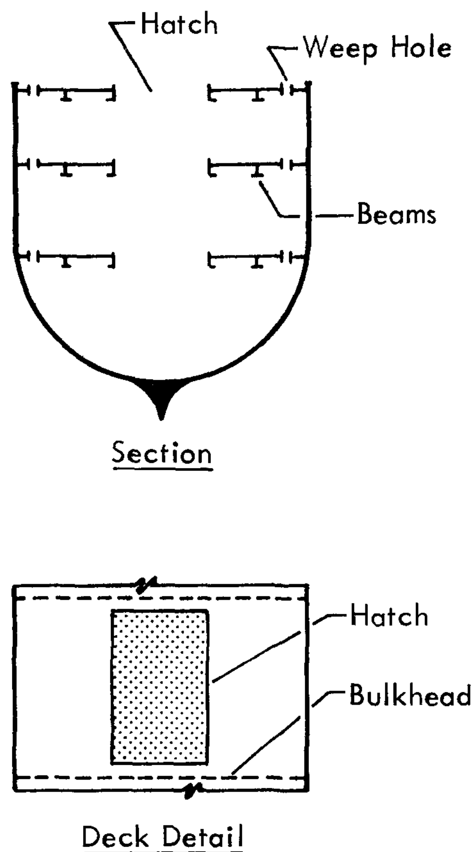


Figure 43. Diagrammatic representation of a 'tween decker.

Trimming is not required in these cases. The older type 'tween deckers require a feeder box that extends up from the lower hold and ensures that grain can continue to fill the lower hold when the grain settles. This feeder box makes it very difficult to load the upper portions of the hold since only a 3 to 4 ft opening exists around the outer edge.[14]

Any air pollution control system employed for ship loading must be capable of capturing airstreams issuing from hatch openings varying from 10 ft x 20 ft to 50 ft x 90 ft; it must fit readily in the cluttered deck space; it must allow for periodic observation of the progress of loading so that adjustments in load placement can be made; it must not be excessively difficult or time-consuming to put in place; it must withstand the humid and corrosive harbor atmosphere; and it must operate on abrasive and hygroscopic dusts.[13]

Currently, several techniques are employed for the control of ship loading. Nearly all employ fabric filters as the control device but vary their enclosure of the hatch being loaded or the way the loading spout is positioned. Reference 13 presents a discussion of several techniques developed to control dust emissions from ship loading operations at the Ports of Los Angeles and Long Beach in Los Angeles County. Table 158 summarizes the pertinent features of these techniques.

Cargill, Inc., and the Port of Seattle have been engaged for about 2 years in an effort to develop a dust control system for the new grain terminal on Elliott Bay in Seattle.[14] Their efforts have resulted in the development of a quite successful procedure for controlling dust emissions during ship loading. Since control of these emissions does present a significant problem to export elevators, the key features of the system are highlighted in the following paragraphs.

Initially, a dust collection system rated at 20,000 cfm was installed to remove the dust from the hold. In this design, air was to be drawn up through the void in the loading spout; this would eliminate the need for an auxiliary hose on deck. However, unforeseen problems hampered the dust removal; as the grain flowed across the knuckle that allows vertical spout movement; it would bounce from top to bottom of the spout and hinder the reverse air supply. Bypassing the knuckle with a supplemental duct was tried, however, such an arrangement failed to correct the problem. Subsequently, a separate duct was attached to the top of the spout and ducted back into it at the lower end, thus restoring the desired reverse airflow (Figure 44). However, this arrangement was found to be inadequate to meet the equivalent opacity standard requiring dust emissions not to exceed 40% opacity, or Ringlemann II.

Table 158. DUST CONTROL SYSTEMS FOR SHIP LOADING[13]

Location	Material Handled	Enclosure Configuration	Control System	Comment
Pier D, Long Beach	Calcined coke, potash, and superphosphate fertilizer at rates of 300-450 ton/hr	Tarpaulin suspended from top of loading spout and emplaced over hatch opening enshrouding the loading spout and exhaust duct.	Type D Rotoclone followed by reverse-jet fabric filter. Exhaust ducting is suspended alongside the loading spout into the ship's hold. System provides flow of approximately 9,000 cfm at 10 in. pressure drop. Electrically heated air is used to clean the orlon bags.	The problems encountered have concerned the pickup at the ship hatch. If the hatch is not completely enclosed, the capture of dust at the ship loading is poor. The enclosure is subject to wind loads, i.e., sail effect.
Berth 166, Los Angeles Harbor	Hydrates of borax at rates up to 900 tons/hr.	Cargo parachute is used to cover hatch being loaded and it is discarded after each loading.	Fabric filter located on loading tower. Exhaust ducting leads from the baghouse, along the side of the loading boom to the loading spout and then drops into the hatch alongside the loading spout. The connection between the loading boom and tower is flexible ducting, as is the vertical section into the ship's hold. The system exhausts approximately 10,000 cfm from the ship's hold at a system pressure drop of 10 in. water with a 40 HP exhaust fan. This provides an exhaust rate of 11 cfm/ton/hr loading rate. The baghouse is cleaned by a reverse jet airflow that is not heated. The bags are wool felt.	The collection system is quite effective under normal conditions. However, due to the large span covered by the tent, the enclosure is subject to wind loads that cause a bellows-type action with the result that the loading of a ship in winds of 20 knots or greater causes excessive dust emissions. Since only one type and size of ship is loaded at this facility, many of the techniques developed here are not directly applicable to other facilities. Much of the success in controlling air pollution is due to the relatively simple geometry problems presented to the ship loader.
Pier A, Long Beach	Large grain elevator that loads wheat, milo, alfalfa pellets and safflower seed at rates of 600 to 1,000 tons/hr.	Nonreinforced plastic sheeting. (4 ml thickness) is secured over hatch by cutting, trimming, fitting and taping it down flat over the hatch openings.	The baghouse of the control system is located on the dock below at the farthest end of the loading gallery. A main exhaust duct manifold parallels the dock and flexible ducting is connected to the takeoff point nearest the hold being loaded.	The emplacement of flat sheets of plastic horizontally over the hatch opening is effective only under calm wind conditions. During even low wind speeds the plastic sheeting separates into its component...

Table 158 (Concluded)

Location	Material Handled	Enclosure Configuration	Control System	Comment
Pier A, Long Beach (Concluded)			The flexible exhaust duct extends over the side of the ship, under the hatch covering and into the hold. Control system exhausts 20,000 cfm at 8 in. pressure drop and provides better than 20 cfm exhaust air/ton/hr loading rate.	...parts with a resultant increase in open area that severely reduces indraft air velocity. The reduced indraft velocity cannot cope with the excessively exposed hatch condition; i.e., dust is emitted in one portion of the hatch while the vent system operates in the other portion.
Pier G, Long Beach	Iron ore, iron ore pellets, raw petroleum coke, calcined petroleum coke and other dry bulk materials at rates up to 2,000 tons/hr.	Sheet metal housing encloses the upper 6 ft of telescopic loading spout. A tubular nylon sleeve is suspended from the housing and encloses the remainder of the loading spout down to hatch level. Hatch covering is attached to the nylon sleeve by an overlapping closure with a metal band and sealed with adhesive tape. Hatch covering is flat glass-fiber reinforced polyethylene sheeting tied down to the sides of the hatch.	The two control system baghouses are mounted on the gantry and exhaust the hold being loaded through a flexible duct suspended from a knee action main duct. The exhaust system removes 28,000 cfm at a system pressure differential of 10 in. with a 75 HP exhauster. This provides an air exhaust rate of over 23 cfm/ton/hr loading capacity. The baghouses are cleaned by reverse airflow heated by two 30 KW heaters. In addition, the baghouse enclosures are heated by two 2 KW heaters to prevent condensation of moisture during nonoperational periods.	This control system is so effective that the hatch enclosure collapses due to the negative pressure produced in the hold and yet the baghouse collection is minimal. Its low silhouette has been unaffected by wind speeds up to 20 knots. Efficient use of the trimmer during loading permits loading of a hold without displacement of the loading spout and its enclosure. This facility limits its operations to those ships specifically designed for bulk loading. A good measure of its success garners from this limitation.

EXHAUST SYSTEM

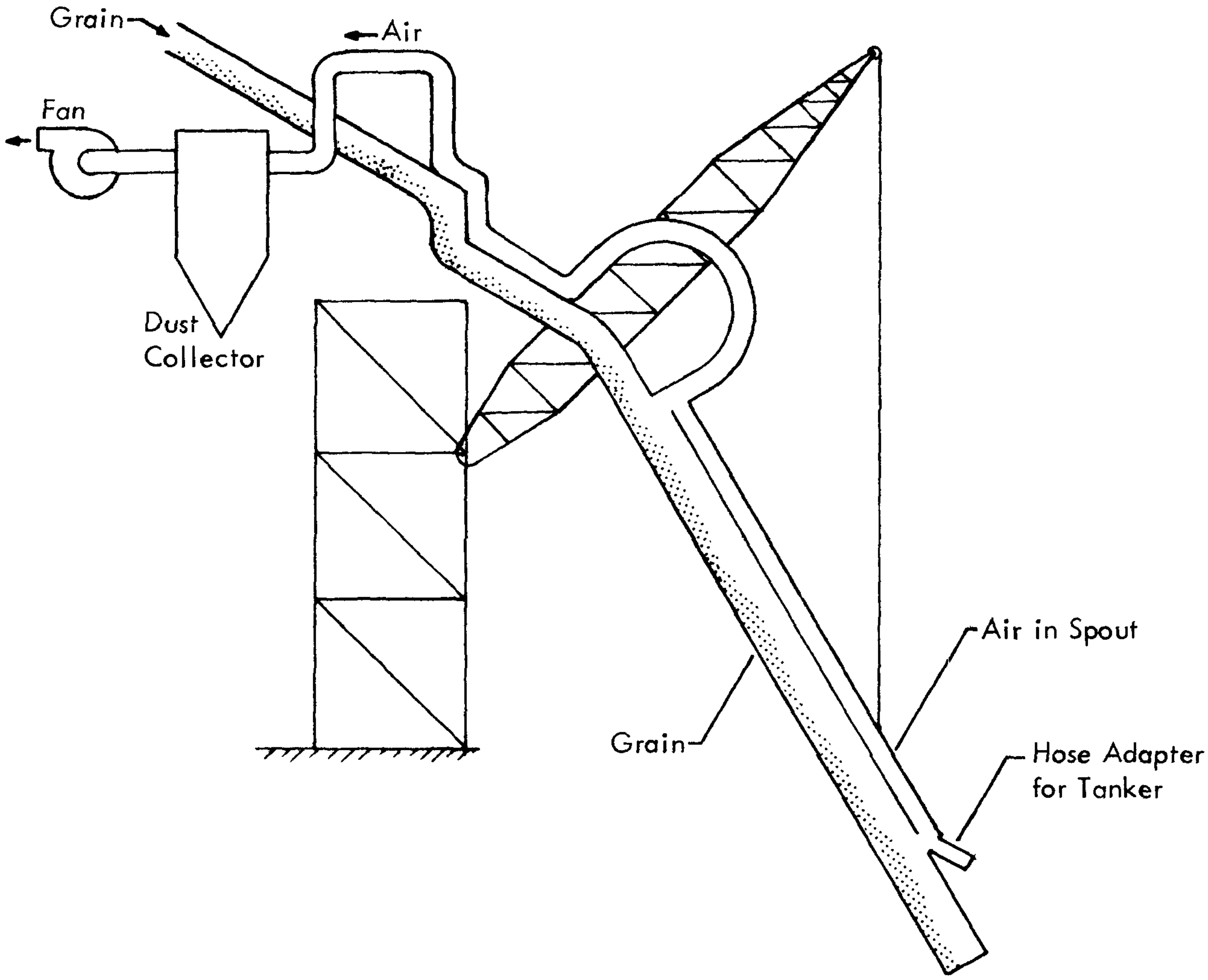


Figure 44. Diagrammatic representation of the existing air exhaust system at Pier 86, Seattle, Washington.

A major breakthrough in dust control occurred when attempts were made to determine whether dust would be reduced when the spout was held very close to the grain pile. It was found that the loading spout could be placed 4 to 6 in. into the grain pile without backup of grain in the loading spout. By maintaining the spout in the grain 4 to 6 in., the grain had sufficient energy to push out of the spout without dust generation. Following the addition of the auxiliary duct on top of the grain loading spout (which by-passes the restricting grain) and by drawing air up the void, the spout could be held as far as 5 in. out of the grain and as much as 6 in. into the grain without excessive dust emissions.

Using this and other new techniques, a system of loading has been developed that can accommodate 95% of all grain loaded at the pier. Recommended methods for various types of ships are summarized in the following paragraphs. All the techniques listed below have been tested and with the exception of trimming, have been shown to provide adequate dust control.

Bulk carriers and 'tween deckers - To develop techniques for these ships, the loading operation was broken down into four main activities: (1) start-up; (2) general filling; (3) trimming, and (4) topping.

Start-up - 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 procedure will build a pile sufficient to bury the spout in less than 2 min. In some cases, as many as two, 10-ft extensions are needed to reach the bottom of the ship. If the spout cannot be placed sufficiently close to the bottom, an alternate method should be used. One method 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 x 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 types of ships.

General filling - 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 a 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 then can be continued.

Trimming - The trimming operation is unique to 'tween deckers and is required when grain cannot fill the voids under the lower decks by general filling. During this period, the grain must be "thrown" under this deck, a distance that may reach 32 ft. Either a trimming machine ("slinger") or a simple deflector must be used for this operation. If a simple deflector is used, the hatch can be covered and most of the dust eliminated. To date, control of 50% of the dust emissions generated by the trimming machine has been accomplished by adding a flexible hose to the air duct, inserting this in the funnel of the trimming machine and covering the unit to channel this airflow.

Topping - The filling of the top 4 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 is available to reduce the dust. The topping operation is not hampered by this practice; it is much faster and cleaner than other methods which held the spout above the grain.

Tankers or bulk carrier wing tanks - Filling of tanks is broken down into two operations: general filling through the "hard hat" and final filling of the void in the tank through the Butterworths.

Hard hat filling - In most cases, the "hard hat" can be filled by inserting the main spout directly in the hold 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.

Butterworth filling - To fill Butterworths, the spout must be reduced and attached to an airtight 12-in. flexible steel tube; the end is inserted into the "Butterworth" and filled at a rate not exceeding 600 ton/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.

Grain Transfer Points - 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.

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 duct 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.

One of the latest developments 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 posibility 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.

Grain Dryers

Screen systems used to control emissions from grain dryers were described on pages 287 to 289. Emission test results on a limited number of installations are reported on pages 131 to 142.

Feed Mills

Reference 15 presents an extensive discussion of dust control systems for feed mills. Only the dust control systems for grinding and pelletizing operations will be briefly discussed.

Grinding Operations - Cyclones used on pneumatic conveying operations associated with grinding operations can be significant sources of emission. Many feed mills are reluctant to use fabric filters on pneumatic conveyor systems because of the possibility of cross-contamination of ingredients. However, fabric filters can be used to control the exhaust stream from the product recovery cyclone on the conveying system if the cyclone is not operating with high enough efficiency. Use of full circle hammermills, which may or may not require airflow for proper grinding depending upon the desired product, can reduce the emission potential.

Locating the grinders above the storage bin so gravity feed rather than pneumatic conveying can be used is advocated by some; however, it can pose a serious fire hazard since fire could spread to the bins and not be confined to the grinder as it is in conventional systems.

To reduce emissions when grinding potentially dusty materials (e.g., dehydrated alfalfa), some plants are spraying small amounts of water into the grinding system.

Pelletizing Operations - Because of the high moisture content of the effluent stream, only cyclones have operated reliably to control emissions from pellet coolers. Efficiencies typically range between 90 and 97%. The units can normally operate with little or no visible emissions unless a powder such as cottonseed meal is being used to prevent caking of pellets. In such cases, dust emissions can be profuse, up to 50% equivalent opacity. A fabric filter installation has been tried but the unit has not operated satisfactorily because the high moisture content of the effluent stream produces fabric blinding.

Wet Corn Milling

Steeping - Sulfur dioxide emissions from steeping operations are generally not controlled. The use of packed scrubbers has been proposed and should work satisfactorily if the pH of the scrubbing liquor is controlled.

Drying Operation - Dryers are almost universally controlled by cyclones which in some instances are the high pressure drop recirculating type cyclone. For germ and meal drying, these devices can operate with high efficiency and minimal visible emissions.

Controlling emissions from feed dryers can pose a substantial problem since the emissions consist of solid particulates and condensable gases. Extremely high drying temperatures, coupled with variations in the characteristics of the materials to be dried, can sometimes create an aerosol type emission which may be visible as a blue haze. Lower drying temperatures will often minimize this condition. However, lower drying temperatures require more air, more equipment and more fuel resulting in more dilution.

The volatile organics emitted from the drier are in the gas phase and condense when emitted to the atmosphere. Various types of scrubbers have been tried on pilot scale with only limited success. Afterburners could be used to control both the condensable particulate and odors, but the large gas volumes would make their use very costly.

Soybean Processing

Processing Operations - The operations in the processing section of a soybean plant are cracking mills, dehulling, conditioning, flaking, drying, cooling, grinding and toasting. Of these, the product recovery systems for the meal drying, cooling, and grinding, and the hull grinding operations are the major sources of emissions.

Cracking mills are not a major emission source. Medium to high energy cyclones operate with 95 to 99% control efficiency. Fabric filters operating at 99+% collection efficiency are often used, usually preceded by a low to medium energy cyclone.

Dehulling, conditioning, flaking, and toasting operations are other emission sources. Control efficiencies of high energy cyclones of 87 to 99% have been determined from stack tests on these operations. Fabric filters are also used on sources where the moisture content of the exhaust stream permits their use.

Product recovery systems for meal dryers (usually medium to high energy cyclones) are most often controlled by high energy cyclones or wet scrubbers. Control systems must be insulated because of the high moisture content of the effluent gas stream, i.e., to prevent condensation.

Meal grinding and hull grinding operations produce very fine (1 μm) particulate emissions which are often controlled by high energy inertial devices or by use of a fabric filter. Product value precludes the use of a wet scrubber system on these operations.

Grain Milling

With the exception of intermediate product drying in dry corn milling plants, control of dust emission from milling operations can best be accomplished with fabric filter systems. Cyclones are used on the dryers in dry corn mills as the moisture content of the exhaust stream precludes the use of fabric filters. In the milling section of a grain milling plant, the product recovery systems associated with the various pieces of milling equipment are the potential sources of emission. If fabric filters are used for the product recovery, secondary dust control systems would not be required.

CONTROL SYSTEM COSTS

Control Device Costs

Figures 45 through 51 present capital cost as a function of capacity for various types of control devices used on the grain processing emission sources.* These figures represent the cost of the control and those appurtenances usually considered a part of the control device (e.g., rotary valves, bags) but not such items as ductwork, fans, starters, motors whose costs vary considerably from one installation to another; nor do they include the installation costs.[17/]

The total installed cost for a given installation is highly variable, depending upon such factors as:

- Type of installation, new or existing plant;
- Type of labor used, plant or contract labor;
- Type of process controlled; amount of ductwork required; and geographical location.

Existing plants may have much of the hooding systems and ductwork already installed and require only the installation of a new control device and fan. Thus the total installed cost for upgrading the controls on such a facility might be less than for a new plant. On the other hand, such factors as space limitations, the necessity of working around existing process equipment, and providing additional structural support for the collectors, increase the total installed cost. In general, the costs to a new plant, where the control system is an integral part of the plant design, are less expensive than the control cost for older plants. Table 159 lists the approximate cost range for controlling specific types of emission sources. These figures represent only the normal cost range, which would be applicable to perhaps 90% of the various source types. Control by cyclones is less expensive than control by fabric filters, and the lower cost figures in Table 159 are for cyclone systems. Because of the large variability in costs, the cost to control an individual facility must be determined by careful evaluation of the particular requirements of that facility.

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* October 1972 dollars.

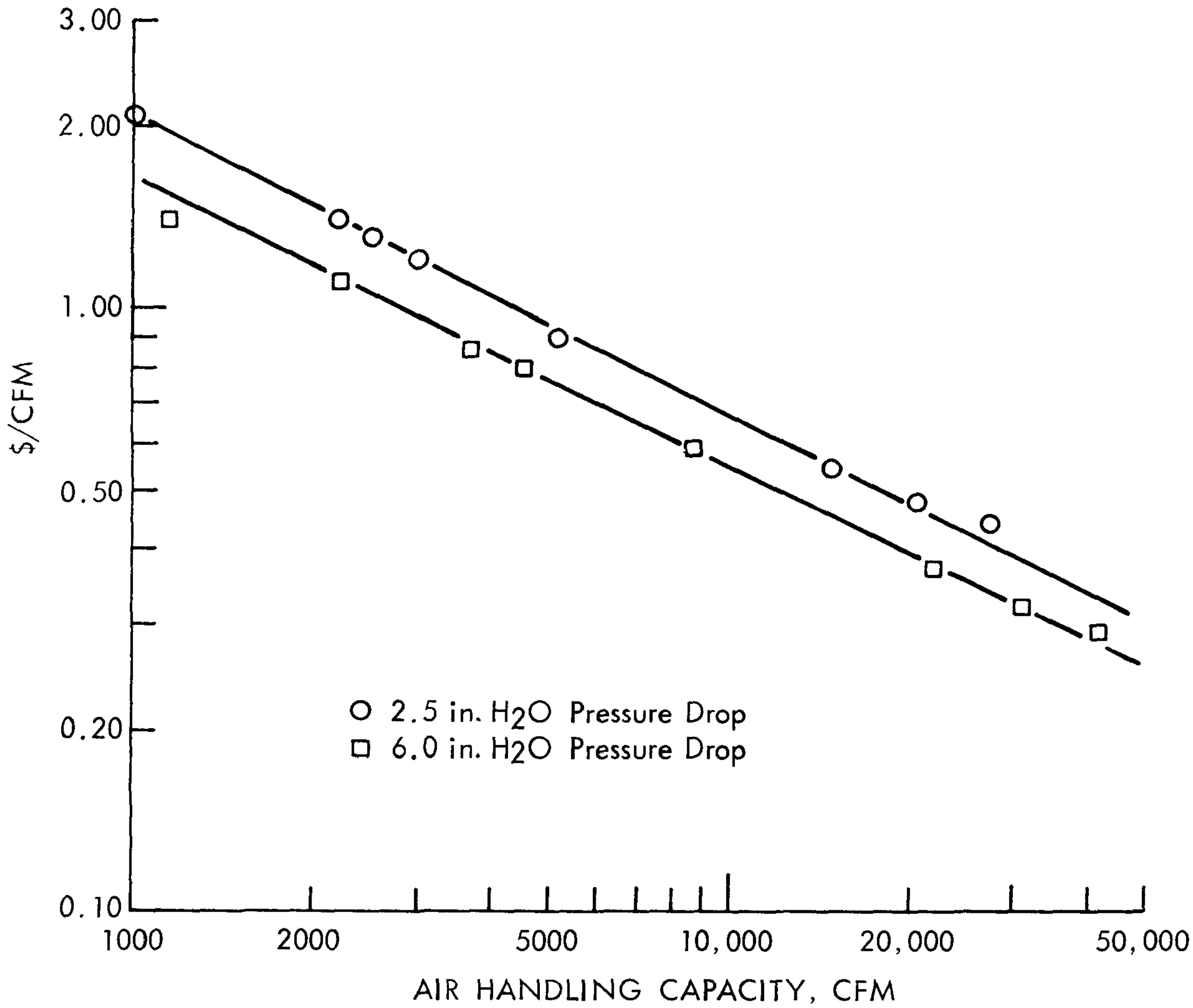

Figure 45. Cyclone collector - equipment cost includes basic unit, dust hopper, scroll outlet, weather cap and support stand.[17]

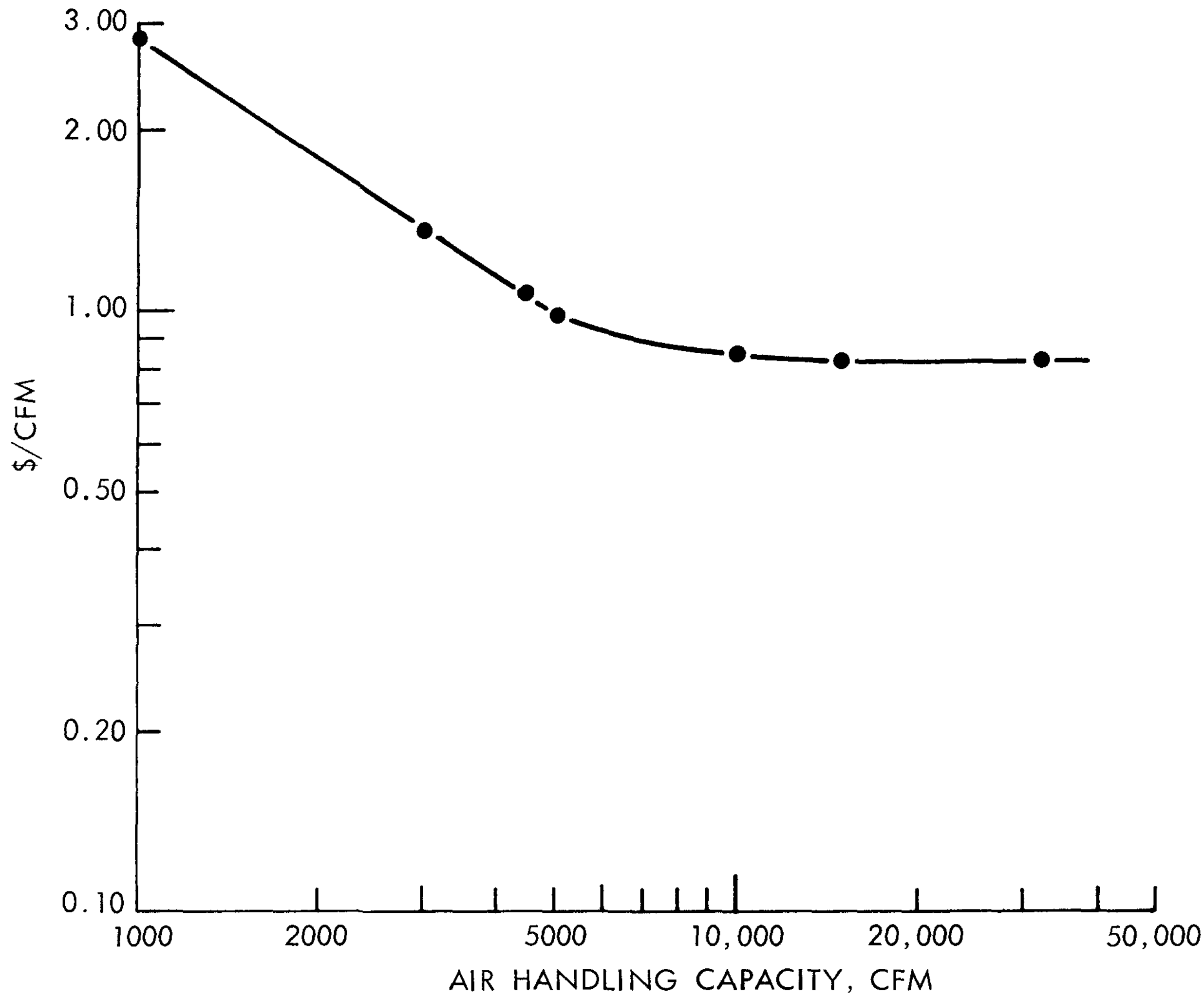

Figure 46. Inertial cyclonic recycle type-equipment cost includes: basic collector; rotary valve and motor; secondary fan and motor.[17/]

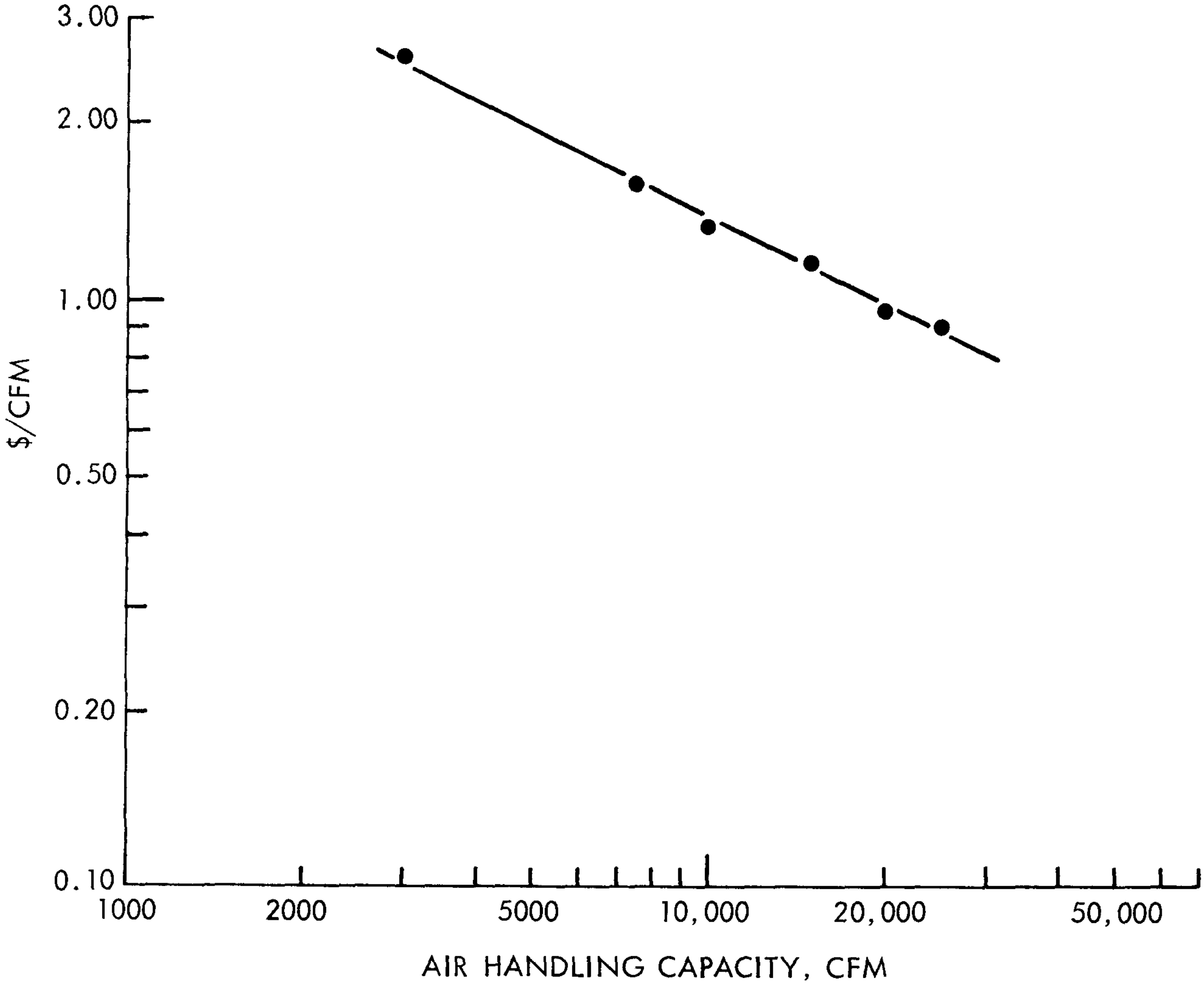

Figure 47. Fabric filter - equipment cost includes basic unit, complete with air pump and rotary valves, motor, starter.[17]

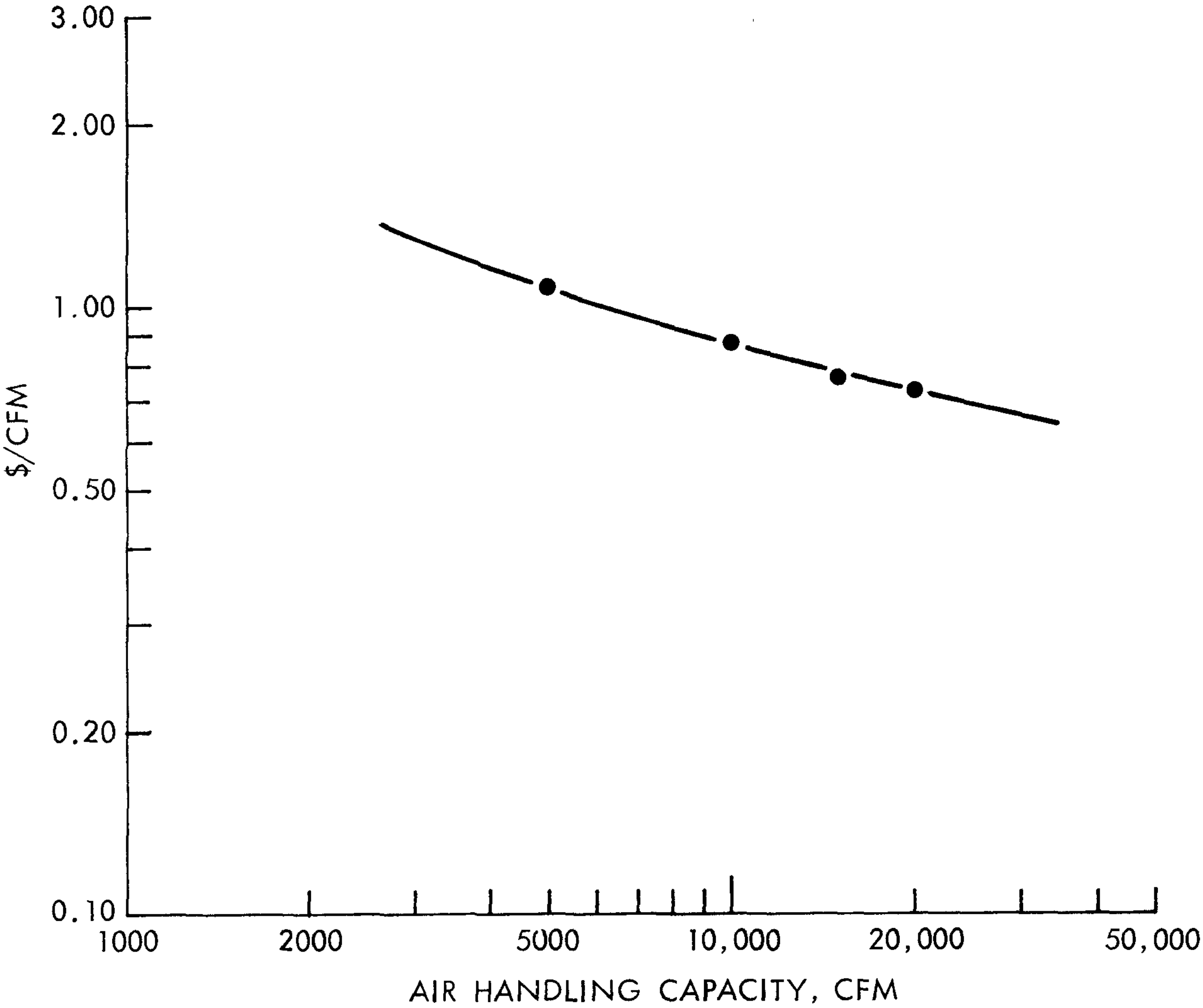

Figure 48. Wet scrubber for gaseous pollutant control - equipment cost includes pump, pump motor, and recycle piping.[17]

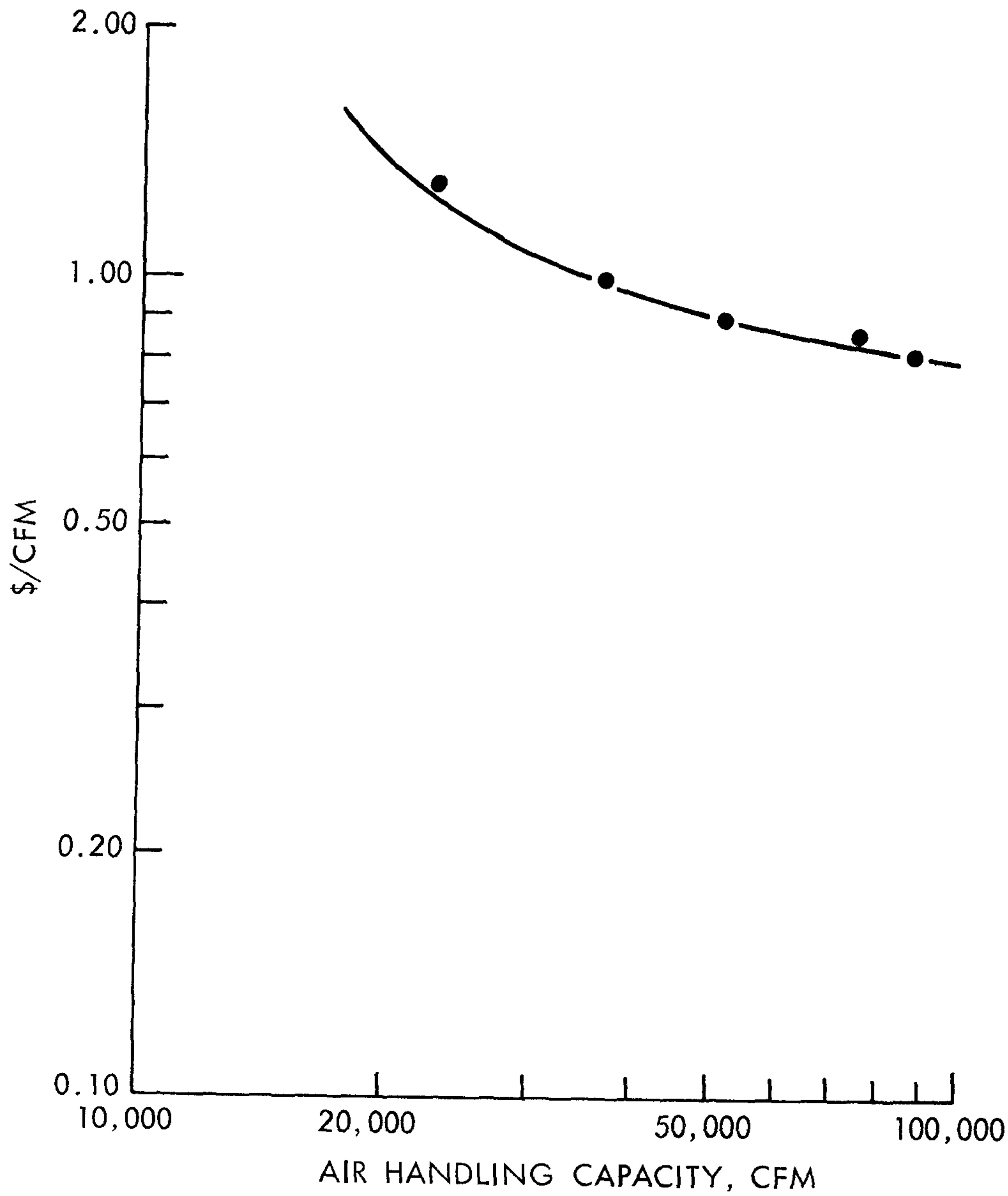

Figure 49. Wet scrubber for gaseous and particulate control-equipment costs include: basic scrubber stand; piping; recirculation pump; control panel; fuse connect; and instrumentation.[17]

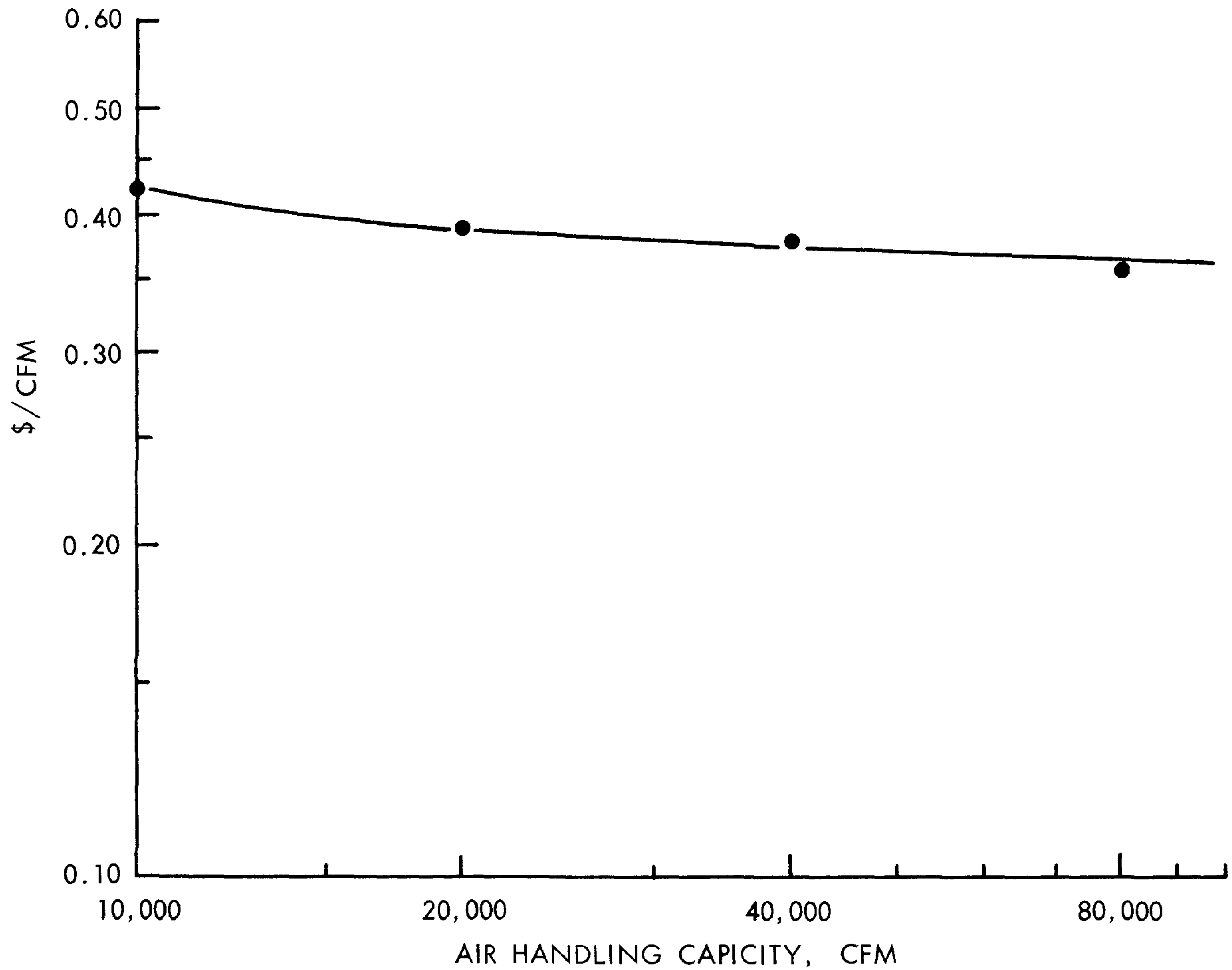

Figure 50. Impellar scrubber-equipment cost includes scrubber, plumbing, fan, motor. Does not include tank and pump or water slurry disposal system.[17/]

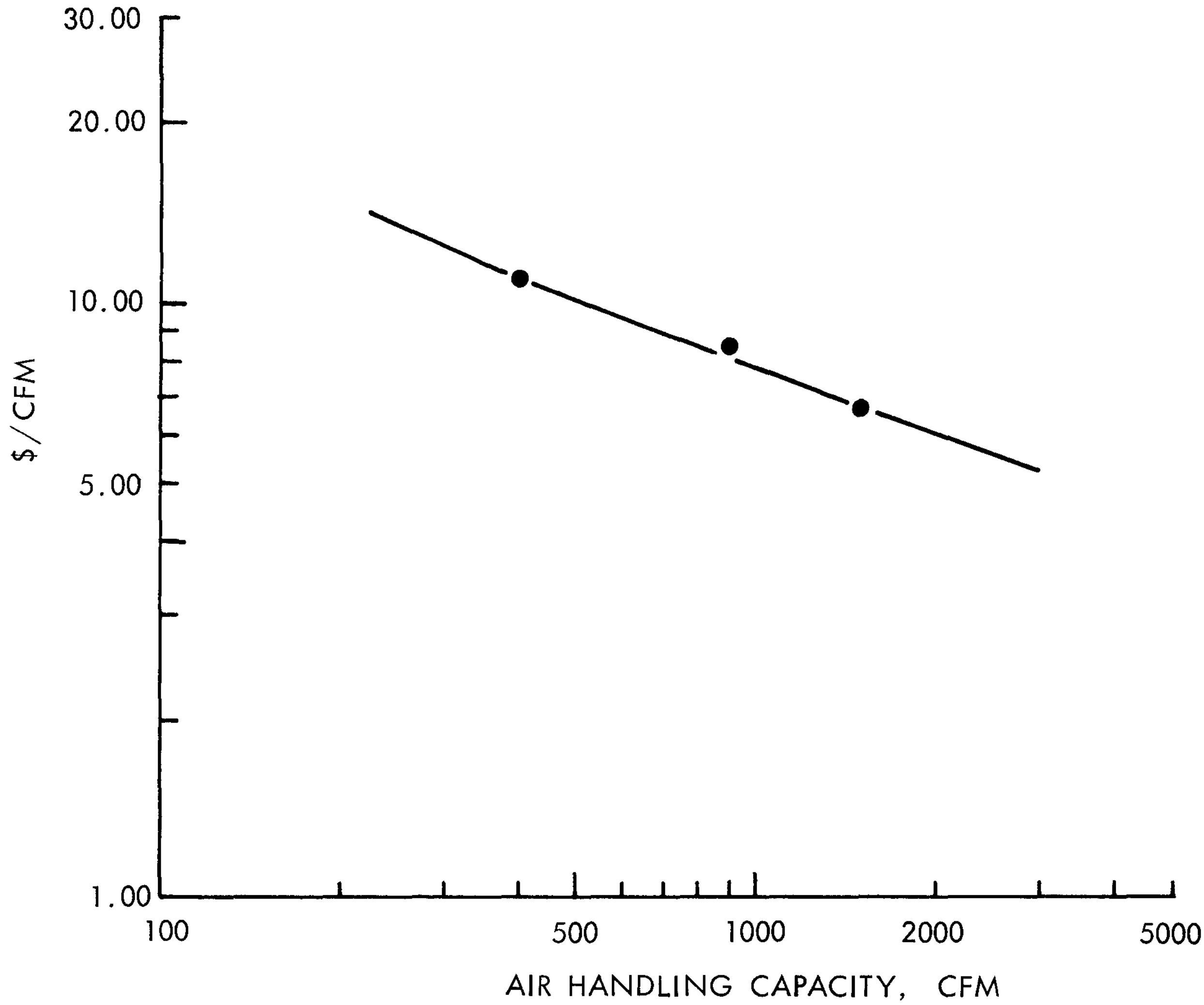

Figure 51. Afterburner-equipment cost.[17]

Table 159. APPROXIMATE RANGE OF CONTROL COST
(Total Installed Cost)

Operation	Typical Range of cfm	Installed Cost $/cfm
I. Grain Handling		
Receiving		
Truck dump	10,000 - 20,000	1.75 - 4.00
Boxcar receiving	10,000 - 20,000	1.75 - 4.00
Hopper car receiving	10,000 - 20,000	1.75 - 4.00
Barge receiving	10,000 - 20,000	1.75 - 4.00
Drying	30-100 cfm/bu/hr	0.25 - 0.75
Cleaning	5,000 - 15,000 (each)	2.00 - 3.00
Transfer operations		
Scale and garner	1,000 - 10,000	1.50 - 3.00
Transfer	Depends on plant configuration	-
Loadout (truck, boxcar, hopper car, ship, barge)	5,000 - 20,000 (each)	2.00 - 4.50
II. Feed Mills		
Receiving, transfer and loadout	(see grain handling operations above)	
Grinding	4,000 - 8,000	1,50 - 3.00
Bin vents	200 cfm/bin	3.00 - 8.00
Pelletizer and pellet cooler	20,000 - 30,000 (each)	1.20 - 3.00

Table 159. (Continued)

Operation	Typical Range of cfm	Installed Cost $/cfm
III. Flour Milling		
Receiving and transfer	(see grain handling above)	
Cleaning and tempering operations	25,000 - 35,000 (total)	1.50 - 2.50
Milling (break rolls, sifter, purifiers, hammermills)	35,000 - 45,000 (total)	1.50 - 2.50
Pneumatic loadout	5,000 - 10,000	2.00 - 5.00
IV. Durum Milling		
Receiving and transfer	(see grain handling above)	
Cleaning house (separator, aspirator, disc separator, scourer, tempering bins)	50,000 - 65,000 (total)	1.50 - 2.50
Milling (break rolls, sifters, purifiers, hammermills)	80,000 - 110,000 (total)	1.50 - 2.50
Pneumatic loadout	(see flour milling)	
V. Dry Corn Milling		
Receiving and transfer	(see grain handling operation)	

Table 159. (Continued)

Operation	Typical Range of cfm	Installed Cost $/cfm
V. Dry Corn Milling (Continued)		
Cleaning house (screens, millerator, scourer, stoners)	15,000 - 25,000 (total)	1.50 - 2.50
Tempering and milling (break rolls, sifters, purifiers, expeller cake hammermills)	25,000 - 35,000 (total)	1.50 - 3.00
Drying, sifting, and cooling	10,000 - 30,000 (total)	1.50 - 3.00
VI. Wet Corn Milling		
Receiving and transfer	(see grain handling above)	
Steeping and wet milling	8,000 - 12,000	not normally controlled
Germ and gluten drying and cooling; feed cooling	5,000 - 20, 000 (each)	2.00 - 3.00
Feed drying	30,000 - 45,000 (each)	3.50 - 5.00
Pellet mills and pellet cooling	8,000 - 12,000	2.00 - 3.00
Feed house	8,000 - 12,000	2.00 - 5.00
Dry starch grinding	2,000 - 5,000	4.00 - 5.00
Starch drying		
Flash	35,000 - 40,000	1.50 - 2.00
Rotary	4,000 - 6,000	3.00 - 4.00
Corn syrup solids drying	18,000 - 25,000	2.50 - 3.50

Table 159. (Concluded)

Operation	Typical Range of cfm	Installed Cost ($/cfm)
VII. Soybean Processing		
Receiving and transfer	(see grain handling above)	
Cracking mills, flaking, conditioning, dehulling and screening	5,000 - 15,000 (each)	2.50 - 4.50
Meal drying	8,000 - 12,000	2.00 - 6.00
Meal cooling	10,000 - 20,000	2.00 - 3.00
Hull toaster and grinder	5,000 - 20,000 (each)	2.00 - 3.50
VIII. Rice Milling		
Receiving and transfer	(see grain handling above)	
Cleaning house (scalper, screen, disc separator, scourer)	25,000 - 35,000 (total)	1.25 - 2.00
Grinding, hulling, shelling, paddy separation	8,000 - 10,000 (each)	2.00 - 3.50

Recovered Dust Value

In some cases, the recovered dust from the control devices may be sold for use as animal feed. Because of the local nature of such markets, the prices received for the recovered dust are highly variable. In some cases there are simply no developed markets, whereas in others, plants can sell the material. In most cases, the disposal of this material does not present a solid waste problem since local sources can usually be found which will take the material.

Insurance Credits for Installation of Control Devices

Insurance rates are affected by the use of air pollution control systems. However, only those aspects of the control system which have a bearing on the explosion or fire potential of the facility are considered. Thus, for control devices venting to the atmosphere, there is no additional credit for use of a high efficiency over a low efficiency collector. Control of outside sources of emission (e.g., truck dumps) does not influence the insurance rate.

Fabric filters located inside the building are considered an increased fire hazard. If a fire or explosion should occur elsewhere in the elevator or mill, the fabric filter is susceptible to ignition. Fabric filters located outside the building are not considered an increased fire hazard. To minimize this fire and explosion hazard, some plants have installed CO_2 purge systems in the baghouse. The increased premium for baghouses inside the building may amount to several cents per $100 of coverage. A typical mill with six fabric filters installed inside the building paid an added charge of 11-1/2 cents per $100 of coverage. However, this same mill received a credit of 19 cents per $100 of coverage for the pneumatic conveying system.

An elevator with good dust pickup or hooding systems may receive a credit of approximately 3 to 5 cents per $100 of coverage.

CHAPTER 4

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CHAPTER 5

ECONOMIC IMPACT OF DUST CONTROL

INTRODUCTION

This chapter presents an assessment of the economics of dust control costs upon the grain and feed industry. The initial intent of the analysis was to determine the economic impact of dust control systems only for new facilities in accordance with the directives of the Clean Air Act of 1970. However, since there are few new facilities being constructed when compared to the number of existing facilities in the grain and feed industry, the long-term economic impact of air pollution control regulations in this industry will be borne by existing facilities. In order to accurately reflect the probable economic impact of air pollution control regulations, the analysis was expanded to include both new and existing facilities.

A series of plant financial models were used to perform the analysis of the economic impact. Separate models were developed for each type of plant within the grain and feed industry, and in some cases, for various sizes of operations within each industry segment. The capacities, handling rates, operating hours, and other items listed in the individual plant specifications were selected to represent average or medium-size plants in most instances. The model plant is representative of the particular industry; however, it is not meant to represent the total industry. In each industry segment there are significant variations in the size, configuration and operating characteristics of different facilities. These variations will affect the economic impact which air pollution control requirements will have on specific facilities.

The limited scope of the present study barred a detailed parametric study of the economic impact as a function of plant size and configuration, and the model plants used in the analysis only present a simplified flow diagram for each type of facility. As a consequence, there are some weaknesses and shortcomings in the model plant concept. For example, it was not possible to incorporate variable factors such as:

(a) Product mix between plants and within a plant;

(b) Alternative processing techniques and equipment selection;

(c) Plant site and layout; and

(d) Plant size.

Because of the limitations imposed by the model plant approach, the results of the economic impact analysis should be viewed as indicative of the probable economic impact and not the absolute impact.

In addition, the economic analysis for each model plant had to be made using prices, interest rates and operating expenses for a specific time period. In all cases, the analysis was made using the most current figures available; however, these figures will change over time. The prices and general economic conditions in the grain and feed industry have been changing rapidly since the middle of 1972. These changes in raw material, operating and construction costs can alter the economic impact of pollution control equipment on the various industry segments.

The economic impact analysis was performed for two distinct cases of dust control in each industry category:

Case 1 - Installation of the best demonstrated control system currently available for each specific source.

Case 2 - Installation of control systems that generally reflect current industry practices.

The dust control equipment selected for individual emission sources in Case 1 represents MRI's judgment of the "best" demonstrated control system currently available for the specific source. Selections of dust control equipment for Case 2 were based on the understanding obtained during the course of the program of general industry practice for plants which have pollution control equipment. In general, fabric filter collectors were selected in Case 1, and cyclone collectors were selected in Case 2, except for those sources where industry practice (e.g., fabric filters being used in the mill house of a flour mill) indicated that fabric filter systems were generally being used to improve recovery of intermediate or final products.

In selecting the dust control equipment for Cases 1 and 2, consideration was not given to the need to comply with any specific air pollution regulation. Once specific regulations are adopted at either the federal, state or local level, it may be possible to meet the regulations using different methods or less efficient equipment than specified for the model plants.

The basic procedures used to determine the economic impact were the same for each industry segment. For each analysis, a model plant was developed with a specified configuration of processing operations. Air pollution control equipment was selected for each individual emission source and estimates of the corresponding investment and operating costs were calculated.

The investment cost required for control equipment on each emission source represents the total installed cost for a new model plant. These costs were obtained from detailed engineering cost analysis of the model plant's operation and the corresponding pollution control equipment.

The total annual operating costs required for the control devices include electrical charges, maintenance expenses, depreciation expenses and capital charges. Since these operating costs can vary significantly over time and from one plant to the next, a number of basic assumptions were made in calculating the costs for the model plants. The general procedures used in the analysis for each of the model plants are described below.

The electrical expense was determined from the hourly operating expense as quoted by the equipment manufacturers and the hours per year which the device would be required to operate. The operational hours per year which are listed for the model plants were estimated from an analysis of the operational requirements and capacities of each device. Allowances were made for the fact that some control devices must operate longer than would be required if each operation were optimally scheduled at plant equipment capacities. These allowances were made to recognize the operational realities of the particular facility.

The electrical cost for cyclones in the Case 2 analysis was estimated at 80% of the electrical cost for a fabric filter. This reduction is mainly based on the assumption that, not including pressure drop through ducting, the pressure drop in the filter would be about 4 in. wc while that of the cyclone would be 2-3 in. wc. The cyclone systems would also have somewhat less operating cost than a filter because the cyclone does not require a cleaning air compressor.

The maintenance costs were based on an estimate that 10¢/cfm/year would be required to maintain and repair fabric filter control devices. This rate includes the labor required for operation and maintenance. The maintenance cost for cyclone control devices was estimated at approximately half that required for fabric filters,or 5¢/cfm/year. Although this number is only an estimate relative to that for fabric filters, it is based on the fact that fabric filters require bag replacement or cleaning plus maintenance of the cleaning mechanism and possibly a cleaning air compressor. The cyclone on the other hand has few moving parts, perhaps only a rotary valve (air lock) at the dust outlet, but may require some maintenance for repair of leaks due to erosion, etc.

Depreciation expense was based on a 10-year straight-line depreciation schedule. A variety of accelerated depreciation methods and optional depreciation periods could have been used. The period over which the equipment is depreciated could be based on a (1) 5-year life as allowed by the Internal Revenue Service for the depreciation of pollution control equipment, (2) 17-year life which is the IRS guideline for the grain and feed industry, (3) 60-year life which is the guideline for elevators, or (4) the actual life of the equipment as estimated by the manufacturers. Straight-line depreciation over a 10-year period was selected because it is between the extremes and provides a realistic estimate from which to determine total annual control costs.

A 5% effective annual interest rate was used to calculate the capital charges for the control equipment. The 5% rate results from an assumption that the capital required to purchase the control equipment was obtained from an 8%, 10-year note which is repayable in equal yearly installments. Yearly payments equal to 15% of the original loan are required to retire the note in 10 years. For the purpose of the model plant analysis, it was assumed that one-third of the yearly payments, i.e., 5%, is interest and the remaining portion is principal. Although not technically correct, this assumption provides an equal annual interest charge for the 10-year life of the equipment, and provides for a balance between debt and equity financing. In actual practice, any combination of debt or equity capital could be used depending upon the individual company involved. Also, the interest rate which a plant is required to pay for a long-term loan will vary depending upon a variety of factors, such as the location, size, stability and financial condition of the company.

To determine the financial impact of air pollution control costs, an income statement and balance sheet were developed for each of the model plants. For the two alternate types of control equipment, separate financial statements were developed for the operation of each model plant, both without and with pollution control equipment. These statements were compared to determine the impact of the control equipment on the financial condition of new plants.

The financial analysis was extended to include the impact on existing facilities. For both new and existing facilities, only the primary or direct economic impact was calculated; that is, the impact from increased investment and operating costs. Secondary economic impacts were not quantified.

GRAIN ELEVATORS

Description of Model Plants

Model plants were developed for country, inland terminal, and port terminal elevators. Figures 52, 53, and 54 present the flow diagrams and other pertinent specifications for the model plants with "best" control equipment. The specific features of the model plants represent a distillation of the knowledge gained from plant trips, discussions with industry personnel, and data provided in the emission inventory questionnaires. The model plants are not intended to represent any specific facility, but rather they present a description of the general nature of operations.

Control Equipment Costs

For each of the model plants, two alternate pollution control systems are specified. Case 1 represents the "best" demonstrated control system currently available for each specific air pollution source. The control devices are not necessarily the optimum equipment configuration which would be selected from an analysis of the cost-efficiency of the equipment or from an analysis of the economic cost-benefit to the plant. Rather the control devices were selected because they offer the highest level of control which is technically feasible at this time.

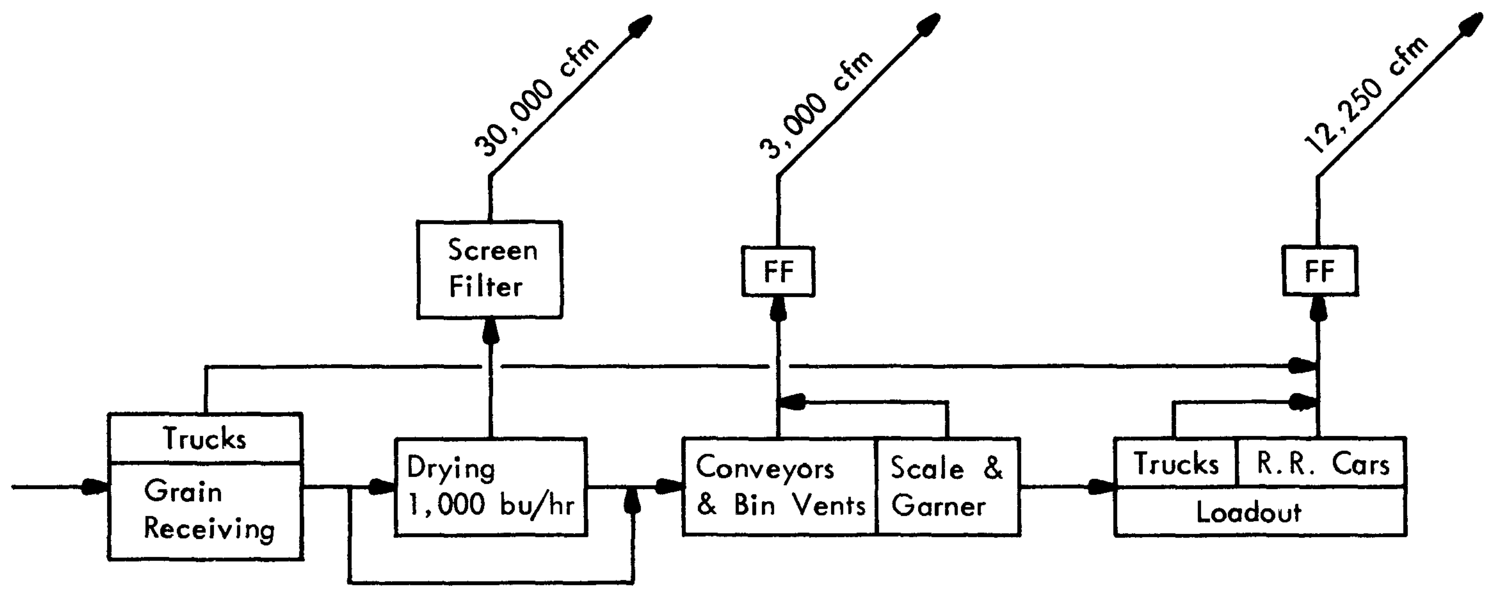
In Case 2 the model plants are equipped with cyclones in place of fabric filters on the grain handling operations. From an operational reliability standpoint, cyclones may be the only feasible systems for grain receiving operations at elevators which receive grain with a high moisture content. Fabric filter systems are reported to blind or plug readily when high moisture content grains are handled.

COUNTRY ELEVATORS (< 1 x 10^6 Bushel Storage Capacity)

Basis:

a. Receive by truck from farmer
b. Ship by truck and rail
c. Leg capacity - 7,500 bu/hr
d. Dryer capacity - 1,000 bu/hr

Storage Capacity - 0.5 x 10^6 bu
Throughput - 1.0 x 10^6 bu/yr



Grain Handled

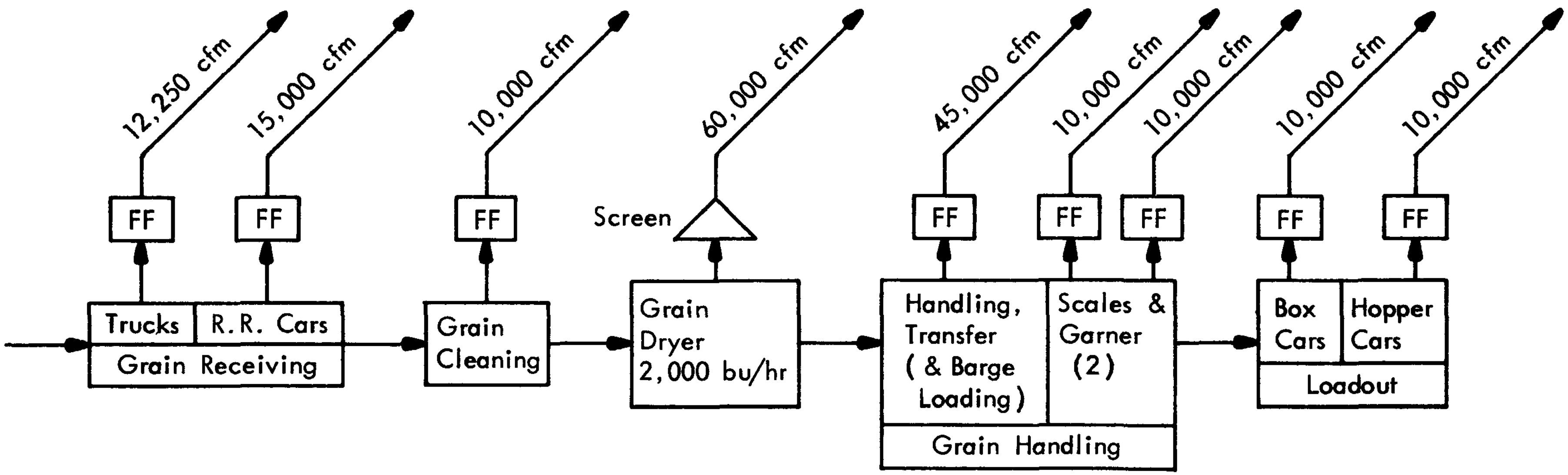
Wheat	40%	
Corn	30%	(dry 100%)
Soybean	30%	(dry 50%)

FF - Fabric Filter

Figure 52. Model new country elevator--best controls.

TERMINAL ELEVATOR (Inland)

Storage Capacity - 5.0 x 10^6 bu
Throughput - 15.0 x 10^6 bu/yr
2 Legs, 35,000 bu/hr each



Grain Handled

Wheat	40%	
Corn	30%	(dry 50%)
Soybean	30%	(dry 25%)

Receiving	
Truck	40%
Rail	60%
Barge	0

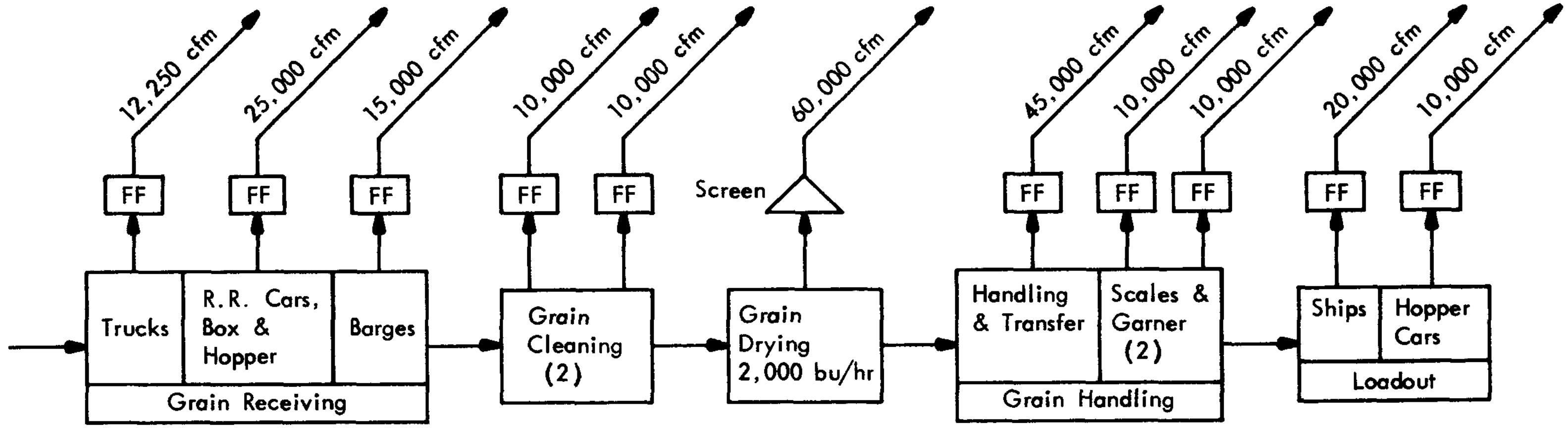
Shipping	
Truck	0
Rail	85%
Barge	15%

FF - Fabric Filter

Figure 53. Model new terminal elevator (inland)--best controls.

TERMINAL ELEVATOR (Port)

Storage Capacity - 5.0 x 10^6 bu
Throughput - 40.0 x 10^6 bu/yr
Leg Capacity - 4 Legs, 35,000 bu/hr each



Grain Handled

Wheat	40%	
Corn	40%	(dry 5%)
Soybean	20%	(dry 2.5%)

Receiving	
Truck	15%
Rail	75%
Barge	10%

Shipping	
Ship	99%+
Rail	< 1%

FF - Fabric Filter

Figure 54. Model new terminal elevator (port)--best controls.

For each operation an estimate is given for the investment cost required for the control devices. Also included are estimates for the total annual operating costs of the equipment including electrical, maintenance and depreciation expenses and capital charges. Assumptions regarding these expenses were discussed in the introduction to this chapter.

A summarization of the total annual operating costs and investment costs for each alternative is given in Table 160. Annual operating costs are based upon yearly throughput and installed costs upon plant capacity. Details of the costs associated with Cases 1 and 2 for the country elevator are presented in Tables 161 and 162, the inland terminal in Tables 163 and 164, and the port terminal in Tables 165 and 166.

Table 160. SUMMARY OF TOTAL ANNUAL OPERATING COSTS AND INVESTMENT COSTS FOR CONTROL SYSTEMS ON GRAIN ELEVATORS

	Total Annualized Cost Per Year		Total Installed Cost	
	Case 1 ($)	Case 2 ($)	Case 1 ($)	Case 2 ($)
Country elevator	17,642	14,623	94,040	80,262
Inland terminal elevator	75,238	57,238	354,720	286,030
Port terminal elevator	96,209	71,367	444,830	355,190
	Total Annual Cost Per Bushel of Throughput		**Total Installed Costs Per Bushel of Capacity**	
	Case 1 (¢)	Case 2 (¢)	Case 1 (¢)	Case 2 (¢)
Country elevator	1.76	1.46	18.8	16.1
Inland terminal elevator	0.50	0.38	7.1	5.7
Port terminal elevator	0.21	0.18	8.9	7.1

These figures represent the cost of purchasing and installing the control equipment for a new elevator and the costs associated with operating them per year. For elevators of similar design, the installed cost of the equipment will not vary considerably with the storage capacity or the volume of grain handled. The type and size of the pollution control equipment are more dependent upon the operations required in receiving, handling, and shipping grain rather than upon volume.

Table 161. MODEL PLANT FOR NEW COUNTRY ELEVATORS

Case 1 - Best Controls

Operation	Model Plant Control and Cost Estimate								
	Selected Device	Air Flow (cfm)	Operation (hr/yr)	Electrical ($/yr)	Maintenance ($/yr)	Depreciation ($/yr)	Capital Charges ($/yr)	Annualized Cost ($/yr)	Installed Cost ($)
Loadout and receiving[a]	Filter	12,250	1,000	550	1,230	6,145	3,073	10,998	61,450[b]
Grain dryer 1,000 bu/hr[c]	Self-cleaning screen	30,000	500	85	1,000	2,000	1,000	4,085	20,000
Scale, garner, leg, bin vents	Filter	3,000	2,000	370	300	1,259	630	2,559	12,590
Total		45,250		1,005	2,530	9,404	4,703	17,642	94,040

a/ One filter serves truck receiving, truck loading, and car loading.
b/ Includes $24,269 for railroad car loading shed. (Assume truck loading is normally covered.)
c/ Recirculating dryer (50% of air recirculated).

Storage Capacity - 500,000 bu
Throughput - 1,000,000 bu/yr
Leg Capacity - 1 leg (7,500 bu/hr)

Table 162. MODEL PLANT FOR NEW COUNTRY ELEVATORS

Case 2 - Alternate Controls

	Model Plant Control and Cost Estimate								
Operation	Selected Device	Air Flow (cfm)	Operation (hr/yr)	Electrical ($/yr)	Maintenance ($/yr)	Depreciation ($/yr)	Capital Charges ($/yr)	Annualized Cost ($/yr)	Installed Cost ($)
Loadout and receiving[a/]	Cyclone	12,250	1,000	440	613	5,226	2,613	8,892	52,262[b/]
Grain dryer 1,000 bu/hr[c/]	Self-cleaning screen	30,000	500	85	1,000	2,000	1,000	4,085	20,000
Scale, garner, leg, bin vents	Cyclone	3,000	2,000	296	150	800	400	1,646	8,000
Total		45,250		821	1,763	8,026	4,013	14,623	80,262

a/ One filter serves truck receiving, truck loading, and car loading.
b/ Includes $24,269 for railroad car loading shed. (Assume truck loading is normally covered.)
c/ Recirculating dryer (50% of air recirculated).

Storage Capacity - 500,000 bu
Throughput - 1,000,000 bu/yr
Leg Capacity - 1 leg (7,500 bu/hr)

Table 163. MODEL PLANT FOR NEW TERMINAL ELEVATORS (INLAND)

Case I - Best Controls

Operation	Selected Device	Air Flow (cfm)	Operation (hr/yr)	Electrical ($/yr)	Maintenance ($/yr)	Depreciation ($/yr)	Capital Charges ($/yr)	Annualized Cost ($/yr)	Installed Cost ($)
	Model Plant Control and Cost Estimate								
Truck receiving[a]	Filter	12,250	1,000	550	1,230	3,564	1,782	7,126	35,640
Railroad car receiving	Filter	15,000	500	320	1,500	3,000	1,500	6,320	30,000
Boxcar loading[b]	Filter	10,000	200	100	1,000	5,874	2,937	9,911	58,740
Hopper car loading	Filter	10,000	300	150	1,000	2,574	1,287	5,011	25,740
Grain cleaning	Filter	10,000	500	320	1,000	2,470	1,235	5,025	24,700
Grain dryer 2,000 bu/hr[c]	Self-cleaning screen	60,000	2,000	400	1,500	2,890	1,445	6,235	28,900
Scale and garner	Filters (2)	2 x 10,000	1,000	740	2,000	4,350	2,175	9,265	43,500
Grain handling and turning (including barge loading)	Filter	45,000	2,500	5,720	4,500	10,750	5,375	26,345	107,500
Total		182,250		8,300	13,730	35,472	17,736	75,238	354,720

a/ Includes cost of truck shed, $10,350.
b/ Includes cost of double track shed, $33,000 (for car loading and receiving).
c/ *Recirculating dryer (50% of air recirculated).*

Storage Capacity - 5,000,000 bu
Throughput - 15,000,000 bu/yr
Leg Capacity - 2 legs (35,000 bu/hr each)

Table 164. MODEL PLANT FOR NEW TERMINAL ELEVATORS (INLAND)

Case 2 - Alternate Controls

Operation	Selected Device	Air Flow (cfm)	Operation (hr/yr)	Electrical ($/yr)	Maintenance ($/yr)	Depreciation ($/yr)	Capital Charges ($/yr)	Annualized Cost ($/yr)	Installed Cost ($)
	Model Plant Control and Cost Estimate								
Truck receiving[a]	Cyclone	12,250	1,000	440	613	2,645	1,323	5,021	26,450
Railroad car receiving	Cyclone	15,000	500	256	750	1,950	975	3,931	19,500
Boxcar loading[b]	Cyclone	10,000	200	80	500	5,074	2,537	8,191	50,740
Hopper car loading	Cyclone	10,000	300	120	500	1,774	887	3,281	17,740
Grain cleaning	Cyclone	10,000	500	256	500	1,670	835	3,261	16,700
Grain dryer 2,000 bu/hr[c]	Self-cleaning screen	60,000	2,000	400	1,500	2,890	1,445	6,235	28,900
Scale and garner	Cyclones (2)	2 x 10,000	1,000	592	1,000	2,750	1,375	5,717	27,500
Grain handling and turning (including barge loading)	Cyclone	45,000	2,500	4,576	2,250	9,850	4,925	21,601	98,500
Total		182,250		6,720	7,613	28,603	14,302	57,238	286,030

a/ Includes cost of truck shed, $10,350.
b/ Includes cost of double track shed, $33,000 (for car loading and receiving).
c/ Recirculating dryer (50% of air recirculated).

Storage Capacity - 5,000,000 bu
Throughput - 15,000,000 bu/yr
Leg Capacity - 2 legs (35,000 bu/hr each)

Table 165. MODEL PLANT FOR NEW TERMINAL ELEVATORS (PORT)

Case 1 - Best Controls

	Model Plant Control and Cost Estimate								
Operation	Selected Device	Air Flow (cfm)	Operation (hr/yr)	Electrical ($/yr)	Maintenance ($/yr)	Depreciation ($/yr)	Capital Charges ($/yr)	Annualized Cost ($/yr)	Installed Cost ($)
Truck receiving[a/]	Filter	12,250	500	275	1,230	3,564	1,872	6,851	35,640
Railroad car receiving[b/]	Filter	25,000	1,000	1,070	2,500	4,090	2,045	9,705	40,900
Barge receiving	Filter	15,000	300	200	1,500	3,125	1,562	6,387	31,250
Hopper car loading[c/]	Filter	10,000	100	50	1,000	5,874	2,937	9,861	58,740
Grain cleaning	Filter	20,000	350	440	2,000	4,940	2,470	9,850	49,400
Grain dryer 2,000 bu/hr[d/]	Self-cleaning screen	60,000	500	100	1,500	2,890	1,445	5,835	28,900
Scale and garner	Filters (2)	2 x 10,000	1,500	1,100	2,000	4,350	2,175	9,625	43,500
Handling and turning	Filter	45,000	2,500	5,720	4,500	10,750	5,375	26,345	107,500
Ship loading	Filter	20,000	1,000	1,300	3,000	4,900	2,450	11,650	49,000
Total		227,250		10,255	19,230	44,483	22,241	96,209	444,830

a/ Includes cost of truck shed, $10,350.
b/ 25,000 cfm for two rail car receiving stations (boxcar and hopper car).
c/ Includes cost of double track shed, $33,000 (for car loading and receiving).
d/ Recirculating dryer (50% of air recirculated).

Storage Capacity - 5,000,000 bu
Throughput - 40,000,000 bu/yr
Leg Capacity - 4 legs (35,000 bu/hr each)

Table 166. MODEL PLANT FOR NEW TERMINAL ELEVATORS (PORT)

Case 2 - Alternate Controls

Operation	Selected Device	Air Flow (cfm)	Operation (hr/yr)	Electrical ($/yr)	Maintenance ($/yr)	Depreciation ($/yr)	Capital Charges ($/yr)	Annualized Cost ($/yr)	Installed Cost ($)
	Model Plant Control and Cost Estimate								
Truck receiving[a]	Cyclone	12,250	500	220	613	2,645	1,323	4,801	26,450
Railroad car receiving[b]	Cyclone	25,000	1,000	856	1,250	2,715	1,358	6,179	27,150
Barge receiving	Cyclone	15,000	300	160	750	2,075	1,038	4,023	20,750
Hopper car loading[c]	Cyclone	10,000	100	40	500	5,074	2,537	8,151	50,740
Grain cleaning	Cyclone	20,000	350	352	1,000	3,780	1,890	7,022	37,800
Grain dryer 2,000 bu/hr[d]	Self-cleaning screen	60,000	500	100	1,500	2,890	1,445	5,935	28,900
Scale and garner	Cyclones (2)	2 x 10,000	1,500	880	1,000	2,750	1,375	6,005	27,500
Handling and turning	Cyclone	45,000	2,500	4,576	2,250	9,850	4,925	21,601	98,500
Ship loading	Cyclone	20,000	1,000	1,040	1,000	3,740	1,870	7,650	37,400
Total		227,250		8,224	9,863	35,519	17,761	71,367	355,190

a/ Includes cost of truck shed, $10,350.
b/ 25,000 cfm for two rail car receiving stations (boxcar and hopper car).
c/ Includes cost of double track shed, $33,000 (for car loading and receiving).
d/ Recirculating dryer (50% of air recirculated).

Storage Capacity - 5,000,000 bu
Throughput - 40,000,000 bu/yr
Leg Capacity - 4 legs (35,000 bu/hr each)

For example, a truck-receiving station in a country elevator will require the same basic filter and cubic feet per minute regardless of the number of trucks which are unloaded during the year. The model country elevator has the facilities to receive grain by truck and to ship by either truck or rail--facilities which are available at almost all country elevators.

In each of the new model elevators, the control equipment required is dependent upon the operational facilities which are available. For example, less control equipment will be required if the country elevator does not have a grain dryer. On the other hand, additional control equipment will be required if the elevator has facilities to receive grain by rail or to load by barge.

Additional variations in equipment could result from basic design changes in an elevator's grain-handling operations. For example, a few elevators have been constructed which utilize an enclosed high-capacity belt conveyor. At no point in the system is the grain exposed to the atmosphere, from the time it leaves the unloading pits until it reaches the storage bins. The pollution control equipment required for such a system would be less than that specified for the model plant; however, it is estimated that the increased cost of the enclosed system is as great as the corresponding decreased cost of control equipment.

Credits for Dust Control

There are a number of control credits or positive impacts which will result from the installation of pollution control equipment on an elevator. Possible positive impacts include:

1. Reduction in product shrink,

2. Reduction of maintenance costs through savings on lubricants and similar materials,

3. Increased life of protective coatings,

4. Labor savings in elevator clean-up,

5. Reduction in fire insurance premiums for stocks, property and business interruptions, and

6. Tighter insect and rodent control with attendant reduction in grain losses.

The major control credit which will be quantified in the model plant analysis is the reduction in product shrink. A dollar value will be assigned to the dust which is collected from the elevator's operation.

Available emission factor information indicates that if the majority of emissions were collected from grain-handling operations it would amount to 1 lb/ton to 5 lb/ton of grain received.[1/] If the cleaning and drying operations were included, the total emission rate could amount to over 10 lb/ton of grain handled. The emission rates will vary depending upon a number of factors including the type of grain handled, moisture content and handling processes.

As grain goes through the processing sequence it may be subjected to several dust control systems and in most cases the collected dust is returned to the grain stream. Therefore, if the same dust were collected several times, a savings to the elevator based on value of dust collected by each system would be high.

Dust collected in a pollution control system can be (1) returned to the grain stream or, (2) separated from the grain and sold as a by-product. Some of the existing control systems on elevators automatically return the dust to the grain stream; however, in most cases a new elevator may choose either option. The exception results from the federal and state regulations for official weights and measures which specify that once the grain has been weighted for loading, nothing can be extracted. These regulations require terminal elevators to return dust collected in the load-out operation to the grain stream.

The value of dust which is collected and returned to the grain stream is dependent upon the price discounts for "dockage" and "foreign material" in various grains. The Official Grain Standards of the United States[27/] specifies the dockage and foreign material standards for each type of grain. For wheat and grain sorghum, the grain dust is included as "dockage." For corn and soybeans, dust is included in "foreign material."

The discount for dockage or foreign material varies for each type of grain. For wheat, dockage is expressed in half percent increments, e.g., dockage ranging from 0.5 to 0.9% is expressed as 0.5%, from 1.0 to 1.4% as 1.0%, etc. Up to 0.5% dockage is allowed without a discount in price. If dockage is 0.5% or greater, then the weight of the grain is discounted or docked by the same percentage. The amount of dockage will vary by geographic area, year and other variables; however, the majority (over 75%) of wheat shipments will have at least 0.5% dockage.

For grain sorghum, dockage is expressed in 1.0% increments and a maximum of 1.0% is allowed without penalty. If dockage is over 1.0%, then the weight of the grain is discounted or docked by the dockage percentage.

For corn the dust is included with "broken corn and foreign material," which is measured in 1.0% increments. For U.S. No. 2 grade corn, a maximum of 3.0% broken corn and foreign material is allowed. For each 1.0% over the 3.0% limit, corn is discounted by 0.5 to 2.5¢/bu. The percentage of broken corn and foreign material can vary significantly. Corn received at the Kansas City Board of Trade in 1973 was usually in the 2.5 to 3.0% range; however, corn which has been dried may go to up to 8.0%.

For soybeans, foreign material is measured on 0.1% increments. A maximum of 1.0% is allowed for U.S. No. 1 grade soybean and 2.0% for No. 2 grade. For soybeans, the foreign material percentage over 1.0% is deducted from the shipment weight. Almost all of soybean shipments received some discount for foreign material.

For each of the major grains, the addition of dust to the grain stream will usually reduce the value of the grain in direct proportion to the weight of dust. This means that the dust has no value if added to the grain.

There are some exceptions to this generalization. For example, an elevator could add wheat dust back to the grain stream and increase the dockage from 0.4% to 0.6%. In this case, the addition of 0.2% dust decreases the value of the wheat by 0.5%, i.e., the dust has a negative value. On the other hand, the addition of wheat dust to the grain could change the dockage from 0.2 to 0.4%. In this case, the 0.4% dockage is still under the limit for wheat and the dust will be equal to the value of the grain.

A few of the modern terminal elevators may be able to accurately control the addition of wheat and corn dust to the grain streams in order to take advantage of the maximum allowable dockage or foreign materials limits. However, in most cases the dust will have a greater value if sold separately as a feed ingredient.

For the purpose of this study it was assumed that the dust collected from all operations could be sold for $10/ton. Depending upon the market conditions, the value of elevator dust can vary from $0 to $30/ton. According to industry sources the value over the past 2 years has averaged around $5/ton. However, if a reliable supply were established, more feed companies could develop procedures to utilize the dust and as a result, the average price would probably increase. Even with a more established market, the small country elevator could still have problems in establishing a market for their dust.

For the purposes of the impact analysis, five optional emission factors were evaluated--from 1 lb/ton to 5 lb/ton of grain handled. The resulting control credits for each model elevator are shown in Table 167. The credit at an emission rate of 5 lb/ton would amount to 4.3% of the annual operating costs of best controls for the model country elevator, 15.0% for the model inland terminal and 31.2% for the model port terminal.

In addition to the value of dust collected, the other positive impacts undoubtedly produce some tangible economic benefits to the model plants. However, it is difficult to quantify these benefits and their total impact, even if quantified, would probably not significantly reduce the impact of the pollution control system on the model plants.

Financial Statements

To determine the financial impact of air pollution control costs upon elevators, an income statement and balance sheet were developed for each of the model elevators. Separate financial statements were developed for the operation of each model plant both without and with pollution control equipment. These statements were compared to determine the impact of the alternate types of control equipment on the financial condition of new plants.

Income statements for the country elevator, inland terminal, and port terminal were developed using a number of published sources and numerous contacts with knowledgeable individuals in industry and government. The principal source of information, particularly for expenses, was the Economic Research Service publication, Cost of Storing and Handling Grain in Commercial Elevators, 1970-71 and Projecting for 1972-73.[3] Other references used in the development of the financial statements are listed in the bibliography--Refs. 3-13.

The operational specifications for the model plants are listed in Table 168. These specifications were selected to represent an "average" elevator's operation and do not apply to any specific establishment. If available, information was selected which represented the 1972-1973 crop year.

Table 167. POTENTIAL CONTROL CREDITS FOR DUST CONTROL TO MODEL ELEVATORS

Assumed Recovery of Grain Dust (lb/ton grain handled)	Grain Handled (ton/yr)	Total Dust Recovered (tons)	Value of Dust[a/] Recovered ($)	Value Recovered as Percent of Annual Control Cost	
				Case I(%)	Case II(%)
Country Elevator:					
1	30,000	15	150	0.9	1.0
2		30	300	1.7	2.1
3		45	450	2.6	3.1
4		60	600	3.4	4.1
5		75	750	4.3	5.1
Inland Terminal Elevator:					
1	450,000	225	2,250	3.0	3.9
2		450	4,500	6.0	7.9
3		675	6,750	9.0	11.8
4		900	9,000	12.0	15.7
5		1,125	11,250	15.0	19.7
Port Terminal Elevator:					
1	1,200,000	600	6,000	6.2	8.4
2		1,200	12,000	12.5	16.8
3		1,800	18,000	18.7	25.2
4		2,400	24,000	24.9	33.6
5		3,000	30,000	31.2	42.0

a/ Assumed that recovered material could be sold at $10/ton.

Table 168. OPERATION SPECIFICATIONS FOR MODEL PLANTS (GRAIN ELEVATORS)

	Country Elevator	Inland Terminal	Port Terminal
Storage Capacity	500,000 bu	5,000,000 bu	5,000,000 bu
Turnover Rate	2.0	3.0	8.0
Grain Handled			
Wheat	400,000 bu	4,500,000 bu	16,000,000 bu
Corn	300,000 bu	6,000,000 bu	16,000,000 bu
Soybeans	300,000 bu	4,500,000 bu	8,000,000 bu
Receiving by -			
Truck	100%	40%	15%
Rail		60%	75%
Water			10%
Shipping by -			
Truck	50%		
Rail	50%	85%	
Water		15%	100%
Drying Volume (Each Bu Dried 5 Points Moisture)	450,000 bu	4,125,000 bu	1,000,000 bu
Average Occupancy (% Storage Capacity)	55.2%	57.4%	68.8%
Gross Margin on Handling and Merchandising a/	6¢/bu	4¢/bu	5.5¢/bu
Storage rates b/	14.6¢/bu yr	14.6¢/bu yr	14/6¢/bu yr
Net Margin on Drying c/	5¢/bu	5¢/bu	5¢/bu
Construction Cost d/	$1.15/bu	$1.20/bu	$3.00/bu
Weighted Average Price of Grain e/	$1.75/bu	$1.92/bu	$1.89/bu

a/ Average gross margins provided by industry contacts.
b/ CCC Schedule of Rates as of July 1, 1971.
c/ USDA, Farmer Cooperative Service, Marketing Research Report 449.
d/ Average construction costs obtained from industry contacts and USDA publications 6/, 7/.
e/ Based on average prices for 1971-72 crop year.

The resulting income statements for the three model plants are presented in Tables 169, 170 and 171. Income taxes were not calculated because many of the elevators are owned by farmer cooperatives which do not pay corporate income taxes. The net margins (net income before taxes per bushel handled) shown in the income statements are for new elevators. Because of greater depreciation expenses, the profitability of a new elevator, particularly a country elevator, may not be as great as that for the average existing elevator.

In general, the operations, expenses and profits of elevators have changed significantly during 1972 and 1973. Storage income has decreased because of a reduction in the quantity of grain stored by the USDA Commodity Credit Corporation; additional interest expenses have been incurred because of increased prices of grain and transportation shortages, and in many cases the gross margins for handling and merchandising have been increased. Because of these rapid changes and the general economic instability, the variations in the financial operations among elevators are significant. The financial statements for an "average" elevator will not represent the total industry.

For the new model elevators, the income statements in Tables 169, 170, and 171 are summarized as follows:

Pollution Control Equipment

	Net Income Per Bushel of Throughput			
	Without Controls (¢)	With Controls (¢)	Decrease (¢)	Decrease (%)
Country elevators:				
Case 1 - Best controls	2.82	1.05	1.76	62.7
Case 2 - Alternate controls	2.82	1.36	1.46	51.8
Inland terminals:				
Case 1 - Best controls	1.58	1.08	0.50	31.6
Case 2 - Alternate controls	1.58	1.20	0.38	24.0
Port terminal:				
Case 1 - Best controls	1.24	1.00	0.24	19.4
Case 2 - Alternate controls	1.24	1.06	0.18	14.5

Table 169. YEARLY INCOME STATEMENT FOR NEW COUNTRY ELEVATOR (1972)

	Without Controls (Dollars)	Case 1 - Best Controls: Control Costs (Dollars)	Case 1 - Best Controls: With Controls (Dollars)	Case 2 - Alternate Controls: Control Costs (Dollars)	Case 2 - Alternate Controls: With Controls (Dollars)
Income					
Handling and Merchandising at 6¢/bu	60,000		60,000		60,000
Storage					
55.2% Average Occupancy at 14.60¢/bu/year	40,300		40,300		40,300
Drying					
Net Income of 5¢/bu for Drying 450,000 bu, 5 Points	22,500		22,500		22,500
Gross Income	122,800		122,800		122,800
Expenses					
Fixed Expenses					
Depreciation	19,065	9,404	28,469	8,026	34,291
Insurance	2,500	--	2,500	--	2,500
Property Taxes	4,040	--	4,040	--	4,040
Licenses and Bonds	430	--	430	--	430
Interest on Investment	19,385	4,703	24,088	4,013	23,398
Total Fixed Expenses	45,420	14,107	59,527	12,039	64,659
Variable Expenses					
Direct Labor	16,470	2,530	19,000	1,763	18,233
Administrative Overhead	13,840	--	13,840	--	13,840
Other	17,380	1,005	18,385	821	18,201
Interest on Working Capital	1,510	--	1,510	--	1,510
Total Variable Expenses	49,200	3,535	52,735	2,584	51,784
Total Expenses	94,620	17,642	112,262	14,623	109,243
Net Income Before Taxes	28,180		10,538		13,557
% Net Income/Net Worth	5.4%		2.0%		2.6%
% Net Income/Total Assets	2.7%		0.92%		1.2%
Net Income/Bushel Handled	2.82¢		1.05¢		1.36¢

Table 170. YEARLY INCOME STATEMENT FOR NEW INLAND TERMINAL (1972)

	Without Controls (Dollars)	Case 1 - Best Controls: Control Costs (Dollars)	Case 1 - Best Controls: With Controls (Dollars)	Case 2 - Alternate Controls: Control Costs (Dollars)	Case 2 - Alternate Controls: With Controls (Dollars)
Income					
Handling and Merchandising at 4¢/bu	600,000		600,000		600,000
Storage					
57.4% Average Occupancy at 14.6%/bu/year	419,020		419,020		419,020
Drying					
Net Income of 5¢/bu for Drying 4,125,000 bu, 5 Points	206,250		206,250		206,250
Gross Income	1,225,270		1,225,270		1,225,270
Expenses					
Fixed Expenses					
Depreciation	210,000	35,472	245,472	28,603	238,603
Insurance	7,850	--	7,850	--	7,850
Property Taxes	30,050	--	30,050	--	30,050
Licenses and Bonds	3,000	--	3,000	--	3,000
Interest on Investment	204,650	17,736	222,386	14,302	218,952
Total Fixed Expenses	455,550	53,208	508,758	42,905	498,455
Variable Expenses					
Direct Labor	226,510	13,730	240,240	7,613	234,123
Administrative Overhead	147,630	--	147,630	--	147,630
Other	149,180	8,300	157,480	6,720	155,900
Interest on Working Capital	9,900	--	9,900	--	9,900
Total Variable Expenses	533,220	22,030	555,250	14,333	547,553
Total Expenses	988,770		1,064,008	57,238	1,046,008
Net Income Before Taxes	236,500		161,262		179,262
% Net Income/Net Worth	4.5%		3.1%		3.4%
% Net Income/Total Assets	2.3%		1.5%		1.7%
Net Income/Bushel Handled	1.58¢		1.08¢		1.20

Table 171. YEARLY INCOME STATEMENT FOR NEW PORT TERMINAL
(1972)

	Without Controls (Dollars)	Case 1 - Best Controls: Control Costs (Dollars)	Case 1 - Best Controls: With Controls (Dollars)	Case 2 - Alternate Controls: Control Costs (Dollars)	Case 2 - Alternate Controls: With Controls (Dollars)
Income					
Handling and Merchandising at 5-1/2¢/bu	2,200,000		2,200,000		2,200,000
Storage 68.8% Average Occupancy at 14.6¢/bu/year	502,240		502,240		502,240
Drying Net Income of 5¢/bu for Drying 1,000,000 bu, 5 Points	50,000		50,000		50,000
Gross Income	2,752,240		2,752,240		2,752,240
Expenses					
Fixed Expenses					
Depreciation	653,550	44,483	698,033	35,519	689,069
Insurance	32,300	--	32,300	--	32,300
Property Taxes	56,800	--	56,800	--	56,800
Licenses and Bonds	1,500	--	1,500	--	1,500
Interest on Investment	571,550	22,241	593,791	17,761	589,311
Total Fixed Expenses	1,315,700	66,724	1,382,424	53,280	1,368,980
Variable Expenses					
Direct Labor	477,800	19,230	497,030	9,863	487,663
Administrative Overhead	150,610	--	150,610	--	150,610
Other	293,150	10,255	303,405	8,224	301,374
Interest on Working Capital	17,670	--	17,670	--	17,670
Total Variable Expenses	939,230	29,485	968,715	18,087	968,715
Total Expenses	2,254,930	96,209	2,351,139	71,367	2,326,297
Net Income Before Taxes	497,310		401,101		425,943
% Net Income/Net Worth	5.0%		4.0%		4.3%
% Net Income/Total Assets	2.5%		2.0%		2.1%
Net Income/Bushel Handled	1.24¢		1.00¢		1.06¢

The income statements do not reflect the control credits which could be received from the sale of the dust as a by-product. The control credits shown in Table 167, assuming an emission rate of 5 lb/ton of grain handled, would reduce the impact of installing pollution control equipment. The impact of the control credit upon profitability as measured by net income per bushel handled is summarized as follows:

Pollution Control Equipment With Control Credit

	Net Income Per Bushel of Throughput			
	Without Control (¢)	With Controls and Control Credit (¢)	Decrease (¢)	Decrease (%)
Country elevators:				
Case 1 - Best controls	2.82	1.13	1.69	59.9
Case 2 - Alternate controls	2.82	1.43	1.39	49.3
Inland terminals:				
Case 1 - Best controls	1.58	1.15	0.43	27.2
Case 2 - Alternate controls	1.58	1.27	0.31	19.6
Port terminal:				
Case 1 - Best controls	1.24	1.07	0.17	13.7
Case 2 - Alternate controls	1.24	1.14	0.10	8.1

For each model plant the balance sheet corresponding to the income statements are listed in Tables 172, 173 and 174. The current assets are composed primarily of grain inventories, and the fixed assets are equivalent to the construction costs of each elevator. The per unit costs were chosen to represent the average construction cost for each type of elevator. However, these costs would vary significantly depending upon the type of structure. For example, a concrete country elevator or inland terminal would cost around $2.00/bu, or approximately 40% more than the construction costs which were used.

A summary of the impact of pollution control equipment on new plant construction costs is as follows:

Table 172. BALANCE SHEET FOR NEW COUNTRY ELEVATOR (1972)

	Without Controls ($000)	Case 1 - Best Controls: Control Costs ($000)	Case 1 - Best Controls: With Controls ($000)	Case 2 - Alternate Controls: Control Costs ($000)	Case 2 - Alternate Controls: With Controls ($000)
Assets					
Current	425		425		425
Fixed	575	94	669	80	655
Other	50		50		50
Total Assets	1,050		1,144		1,130
Liabilities					
Current	295		295		295
Deferred	230	94	324	80	310
Total Liabilities	525	94	619	80	605
Net Worth	525		525		525
Total Liabilities and Net Worth	1,050	94	1,144	80	1,130

Table 173. BALANCE SHEET FOR NEW INLAND TERMINAL (1972)

	Without Controls ($000)	Case 1 - Best Controls: Control Costs ($000)	Case 1 - Best Controls: With Controls ($000)	Case 2 - Alternate Controls: Control Costs ($000)	Case 2 - Alternate Controls: With Controls ($000)
Assets					
Current	4,000		4,000		4,000
Fixed	6,000	355	6,355	286	6,286
Other	500		500		500
Total Assets	10,500		10,855		10,786
Liabilities					
Current	2,820		2,820		2,820
Deferred	2,430	355	2,785	286	2,716
Total Liabilities	5,250	355	5,605	286	5,536
Net Worth	5,250		5,250		5,250
Total Liabilities and Net Worth	10,500	355	10,855	286	10,786

Table 174. BALANCE SHEET FOR NEW PORT TERMINAL
(1972)

	Without Controls ($000)	Case 1 - Best Controls		Case 2 - Alternate Controls	
		Control Costs ($000)	With Controls ($000)	Control Costs ($000)	With Controls ($000)
Assets					
Current	4,270		4,270		4,270
Fixed	15,000	445	15,445	355	15,355
Other	730		730		730
Total Assets	20,000		20,445		20,355
Liabilities					
Current	3,010		3,010		3,010
Deferred	6,990	445	7,435	355	7,345
Total Liabilities	10,000	445	10,445	355	10,355
Net Worth	10,000		10,000		10,000
Total Liabilities and Net Worth	20,000	445	20,445	355	20,355

Construction Cost Per Bushel of Capacity

	Without Controls ($/bu)	With Controls ($/bu)	Increase ($/bu)	(%)
Country elevators:				
Case 1 - Best controls	1.15	1.34	0.19	16.4
Case 2 - Alternate controls	1.15	1.31	0.16	14.0
Inland terminals:				
Case 1 - Best controls	1.20	1.27	0.07	5.9
Case 2 - Alternate controls	1.20	1.26	0.06	4.8
Port terminal:				
Case 1 - Best controls	3.00	3.09	0.09	3.0
Case 2 - Alternate controls	3.00	3.07	0.07	2.4

The financial impacts of the pollution control costs as applied to the model plants are summarized in Table 175.

The Economic Research Service, as part of their annual survey of grain elevators, has provided data[4/] on the investment and operating costs for total dust-control programs for 37 terminal elevators. Included was information for relatively new facilities as well as facilities which are 30 to 50 years old. In most cases, the data reflect a total dust-control program; however, the equipment is not necessarily the "best" control which is specified in the model plants. A comparison between the ERS and model plant data developed in this study is provided in Table 176.

For both the inland and port terminal, the investment and annual operating costs in the ERS survey are lower than the costs of new model plants using best controls (Case 1) and higher than the costs using the alternate control system (Case 2).

Application of Controls to Existing Elevators

In assessing economic impact of air pollution control we have used the concept of "model plants" to represent the construction and operation of new establishments. However, the cost and corresponding impacts for similarly equipping an existing facility with control equipment also needs to be determined. The total economic impact on grain elevators will be

Table 175. ECONOMIC IMPACT OF CONTROLS APPLIED TO NEW MODEL ELEVATORS

	Country Elevator		Inland Terminal		Port Terminal	
	Case 1a/	Case 2b/	Case 1a/	Case 2b/	Case 1a/	Case 2b/
Control Investment	$94,040	$80,262	$354,720	$286,030	$444,830	$355,140
Percent of Plant and Equipment	16.4%	14.0%	5.9%	4.8%	3.0%	2.4%
Per Bushel Capacity	18.8¢	16.1¢	7.1¢	5.7¢	8.9¢	7.1¢
Per Bushel Handled	9.4¢	8.0¢	2.4¢	1.9¢	1.1¢	0.89¢
Annual Control Operating Costs	$17,642	$14,623	$ 75,238	$ 57,238	$ 96,209	$ 71,490
Percent of Net Worth	3.4%	2.8%	1.4%	1.1%	0.96%	0.71%
Percent of Total Assets	1.7%	1.4%	0.72%	0.55%	0.48%	0.18%
Per Bushel Capacity	3.5¢	2.9¢	1.5¢	1.1¢	1.9¢	1.4¢
Per Bushel Handled	1.8¢	1.5¢	0.50¢	0.38¢	0.24¢	0.48¢

a/ Control Equipment for Case 1 is predominately fabric filter.
b/ Control Equipment for Case 2 is predominately cyclones.

Table 176. COMPARISON BETWEEN MODEL PLANTS AND ERS SURVEY ON IMPACT OF CONTROL COSTS (GRAIN ELEVATORS)

	Inland Terminal			Port Terminal		
	Model Plant			Model Plant		
	Case 1 (¢)	Case 2 (¢)	ERS Survey (¢)	Case 1 (¢)	Case 2 (¢)	ERS Survey (¢)
Total Investment						
Per Bushel of Storage Capacity	7.09	5.72	5.10	8.90	7.10	8.53
Per Bushel of Grain Handled	2.36	1.91	1.71	1.11	0.89	0.92
Annual Operating Cost						
Per Bushel of Storage Capacity	1.50	1.14	1.21	1.92	1.43	2.00
Per Bushel of Grain Handled	0.50	0.38	0.41	0.24	0.18	0.22

significantly different if control regulations are applied to existing facilities rather than only to new facilities. To evaluate the impact for both cases, we have estimated the control costs which would result from installing the best control equipment on an average existing facility and have extended the results to determine the total impact on all elevators.

The major assumptions and estimations which were made in determining the impact on existing facilities are listed below.

1. The size and type of pollution control equipment required for each type of elevator--country, inland terminal and port terminal--will be the same regardless of elevator size. This estimation is based on the fact that the control equipment required for an elevator is primarily dependent upon the basic operations which are performed by the elevator rather than upon its size or volume. Also, the available facilities and operations performed by the model plants represent an average country elevator, inland and port terminal. Some existing elevators will have more facilities than the model plants and will require additional controls while others will have less.

2. The cost to install the control equipment on existing plants is 130% of the cost required for a new plant if the existing plant currently has no controls. The cost to install "best" control equipment is 110% of the new plant cost if the existing plant has cyclones. The increased costs to existing facilities reflects the fact that the retrofitting of ducting and equipment would increase the installation charges. No cost is required if the elevator already is equipped with adequate control equipment.

For each of the three types of elevators, the percent of control on each operation is given in Tables 177, 178 and 179. The percentages were obtained from the emission inventory survey which was conducted as part of this project. The average percent of existing controls on the receiving, shipping and handling operations is 26.4% for country elevators, 44.3% for inland terminals and 52.9% for port terminals.

A summary of the costs and control credits resulting from the installation of best control equipment on the average existing elevators is presented in Table 180.

The investment required on the country elevator for best available controls is $117,000--24% greater than for the new model plant. The investment required for alternate controls is $84,000 or 28% less than for best controls.

Table 177. COUNTRY ELEVATOR
POLLUTION CONTROLS OF EXISTING PLANTS
SURVEY OF 324 PLANTS, 1972-73

Operation	Total Volume Per Yr (000 bu)	Number of Plants	Cyclone % Control[a]	Cyclone Number of Plants	Fabric Filters % Control	Fabric Filters Number of Plants	Other Devices % Control	Other Devices Number of Plants	Total % With Control
Receiving	422,823	324	29.65	70			1.02	7	30.7
Shipping	397,424	324	21.29	61			0.47	6	21.8
Drying	107,260	237	18.06	33	1.40	1	6.37	17	25.8
Cleaning	65,562	164	59.95	86			13.38	24	73.3
Transfer	418,975	324	26.67	61			0.45	6	27.1
Garner and Scale	416,143	324	26.30	65			0.60	7	26.9
Legs	422,823	324	57.74	148			1.12	11	58.9

a/ Percent Control is the percentage of the total quantity for the operation which is controlled by the specific device.

Table 178. TERMINAL INLAND ELEVATORS
POLLUTION CONTROLS OF EXISTING PLANTS
SURVEY OF 196 PLANTS, 1972-73

Operation	Total Volume Per Yr (000 bu)	Number of Plants	Cyclone		Fabric Filters		Other Devices		Total % With Control
			% Control[a/]	Number of Plants	% Control	Number of Plants	% Control	Number of Plants	
Receiving	835,959	196	39.37	50	19.32	12			58.7
Shipping	773,139	196	12.08	21	17.15	5	1.04	1	30.3
Drying	79,906	174	19.57	13	4.62	3		1	24.2
Cleaning	184,732	184	33.26	47	9.74	5		2	43.0
Transfer	841,298	196	64.23	67	27.36	11			91.6
Garner and Scale	833,940	196	17.16	36	7.41	8			24.6
Legs	841,298	196	53.23	63	24.10	14	0.31	1	77.6
Tripper	820,356	196	13.52	29	8.49	8			22.0

a/ Percent Control is the percentage of the total quantity for the operation which is controlled by the specific device.

Table 179. TERMINAL PORT ELEVATORS
POLLUTION CONTROLS OF EXISTING PLANTS
SURVEY OF 12 PLANTS, 1972-73

Operation	Total Volume Per Yr (000 bu)	Number of Plants	Cyclone % Control[a]	Cyclone Number of Plants	Fabric Filters % Control	Fabric Filters Number of Plants	Other Devices % Control	Other Devices Number of Plants	Total % With Control
Receiving	429,409	12	30.11	6	45.77	4	0	0	75.88
Shipping	426,440	12	25.78	4	0		0	0	25.78
Drying	4,274	2	52.04	1	0		0	0	52.04
Cleaning	62,666	10	22.27	6	15.02	2	0	0	37.29
Transfer	429,409	11	54.57	8	27.53	3	0	0	82.1
Garner and Scale	429,409	7	22.51	5	40.90	3	0	0	63.41
Legs	429,409	7	22.51	4	40.90	3	0	0	63.41
Tripper	368,164	9	56.30	6	0.99	1	0	0	57.29

a/ Percent Control is the percentage of the total quantity for the operation which is controlled by the specific device.

Table 180. COSTS AND CONTROL CREDITS FOR CONTROLS APPLIED TO AVERAGE EXISTING ELEVATOR

	Country Elevator		Inland Terminal		Port Terminal	
	Case 1	Case 2	Case 1	Case 2	Case 1	Case 2
Total Investment for Control	$116,964	$84,380	$367,936	$276,597	$420,273	$152,830
Annual Control Cost						
Variable Expenses	3,535	2,113	22,030	10,722	29,485	4,865
Fixed Expenses	17,545	12,657	55,190	41,490	63,041	22,925
Total Control Cost	$21,080	$14,770	$77,220	$52,212	$92,526	$27,790
Control Credit						
Recovery--1 lb/ton	$ 91	$ 91	$ 1,115	$ 1,115	$ 2,968	$ 2,968
5 lb/ton	$ 457	$ 457	$ 5,575	$ 5,575	$14,842	$14,842
Annual Control Cost						
Per Bushel Cap. (¢)	5.00	3.50	2.42	1.64	1.54	0.56
Per Bushel Handled (¢)	2.55	1.79	1.74	1.17	0.22	0.07
Net Control Costs						
Per Bushel Handled						
Recovery--1 lb/ton	2.54	1.78	1.71	1.15	0.21	0.06
5 lb/ton	2.49	1.73	1.61	1.05	0.18	0.03
Total Control Investment for Existing Plant as Percent of Control Investment for New Plant	124	105	104	97	94	34
Characteristics:						
Storage Capacity (000/bu)	422	422	3,178	3,178	5,529	5,529
Volume Handled (000/bu)	827	859	4,448	4,448	42,016	42,016
Extent of Existing Control (%) (Receiving, Shipping, Handling)a/	26.4	26.4	44.3	44.3	52.9	52.9

a/ Does not include drying operations.

The control credits are less than for the model country elevator because of the presence of existing controls and smaller volume of grain handled. The net annual control cost per bushel handled is 2.55¢ with no recovery and 2.49¢ with maximum control credit of 5 lb/ton.

The investment of $368,000 for best available controls on an average existing inland terminal is 4% greater than required for a new plant. Alternate controls on existing inland terminals require investment of $277,000--25% less than best controls.

For existing port terminals, the average investment in best available controls is $420,000. Alternate controls would require an investment of $153,000 which is 64% less than required for best controls.

The impact associated with the average existing plants were expanded to include all country elevators, inland and port terminals. The resulting total economic impact of pollution control on the industry is summarized in Table 181. The numbers of elevators registered under the Uniform Grain Storage Agreement--7,147 country elevators, 413 inland terminals and 64 port terminals--were used to arrive at the total impact figures. Since not all elevators are registered, the total impact is somewhat understated, particularly for country elevators.

The total investment for the best available control equipment as shown in Table 181 is $1,015 million. Because of their large numbers, the country elevators required 836 million or 82% of the total. The total investment in alternate controls is 28% less than for best controls.

The annual control cost of best controls for the industry is $188 million. The installation of alternate controls reduces the annual control cost by 32% to $129 million.

Economic Impact on New Plants

If the air pollution control requirements were applied only to new grain elevators, then the total economic impact would be minimal, simply because there are few new elevators being built. A small number of country elevators have been built during the past few years in the corn belt and in the Southeast. In addition, a few port terminals have recently been built or are under construction. However, according to industry sources, there is sufficient, and in some places, excess capacity at the present time and few off-farm elevators will be constructed in the near future.

Table 181. TOTAL ECONOMIC IMPACT IF APPLIED TO ALL EXISTING ELEVATORS

	Annual Control Cost		Total Investment	
	Case 1 (000)	Case 2 (000)	Case 1 (000)	Case 2 (000)
Country elevators	$150,659	$105,561	$835,942	$603,064
Inland terminals	31,892	21,564	151,958	114,235
Port terminals	5,922	1,779	26,897	9,781
Total	$188,473	$128,976	$1,014,797	$727,080

From an analysis of the model plant financial statements, it would appear that the installation of control equipment on inland and port terminals will have an impact. However, the investment and annual costs for the specified control systems will not significantly affect the operations or profitability of a new terminal elevator.

The impact of control requirements on new country elevators will be greater than for terminals. If control requirements are applied only to new elevators, then the additional costs will generally have to be absorbed by the country elevator because of the competition from existing facilities.

Clearly, the economics of scale for elevators will change. The investment in control equipment remains basically the same for a country elevator of 200,000 bu storage capacity as for one of 700,000 bu. For the 500,000 bu model plant, the investment in best-control equipment was 14.1% of the total construction cost of a 200,000-bu elevator. As a result of pollution control regulations, large elevators will tend to be more economical than smaller ones.

Because of the investment required for control equipment and the increase in economies of scale, the capital required to build and operate a country elevator will be significantly greater than in the past. As a result, the smaller independent firm will be less likely to have the necessary capital to build new elevators. The existing trend toward ownership by cooperatives and integrated corporations will be increased.

Impact on Existing Facilities

The economic impact resulting from the application of air pollution control regulations to existing grain elevators will be much greater than if regulations are applied only to new plants. By far the greatest impact will be to existing country elevators. The impact on inland and port terminals, although less than country elevators, will still be significant.

Impact on Earnings - For the average country elevator the annual cost of the best available pollution control is 2.55¢/bu handled and the net control cost using maximum recovery credit is 2.47¢. This compares with the present average net margin of 2.82¢/bu. An 87% reduction in net income would occur if the control costs were absorbed by the country elevator. Since the profitability of country elevators is already low, these costs must be passed on to the consumer or back to the farmer. Historically, most cost increases in the grain distribution system have been passed forward, as in the case of increased transportation expenses. It is expected that pollution control costs will also be passed on to the consumer; however, because of the constant fluctuation in grain prices, it is possible that some of the increase could be passed back to the farmer.

The small country elevator which handles less than 500,000 bu/year will be even more severely effected than the average or larger country elevators. This impact can be illustrated by the fact that an existing small elevator even without a dryer would still require an investment of $96,300 for best-control equipment and corresponding annual operating costs of $17,100. If the elevator handles 200,000 bu annually, the control costs are equivalent to 8.55¢/bu. This compares with 2.55¢/bu cost for an elevator which handles 1 million bushels annually, a difference of 6¢/bu. Because of the competition which exists, some of these small elevators will have to absorb most of this difference in order to remain competitive and maintain their volume. However, with an existing average net margin of only 2.8¢, they will not be able to absorb 6¢/bu additional costs and remain profitable. A number of small elevators will be forced out of business if the best available control equipment were applied to all emission points.

Requirements for the installation of the cyclone-based control system (Case 2) on existing country elevators will still have a significant economic impact; however, the impact will be less than for best controls. For an average existing elevator, the installation of the alternate controls will require an investment cost of $84,000 which is 28% less than the investment required for best controls.

For the average inland terminal, the annual cost of the best available pollution control equipment using maximum recovery credit is 1.61¢/bu handled. Since the average net income per bushel is around 1.60¢, the control costs cannot be absorbed and will most likely be passed on to the grain consumer. As is the case with country elevators, the pollution control costs per bushel will be greater for the smaller inland terminals. Since some of the inland terminals are marginally profitable or even unprofitable at the present time, it is possible that a number of terminals could go out of business rather than install $368,000 worth of pollution control equipment.

The installation of the alternate control system (Case 2) on an average existing inland terminal would require an investment of $277,000, which is 25% less than for best controls. The annual operating costs for the alternate control system is 1.17¢/bu handled or 33% less than for best controls.

The economic impact of the best-available pollution control equipment on port terminals will not be as great as for inland terminals. For the average existing port terminal, the annual cost of best-available controls is 0.18¢/bu if maximum control credits are used. This compares to an average net income per bushel without controls of around 1.25¢.

The impact of the alternate control system on existing port terminals would be minimal. The installation cost for alternate controls would be \$153,000 or 64% less than for best controls, and the annual costs would be 0.07¢/bu handled or 70% less than for best controls. The impact of installing alternate controls on existing port terminals is significantly less than for best controls, primarily because many of the port terminals already are equipped with control equipment adequate to meet the specification.

In either case, the port terminals are in a position to pass the increased costs on rather than absorb them.

Demand Elasticity - Country and terminal elevators have historically been an integral part of the nation's grain distribution system. As such, demand for their services as a group will be relatively inelastic with regard to price. Elevators should be able to shift most of the average control costs into price increases without adversely affecting demand. However, there are a number of factors which will tend to reduce demand as prices increase.

First, because of competition, the demand for an individual elevator's services will be sensitive to price changes. Therefore, an elevator will not be able to pass on cost increases which are above the average per bushel costs for competing elevators without affecting demand.

Second, there is enough flexibility in the distribution system so that the demand for services from a particular type of elevator can be moderately changed. For example, it is possible that an increasing number of farmers will bypass the country elevator and deliver their grain directly to processors, subterminal or terminal elevators. The possibility that farmers can economically bypass the country elevator has increased as a result of additional on-farm storage facilities which have been constructed during the past decade.

Also, it is possible for the country elevator to bypass the inland terminal and ship grain directly to processors and port terminals. This capability will increase if country elevators become larger or if smaller elevators cooperate with each other to obtain train-load rates from the railroads.

A third factor contributing to demand elasticity is international competition. If the control costs are reflected in the price of grain, the relative competitive position of U.S. grain and grain products on the world market will be affected. The 3 to 4¢/bu increase in the price of grain resulting from pollution controls could reduce U.S. exports. The increase in price may not significantly affect grain exports during periods such as the past year, when world-wide demand exceeds available supplies.

However, during years when world supply exceeds demand, U.S. exports of grain may be affected by increased prices.

Effect on Industry Structure - The placement of control regulations on existing facilities will have a significant effect on industry structure. The number of independent firms will be reduced because of several factors. First, some of the small country elevators operated by these firms would not be profitable with the installation of control equipment. Second, the small firm may not be able to obtain the capital required to install control equipment. Because of the marginal profitability of existing facilities and the minimum salvage value of an elevator, many of the large commercial banks would not provide the necessary capital to a small country elevator.

Large integrated firms and farmer cooperatives will have less problems in obtaining capital. However, they may determine that an elevator will not be profitable with the investment required in control equipment, and as a result will close the elevator. A major problem which large firms may have, results from the fact that several terminal elevators are owned by second parties and leased to the operating company. The owners of these facilities may not be willing to invest in pollution control equipment, in which case the operating company may be forced to purchase the elevator as well as the control equipment in order to remain in operation. A few marginal terminal elevators could possibly be forced to close.

FEED MILL

Description of Model Plant

A schematic diagram of the model plant for a feed mill with best controls is presented in Figure 55. The processing capacity of the mill is assumed to be 200 tons/8-hr day or 50,000 tons/year. The model for the feed mill is patterned after a similarly sized unit described in Ref. 14. The specific processes shown in Figure 55 are not meant to fit any specific feed mill. Individual feed mills may vary both in processing steps and operating characteristics. In addition, the size of feed mills covers a wide spectrum, from under 1,000 tons/year production to over 100,000 tons/year, and operations vary with size. Accurate representation of the multitude of feed mill sizes and configurations would require an extensive series of models. Such a detailed study of one segment of the grain and feed industry was deemed inappropriate in this program.

FEED MILL

Basis:

a. Plant capacity 200 T/8 hr day -- 50,000 T/yr
b. Storage capacity, 1,650 T
c. Receive by truck & rail
d. Ship by truck
e. Product mix -- 60% pellets, 40% mash

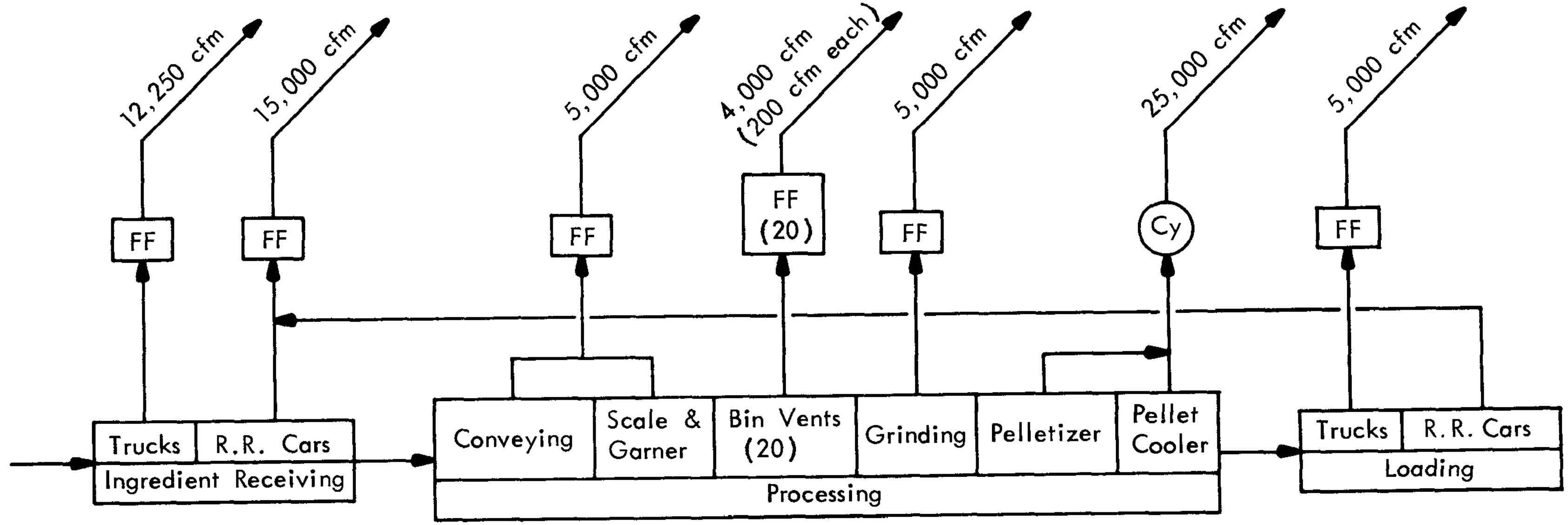


Figure 55. Model feed mill--best controls.

Control Equipment Costs

A summary of two alternative control equipment configurations and associated costs required for the model feed mill is presented in Tables 182 and 183. The control equipment in Case 1, which consists of fabric filters for all grain-handling operations, is the "best" demonstrated control system currently available. Case 2, which specifies cyclones for the grain-handling operations, generally reflects the current industry practice for feed mills which have installed pollution control equipment. Estimates are given for the investment cost for control devices for each operation, as well as estimates for the total annual cost, including electrical charges, maintenance expenses, depreciation expenses and capital charges.

The operational hours per year were estimated from an analysis of (1) the operational requirements and capacities of each device, and (2) the volume of material which would be processed by each operation. Assumptions regarding electrical, maintenance, depreciation and capital costs were discussed in the introduction to this chapter.

A summary of the investment and annual operating costs required for both pollution control equipment alternatives is as follows:

	Pollution Control and Product Recovery Equipment	
Primary Device	Total Annualized Cost ($/year)	Total Installed Cost ($)
Case 1 - (Fabric filters)	44,035	196,370
Case 2 - (Cyclones)	35,609	158,680

If the grinding operation uses air for product transfer, then the selected control device listed in the model plant for this operation actually functions as a product recovery device rather than as a pollution control device. In this alternative, the estimated investment and operating costs for pollution control equipment are as follows:

	Pollution Control Equipment Only	
Primary Device	Total Annualized Cost ($/year)	Total Installed Cost ($)
Case 1 - (Fabric filters)	40,255	181,570
Case 2 - (Cyclones)	33,197	149,880

Table 182. MODEL PLANT FOR NEW FEED MILLS

Case 1 - Best Controls

Operation	Selected Device	Air Flow CFM	Oprn. Hr/Year	Electrical $/Year (Model Plant Control and Cost Estimate)	Maintenance $/Year	Depreciation $/Year	Capital Charges $/Year	Annualized Cost $/Year	Installed Cost $
Truck Receiving[a/]	Filter	12,250	250	120	1,230	3,564	1,782	6,696	35,640[a/]
Railroad Car Receiving and Loadout[b/]	Filter	15,000	1,000	640	1,500	3,662	1,831	7,633	36,620[b/]
Grinding	Filter	5,000	2,000	1,060	500	1,480	740	3,780	14,800
Scale, Garner and Conveying	Filter	5,000	2,000	1,270	500	2,020	1,010	4,800	20,200
Bin Filters (20)	Filter Socks	20 x 200	-	-	400	3,190	1,595	5,185	31,900
Pellet Machine and Pellet Cooler	Cyclone	25,000	2,000	4,200	2,500	3,031	1,515	11,246	30,310
Truck Loadout[c/]	Filter	5,000	500	160	500	2,690	1,345	4,695	26,900[c/]
Total				7,450	7,130	19,637	9,818	44,035	196,370

a/ Includes cost of truck receiving shed - $10,350.
b/ Includes cost of RR car shed - $24,260.
c/ Includes cost of truck loading shed - $10,350.

Storage Capacity - 1,650 tons
Plant Capacity - 200 tons/8 hr day
(50,000 tons/year)

Table 183. MODEL PLANT FOR NEW FEED MILLS

Case 2 - Alternate Controls

	Model Plant Control and Cost Estimates								
Operation	Selected Device	Air Flow CFM	Oprn. Hr/Year	Electrical $/Year	Maintenance $/Year	Depreciation $/Year	Capital Charges $/Year	Annualized Cost $/Year	Installed Cost $
Truck Receiving[a/]	Cyclone	12,250	250	96	613	2,645	1,323	4,677	26,450
Railroad Car Receiving and Loadout[b/]	Cyclone	15,000	1,000	512	750	2,612	1,306	5,180	26,120
Grinding	Cyclone	5,000	2,000	848	250	880	440	2,418	8,800
Seale, Garner and Conveying	Cyclone	5,000	2,000	1,016	250	1,420	710	3,396	14,200
Bin Filters (20)	Filter Socks	20 x 200	--	--	400	3,190	1,595	5,185	31,900
Pellet Machine and Pellet Cooler	Cyclone	25,000	2,000	4,200	2,500	3,031	1,515	11,246	30,310
Truck Loadout[c/]	Cyclone	5,000	500	128	250	2,090	1,045	3,513	20,900
Total				6,800	5,013	15,868	7,934	35,615	158,680

a/ Includes cost of truck receiving shed - $10,350
b/ Includes cost of RR car shed - $24,260
c/ Includes cost of truck loading shed - $10,350

Storage Capacity - 1,650
Plant Capacity - 200 tons/8 hr day
(50,000 tons/year)

Credits for Dust Control

The wide range of materials received, conveyed, and processed at a feed mill make it difficult to determine control equipment credits or positive impacts which could result from the installation of high-efficiency pollution control equipment. Lack of emission factor data for feed mill processes also hinders such determinations. In addition, cross-contamination of materials is avoided in feed mill operations and, therefore, a significant portion of the recovered dust may have no real value unless the dust from different sources is segregated. For these reasons, no attempt was made to compute credits for dust control in feed mills.

Financial Statements

Income statements and balance sheets for the model feed mill are presented in Tables 184 and 185. Separate financial statements were developed for the operation of the model plant, both without and with the two alternative pollution control systems. These statements were compared to determine the impact of the control equipment on the financial condition of new plants.

The financial statements were developed using information from the 1970 Annual Survey of Manufacturers,[15] 1967 Census of Manufacturers,[16] USDA Economic Research Service Data,[17] the 1972 Annual Statement Studies by Robert Morris Associates,[8] and financial statements from various publicly owned feed manufacturing companies. The financial condition of feed manufacturing companies can vary significantly by company and over time; therefore, the statements presented here should be considered as examples which reflect general financial conditions of the industry. Because of the unprecedented changes in grain and feed prices since the last half of 1972, the financial conditions of many feed companies have been significantly altered during the past year. In an attempt to reflect these changes, the income statements and balance sheets were developed using the grain and feed prices during the first quarter of 1973.

Average price of poultry and livestock feed in 1970 was \$90/ton according to data from the 1970 Annual Survey of Manufacturers. However, by April of 1973, feed prices had almost doubled and the prices were still increasing. In developing the income statement, it was assumed that the price of feed was \$178/ton and the average price of ingredients was \$149.50/ton. These estimates were obtained by proportionally increasing the average sales and cost of materials prices from the 1970 Annual Survey of Manufacturers[15] to reflect commodity prices during the first quarter of 1973.

Table 184. INCOME STATEMENT FOR NEW MODEL FEED MILL (1973)[a/]

	Without Controls		Case 1 - Best Controls			Case 2 - Alternate Controls		
			Control Costs	With Controls		Control Costs	With Controls	
	Dollars	Percent	(Dollars)	Dollars	Percent	(Dollars)	Dollars	Percent
Sales								
50,000 Tons at $178/Ton	8,900,000	100.0		8,900,000	100.0		8,900,000	100.0
Cost of Materials	7,473,600	84.0		7,473,600	84.0		7,473,600	84.0
Wages and Benefits	265,000	3.0		265,000	3.0		265,000	3.0
Cost of Goods Sold	7,738,600	87.0		7,738,600	87.0		7,738,600	87.0
Gross Income	1,161,400	13.0		1,161,400	13.0		1,161,400	13.0
Expenses								
Administration	149,000	1.7		149,000	1.7		149,000	1.7
Selling and Delivery	276,000	3.1		276,000	3.1		276,000	3.1
Other Expenses	372,000	4.2	14,600	386,600	4.3	11,800	383,800	4.3
Depreciation	68,900	0.8	19,600	88,500	1.0	15,900	84,800	1.0
Interest	84,500	0.9	9,800	94,300	1.1	7,900	92,400	1.0
Total Operating Expenses	950,400	10.7	44,000	994,400	11.2	35,600	986,000	11.1
Net Income Before Taxes	211,000	2.4		167,000	1.9		175,400	2.0
Net Income/Ton Production	$4.22			$3.34			$3.51	
% Net Income/Net Worth	12.1%			9.6%			10.1%	
% Net Income/Total Assets	6.1%			4.6%			4.8%	

a/ Based on price levels during 1st quarter 1973.

Table 185. BALANCE SHEET FOR NEW MODEL FEED MILL (1973)[a]

	Without Controls		Case 1 - Best Controls			Case 2 - Alternate Controls		
			Control Costs	With Controls		Control Costs	With Controls	
	Dollars	Percent	(Dollars)	Dollars	Percent	(Dollars)	Dollars	Percent
Assets								
Current Assets								
Receivables Net	1,165,900	33.7		1,165,900	31.9		1,165,900	31.9
Inventory	858,400	24.8		858,400	23.5		858,400	23.5
Other Current Assets	110,000	3.2		110,000	3.0		110,000	3.0
Total Current Assets	2,134,300	61.7		2,134,300	58.3		2,134,300	58.3
Fixed Assets								
Structure and Building	752,300	21.7		752,300	20.6		752,300	20.0
Machinery and Equipment	418,900	12.1	196,400	615,300	16.8	158,700	577,600	16.0
Other Fixed Assets	156,200	4.5		156,200	4.3		156,200	4.3
Total Fixed Assets	1,327,400	38.3	196,400	1,523,800	41.7	158,700	1,486,100	41.0
Total Assets	3,461,700	100.0	196,400	3,658,100	100.0	158,700	3,620,400	100.0
Liabilities								
Current Liabilities								
Accounts Payable	436,200	12.6		436,200	11.9		436,200	11.9
Short-Term Notes	588,500	17.0		588,500	16.1		588,500	16.1
Other Current Liabilities	193,800	5.6		193,800	5.3		193,800	5.3
Total Current Liabilities	1,218,500	35.2		1,218,500	33.3		1,218,500	33.3
Long-Term Debt	498,500	14.4	196,400	694,900	19.0	158,700	657,200	18.2
Total Liabilities	1,717,000	49.6	196,400	1,913,400	52.3	158,700	1,875,700	51.8
Net Worth	1,744,700	50.4		1,744,700	47.7		1,744,700	47.7
Total Liabilities and Net Worth	3,461,700	100.0	196,400	3,658,100	100.0	158,700	3,620,400	100.0

a/ Based on price levels during 1st quarter 1973.

Economic Impact of Control Systems on Industry

New Plants - Separate analyses were made to determine the impact of pollution control equipment on the model feed mill for: (1) pollution control and product recovery equipment, and (2) pollution control equipment only. In the latter case, the control device for the grinding operation was not considered as control equipment.

As shown in Table 184, the net income before taxes per ton of production with and without pollution control equipment is as follows:

	Pollution Control and Product Recovery Equipment			
	Net Income Without Controls	Net Income With Controls	Reduction	
Primary Device	($/ton)	($/ton)	($/ton)	(%)
Case 1 - (Fabric filters)	4.22	3.34	0.88	20.9
Case 2 - (Cyclones)	4.22	3.51	0.71	16.8

If the control device on the grinder is considered to be a product recovery system rather than a pollution control device, then the impact of pollution control regulations on net income before taxes is as follows:

	Pollution Control Equipment Only			
	Net Income Without Controls	Net Income With Controls	Reduction	
Primary Device	($/ton)	($/ton)	($/ton)	(%)
Case 1 - (Fabric filters)	4.14	3.34	0.80	19.3
Case 2 - (Cyclones)	4.17	3.51	0.66	15.8

The installation of fabric filter control equipment could reduce the profitability of the model plant by 19 to 21%, while the installation of cyclones could reduce profitability by 16 to 17%.

The balance sheets in Table 185 show the financial position of the model plant without and with pollution control equipment for both control systems. The impact on a new model plant of the investment in control and recovery equipment on the construction cost per ton of yearly capacity is as follows:

	Pollution Control and Product Recovery Equipment			
Primary Device	Plant Investment Costs Without Controls ($/ton)	Plant Investment Costs With Controls ($/ton)	Increase ($/ton)	Increase (%)
Case 1 - (Fabric filters)	23.40	27.35	3.95	16.8
Case 2 - (Cyclones)	23.40	26.60	3.20	13.6

If the control device on the grinder is considered to be a product recovery system rather than a pollution control device, the impact of the investment in control equipment is as follows:

	Pollution Control Equipment Only			
Primary Device	Plant Investment Costs Without Controls ($/ton)	Plant Investment Costs With Controls ($/ton)	Increase ($/ton)	Increase (%)
Case 1 - (Fabric filters)	23.70	27.35	3.65	15.4
Case 2 - (Cyclones)	23.60	26.60	3.00	12.7

In Table 186 the control investment and annual operating costs for each alternative are compared to standard operational and financial statistics for the model plant.

From an analysis of these data it would appear that the costs associated with the installation of pollution control equipment will not have a significant impact on new plants in the size range of 200 tons/day and above.

Table 186. CONTROLS APPLIED TO NEW MODEL PLANT FOR FEED MILL

	Pollution Control and Product Recovery Equipment		Pollution Control Equipment Only	
	Case 1 (fabric filter) 1973	Case 2 (cyclone) 1973	Case 1 (fabric filter) 1973	Case 2 (cyclone) 1973
Control Investment	$196,370	$158,680	$181,570	$149,880
Percent of Original Plant and Equipment	16.8%	13.6%	15.3%	12.7%
Percent of Dollar Sales	2.21%	1.78%	2.04%	1.68%
Per Ton of Feed Production	$3.93	$3.17	$3.63	$3.00
Annual Control Operation Costs	$ 44,035	$ 35,615	$ 40,255	$ 33,197
Percent of Net Worth	2.52%	2.04%	2.31%	1.90%
Percent of Total Assets	1.20%	1.03%	1.10%	0.96%
Percent of Dollar Sales	0.49%	0.40%	0.45%	0.37%
Per Ton of Feed Production	$0.881	$0.712	$0.805	$0.663

However, the investment required for control equipment does not decrease proportionally to decreases in plant capacity. An estimation of the effect of annual costs for "best" pollution control as a function of plant size is shown in Table 187. The annual cost per ton of feed production increases from 88¢ for a 200 ton/day plant to $5.40 for a 50 ton/day plant. Considering that the net income before taxes for the model plant was only $4.22/ton, the additional cost of $5.40/ton would make the 50 ton/day plant unprofitable. Clearly, regulations requiring the installation of control equipment on all new plants will significantly change the economics of scale for feed mills. The small automated plants which have been built in recent years near large feed lots will not be as economical as they are now.

Existing Plants - To determine the economic impact of equipping existing feed mills with the pollution control systems specified for the model feed mill, the extent to which existing plants are already equipped with control systems must be defined. Table 188 summarizes the current status of air pollution control on feed mills as determined from emission inventory questionnaires received from individual mills. Using the data in Table 188 as a guide, the capital investment and annual costs for control systems for existing mills shown in Table 189 were developed for feed mills with a yearly production of 1,000 tons or more.

The major assumptions and estimations which were made in determining the costs for existing feed mills are as follows:

1. The pollution control equipment for the receiving, handling and loading operations will be the same regardless of the plant size. The control equipment for these operations is primarily dependent upon the basic operations which are performed rather than the size of the plant or the volume of grain and feed handled. The equipment for the bin filters and the pellet machine and cooler will vary directly with the size of plant.

2. The cost to install the control equipment on an existing plant which does not have pollution controls is 125% of the cost required for a new plant. The increased costs reflect the fact that additional installation charges will be incurred on an existing or older plant. Existing plants which already have the specified or better control equipment on specific operations will not incur any additional costs.

3. To determine the total cost to the industry, it was assumed that there are 7,917 feed mills as reported in the 1969 Economic Research Service Survey. The number of plants with various types of operations in truck receiving, railroad receiving, truck and railroad load, was also obtained from the EPS Survey and used in the calculation of impact to existing plants.

Table 187. VARIATION IN CONTROL COSTS BY SIZE OF PLANT (FEED MILLS)

Case 1 - Best Controls

Size of Feed Mill (ton/day)	Annual Control Cost per ton of Feed Production ($)	% of Dollars Sales	
		1970 Prices	1973 Prices
200	0.88	0.98	0.49
80	2.69	3.02	1.51
50	5.40	6.06	3.03

Table 188. AIR POLLUTION CONTROLS ON EXISTING FEED MILLS (SURVEY OF 402 PLANTS - 1972-1973)

	Total Volume (1,000 bu/year)	Percent of Volume Controlled by				Percent Without Control
		Cyclone	Fabric Filter	Other	Total With Control	
Receiving[a]						
Cars	6,982	13.8	21.8	0.2	35.1	64.9
Trucks	3,897	12.7	14.9	0.6	28.2	71.8
Shipping (bulk)[a]						
Cars	1,437	1.8	0	0	1.8	98.2
Trucks	7,310	5.2	0.1	0.1	5.4	94.6
Transfer Points[a]	11,092	16.1	15.9	0.2	32.3	67.7
Garner and Scale[a]	10,058	22.8	12.7	3.7	39.2	60.8
Legs[a]	11,305	20.1	13.7	2.7	36.5	63.5
Bin Vents[a]	11,172	13.8	9.3	4.3	27.4	72.6
Processing						
Grinding	11,191	40.9	14.0	1.4	56.3	43.7
Pellet Cooler	10,534	86.9	0	1.1	88.1	11.9

a/ Does not include bagged receipts of 92,000 bu/year.

Table 189. POLLUTION CONTROLS APPLIED TO EXISTING FEED MILLS

	Average Per Establishment		Total for Industry[a]	
	Case 1 (fabric filter)	Case 2 (cyclone)	Case 1 (fabric filter)	Case 2 (cyclone)
Investment for Control	$131,600	$85,000	$1,042,000,000	$673,000,000
Annual control costs	$25,900	$17,000	$205,000,000	$134,400,000
Annual control costs per ton of feed			$2.03	$1.33
Annual control cost as percent of sales[b]			1.14%	0.75%

a/ Establishments (7,917) producing 1,000 tons or more of formula feed per year.
b/ First quarter 1973 prices were used to obtain values.

For the average existing feed mill, the installation of "best" control equipment will require $131,600 investment and $25,900 annual operating costs. Annual control costs are estimated at about $2/ton of feed production for the industry or about 1.1% of sales at 1973 prices.

The installation of the cyclone rather than the fabric filter-based control system will reduce by 35% the required investment and annual control costs for the average existing plant. The impact of the cyclone system on existing plants is less because of its lower costs and because a greater number of existing plants already have cyclones.

The $1 billion investment and $200 million annual control costs required for the installation of "best" control on existing feed mills will clearly have a significant impact on the industry. Even the installation of cyclones will have a major impact. In either case, the impact will be greatest for small companies and small feed mills.

Demand Elasticity - The total demand for formula feed is closely tied to the demand for meat and other products from the livestock and poultry industries. Because of the relatively long lead time required to significantly alter the number of livestock or poultry requiring feed, the average increase in feed costs will probably be passed on to the customer. However, over the long run the demand for feed may be adversely effected by increases in price.

The 100% and greater increases in feed costs which have resulted from increased ingredient prices from 1972 to 1973 have for the most part been passed on to the feed customer. However, the poultry farms and feed lots can choose to reduce the amount of feed used and the number of poultry and livestock which require feed when a rise in feed prices does not coincide with an increase in the market price of meats. Complexity is compounded in that many feed manufacturers are integrated into the livestock and poultry business, effectively making the feed mill a captive operation. In any event, the average price increase of 1.1% required by the best pollution control is small in comparison to the increases in feed prices which have occurred during the past year.

Even though the average price increase for feed may be passed on, an individual plant which has control costs per unit of production higher than the industry average will in many cases have to absorb the additional costs to remain competitive with other feed mills. Unless the small feed mill has a captive customer or has significant transportation advantages, it will have to absorb most of its pollution control costs (see Table 187).

Effect on Industry Structure - Regulations requiring control equipment on all new and existing feed mills will have a major impact on industry structure. New feed mills, because of changes in economics of scale resulting from installation of control equipment, will be larger than most existing establishments. The increased capital requirements for a new plant will tend to limit the number of new mills which will be constructed by small companies.

The impact on existing facilities will be even greater than for new plants. Many of the small feed mills operated by nonintegrated companies will not be profitable with the installation of control equipment. In addition, the small firm will be less able to obtain the capital required to install control equipment than the large integrated firms and farmer cooperatives.

Of the 7,917 establishments producing 1,000 tons or more per year, 75% or 5,952 produce less than 10,000 tons/year or 40 tons/day. A number of these small plants would be forced to close if required to install pollution control equipment.

ALFALFA DEHYDRATING PLANT

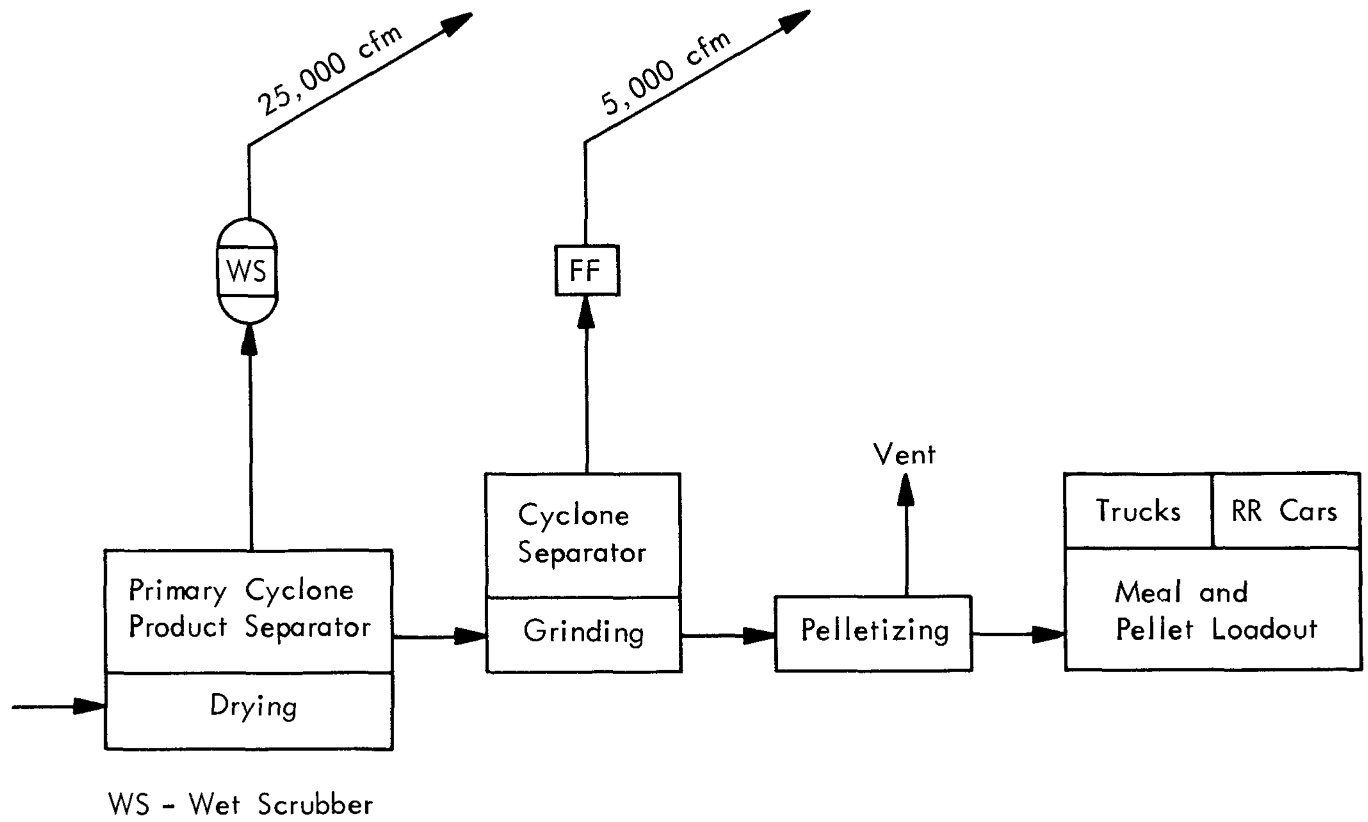
Description of Model Plant

Figure 56 presents the model selected for the alfalfa dehydrating plant. A plant which uses a wet scrubber for the dryer-cyclone operation and a fabric filter for the grinding operation was selected as being representative for a new facility in this segment of the grain and feed industry. An alternate model with a cyclone on the grinding operation is also analyzed. Plant capacity is 3.5 tons/hr of dry meal or pellets and the plant operates 2,400 hr/year to produce 8,400 tons of product.

Control Equipment Costs

A summary of two alternative control equipment configurations and associated costs for the model plant are presented in Table 190. Estimates are shown for the investment cost for the control device, as well as the total annual cost, including electrical charges, maintenance expenses, depreciation expenses, and capital charges.

Summarized below are investment costs and annual control operating costs for both alternatives:



Basis: Plant Capacity - 3.5 Tons/hr of dry meal or pellets
Operate - 2,400 hrs/yr

Figure 56. Model alfalfa dehydrating plant--best controls.

Table 190. NEW MODEL PLANT FOR ALFALFA DEHYDRATION

Case 1 - Best Controls

Model Plant Control and Cost Estimates

Operation	Selected Device	Air Flow (cfm)	Operation (hr/year)	Electrical ($/year)	Maintenance ($/year)	Depreciation ($/year)	Capital Charges ($/year)	Annualized Cost ($/year)	Installed Cost ($)
Dryer Cyclone	Wet Scrubber	25,000	2,400	1,700	850	4,000	2,000	8,550	40,000
Grinding	Fabric Fiber	5,000	2,400	1,300	500	1,480	740	4,020	14,800
				3,000	1,350	5,480	2,740	12,570	54,800

Case 2 - Alternate Controls

Model Plant Control and Cost Estimate

Operation	Selected Device	Air Flow (cfm)	Operation (hr/year)	Electrical ($/year)	Maintenance ($/year)	Depreciation ($/year)	Capital Charges ($/year)	Annualized Cost ($/year)	Installed Cost ($)
Dryer Cyclone	Wet Scrubber	25,000	2,400	1,700	850	4,000	2,000	8,550	40,000
Grinding	Cyclone	5,000	2,400	1,040	250	855	428	2,573	8,550
				2,740	1,100	4,855	2,428	11,123	48,550

Plant capacity - 3 tons/hr of meal or pellets.
Operate - 2,400 hr/year.

	Total Annual Control Costs ($)	Total Installed Cost ($)
Case 1 - Best controls	12,570	54,800
Case 2 - Alternate controls	11,123	48,550

The material recovered by the control device is assumed to have no value, and therefore, no credits result from the installation of the pollution control device.

Financial Statement

The financial statements developed for the model alfalfa dehydrating plant are for the processing plant only. Not included in the statements are the harvesting, hauling, and product storage equipment and operations. The financial statements were developed for the operation of the model plant, both without and with pollution control equipment.

The principal sources of information used to develop the financial statements were the USDA Economic Research Service Report MRR No. 881,[18/] and the USDA Farmer Cooperative Service, FCS Information 68.[19/]

A summary of the financial impact upon plant profitability shown in Table 191 is as follows:

	Pollution Control Equipment			
	Net Income Without Controls ($/ton)	Net Income With Controls ($/ton)	Reduction ($/ton)	Reduction (%)
Case 1 - Best controls	6.40	4.91	1.49	23.3
Case 2 - Alternate controls	6.40	5.08	1.32	20.7

Table 192 provides comparative balance sheet data. The affect of pollution control equipment upon new plant construction costs is presented below:

Table 191. INCOME STATEMENT FOR NEW MODEL ALFALFA DEHYDRATION PLANT
(1972)

	Without Controls		Case 1 - Best Controls				Case 2 - Alternate Controls			
			Controls		With Controls		Controls		With Controls	
	Dollars	Per Ton	Dollars	Per Ton	Dollars	Per Ton	Dollars	Per Ton	Dollars	Per Ton
Sales	420,000	50.00			420,000	50.00			420,000	50.00
Cost of Material	178,400	21.24			178,400	21.24			178,400	21.24
Gross Margin	241,600	28.76			241,600	28.76			241,600	28.76
Expenses Fixed										
Administrative	4,000	0.48			4,000	0.48			4,000	0.48
Salary (supervisor)	5,200	0.62			5,200	0.62			5,200	0.62
Depreciation[a/]	18,700	2.23	5,480	0.65	24,180	2.88	4,855	0.58	23,555	2.80
Insurance[b/]	3,100	0.37			3,100	0.37			3,100	0.37
Taxes[c/]	4,800	0.57			4,800	0.57			4,800	0.57
Interest[d/]	13,200	1.57	2,740	0.33	15,940	1.90	2,428	0.29	15,628	1.86
Total Fixed	49,000	5.83	8,220	0.98	57,220	6.81	7,283	0.87	12,183	1.45
Variable										
Labor	24,700	2.94			24,700	2.94			24,700	2.94
Utilities	46,200	5.50	3,000	0.36	49,200	5.86	2,740	0.33	48,940	5.83
Maintenance and Repair	15,800	1.88	1,350	0.16	17,150	2.04	1,100	0.13	16,900	2.01
Additive[e/]	4,900	0.58			4,900	0.58			4,900	0.58
Storage and Handling	10,600	1.26			10,600	1.26			10,600	1.26
Freight-Out	32,100	3.82			32,100	3.82			32,100	3.82
Brokerage and Commission	4,200	0.50			4,200	0.50			4,200	0.50
Advertising	300	0.03			300	0.03			300	0.03
Total Variable	138,800	16.51	4,350	0.52	143,150	17.04	3,840	0.46	142,640	16.98
Total Expenses	187,800	22.36	12,570	1.50	200,370	23.85	11,123	1.32	198,923	23.68
Net Income Before Taxes	53,800	6.40	-12,570	-1.50	41,230	4.91	-11,123	-1.32	42,677	5.08
% Net Income/Net Worth	12.0%				9.2%				9.5%	
% Net Income/Total Assets	6.0%				4.6%				4.8%	

a/ Depreciation; straight line method: equipment 15 years; bins and tanks 20 years; building 25 years.
b/ Insurance: $1.00 per $100 initial investment.
c/ Taxes: 1-1/2% initial investment.
d/ Interest: 8% on one-half average investment.
e/ Additive: Cost of antioxidant.

Table 192. BALANCE SHEET FOR NEW MODEL ALFALFA DEHYDRATION PLANT (1972)

	Without Controls		Case 1 - Best Controls			Case 2 - Alternate Controls		
			Control Costs	With Controls		Control Costs	With Controls	
	Dollars	Percent	(Dollars)	Dollars	Percent	(Dollars)	Dollars	Percent
Assets								
Current Assets	538,100	60.0		538,100	56.5		538,100	56.9
Fixed Assets								
Plant and Equipment	309,400	34.5	54,800	364,200	38.3	48,550	357,950	37.9
Other Fixed Assets	49,300	5.5		49,300	5.2		49,300	5.2
Total Assets	896,800	100.0	54,800	951,600	100.0	48,550	945,350	100.0
Liabilities								
Current Liabilities	313,900	35.0		313,900	33.0		313,900	33.2
Long-Term Debt	134,500	15.0		134,500	14.1		134,500	14.2
Total Liabilities	448,400	50.0	54,800	503,200	52.9	48,550	496,950	52.6
Net Worth	448,400	50.0		448,400	47.1		448,400	47.4
Total Liabilities and Net Worth	896,800	100.0	54,800	951,600	100.0	48,550	945,350	100.0

	Pollution Control Equipment			
	Plant Investment Without Controls ($/ton)	Plant Investment With Controls ($/ton)	Increase	
			($/ton)	(%)
Case 1 - Best controls	36.80	43.40	6.60	17.9
Case 2 - Alternate controls	36.80	42.60	5.80	15.8

Case 1 pollution control equipment increases the new plant construction cost per ton 14% over Case 2 controls.

Economic Impact of Control Systems on Industry

New Plants - Table 193 presents a summary of the impact of pollution control equipment on the model plant. The capital investment for control equipment increases the investment in a new plant by 18% in Case 1 and 16% in Case 2. The annual operating costs for control equipment would reduce profitability as measured by net income after taxes by 23% in Case 1 and 19% in Case 2. The installation of control equipment will have an impact on new plants.

Existing Plants - The emission inventory questionnaires returned by individual alfalfa dehydrating plants indicated that none of the existing plants are equipped with the wet scrubber system selected as the "best" control equipment. Installation costs for existing plants will be somewhat higher than if the equipment were installed in a new plant. Cost also will vary, depending upon the existing plant's size and configuration.

Table 194 summarizes the estimated economic impact of equipping existing plants with the control devices. Annual control costs are estimated to be $1.69/ton (Case 1) and $1.50/ton (Case 2).

Demand Elasticity - Dehydrated alfalfa in meal or pellet form is used as an ingredient in mixed feed for livestock and poultry. Since it is in direct competition with a number of other major feed ingredients, the demand for dehydrated alfalfa is sensitive to price changes. If all other ingredient prices remained unchanged or were changed less than dehydrated alfalfa, the alfalfa dehydrating plants would have to absorb most of the increased costs resulting from the installation of pollution control equipment. If other types of plants--flour mills, soybean processing, feed

Table 193. ECONOMIC IMPACT OF CONTROLS APPLIED TO NEW MODEL ALFALFA DEHYDRATING PLANT

	Case 1	Case 2
Control Investment	$54,800	$48,550
Percent of plant and equipment	17.7%	15.7%
Percent of dollar sales	13.0%	11.6%
Per ton of meal	$6.52	$5.78
Annual Control Operating Costs	$12,570	$11,980
Percent of net worth	2.8%	2.7%
Percent of total assets	1.4%	1.3%
Percent of dollar sales	3.0%	2.8%
Per ton of meal	$1.50	$1.43

Table 194. CONTROLS APPLIED TO EXISTING ALFALFA DEHYDRATION PLANTS

	Average Per Establishment		Total for Industry[a/]	
	Case 1 ($)	Case 2 ($)	Case 1 ($)	Case 2 ($)
Investment for Control Equipment	42,640	37,780	12,792,000	11,333,000
Annual Control Costs	9,217	8,157	2,765,000	2,447,000
Annual Control Costs Per Ton of Meal			1.69	1.50

a/ Assumes 300 dehydrating plants with annual production, 1,634 thousand tons.

mills, etc.--which also supply feed ingredients were required to install pollution control equipment, the incremental dehydrated alfalfa prices would probably be passed on to the consumer.

Effect on Industry Structure - Regulations requiring the installation of "best" pollution control equipment on new and existing facilities would not have a significant impact on the economies of scale for alfalfa dehydrating plants. Since the cost of control equipment varies in relation to the plant size, the smaller dehydrating plants will still be competitive with larger plants. As a result, the installation of controls will not significantly affect the industry structure. However, the installation of controls will clearly have an affect on the industry. Some existing facilities which are currently operated by small companies with marginal profits may be forced to close.

WHEAT, RYE, AND DURUM MILLING

There is a great deal of similarity in the milling of wheat and rye. As a result, a single model plant, processing wheat to regular flour, will be used to assess the economics of pollution control for both of these milling plants. This simplification results in some sacrifices in detail for rye mills, but the assessment of total economic impact will not be affected significantly. A separate model is used for the durum mill.

Description of Model Plant

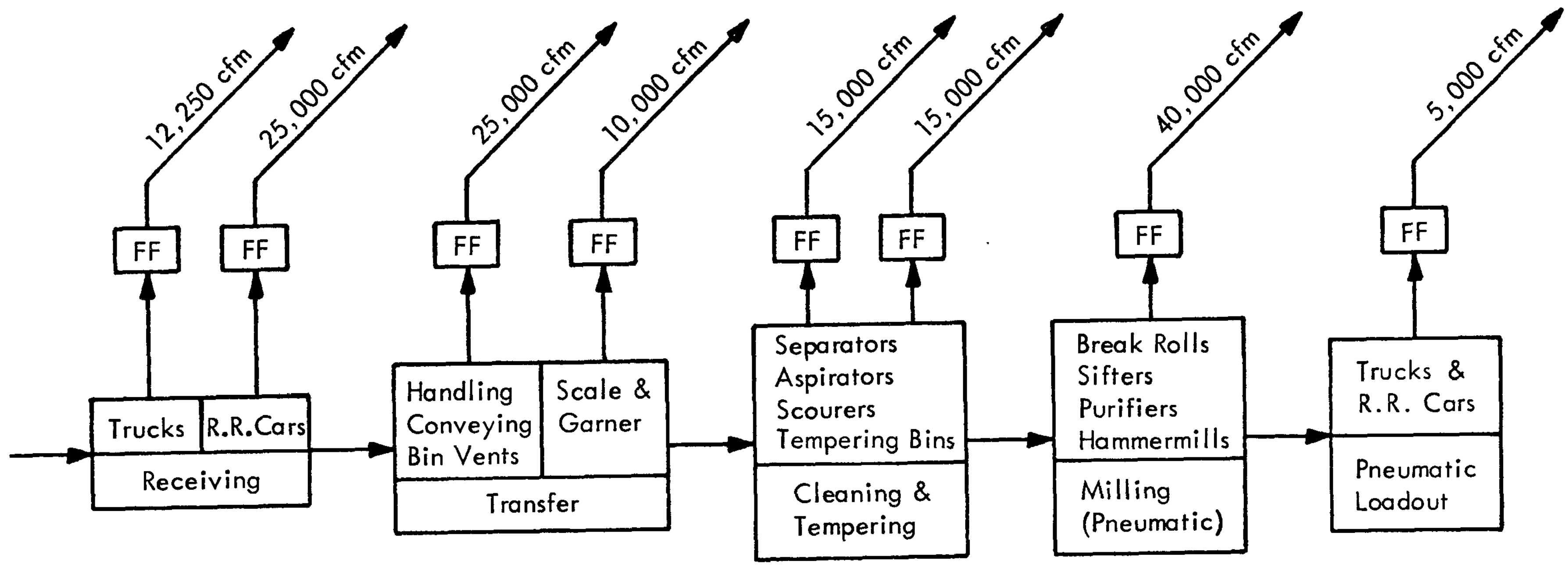
The new model plant for the wheat mill equipped with the "best" demonstrated control system is depicted in Figure 57. An alternate model (Case 2) would substitute cyclones for fabric filters in the first three phases of operation. The milling capacity of the plant is 5,000 cwt/24-hr day. The mill is assumed to operate 6,000 hr/year for the production of 1,250,000 cwt of flour. The milling operation of the plant is assumed to be a pneumatic unit.

Control Equipment Costs

Control equipment and associated costs required for the new model flour mill are summarized in Table 195 (Case 1) and Table 196 (Case 2). Estimates are given for the investment cost of control devices for each operation, as well as estimates for the total annual cost including electrical charges, maintenance expenses, depreciation expenses and capital charges.

Basis:

Plant Capacity - 5,000 cwt/24 hr day
Operate - 6,000 hr/yr



FF - Fabric Filter

Figure 57. Model wheat flour mill--best controls.

Table 195. MODEL PLANT FOR NEW WHEAT FLOUR MILLING

Case 1 - Best Control

Model Plant Control and Cost Estimate

Operation	Selected Device	Air Flow CFM	Oprn. Hr/Year	Electrical $/Year	Maintenance $/Year	Depreciation $/Year	Capital Charges $/Year	Annualized Cost $/Year	Installed Cost $
Truck Receiving[a]	FF	12,250	2,500	1,380	1,230	3,564	1,782	7,956	35,640[a]
Car Receiving[b]	FF	25,000	2,500	2,613	2,500	6,515	3,248	14,886	65,150[b]
Handling and Transfer	FF	25,000	6,000	6,280	2,500	5,935	2,968	17,683	59,350
Scale and Garner	FF	10,000	2,500	923	1,000	2,300	1,150	5,373	23,000
Wheat Cleaning and Tempering Separators Aspirators Disc Seprs Scourers	FF	30,000[c]	6,000	9,545	3,000	4,940	2,470	19,955	49,400
Milling Break Rolls Sifters Purifiers Hammer Mills	FF	40,000[d]	6,000	11,855	4,000	7,653	3,826	27,334	76,530
Pneumatic Loadout	FF	5,000	6,000	1,903	500	2,096	1,048	5,547	20,960
Total				34,499	14,730	33,003	16,502	98,734	330,030

a/ Includes cost of truck shed - $10,350
b/ Includes cost of 2-track unloading shed - $24,260
c/ Two 15,000 cfm fabric filters
d/ Four 10,000 cfm fabric filters

Plant Capacity - 5,000 cwt/24 Hr
Operate - 6,000 Hr/Year

Table 196. MODEL PLANT FOR NEW WHEAT FLOUR MILLING

Case 2 - Alternate Controls

	Model Plant Control and Cost Estimate								
Operation	Selected Device	Air Flow CFM	Oprn. Hr/Year	Electrical $/Year	Maintenance $/Year	Depreciation $/Year	Capital Charges $/Year	Annualized Cost $/Year	Installed Cost $
Truck Receiving[a]	Cyclone	12,250	2,500	1,104	613	2,645	1,323	5,685	26,450[a]
Car Receiving[b]	Cyclone	25,000	2,500	2,090	1,250	4,560	2,280	11,050	51,400[b]
Handling and Transfer	Cyclone	25,000	6,000	5,024	1,250	5,140	2,570	13,114	45,600
Scale and Garner	Cyclone	10,000	2,500	738	500	1,500	750	3,488	15,000
Wheat Cleaning and Tempering Separators Aspirators Disc Seprs Scourers	Cyclones (2)	30,000[c]	6,000	7,636	1,500	2,840	1,420	13,396	28,400
Milling Break Rolls Sifters Purifiers Hammer Mills	FF	40,000[d]	6,000	11,855	4,000	7,653	3,826	27,334	76,530
Pneumatic Loadout	FF	5,000	6,000	1,903	500	2,096	1,048	5,547	20,960
Total				30,350	9,613	26,434	13,217	79,614	264,340

a/ Includes cost of truck shed - $10,350.
b/ Includes cost of 2-track unloading shed - $24,260.
c/ Two 15,000 cfm cyclones.
d/ Four 10,000 cfm fabric filters.

Plant Capacity - 5,000 cwt/24 Hr
Operate - 6,000 Hr/Year

The operational hours per year which are shown for the model plant were estimated from an analysis of (1) the operational requirements and capacities of each device, and (2) the volume of material which could be processed by each operation. Assumptions regarding electrical, maintenance, depreciation and capital charges are discussed in the introduction to this chapter.

Estimated total annualized cost and investment cost for Case 1 and Case 2 are summarized as follows:

Primary Device	Total Annualized Cost ($/year)	Total Installed Cost ($)
Case 1 - (Fabric filters)	98,730	330,030
Case 2 - (Cyclones)	79,610	264,340

These figures actually overstate the costs associated with pollution control equipment. In the milling section of the plant, the fabric filter system(s) function principally as product recovery systems and not as air pollution equipment. Therefore, it is more in keeping with actual equipment usage not to include the cost of this equipment as an air pollution control item. Under this condition, the annual costs for pollution control equipment are reduced 28% in Case 1 and 34% in Case 2; investment costs are reduced 23% in Case 1 and 29% in Case 2.

	Pollution Control Equipment Only	
	Total Annualized Cost ($/year)	Total Installed Cost ($)
Case 1 - Best controls	71,400	253,500
Case 2 - Alternate controls	52,280	187,810

Credits for Dust Control

There are several control credits or positive impacts which could result from the installation of high-efficiency pollution control equipment on flour mills.

Since the equipment in the milling section is considered to function for product recovery rather than for pollution control, the grain receiving, transfer, storage, and cleaning house segments of the complex represent the main area where credits would accrue. In the absence of reliable emission factor data, only an indication of the potential positive impact from dust control in the grain receiving, storage, and cleaning segments of the mill can be provided. Table 197 presents an indication of the positive impact for various assumed values of recovered dust and millfeed prices. In developing these data it was assumed that the recovered material entered the millfeed stream and could be sold at a value of $45/ton which was the average price the last half of 1972, and $90/ton, the average price during the last half of 1973. The value of millfeed varies with time and market conditions, and the positive impact will correspondingly change.

Financial Statements

Income statements and balance sheets for the model flour mill are presented in Tables 198 and 199. Separate statements were developed for the operation of the model plant both without and with pollution control equipment. These statements reflect the costs of both the pollution control and product recovery equipment in the control equipment costs.

The primary information sources used in the development of these statements were (1) financial data presented by Dr. Otto Eckstein in 'Breadstuff Seminar 1972 issue of The Southwestern Miller;[20] (2) National Commission of Food Marketing, Organization and Competition in the Milling and Baking Industries;[21] and (3) 1970 Annual Survey of Manufacturers.[15] Since the financial condition of the milling industry can vary signficantly by company and over time, the statements presented here can be considered as a reflection of the general financial condition of a modern plant during 1971 and 1972.

The income statement of Table 198 is summarized for purposes of comparison as follows:

	Pollution Control and Product Recovery Equipment			
	Net Income Without Controls (¢/cwt)	Net Income With Controls (¢/cwt)	Reduction (¢/cwt)	Reduction (%)
Case 1 - Best controls	33.6	25.7	7.9	23.5
Case 2 - Alternate controls	33.6	27.2	6.4	19.1

Table 197. POTENTIAL POSITIVE IMPACT OF DUST CONTROL IN RECEIVING AND HANDLING SECTIONS OF MODEL FLOUR MILL

Assumed Recovery of Grain Dust (lb/ton of grain handled)	Grain Handled (ton/year)	Total Dust Recovered (tons)	Value of Dust Recovered		Value Recovered as Percent of Annual Control Cost			
					Case 1 - Best Controls		Case 2 - Alternate Controls	
			at \$45/ton[a]	at \$90/ton[b]	at \$45/ton[a]	at \$90/ton[b]	at \$45/ton[a]	at \$90/ton[b]
1	83,333	41.7	\$1,876	\$3,750	1.9%	3.8%	2.4%	4.7%
2		83.3	3,748	7,500	3.8	7.6	4.7	9.4
3		125.0	5,625	11,250	5.7	11.4	7.1	14.1
4		166.7	7,501	15,000	7.6	15.2	9.4	18.8
5		208.3	9,373	18,747	9.5	19.0	11.8	23.6

a/ Average price of millfeed and screening during last half of 1972. Average price calculated from prices reported in Feedstuffs.
b/ Average price of milifeed and screening during last half of 1973.

Table 198. INCOME STATEMENT FOR NEW MODEL FLOUR MILL
(1972)

	Without Controls		Case 1 - Best Controls			Case 2 - Alternate Controls		
			Control Costs	With Controls		Control Costs	With Controls	
	($000)	Percent	($000)	($000)	Percent	($000)	($000)	Percent
Sales	8,900	100.0		8,900	100.0		8,900	100.0
Cost of Materials	7,520	84.5		7,520	84.5		7,520	84.5
Wages	401	4.5		401	4.5		401	4.5
Cost of Goods Sold	7,921	89.0		7,921	89.0		7,921	89.0
Gross Profit	979	11.0		979	11.0		979	11.0
Expenses								
Sales and Administration	178	2.0		178	2.0		178	2.0
Operation, Etc.	125	1.4	49	174	2.0	40	165	1.9
Depreciation	141	1.6	33	174	2.0	26	167	1.9
Interest	115	1.3	17	132	1.5	13	128	1.4
Total Expenses	559	6.3	99	658	7.4	80	639	7.2
Net Income Before Taxes	420	4.7	-99	321	3.6	-80	340	3.8
Net Income/Cwt Flour Production	33.6¢			25.7¢			27.2¢	
% Net Income/Net Worth	17.4%			13.3%			14.1%	
% Net Income/Total Assets	10.0%			7.1%			7.6%	

Table 199. BALANCE SHEET FOR NEW MODEL FLOUR MILL (1972)

	Without Controls		Case 1 - Best Controls			Case 2 - Alternate Controls		
			Control Costs	With Controls		Control Costs	With Controls	
	($000)	Percent	($000)	($000)	Percent	($000)	($000)	Percent
Assets								
Current Assets								
Receivables Net	630	15.0		630	13.9		630	13.9
Inventory	560	13.3		560	12.4		560	12.4
Other Current	434	10.3		434	9.6		434	9.6
Total Current Assets	1,624	38.7		1,624	35.8		1,624	35.8
Fixed Assets								
Structure and Building	860	20.5		860	19.0		860	19.0
Machinery and Equipment	1,490	35.5	330	1,820	40.2	264	1,754	39.3
Total Depreciable Assets	2,350	56.0	330	2,680	59.2	264	2,614	58.8
Other Fixed	226	5.4		226	5.0		226	5.0
Total Fixed Assets	2,576	61.3	330	2,906	64.2	264	2,840	63.6
Total Assets	4,200	100.0	330	4,530	100.0	264	4,464	100.0
Liabilities								
Accounts Payable	268	6.4		268	5.9		268	5.9
Short-Term Notes	317	7.5		317	7.0		317	7.0
Other Current Liabilities	255	6.1		255	5.6		255	5.6
Total Current Liabilities	840	20.0		840	18.5		840	18.5
Long-Term Debt	950	22.6	330	1,280	28.3	264	2,054	27.2
Total Liabilities	1,790	42.6	330	2,120	46.8	264	2,054	46.0
Net Worth	2,410	57.4		2,410	53.2		2,410	53.2
Total Liabilities and Net Worth	4,200	100.0	330	4,520	100.0	264	4,464	100.0

If the control devices in the milling section are considered to be a product recovery system rather than for pollution control, then the impact of pollution control regulations on net income before taxes is as follows:

	Pollution Control Equipment Only			
	Net Income Without Controls (¢/cwt)	Net Income With Controls (¢/cwt)	Reduction (¢/cwt)	Reduction (%)
Case 1 - Best controls	31.4	25.7	5.7	18.1
Case 2 - Alternate controls	31.4	27.2	4.2	13.1

Even this latter case overstates the impact of pollution control equipment on the model plant, because no credit has been given for the recovery of dust from the grain receiving, transfer, storage, and cleaning operations. The maximum credit of $18,750 as shown in Table 197 would result in even less of a reduction in profitability as shown below:

	Pollution Control Equipment Only With Control Credits			
	Net Income Without Controls (¢/cwt)	Net Income With Controls (¢/cwt)	Reduction (¢/cwt)	Reduction (%)
Case 1 - Best controls	31.4	27.2	4.2	13.4
Case 2 - Alternate controls	31.4	28.5	2.9	9.2

Another facet that influences the actual impact on a milling complex is the fact that some mills have multiple grain milling capability (e.g., wheat and rye, or wheat, dry corn and oats). In those cases, several pieces of equipment, especially the grain receiving, cleaning and storage facilities, are used for all the grains. Allocation of costs for pollution control equipment cannot be easily accomplished in these cases.

Table 199 presents the comparative balance sheets for the model plant. A construction cost of $470 for each hundredweight of capacity per 24-hr day was used to estimate the total plant and equipment cost without pollution control or product recovery equipment. According to industry sources, the construction costs for new flour mills can vary from $400 to $1,100/cwt of capacity. This means that the figures as presented in the balance sheet for the new model plant can vary accordingly. In general, the installation of control equipment will have a greater impact on the less expensive plants because the control equipment investment will be a greater percentage of the total plant and equipment investment.

For the selected model plant, the addition of pollution control and product recovery equipment increases the investment cost per hundredweight in total plant and equipment as follows:

	Pollution and Product Recovery Equipment			
	Investment Cost Without Controls ($/cwt)	Investment Cost With Controls ($/cwt)	Increase ($/cwt)	Increase (%)
Case 1 - Best controls	470	536	66	14
Case 2 - Alternate controls	470	523	53	11

If the product recovery equipment is included in the original investment cost, then the construction costs will be as follows:

	Pollution Control Equipment Only			
	Investment Cost Without Controls ($/cwt)	Investment Cost With Controls ($/cwt)	Increase ($/cwt)	Increase (%)
Case 1 - Best controls	485	536	51	10.5
Case 2 - Alternate controls	485	523	38	7.8

Economic Impact of Control Systems on Industry

New Plants - The impact of pollution control equipment on the model flour mill is summarized in Table 200. The annual operating costs of pollution control and product recovery equipment amount to 1.1% of dollar sales at 1972 prices in Case 1, and 0.9% of sales in Case 2. If only pollution control equipment is included, the increased cost is 0.8% of sales in Case 1 and 0.6% of sales in Case 2.

Table 200. ECONOMIC IMPACT OF CONTROLS APPLIED TO NEW MODEL FLOUR MILL

	Pollution Control and Product Recovery Equipment		Pollution Control Equipment Only	
	Case 1	Case 2	Case 1	Case 2
Control investment	$330,030	$264,340	$253,500	$187,810
Percent of plant and equipment	14.0%	10.1%	10.4%	7.7%
Percent of dollar sales	3.7%	3.0%	2.8%	2.1%
Per cwt of flour produced	26.4¢	21.1¢	20.3¢	15.0¢
Annual control				
Operations costs	$ 98,734	$ 79,614	$ 71,400	$ 52,280
Percent of net worth	4.1%	3.3%	3.0%	2.2%
Percent of total assets	2.4%	1.9%	1.6%	1.2%
Percent of dollar sales	1.1%	0.9%	0.80%	0.59%
Per cwt of flour produced	7.9¢	6.4¢	5.7¢	4.2¢

The annual costs of only the pollution control equipment for Case 1 and Case 2 are 3% and 2.2% of net worth, respectively. If profitability of the plant is measured by net income before taxes per hundredweight of flour production, the control equipment reduces the profitability 23.5% in Case 1 and 19.0% in Case 2.

Analyses of the financial data for the model plant indicate that required installation of "best" or "alternate" control equipment on new flour mills will reduce profits. However, it is unlikely that control regulations will prevent new plants with capacities of 5,000 cwt and greater from being built. Because of the 20% greater investment and annual operating costs, the installation of "best" controls in Case 1 will have a greater impact than the installation of the alternate controls in Case 2.

Regulations requiring either of the specified control configurations on all new plants will significantly change the economies of scale. Because of the relatively fixed costs of pollution control equipment for the receiving, handling and loadout operations, the small flour mill will not be as profitable.

Existing Plants - To determine the economic impact of installing the control systems on existing plants, it is necessary to take into account the current level of control on these facilities. Table 201 presents the current status of control at flour mills as determined from emission inventory questionnaires submitted by 185 individual plants. Current plants are well controlled in the handling and processing sections. However, only approximately 15% are equipped with "best" control devices in the receiving and handling sections, 35% in the cleaning section, and 50% in the milling section. If the controls in Case 2 are specified, then approximately 52% of existing plants are equipped with adequate controls in receiving operations, 33% in handling, 100% in cleaning and 50% in milling.

Using the data in Table 201 as the industry average, the capital investment and annual costs required by existing plants to install and operate the two alternative control systems were developed. The major assumptions made in determining these costs are as follows:

1. The cost to install control equipment on an existing plant which does not have pollution controls is 120% of the cost required for a new plant. The increased costs reflect the fact that additional installation charges will be incurred on an existing or older plant.

2. Existing plants which already have adequate control equipment on specific operations will not incur any additional charges.

TABLE 201. FLOUR MILLING - POLLUTION CONTROLS OF EXISTING PLANTS

(SURVEY OF 185 PLANTS 1972-1973)

Operation	Quantity (bu/yr)	No. of Plants	Cyclone % Control[a]	Cyclone No. of Plants	Fabric Filters % Control[a]	Fabric Filters No. of Plants	Other Devices % Control[a]	Other Devices No. of Plants	Total % With Control
Receiving:									
Hopper	153,462,000	96	26.3	28	36.4	22	0	0	62.7
Boxcar	114,507,000	78	31.1	29	40.6	21	0	0	71.7
Truck	90,827,000	149	29.3	47	24.4	19	0	0	53.7
Barge	54,469,000	10	75.0	5	12.9	2	0	0	87.9
Total	413,265,000	173	34.7	61	31.8	29	0	0	66.5
Drying	3,647,000	34	0	0	0	0	18.2	3	18.2
Cleaning (Controlled)[b]	316,439,000	142	50.8	102	48.7	36	0.5	4	- c/
Handling:									
Transfer	405,773,000	165	41.8	53	45.7	34	0.1	2	87.6
Garner and Scale	410,643,000	165	39.8	50	40.6	29	0.1	2	80.5
Legs	422,344,397	172	45.3	64	44.7	33	0.1	2	90.1
Tripper	348,622,000	130	35.9	24	38.1	19	0	0	74.0
Cleaning House (Controlled)[b]	428,394,000	133	24.1	69	75.9	64	0	0	- c/
Break Rolls	444,943,000	184	13.6	58	83.7	98	0.1	2	97.4
Reduc. Rolls	444,685,000	182	10.6	55	85.7	98	0	0	96.3
Purifiers	424,794,000	163	21.9	24	73.6	78	0.0	1	95.8

a/ Percent control is the percentage of the total quantity for the operation which is controlled by the specific device.

b/ Percentages are based on controlled plants only.

c/ Insufficient data to determine extent of control.

3. The pollution control equipment specifications for the model plant will be used as the average for the existing plants in the industry.

4. The maintenance and electrical expenses for a new fabric filter system will be 50% and 80%, respectively, of the expense required for an existing cyclone system.

A summary of the investment and annual operating costs required to install controls or existing plants is presented in Table 202.

Table 202. CONTROLS APPLIED TO EXISTING FLOUR MILLS

	Average Per Establishment		Total for Industry[a]	
	Case 1	Case 2	Case 1	Case 2
Investment for control equipment	232,000	125,000	75,000,000	40,471,000
Annual control costs	47,600	25,000	15,375,000	8,075,000
Annual costs per cwt of flour production			6.1¢	3.2%

a/ Assumes 323 establishments.

For the total industry of 323 flour mills, the installation of best controls would require $75 million investment and $15.4 million annual operating costs. The installation of controls specified in Case 2 would reduce the total investment by 46% and the annual costs by 49%.

As was the case with new plants, the impact of pollution control costs on existing plants will be greater for small flour mills. It is possible that some of the smaller or marginally profitable existing flour mills will go out of business if forced to install control equipment. The enforcement of pollution control regulations would accelerate the present trend in which small and obsolete mills are being forced to close.

Demand Elasticity - Per capita consumption of flour declined to 110 lb in 1971, from 118 lb in 1960. This drop in per capita consumption has been offset by an increase in population at an annual rate of 1.2%. As a result, from 1963 through 1971, total domestic flour consumption increased at an average annual rate of about 1%. The individual miller has little or no control over the total domestic demand for flour. Since demand is relatively flat and inelastic, the average price increase resulting from the installation of control equipment would probably be passed on to the baker. However, the family flour which is sold by the miller directly to retailers has been subject to government price controls. In those cases where price controls are in effect, the miller would have to absorb the increased production costs.

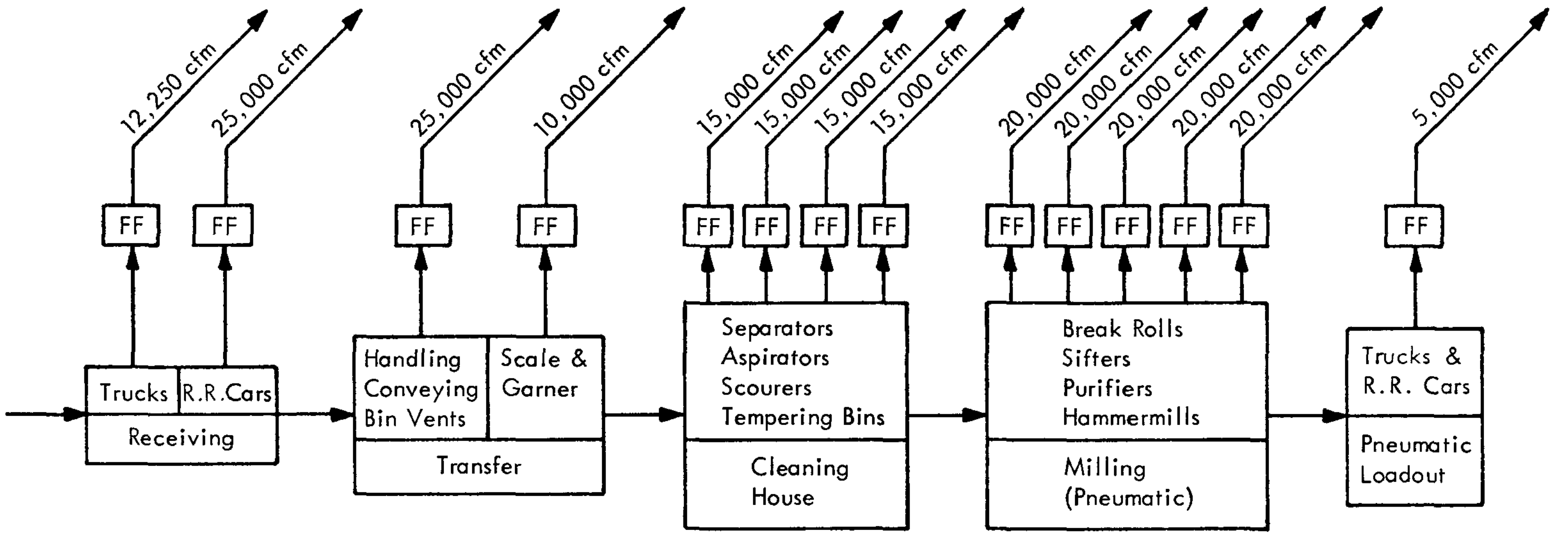
Foreign demand which accounted for 7.6% of U.S. flour in 1972 to 1973, has been sensitive to price changes during past years. The U.S. flour milling industry has operated at a competitive disadvantage on the world market because of the subsidy level on flour provided by the Common Market. It is difficult to predict world demand for flour; however, under certain conditions, the U.S. millers might have to absorb the control costs if they are to maintain or increase flour exports.

Durum Flour Milling

Description of Model Plants - There is a great deal of similarity in the milling of wheat and durum. As a result, some of the analyses which were made for wheat flour milling also apply to durum flour milling. However, there are enough differences to justify the development of a separate model plant as depicted in Figure 58. The control devices specified represent the best controls currently available. A similar model with alternative controls, which replace fabric filters for cyclones in the first five operation phases, will also be analyzed. The milling capacity of the plant is 5,000 cwt/24-hr day, and the mill is assumed to operate 6,000 hr/year for production of 1,250,000 cwt of semolina and durum flour. The milling portion of the plant is assumed to be a pneumatic unit.

Control Equipment Costs - A summary of control equipment and associated costs required for the model durum flour mill is presented in Table 203 (Case 1 - best control) and Table 204 (Case 2 - alternate controls). Estimates are given for the investment cost for control devices for each operation, as well as estimates for the total annual cost, including electrical charges, maintenance expenses, depreciation expenses and capital charges.

Basis:
Plant Capacity - 5,000 cwt/24 hr day
Storage Capacity - 500,000 bu
Operate - 6,000 hr/yr



FF - Fabric Filter

Figure 58. Model durum flour mill--best controls.

Table 203. MODEL PLANT FOR DURUM FLOUR MILLING

Case 1 - Best Controls

	Model Plant Control and Cost Estimate								
Operation	Selected Device	Air Flow CFM	Oprn. Hr/Year	Electrical $/Year	Maintenance $/Year	Depreciation $/Year	Capital Charges $/Year	Annualized Cost $/Year	Installed Cost $
Truck Receiving[a]	FF	12,250	2,500	1,380	1,230	3,564	1,782	7,956	35,640
Car Receiving[b]	FF	25,000	2,500	2,613	2,500	6,515	3,258	14,886	65,150
Handling and Transfer	FF	25,000	6,000	6,280	2,500	5,935	2,967	17,682	59,350
Scale and Garner	FF	10,000	2,500	923	1,000	2,300	1,150	5,373	23,000
Cleaning House Separators Aspirators Disc Seprs Scourers	FF	60,000[c]	6,000	17,472	6,000	9,556	4,778	37,806	95,560
Milling Break Rolls Sifters Purifiers Hammer Mills	FF	100,000[d]	6,000	31,200	10,000	15,837	7,918	64,955	158,370
Pneumatic Loadout	FF	5,000	6,000	1,903	500	2,096	1,048	5,547	20,960
Total				61,771	23,730	45,803	22,901	154,205	458,030

a/ Includes cost of truck shed - $10,350
b/ Includes cost of 2-track unloading shed - $24,260
c/ Four 15,000 cfm fabric filters
d/ Five 20,000 cfm fabric filters

Plant Capacity - 5,000 cwt/24 Hr
Operate - 6,000 Hr/Year

Table 204. MODEL PLANT FOR NEW DURUM FLOUR MILLING

Case 2 - Alternate Controls

Operation	Selected Device	Air Flow CFM	Oprn. Hr/Year	Model Plant Control and Cost Estimate: Electrical $/Year	Maintenance $/Year	Depreciation $/Year	Capital Charges $/Year	Annualized Cost $/Year	Installed Cost $
Truck Receiving[a/]	Cyclone	12,250	2,500	1,104	613	2,645	1,323	5,685	26,450
Car Receiving[b/]	Cyclone	25,000	2,500	2,090	1,250	5,140	2,570	11,050	51,400
Handling and Transfer	Cyclone	25,000	6,000	5,024	1,250	4,560	2,280	13,114	45,600
Scale and Garner	Cyclone	10,000	2,500	738	500	1,500	750	3,488	15,000
Cleaning House Separators Aspirators Disc Seprs Scourers	4-Cyclones	60,000[c/]	6,000	13,978	3,000	5,356	2,678	25,012	53,560
Milling Break Rolls Sifters Purifiers Hammer Mills	FF	100,000[d/]	6,000	31,200	10,000	15,837	7,918	64,955	158,370
Pneumatic Loadout	FF	5,000	6,000	1,903	500	2,096	1,048	5,547	20,960
Total				56,037	17,113	37,134	18,567	128,851	371,340

a/ Includes cost of truck shed - $10,350
b/ Includes cost of two track unloading shed - $24,260
c/ Four 15,000 cfm fabric filters
d/ Five 20,000 cfm fabric filters

Plant Capacity - 5,000 cwt/24 Hr
Operate - 6,000 Hr/Year

The major difference between the durum and wheat flour model plants is the increased cubic feet per minute required for control equipment on the cleaning house and milling operations of the durum mill. The durum mill requires 60,000 cfm on the cleaning house and 100,000 cfm on the milling section, as compared to 30,000 and 40,000, respectively, for the wheat flour mill. The greater cubic feet per minute requirements result in higher costs. For the pollution control equipment listed in Tables 203 and 204, the durum flour mill would require estimated investments and annualized costs as follows:

	Pollution Control and Product Recovery Equipment	
Primary Device	Total Annualized Cost ($/year)	Installed Cost ($)
Case 1 - Fabric filters	154,210	458,030
Case 2 - Cyclones	128,850	371,340

In the milling section of the plant, the fabric filter systems function primarily as product recovery rather than pollution control systems. If the costs associated with this equipment are removed from the control costs, the investment cost for pollution control equipment would be reduced 34.6% in Case 1 and 42.7% in Case 2.

	Pollution Control Equipment Only	
Primary Device	Annualized Cost ($/year)	Installed Cost ($)
Case 1 - Fabric filters	89,250	299,660
Case 2 - Cyclones	63,900	212,970

Credits for Dust Control - The control credits which would result from the installation of high-efficiency pollution control equipment on durum flour mills is assumed to be the same as that shown in Table 197 for wheat flour mills. The value of dust recovered, depending upon the emission rates and millfeed prices, would range from $1,800 to $18,700. The $18,700 reflects fourth quarter 1973 prices. These credits are 1.2% and 12.2%, respectively, of the total annual control costs.

Financial Impact - According to the listings in the September 1971 issue of the Northwestern Miller,[22/] there are only 13 durum flour mills. Since most of the companies operating these mills are integrated into other sectors of the milling industry, there are almost no available statistics on the financial operations of durum flour mills as distinguished from other milling operations. As a result, the income statement and balance sheet for the wheat flour mill--Tables 198 and 199--were used for the model durum mill with the following changes.

1. The selling price of durum products are 5.6% higher than wheat products, and the prices of ingredients required by the durum mill are 10% higher. These price differentials were the same in the figures from the 1963 and 1967 Census of Manufacturers.

2. The investment required for plant and equipment was assumed to be $500 for each hundredweight per 24 hr of capacity.

3. The wages and operating costs for the durum flour mill are lower than for the wheat flour mill. The profitability at both mills was assumed to be the same.

The resulting financial impacts of the installation of best controls on the durum flour mill are summarized in Table 205. The annual costs of pollution control and product recovery equipment in Case 1 amount to 12.3¢/cwt, 10.3¢/cwt in Case 2. If only pollution control equipment is included, the increased costs are 7.1¢/cwt and 5.1¢/cwt, for Cases 1 and 2, respectively.

Regulations requiring the installation of best control equipment on new durum mills will have no significant impact on the industry, if for no other reason than very few, if any, new durum mills are being built. The installation of control equipment on existing facilities will have a greater impact. However, it is doubtful that any existing plants will be forced to close. Since all of the existing durum mills have capacities greater than 2,000 cwt/24 hr, the durum milling industry is not affected by the adverse economics of scale which will be encountered by small wheat flour mills as a result of installation of control equipment.

The demand for durum products (semolina and durum flour) are relatively inelastic. As a general rule the fluctuations in price of durum wheat are reflected in the prices of the durum products. The price increase resulting from the installation of control equipment will probably be passed on to customers which are primarily in the macaroni manufacturing industry.

TABLE 205. ECONOMIC IMPACT OF CONTROLS APPLIED TO NEW MODEL DURUM FLOUR MILL

	Pollution Control and Product Revocery Equipment		Pollution Control Equipment Only	
	Case 1	Case 2	Case 1	Case 2
Control Investment	$458,030	$371,340	$299,660	$212,970
Percent of Plant & Equipment	18.3%	14.9%	11.3%	8.0%
Percent of Dollar Sales	4.9%	4.0%	3.2%	2.3%
Per cwt of Flour Products	36.6 cents	29.7 cents	24.0 cents	17.0 cents
Annual Control Oper. Cost	$154,205	$128,851	$89,250	$63,896
Percent of Net Worth	6.0%	5.0%	3.5%	2.5%
Percent of Total Assets	3.1%	2.6%	1.8%	1.3%
Percent of Dollar Sales	1.6%	1.4%	0.95%	0.68%
Per cwt of Flour Products	12.3 cents	10.3 cents	7.1 cents	5.1 cents

DRY CORN MILLING

Description of Model Plants

Figure 59 depicts the model plant for the dry corn mill. The milling capacity of the plant is 5,000 cwt/24-hr day, and the mill is assumed to operate 6,000 hr/year. Grain storage capacity is assumed to be 500,000 bu. Individual dry corn mills may vary significantly in processing steps, operating characteristics, and product mix. In addition, the size of dry corn mills covers a wide spectrum, and operations vary with size. Accurate representation of the various corn mill sizes and configurations would require an extensive series of models. However, the model plant selected should provide a basis from which alternative configurations could be readily analyzed.

Control Equipment Costs

A summary of two alternative control equipment configurations and associated costs required for the model dry corn mill is presented in Tables 206 and 207. The control equipment in Case 1 which consists of fabric filters for all-grain handling operations, is the "best" demonstrated control system currently available. Case 2, which specifies cyclones for the grain-handling operations, generally reflects the current industry practice for dry corn mills which have installed pollution control equipment. Estimates are given for the investment cost of control devices for each operation, as well as estimates for the total annual cost. Assumptions regarding electrical charges, maintenance expenses, depreciation and capital charges are discussed in the introduction to this chapter.

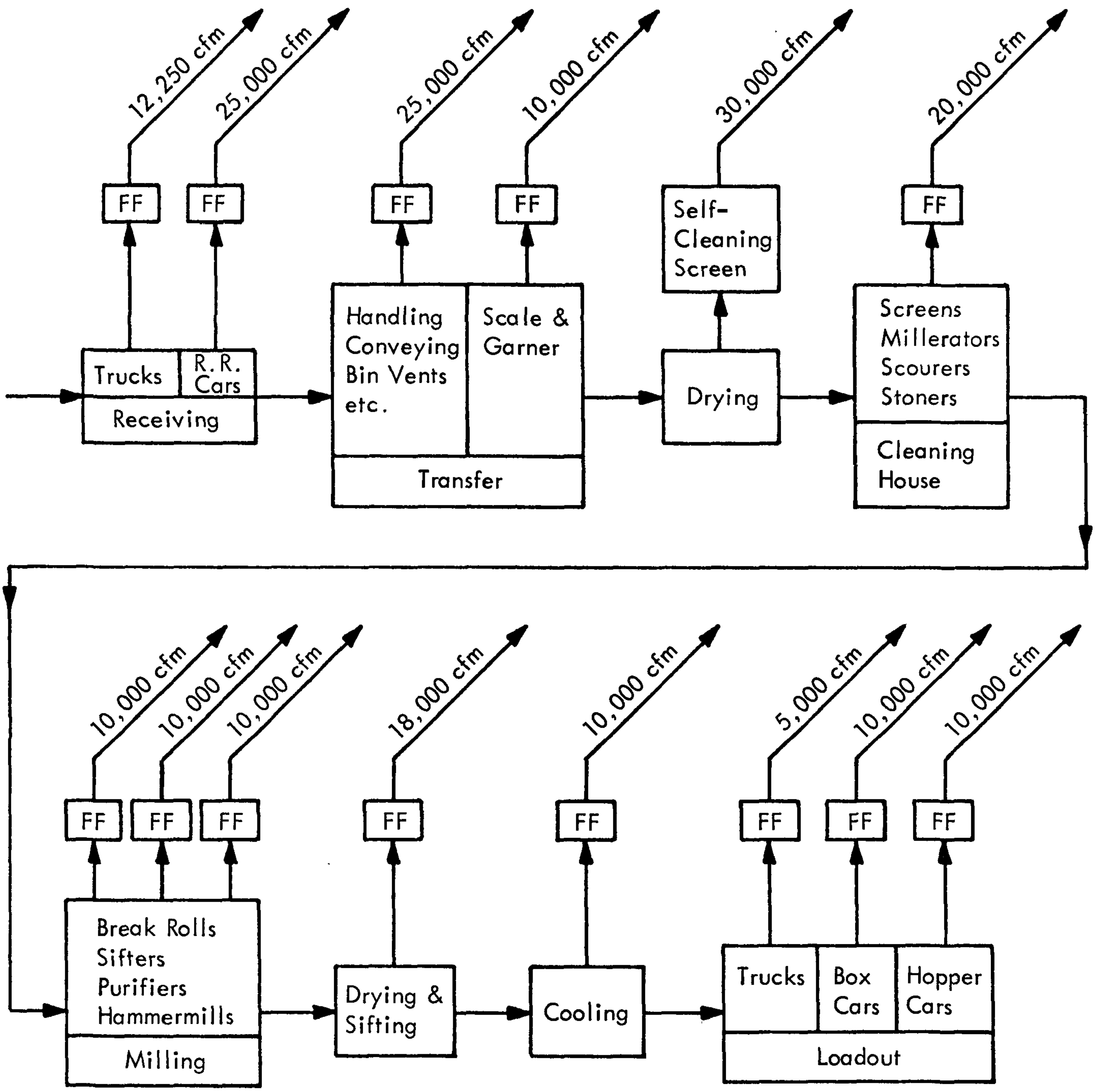
A summary of the investment and annual operating costs required for both pollution control equipment alternatives is as follows:

Primary Device	Annualized Cost ($/year)	Installed Cost ($)
Case 1 - Fabric filters	117,820	430,260
Case 2 - Cyclones	99,790	373,970

As was the case with flour mills, the equipment in the milling section of the plant functions primarily as product recovery systems and not as air pollution control devices, and the costs for this equipment should not really be attributed to pollution control.

Basis:

Plant Capacity - 5,000 cwt/24 hr day
Storage Capacity - 500,000 bu
Operate - 6,000 hr/yr



FF - Fabric Filter

Figure 59. Model dry corn mill--best controls.

Table 206. MODEL PLANT FOR NEW DRY CORN MILLING

Case 1 - Best Controls

	Model Plant Control and Cost Estimate								
Operation	Selected Device	Air Flow CFM	Oprn. Hr/Yr	Electrical $/Yr	Maintenance $/Yr	Depreciation $/Yr	Capital Charges $/Yr	Annualized Cost $/Yr	Installed Cost $
Truck Receiving[a]	FF	12,250	2,500	1,380	1,230	3,564	1,782	7,956	35,640
Car Receiving[b]	FF	25,000	2,500	2,613	2,500	6,515	3,258	14,886	65,150
Handling and Transfer	FF	25,000	6,000	6,280	2,500	5,935	2,967	17,682	59,350
Scale and Garner	FF	10,000	2,500	923	1,000	2,300	1,150	5,373	23,000
Drying	Self Cleaning Screen	30,000	500	85	1,000	2,000	1,000	4,085	20,000
Cleaning House Screens Millerators Scourers Dry Stoners	FF	20,000	6,000	5,335	2,000	3,860	1,930	13,125	38,600
Tempering and Milling Break Rolls Sifters Purifiers Hammer Mills	FF	30,000[c]	6,000	7,800	3,000	6,200	3,100	20,100	62,000
Drying and Sifting	FF	18,000	6,000	3,463	1,800	3,260	1,630	10,153	32,600
Cooling	FF	10,000	6,000	3,744	1,000	2,580	1,290	8,614	25,800
Truck Loadout	FF	5,000	2,500	790	500	1,652	826	3,768	16,520
Boxcar Loadout	FF	10,000	2,500	1,170	1,000	2,580	1,290	6,040	25,800
Hopper Car Loadout	FF	10,000	2,500	1,170	1,000	2,580	1,290	6,040	25,800
Total				34,753	18,530	43,026	21,513	117,822	430,260

a/ Includes cost of truck shed - $10,350
b/ Includes cost of 2-track unloading shed - $24,260
c/ Three 10,000 cfm fabric filters

Plant Capacity - 5,000 cwt/24 Hr
Storage Capacity - 500,000 Bu
Operate - 6,000 Hr/Year

Table 207. MODEL PLANT FOR NEW DRY CORN MILLING

Case 2 - Alternate Controls

Operation	Selected Device	Air Flow CFM	Oprn. (Hr/Year)	Electrical ($/Year)	Maintenance ($/Year)	Depreciation ($/Year)	Capital Charges ($/Year)	Annualized Cost ($/Year)	Installed Cost ($)
			Model Plant Control and Cost Estimate						
Truck Receiving[a/]	Cyclone	12,250	2,500	1,104	613	2,645	1,323	5,685	26,450
Car Receiving[b/]	Cyclone	25,000	2,500	2,090	1,250	5,140	2,570	11,050	51,400
Handling and Transfer	Cyclone	25,000	6,000	3,360	1,250	4,560	2,280	11,450	45,600
Scale and Garner	Cyclone	10,000	2,500	738	500	1,500	750	3,488	15,000
Drying	Self Cleaning Screen	30,000	500	85	1,000	2,000	1,000	4,085	20,000
Cleaning House Screens Millerators Scourers Dry Stoners	Cyclone	20,000	6,000	4,268	1,000	2,700	1,350	9,318	27,000
Tempering and Milling Break Rolls Sifters Purifiers Hammer Mills	FF	30,000[c/]	6,000	7,800	3,000	6,200	3,100	20,100	62,000
Drying and Sifting	FF	18,000	6,000	3,463	1,800	3,260	1,630	10,153	32,600
Cooling	FF	10,000	6,000	3,744	1,000	2,580	1,290	8,614	25,800
Truck Loadout	FF	5,000	2,500	790	500	1,652	826	3,768	16,520
Boxcar Loadout	FF	10,000	2,500	1,170	1,000	2,580	1,290	6,040	25,800
Hopper Car Loadout	FF	10,000	2,500	1,170	1,000	2,580	1,290	6,040	25,800
Total				29,782	13,913	37,397	18,699	99,791	373,970

a/ Includes cost of truck shed - $10,350
b/ Includes cost of 2-track unloading shed - $24,260
c/ Three 10,000 cfm fabric filters

Plant Capacity - 5,000 cwt/24 Hr
Storage Capacity - 500,000 Bu
Operate - 6,000 Hr/Year

With this exclusion, the investment and annual costs for pollution control are as follows:

	Pollution Control Equipment Only	
Primary Device	Annualized Cost ($/year)	Installed Cost ($)
Case 1 - Fabric filters	97,720	372,260
Case 2 - Cyclones	79,690	311,970

Credits for Dust Control

The dust recovered by high-efficiency equipment in the grain receiving, storage, and cleaning operations can be added to the millfeed by-product stream. Therefore, this material represents a positive impact resulting from the use of pollution control equipment. Because accurate emission factor data are lacking, only an estimate of the potential positive impact can be made. Table 208 presents an indication of the positive impact for various assumed levels of recovered dust. The recovered dust was assumed to enter the millfeed stream and have a value of $40/ton which was the average price for screenings during April 1973. The value of the recovered material will fluctuate over time and the positive control credit will vary accordingly.

Economic Impact of Control Systems on Industry

Financial Data - Most of the companies operating dry corn mills are integrated into other sectors of the feed and grain industry. Also, dry corn milling data collected by the Census of Manufacturers are included with flour and other grain milling establishments. As a result, there are few available statistics on the financial operations of dry corn mills as distinguished from other milling operations. To determine the financial impact of the best pollution control equipment on the model plant, the income statement and balance sheet for the wheat flour mill--Tables 198 and 199--were used with the following assumptions and changes.

1. The selling price of corn products is an average of 26% lower than products from the wheat flour mill. This difference was derived from the quantity and value of shipments by product classes as reported in the 1967 Census of Manufacturers.[16]

2. The gross margin, operating expenses and net profit are the same for both types of mills.

Table 208. POTENTIAL POSITIVE IMPACT OF DUST CONTROL IN RECEIVING AND HANDLING SECTION OF MODEL DRY CORN MILL

Assumed Recovery of Grain Dust (lb/ton of grain handled)	Grain Handled (ton/year)	Total Dust Recovered (tons)	Value of Dust[a/] Recovered	Value Recovered as Percent of Annual Control Cost			
				Pollution Control and Product Recovery Equipment		Pollution Control Equipment Only	
				Case 1	Case 2	Case 1	Case 2
1	93,750	46.9	$1,876	1.6%	1.9%	1.9%	2.4%
2		93.75	$3,752	3.2%	3.8%	3.8%	4.7%
3		140.63	$5,628	4.8%	5.6%	5.8%	7.1%
4		187.50	$7,504	6.4%	7.5%	7.7%	9.4%
5		234.38	$9,375	8.0%	9.4%	9.6%	11.8%

a/ Assumed that recovered material could be sold at $40/ton, which was the average price for screenings during April 1973, as reported in Feedstuffs.

3. The investment in plant and equipment without pollution control equipment was assumed to be \$500 for each hundredweight per 24 hr of capacity.

The resulting financial impacts of installing best controls on the model dry corn mill are summarized in Table 209. The investment costs for pollution control and product recovery equipment amounts to 17.2% in Case 1 and 15.0% in Case 2 of the original investment in plant and equipment. If the product recovery equipment is excluded, the control investment cost is reduced to 14.4% in Case 1 and 12.2% in Case 2. The annual costs of pollution control and product recovery equipment are 2.1% of 1972 dollar sales for Case 1 and 1.8% in Case 2.

New Plants - The investment required for installation of best control systems is great enough in comparison with the total plant construction cost to be a major factor in determining the economic feasibility of a new dry corn mill. In addition, the economics of scale for a new plant will change. The costs of the control equipment for the grain receiving, handling and transfer, scale and garner, and loadout operations will not decrease in proportion to decreases in plant capacity. As a result, small dry corn mills will become less economical.

The annual costs of pollution control systems will definitely be greater than any direct economic benefits to the plants. However, it is unlikely that the additional costs in either of the alternative control systems will have a great impact on new plants.

Existing Plants - The amount and type of pollution control equipment on existing plants must be determined before an evaluation can be made of the economic impact of regulations requiring best controls on existing plants. Table 210 presents the current status of control equipment on dry corn mills as determined from emission inventory questionnaires submitted by 39 of the 122 existing mills. Of the surveyed plants, approximately 60% have controls on their receiving operations, 40% on handling operations, and 50% on milling operations. However, only 15% of the surveyed plants are equipped with "best" control devices.

Using the data in Table 210 as the industry average, the capital investment and annual costs required by existing plants to install and operate the two alternative control systems were developed. The major assumptions made in determining these costs are as follows:

TABLE 209. ECONOMIC IMPACT OF CONTROLS APPLIED TO NEW MODEL DRY CORN MILL

	Pollution Control and Product Recovery Equipment		Pollution Control Equipment Only	
	Case 1	Case 2	Case 1	Case 2
Control Investment	$430,260	$373,260	$368,260	$311,970
Percent of Plant & Equipment	17.2%	15.0%	14.4%	12.2%
Percent of Dollar Sales	7.8%	6.8%	6.7%	5.7%
Per cwt of Production	34.4 cents	30.0 cents	29.5 cents	25.0 cents
Annual Control Oper. Costs	$117,820	$99,791	$97,750	$79,691
Percent of New Worth	4.9%	4.2%	4.1%	3.3%
Percent of Total Assets	2.5%	2.2%	2.1%	1.7%
Percent of Dollar Sales	2.1%	1.8%	1.8%	1.4%
Per cwt of Production	9.4 cents	8.0 cents	7.8 cents	6.4 cents

Table 210. DRY CORN MILLING POLLUTION CONTROLS OF EXISTING PLANTS

(SURVEY OF 39 PLANTS 1972-1973)

Operation	Quantity (Bu)	No. of Plants	Cyclone		Fabric Filters		Other Devices		Total Percent With Control
			% Control[a]	No. of Plants	% Control	No. of Plants	% Control	No. of Plants	
Receiving:									
Hopper	12,603,000	14	11.5	3	47.8	5	0	0	59.3
Boxcar	31,169,000	12	20.4	3	71.6	5	0	0	92.0
Truck	20,275,000	34	6.5	17	62.6	4	0	0	69.1
Adjacent plant	4,045,000	1	0	0	0	0	0	0	0
Total	68,092,000	39	13.4	17	60.3	6	0	0	73.7
Drying	1,400,000	10	13.7	2	50.0[b]	1	28.6	2	92.3
Cleaning (controlled)[c]	60,722,000	31	46.2	25	53.8	6	0	0	---[d]
Handling:									
Transfer	68,092,000	39	16.8	12	62.9	5	0	0	79.7
Garner and scale	67,442,000	35	19.1	7	64.8	6	0	0	83.9
Legs	67,865,000	38	11.0	8	68.7	7	0	0	79.7
Tripper	61,409,000	22	14.6	3	69.7	4	0	0	84.3
Cleaning House (controlled)[c]	50,750,000	22	38.2	13	61.8	9	0	0	---[d]
Degerm	52,124,000	25	46.8	6	1.2	2	0	0	48.0
Dryers	65,345,000	25	38.1	6	43.8	3	5.6	2	87.5
Coolers	64,961,000	26	33.7	6	50.4	5	4.9	1	89.0
Break Rolls	67,463,322	37	26.4	16	69.4	11	0	0	95.8

a/ Percent control is the percentage of the total quantity for the operation which is controlled by the specific device.
b/ Not fabric filter; Day-Vac Unit.
c/ Percentages are based on controlled plants only.
d/ Insufficient data to determine extent of control.

1. The cost to install control equipment on an existing plant which does not have pollution controls is 120% of the cost required for a new plant. The increased costs reflect the fact that additional installation charges will be incurred on an existing or older plant.

2. Existing plants which already have adequate control equipment on specific operations will not incur any additional charges.

3. The pollution control equipment specifications for the model plant will be used as the average for the existing plants in the industry.

4. The maintenance and electrical expenses for a new fabric filter system will be 50% and 80%, respectively, of the expense required for an existing cyclone system.

A summary of the investment and annual operating costs required to install controls on existing plants is presented in Table 211.

Table 211. POLLUTION CONTROLS APPLIED TO EXISTING DRY CORN MILLS

	Average Per Establishement		Total for Industry[a]	
	Case 1 (best controls) ($)	Case 2 (alternate) ($)	Case 1 (best controls) ($)	Case 2 (alternate) ($)
Investment for controls	325,640	176,660	39,700,000	21,500,000
Annual control costs	66,590	32,270	8,100,000	3,900,000

a/ Assumes 122 dry corn mills.

The installation of the alternate controls specified in Case 2 would reduce the total industry investment required in Case 1 by 46% and the annual control cost by 52%. This reduction results from (1) the lower costs of the alternate control equipment, and (2) the increased number of existing plants already equipped with control devices which satisfy the requirements specified in Case 2.

The application of controls to all existing dry corn mills will have an impact on the industry. Some of the smaller or marginal plants will probably be forced to close. The trend over the past 10 years toward fewer mills with greater capacities would be increased if existing plants were subject to best control regulations.

The increased costs resulting from pollution control will probably be passed on to the consumer for industry products such as brewers grits and corebinder. However, consumer products such as cornmeal or flour which are sold directly to distributors may be subject to price controls. In these cases, the plants may have to absorb the control costs.

RICE MILLING

Description of Model Plant

Figure 60 summarizes the characteristics of the model plant for rice milling. The control devices shown are the "best" controls currently available. An alternative control system which substitutes cyclones for the fabric filter in the grain handling operation also is analyzed. The mill is assumed to be a rough rice mill only (i.e., no parboil). The capacity of the model mill is 200 bu/hr, and the mill is assumed to operate 4,000 hr/year. The mill is equipped with an optional grain dryer, in case rice is not purchased from a commercial rice dryer. Financial figures, where applicable, are expressed in hundredweights, using a conversion factor of 162 lb/barrel.

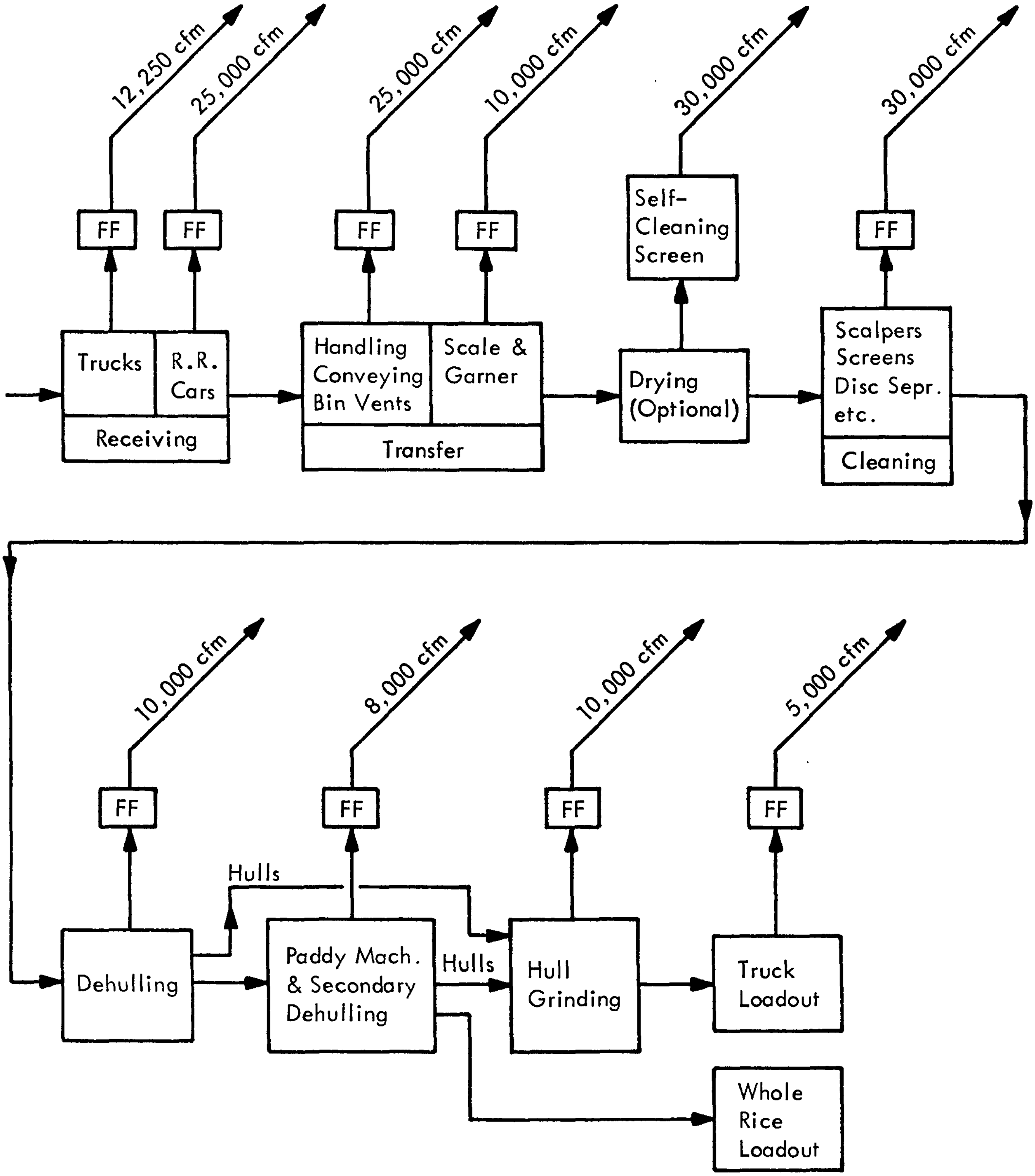
Control Equipment Costs

A summary of the best control equipment (Case 1) and associated costs required for the model plant is presented in Table 212. Similar figures for an alternate control system are presented in Table 213 (Case 2). For each operation, an estimate is given for the investment cost required for the control devices, as well as estimates for the total annual costs.

The model rice mill will require investment costs and annual operating costs as follows:

Basis:

Plant Capacity - 200 barrels/hr
Operate - 4,000 hr/yr



FF - Fabric Filter

Figure 60. Model new rice mill (no parboil)--best controls.

Table 212. MODEL NEW PLANT FOR RICE MILLING

Case 1 - Best Controls

Operation	Model Plant Control and Cost Estimate								
	Selected Device	Air Flow (cfm)	Oprn. (hr/year)	Electrical ($/year)	Maintenance ($/year)	Depreciation ($/year)	Capital Charges ($/year)	Annualized Cost ($/year)	Installed Cost ($)
Truck Receiving[a/]	FF	12,250	2,500	1,380	1,230	3,564	1,782	7,956	35,640[a/]
Car Receiving[b/]	FF	25,000	2,500	2,613	2,500	6,515	3,257	14,885	65,150[b/]
Handling and Transfer	FF	25,000	4,000	4,200	2,500	5,935	2,968	15,603	59,350
Scale and Garner	FF	10,000	2,500	923	1,000	2,300	1,150	5,373	23,000
Drying (optional)	Self Cleaning Screen	30,000	4,000	670	2,000	2,000	1,000	5,670	20,000
Cleaning House Scalpers Disc Seprs Scourers	FF	30,000	4,000	5,823	3,000	4,780	2,390	15,993	47,800
Dehulling	FF	10,000	4,000	1,685	1,000	2,480	1,240	6,405	24,800
Paddy Machine & Sec. Dehull.	FF	8,000	4,000	1,477	800	2,220	1,110	5,607	22,200
Hull Grinding	FF	10,000	4,000	1,685	1,000	2,380	1,190	6,255	23,800
Truck Loadout[c/]	FF	5,000	4,000	1,269	500	2,690	1,345	5,804	26,900[c/]
Total				21,725	15,530	34,864	17,432	89,551	348,640

a/ Includes cost of truck shed - $10,350
b/ Includes cost of 2-track unloading shed - $24,260
c/ Includes cost of truck loading shed - $10,350

Plant Capacity - 200 Barrels/Hr
Storage Capacity - 500,000 Bushels
Operate - 4,000 Hr/Year

Table 213. MODEL NEW PLANT FOR RICE MILLING

Case 2 - Alternate Controls

	Model Plant Control and Cost Estimate								
Operation	Selected Device	Air Flow (cfm)	Oprn. (hr/year)	Electrical ($/year)	Maintenance ($/year)	Depreciation ($/year)	Capital Charges ($/year)	Annualized Cost ($/year)	Installed Cost ($)
Truck Receiving[a/]	Cyclone	12,250	2,500	1.104	613	2,645	1,323	5,685	26,450
Car Receiving[b/]	Cyclone	25,000	2,500	2,090	1,250	5,140	2,570	11,050	51,400
Handling and Transfer	Cyclone	25,000	4,000	3,360	1,250	4,560	2,280	11,450	45,600
Scale and Garner	Cyclone	10,000	2,500	738	500	1,500	750	3,488	15,000
Drying (optional)	Self Cleaning Screen	30,000	4,000	670	2,000	2,000	1,000	5,670	20,000
Cleaning House Scalpers Disc Serprs Scourers	Cyclone	30,000	4,000	4,658	1,500	3,340	1,570	11,068	33,400
Dehulling	Cyclone	10,000	4,000	1,348	500	1,680	840	4,365	16,800
Paddy Machine and Sec. Dehulling	Cyclone	8,000	4,000	1,182	400	1,468	734	3,784	14,680
Hull Grinding	Cyclone	10,000	4,000	1,348	500	1,580	790	4,218	15,800
Truck Loadout[c/]	Cyclone	5,000	4,000	1,015	250	2,100	1,050	4,415	21,000
Total				17,513	8,763	26,013	12,907	65,193	260,130

a/ Includes cost of truck shed - $10,350
b/ Includes cost of 2-track unloading shed - $24,260
c/ Includes cost of truck loading shed - $10,350

Plant Capacity - 200 Barrels/Hr
Storage Capacity - 500,000 Bushels
Operate - 4,000 Hr/Year

Primary Device	Total Annualized Cost ($/year)	Total Installed Cost ($)
Case 1 - (Fabric filter)	89,550	348,640
Case 2 - (Cyclones)	65,190	260,130

Credits for Dust Control

The dust and hulls recovered by the control equipment can be added to the hull by-product stream. Material recovered represents a positive impact if the hulls can be sold as an animal feed ingredient. As was the case with other milling operations, emission factor data are meager for rice milling operations and only an estimate can be made of the potential positive impact. Table 214 presents such an estimate. The recovered dust was assumed to enter the by-products stream and have a value of $30/ton.

Financial Statements

The income statements and balance sheets which were developed for the model rice mill are presented in Tables 215 and 216. Separate statements were prepared to show the operation of the model rice mill both without and with pollution control equipment.

The principal information sources used in the development of these statements were the 1970 Annual Survey of Manufacturers,[15/] the USDA Economic Research Service Report on the Costs of Commercial Drying, Storing, and Handling Rough Rice,[23/] and the USDA Economic Service Report on the Cost of Operating Southern Rice Mills.[24/]

As shown in Table 215, the net income before taxes is reduced by the installation of pollution control equipment.

	Pollution Control Equipment			
	Net Income Without Controls (¢/cwt)	Net Income With Controls (¢/cwt)	Reduction (¢/cwt)	Reduction (%)
Case 1 - Best controls	42.1	35.1	6.9	16.6
Case 2 - Alternate controls	42.1	37.0	5.0	12.1

Table 214. POTENTIAL POSITIVE IMPACT OF POLLUTION CONTROL IN RECEIVING AND STORAGE SECTION OF MODEL RICE MILL

Assumed Recovery (lb/ton of rice handled)	Grain Handled (ton/year)	Total Dust Recovered (tons)	Value of Dust[a/] Recovered ($)	Dust Recovered As Percent of Annual Control Cost: Case 1 (%)	Case 2 (%)
1	64,800	32.4	972	1.1	1.5
2		64.8	1,944	2.2	3.0
3		97.2	2,916	3.3	4.5
4		129.6	3,888	4.3	6.0
5		162.0	4,860	5.4	7.5

a/ Assumes that recovered material could be sold at $30/ton, which was the average price of rice mill-feed during May 1973 as reported in Feedstuffs.

Table 215. INCOME STATEMENT FOR NEW MODEL RICE MILL
(1970)

	Without Controls		Case 1 - Best Controls			Case 2 - Alternate Controls		
			Control Costs	With Controls		Control Costs	With Controls	
	($000)	Percent	($000)	($000)	Percent	($000)	($000)	Percent
Sales	10,830	100.0		10,830	100.0		10,830	100.0
Cost of Materials	8,651	79.9		8,651	79.9		8,651	79.9
Production Wages	311	2.9		311	2.9		311	2.9
Cost of Goods Sold	8,962	82.8		8,962	82.8		8,962	82.8
Gross Profit	1,868	17.2		1,868	17.2		1,868	17.2
Expenses								
Administrative Salaries	208	1.9		208	1.9		208	1.9
Selling and Administration	400	3.7		400	3.7		400	3.7
Operating Expenses	444	4.1	37	481	4.4	27	471	4.3
Depreciation	134	1.2	35	169	1.6	26	160	1.5
Interest	137	1.3	17	154	1.4	13	150	1.4
Total Expenses	1,323	12.2	90	1,413	13.0	65	1,388	12.8
Net Income Before Taxes	545	5.0	-90	455	4.2		480	4.4
% Net Income/Net Worth	17.3%			14.5%			15.3%	
% Net Income/Total Assets	9.5%			7.5%			8.0%	
Net Income/Cwt Processed	$0.421			$0.351			$0.370	

Table 216. BALANCE SHEET FOR NEW MODEL RICE MILL (1970)

	Without Controls		Case 1 - Best Controls			Case 2 - Alternate Controls		
			Control Costs	With Controls		Control Costs	With Controls	
	($000)	Percent	($000)	($000)	Percent	($000)	($000)	Percent
Assets								
Current								
Receivables Net	1,150	20.1		1,150	19.0		1,150	19.0
Inventory	1,202	21.0		1,202	19.8		1,202	19.8
Other Current	679	11.9		679	11.2		679	11.2
Total Current	3,031	53.0		3,031	50.0		3,031	50.7
Fixed								
Structure and Building	1,035	18.1		1,035	17.1		1,035	17.1
Machinery and Equipment	1,235	21.6	349	1,584	26.1	260	1,495	25.0
Total Depreciable Assets	2,270	39.7	349	2,619	43.2	260	2,530	42.3
Other Fixed Assets	418	7.3		418	6.9		418	6.9
Total Fixed Assets	2,688	47.0	349	3,037	50.0	260	2,948	49.3
Total Assets	5,719	100.0	349	6,068	100.0	260	5,979	100.0
Liabilities								
Accounts Payable	686	12.0		686	11.3		686	11.3
Short-Term Notes	572	10.0		572	9.4		572	9.4
Other Current	458	8.0		458	7.5		458	7.5
Total Current	1,716	30.0		1,716	28.3		1,716	28.3
Long-Term Debt	858	15.0	349	1,207	19.9	260	1,118	18.7
Total Liabilities	2,574	45.0	349	2,923	48.2	260	2,834	47.4
Net Worth	3,145	55.0		3,145	51.8		3,145	51.8
Total Liabilities and Net Worth	5,719	100.0	349	6,068	100.0	260	5,979	100.0

Table 216 presents the comparative balance sheets for the model plant. The impact of pollution controls upon plant construction is as follows:

	Pollution Control Equipment			
	Plant Investment Without Controls ($/barrel/hr)	Plant Investment With Controls ($/barrel/hr)	Increase ($/barrel/hr)	(%)
Case 1 - Best controls	11,350	13,095	1,745	15.4
Case 2 - Alternate controls	11,350	12,650	1,300	11.5

The investment in the controls for Case 2 is 25.4% less than the investment required for best controls specified in Case 1.

Economic Impact of Control Systems on Industry

New Plants - The financial impact of pollution control equipment on the model rice mill is summarized in Table 217.

Table 217. IMPACT OF CONTROLS APPLIED TO NEW MODEL RICE MILL

	Case 1	Case 2
Control investment	$348,640	$260,130
Percent of new plant and equipment	15.4%	11.5%
Percent of dollar sales	3.2%	2.4%
Per cwt of rice processed	26.9¢	20.1¢
Annual control operating costs	$ 89,550	$ 65,190
Percent of net worth	2.8%	2.1%
Percent of total assets	1.5%	1.1%
Percent of dollar sales	0.83%	0.6%
Per cwt of price processed	6.9¢	5.0¢

The investment cost for control equipment is great enough in comparison with the total plant investment cost to be a significant factor in the construction of new rice mills. Although there will be positive impacts from the installation of control equipment, the credits from dust recovery will not be great enough to completely offset the costs.

As is the case with other grain handling industries, the economics of scale for rice mills will be changed as a result of requirements for the installation of control equipment. The control costs for grain receiving, handling and loadout operations in the model plant amount to 60% of the total investment in controls. Since the costs for these devices will not decrease significantly for smaller capacity mills, the small mill will become less economical.

The annual control costs for pollution control do not appear to be great enough to have a significant impact on new plants. These costs would amount to only 0.8% (Case 1) and 0.6% (Case 2) of dollar sales and will either be passed on in the price of products or absorbed as a result of operational efficiencies obtained from the new plant. The impact on the industry resulting from new plant regulations will be small, if for no other reason than few new rough rice mills are being built.

Existing Plants - To determine the economic impact of equipping existing rice mills with the best control system specified for the model rice mill, it is necessary to take into account the current level of control on existing plants. Table 218 presents the current status of control of rice mills as determined from emission inventory questionnaires submitted by 26 individual plants. Of the surveyed plants, approximately 50% have controls on their grain handling operations and 75% control milling operations. However, most of the plants which have controls are not equipped with the "best" control devices. Using the data in Table 218, the capital investment and annual costs required by existing plants to install and operate the two alternative control systems were developed. The major assumptions made in determining these costs are as follows:

1. The cost to install control equipment on an existing plant which does not have pollution controls is 120% of the cost required for a new plant. The increased costs reflect the fact that additional installation charges will be incurred on an existing or older plant.

2. Existing plants which already have adequate control equipment or specific operations will not incur any additional charges.

Table 218. RICE MILLS, POLLUTION CONTROLS ON EXISTING PLANTS, SURVEY OF 26 PLANTS

Operation	Quantity (1,000 bu/year)	No. of Plants	Cyclone % Control[a]	Cyclone No. Plants	Fabric Filter % Control[a]	Fabric Filter No. Plants	Wet Scrubber % Control[a]	Wet Scrubber No. Plants	Other Devices % Control[a]	Other Devices No. Plants	Total % With Control
Receiving											
Hopper	11,589	11	7.5	1	0.0	0	0.0	0	0.0	0	7.5
Boxcar	1,246	6	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Truck	68,407	22	29.2	4	24.1	3	12.0	1	1.4	1	66.7
Other	700	1	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Total	81,942	22	25.4	4	20.1	3	10.0	1	1.2	1	56.7
Drying	15,249	20	45.7[d]	4	0.9[e]	1	0.0	0	11.0[f]	2	57.6
Cleaning	121,489	25	67.0	16	13.6	3	0.0	0	0.0	0	80.6
Handling											
Transfer	104,266	23	27.3	6	48.2	7	0.0	0	5.2	1	80.7
Garner and Scale	104,404	24	18.6	4	22.8	4	0.0	0	5.2	1	46.6
Legs	121,602	25	41.8	7	28.0	6	0.0	0	0.0	0	69.8
Tripper	93,282	19	25.6	2	31.0	4	0.0	0	0.0	0	56.6
Cleaning House	107,008	25	39.9	10	23.5	4	0.0	0	0.0	0	63.4
Milling											
Shellers	121,489	25	55.5	15	43.2	7	0.0	0	0.0	0	98.7
Hullers	120,746	24	71.4	17	22.2	5	0.0	0	0.0	0	93.6
Hull Grinding[b]	113,008	22	25.8	6	41.2	6	0.0	0	7.8	3	74.8
Grading	103,056	23	32.6	7	24.3	4	0.0	0	0.9	1	57.8
Bulk Loading[c]	97,808	24	47.6	13	33.0	4	0.0	0	0.0	0	80.6

a/ Percent control is the percentage of the total quantity which is controlled by the specified device.
b/ Extent of control is based on quantity received not on weight of hulls.
c/ Extent of control is based on quantity received not on percent bulk loaded; all plants bulk load.
d/ Control device assumed to be similar to Wiedenmann Screen-Kleen or Carter-Day Day-Vac Systems.
e/ Control device assumed to be Carter-Day Day-Vac System.
f/ Control device assumed to be screen house.

3. The pollution control equipment specifications for the model plant was used as the average for the existing plants in the industry and the controls on the surveyed plants were used as the industry average.

4. The maintenance and electrical expenses for a new fabric filter system will be 50% and 80%, respectively, of the expense required for an existing cyclone system.

The impact on existing plants is shown in Table 219. The investment cost for an average existing plant to install best controls is 14% less than the corresponding costs for the new model plant, and annual operating costs are 26% lower. The costs are lower for existing plants because approximately 20% are already equipped with best controls.

The investment and annual costs required for an average plant to meet the control specifications in Case 2 are, respectively, 61% and 59% lower than for Case 1. Smaller costs are required by Case 2 because approximately 40% of the existing plants have controls which meet the Case 2 specifications.

The application of best controls to existing plants will not have a major impact on the industry. However, some of the smaller and technically obsolete plants will quite possibly be forced to close. The attrition rate of rice mills in recent years has been high because of the closing of mills owned by the small, independent firm and the consolidation of milling facilities by large multi-mill firms. Regulations requiring controls of existing plants will contribute to this trend.

The increased costs from controls, which amount to approximately 0.6% of dollar sales, will probably be passed on to the industrial consumer, e.g., brewery products. However, rice mill products which are sold directly for public consumption have been subject to the price regulations. In these cases, rice mills may have to obtain government approval before they will be able to pass the control costs on to the consumer through higher prices.

COMMERCIAL RICE DRYING

Description of Model Plants

Figure 61 summarizes the characteristics of the model plant for commercial rice drying. The control devices shown are the "best" controls currently available. An alternative control system which substitutes cyclones for the fabric filter will also be analyzed. The storage capacity of the facility is 250,000 cwt and the throughput rate is 345,000 cwt/year.

Table 219. CONTROLS APPLIED TO EXISTING RICE MILLS

	Average Per Establishment		Total for Industry[a]	
	Case 1 ($)	Case 2 ($)	Case 1 ($)	Case 2 ($)
Investment for Control Equipment	299,500	117,490	14,376,000	5,640,000
Annual Control Costs	65,770	27,070	3,157,000	1,299,000
Annual Control Costs Per cwt of Production[b]			5.6¢/cwt	2.3¢/cwt
Annual Control Costs As a Percent of Dollar Sales[c]			0.57%	0.23%

a/ Assumes that there are 48 existing rice mills.

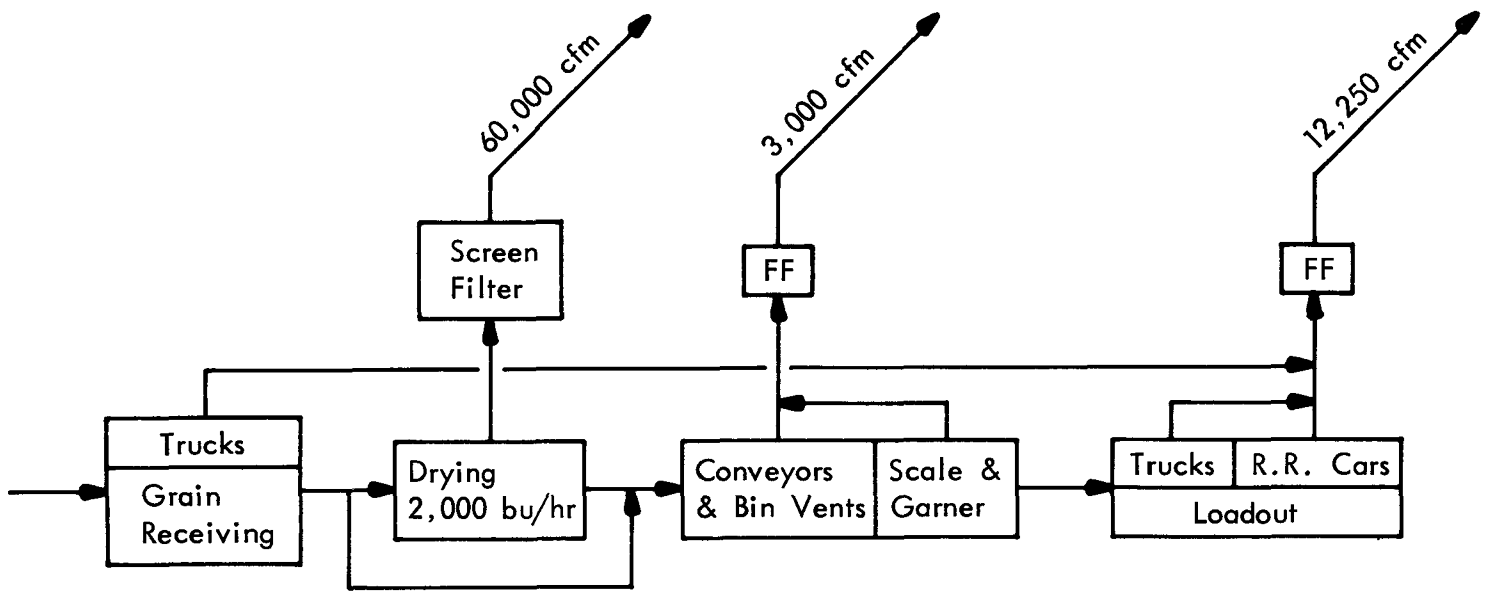
b/ Production in 1970 was 56,870,000 cwt, according to the 1972 USDA *Agricultural Statistics*.

c/ Sales in 1970, according to the *Annual Survey of Manufacturers*, were $553.4 million.

Basis:

a. Receive by truck from farmer
b. Ship by truck and rail
c. Leg capacity - 2,250 cwt/hr
d. Dryer capacity - 900 cwt/hr

Storage Capacity - 250,000 cwt
Throughput - 345,000 cwt/yr



FF - Fabric Filter

Figure 61. Model new commercial rice drying plant--best controls.

The dryer selected is a 2,000 bu/hr (900 cwt/hr) 60,000 cfm recirculating-column dryer.

Control Equipment Costs

A summary of control equipment and associated costs required for the model plant is presented in Table 220 for Case 1 and Table 221 for Case 2. For each operation, an estimate is given for the investment cost required for the control devices as well as estimates for the total annual costs including electrical charges, maintenance expenses, depreciation expenses and capital charges.

The operational hours per year which are listed in the tables were estimated from an analysis of (1) the operational requirements and capacities of each device, and (2) the volume of grain which will be processed by each operation. Allowances were made for the fact that the control devices must operate longer than would be required if each operation--receiving, drying, cleaning, handling, shipping, etc.--were optimally scheduled at plant equipment capacities.

The model rice dryer will require estimated investment expenditures and annual operating costs as follows:

Primary Device	Total Annualized Cost ($/year)	Installed Cost ($)
Case 1 - (Fabric filters)	19,792	102,940
Case 2 - (Cyclones)	16,750	89,013

Credits for Dust Control

There are a number of control credits or positive impacts which might result from the installation of pollution control equipment on a commercial rice drying operation. Possible positive impacts include:

1. Reduction in product shrink,

2. Reduction of maintenance costs through savings on lubricants and similar materials,

3. Increased life of protective coatings,

4. Labor savings in elevator clean-up,

Table 220. MODEL PLANT FOR NEW COMMERCIAL RICE DRYER

Case 1 - Best Controls

	Model Plant Control and Cost Estimate								
Operation	Selected Device	Air Flow (cfm)	Oprn. (hr/year)	Electrical ($/year)	Maintenance ($/year)	Depreciation ($/year)	Capital Charges ($/year)	Annualized Cost ($/year)	Installed Cost ($)
Loadout and receiving[a]	Filter	12,250	1,000	550	1,230	6.145	3,073	10,998	61,450[b]
Grain dryer, 900 cwt/hr	Self-cleaning screen	60,000	2,000	400	1,500	2,890	1,445	6,235	28,900
Scale, garner, leg, bin vents	Filter	3,000	2,000	370	300	1,259	630	2,559	12,590
Total		75,250		1,320	3,030	10,294	5,148	19,792	102,940

a/ One filter serves truck receiving, truck loading, and car loading.
b/ Includes $24,269 for railroad car loading shed. (Assume truck loading is normally covered.)

Storage Capacity - 250,000 cwt
Throughput - 345,000 cwt/year

Table 221. MODEL PLANT FOR NEW COMMERCIAL RICE DRYER

Case 2 - Alternate Controls

	Model Plant Control and Cost Estimate								
Operation	Selected Device	Air Flow (cfm)	Oprn. (hr/year)	Electrical ($/year)	Maintenance ($/year)	Depreciation ($/year)	Capital Charges ($/year)	Annualized Cost ($/year)	Installed Cost ($)
Loadout and receiving[a]	Cyclone	12,250	1,000	440	613	5,226	2,613	8,892	52,263[b]
Grain dryer, 900 cwt/hr	Self-cleaning screen	60,000	2,000	400	1,500	2,890	1,445	6,235	28,900
Scale, garner, leg, bin vents	Cyclone	3,000	2,000	295	150	785	393	1,623	7,850
Total				1,135	2,263	8,901	4,451	16,750	89,013

a/ One filter serves truck loading, and car loading.
b/ Includes $24,269 for railroad car loading shed. (Assume truck loading is normally covered.)

Storage Capacity - 250,000 cwt
throughput - 345,000 cwt/year

5. Reduction in fire insurance premiums for stocks, property, and business interruptions, and

6. Tighter insect and rodent control with attendant reduction in grain losses.

The major control credit which will be quantified in this analysis is the reduction in product shrink. The dust which is collected from the plant operations can be sold as hulls or screenings for use as a feed ingredient. Since emission factor data are not available for rice handling and drying operations, only estimates can be made of the potential positive impact. Alternative emission rates--varying from 1 lb/ton of rice handled to 5 lb/ton--were used to evaluate the control credit which would result if the recovered dust were sold at a value of $30/ton, which was the price of rice millfeed in May 1973. The results are presented in Table 222.

Financial Statements

To determine the financial impact of air pollution control costs on commercial rice dryers, an income statement and balance sheet were developed for the model plant. Separate statements were prepared to show the operation of the model rice dryer without and with pollution control equipment for both Case 1 and Case 2.

The principal information sources used in the development of these statements were the USDA Economic Research Report ERS-407[23] and discussions with knowledgeable individuals in the Fibers and Grain Branch, Marketing Economics Division of USDA. Assumptions which were made concerning operational characteristics of the model commercial rice dryer are listed below.

Specifications for Model Commercial Rice Dryer

Storage capacity	250,000 cwt
Dryer capacity	900 cwt/hr
Rice handled	345,000 cwt/year
Rice dried	327,750 cwt/year (95% of receipts)
Average storage	85,500 cwt (35% of storage capacity)
Gross margin	65¢/cwt handled
Construction cost	
Without controls	$4.30/cwt storage
With controls	$4.71/cwt storage
Receiving	100% by truck
Loadout	50% by truck, 50% by rail

Table 222. POTENTIAL POSITIVE IMPACT OF POLLUTION CONTROL IN RECEIVING, STORAGE, AND LOADING SECTION OF MODEL RICE DRYER

Assumed Recovery (lb/ton of rice handled)	Grain Handled (cwt/year)	Total Dust Recovered (tons)	Value of Dust[a/] Recovered ($)	Dust Recovered As Percent of Annual Control Cost	
				Case 1 (%)	Case 2 (%)
1	345,000	8.6	258	1.3	1.5
2		17.3	519	2.6	3.1
3		25.9	777	3.9	4.6
4		34.5	1,035	5.2	6.2
5		43.1	1,293	6.5	7.7

a/ Assumes that recovered material could be sold as rice millfeed at $30/ton, which was the price in May 1973.

The comparative income statements for the new model plant are presented in Table 223. The gross margin per hundredweight of rice handled was assumed to be 65¢. Depending upon the year and individual plant, this margin could vary from 56¢ to 75¢/cwt. A summary of the income statement shows the following financial impact:

Primary Device	Net Income Without Controls (¢/cwt)	Net Income With Controls (¢/cwt)	Reduction (¢/cwt)	Reduction (%)
Case 1 - (Fabric filters)	16.2	10.4	5.7	35.5
Case 2 - (Cyclones)	16.2	11.3	4.9	30.0

The reduction in net income resulting from the installation of the control devices in Case 2 is 16% less than the corresponding reduction for Case 1.

Table 224 presents the comparative balance sheets for the model plant. A construction cost of $4.30 for each hundredweight of storage capacity was used to estimate the total investment cost in plant and equipment without pollution control equipment. The addition of control equipment increases the cost per hundredweight of storage capacity as follows:

Primary Device	Plant Investment Without Controls ($/cwt)	Plant Investment With Controls ($/cwt)	Increase ($/cwt)	Increase (%)
Case 1 - (Fabric filters)	4.30	4.71	0.41	9.5
Case 2 - (Cyclones)	4.30	4.65	0.36	8.3

Economic Impact of Control Systems on Industry

New Plants - The financial impact of pollution control equipment on the model rice dryer is summarized in Table 225.

Table 223. INCOME STATEMENT FOR NEW MODEL COMMERCIAL RICE DRYER
(1973)

	Without Controls		Case 1 - Best Controls				Case 2 - Alternate Controls			
			Control Costs		With Controls		Control Costs		With Controls	
	(Dollars)	(¢/Cwt)a/	(Dollars)	(¢/Cwt)a/	(Dollars)	(¢/Cwt)a/	(Dollars)	(¢/Cwt)a/	(Dollars)	(¢/Cwt)a/
Gross Margin	220,800	64.0			220,800	64.0			220,800	64.0
Expenses										
Fixed										
Receiving	5,870	1.7	4,120	1.2	9,990	2.9	3,500	1.0	9,370	2.7
Drying	25,710	7.5	4,330	1.3	30,040	8.7	4,340	1.3	30,050	8.7
Storage	56,010	16.2	1,890	0.5	57,900	16.8	1,180	0.3	57,190	16.6
Loading	8,550	2.8	5,100	1.5	13,650	4.0	4,340	1.3	12,890	3.7
Total Fixed	96,140	27.9	15,440	4.5	111,580	32.3	13,360	3.9	109,500	31.7
Variable										
Receiving	11,160	3.2	800	0.2	11,960	3.5	470	0.1	11,630	3.4
Drying	28,630	8.3	1,900	0.6	30,530	8.8	1,900	0.6	30,530	8.8
Storage	16,510	4.8	670	0.2	13,520	3.9	450	0.1	16,960	4.9
Loading	12,540	3.6	980	0.3	17,180	5.0	580	0.2	13,120	3.8
Total Variable	68,840	20.0	4,350	1.3	73,190	21.2	3,400	1.0	72,250	20.9
Total Expenses	164,980	47.8	19,790	5.7	184,770	53.6	16,750	4.9	181,730	52.7
Net Income Before Taxes	55,820	16.2			36,030	10.4			39,070	11.3
% Net Income/Net Worth	6.8%				4.4%				4.7%	
% Net Income/Total Assets	3.6%				2.2%				2.4%	

a/ Entries are calculated as cents per cwt of rough rice handled (received and shipped).

Table 224. BALANCE SHEET FOR NEW MODEL COMMERCIAL RICE DRYER (1973)

	Without Controls		Case 1 - Best Controls			Case 2 - Alternate Controls		
			Control Costs	With Controls		Control Costs	With Controls	
	($000)	Percent	($000)	($000)	Percent	($000)	($000)	Percent
Assets								
Current	425	27.4		425	25.7		425	25.7
Fixed	1,075	69.4	103	1,178	71.3	89	1,164	71.0
Other	50	3.2		50	3.0		50	3.0
Total Assets	1,550	100.0	103	1,653	100.0	89	1,639	100.0
Liabilities								
Current	295	19.0		295	17.8		295	17.8
Deferred	429	27.7	103	532	32.2	89	518	31.6
Total Liabilities	724	46.7	103	827	50.0	89	813	49.6
Net Worth	826	53.3		826	50.0		826	50.0
Total Liabilities and Net Worth	1,550	100.0	103	1,653	100.0	89	1,639	100.0

Table 225. IMPACT OF CONTROLS APPLIED TO NEW MODEL PLANT

	Case 1	Case 2
Control investment	$102,940	$89,013
Percent of investment for new plant and equipment	9.6%	8.3%
Per cwt of rice handled	29.8¢	25.8¢
Annual control operating costs	$ 19,790	$16,750
Percent of net worth	2.4%	2.0%
Percent of total assets	1.2%	1.1%
Percent of net income before taxes	35.5%	30.0%
Per cwt of rice handled	5.7¢	4.9¢

The investment cost for control equipment is great enough in comparison with the total plant investment cost to be a significant factor in the construction of new rice dryers. Although there will be positive impacts from the installation of control equipment, the credits from dust recovery will not be great enough to completely offset the costs.

As is the case with other grain handling industries, the economics of scale for rice dryers will be changed as a result of requirements for the installation of control equipment. The control costs for rice receiving, handling, and loadout operations in the model plant amount to 72% of the total investment in controls. Since the costs for these devices will not decrease significantly for smaller capacity operations, the small rice dryers will become less economical.

The annual control costs for pollution control will also have a significant impact on new plants. These costs amount to 9% of the gross margin in Case 1 and 7.6% in Case 2. These increased costs will have to be passed on through higher prices in order for the plant to maintain an adequate return on investment.

Existing Plants - As determined from emission inventory questionnaires, very few if any of the existing commercial rice dryers are equipped with "best" pollution control equipment. Regulations specifying best controls on existing plants would have a significant impact on the industry. Assuming an installation cost ratio of 1.2 between existing and new plants, the approximately 279 existing commercial rice dryers would require total industry capital investment and annual cost increase as summarized in Table 226.

Table 226. CONTROLS APPLIED TO EXISTING RICE DRYERS

	Average Per Establishment		Total For Industry	
	Case 1 ($)	Case 2 ($)	Case 1 ($)	Case 2 ($)
Investment for control equipment	102,904	89,013	34,500,000	29,800,000
Annual control cost	19,792	16,750	6,600,000	5,600,000

The impact would be greatest for the small rice dryers. Some of these operations would be forced to close or operate at a significantly lower profit margin.

SOYBEAN PROCESSING PLANT

Description of Model Plant

A model for the soybean processing plant equipped with the "best" demonstrated control system is shown in Figure 62. An alternate model, which specifies cyclones in place of the fabric filters, will also be analyzed. The plant capacity is assumed to be 1,000 tons/24 hr, and the plant is assumed to operate 8,000 hr/year. Soybean storage capacity for the model plant is 3,500,000 bu.

Control Equipment Costs

Table 227 (Case 1) and Table 228 (Case 2) list the control equipment and associated costs required for the model soybean processing plant. Both investment and total annual cost for control devices for each operation are presented.

Total estimated investment and annual operating costs for control equipment in the new model plant are summarized as follows:

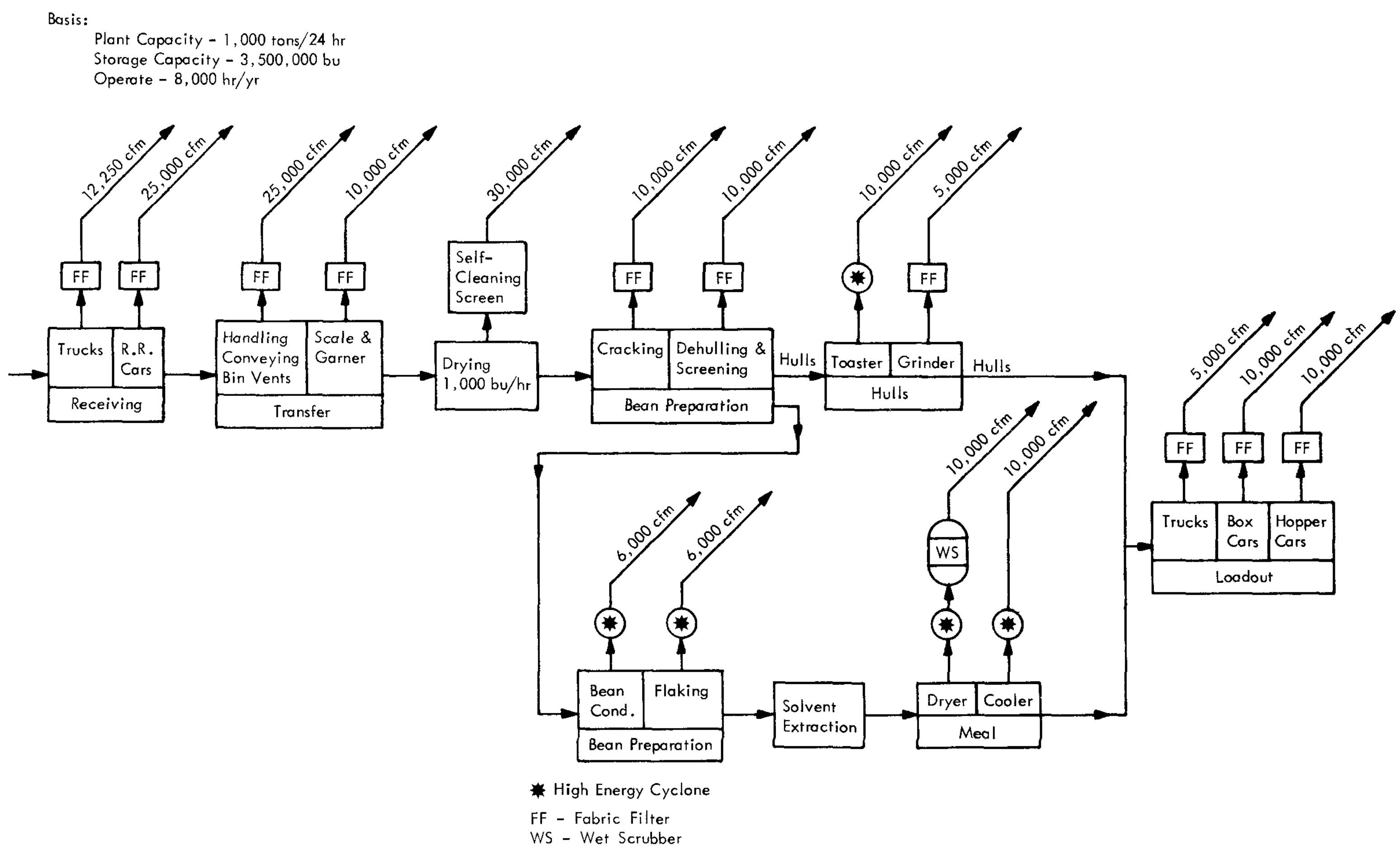


Figure 62. Model new soybean processing plant.

Table 227. MODEL NEW PLANT FOR SOYBEAN PROCESSING

Case 1 - Best Controls

Operation	Selected Device	Air Flow (cfm)	Oprn. (hr/year)	Model Plant Control and Cost Estimate: Electrical ($/year)	Maintenance ($/year)	Depreciation ($/year)	Capital Charges ($/year)	Annualized Cost ($/year)	Installed Cost ($)
Truck Receiving[a]	FF	12,250	2,500	1,380	1,230	3,564	1,782	7,956	35,640
Car Receiving[b]	FF	25,000	2,500	2,613	2,500	6,515	3,258	14,886	65,150
Handling and Transfer	FF	25,000	8,000	8,350	2,500	5,935	2,967	19,752	59,350
Scale and Garner	FF	10,000	2,500	923	1,000	2,300	1,150	5,373	23,000
Drying (Capacity 1,000 bu/hr)	Self Cleaning Screen	30,000	6,000	1,000	2,400	2,000	1,000	6,400	20,000
Cracking Mills	FF	10,000	8,000	5,033	1,000	2,430	1,215	9,678	24,300
Flaking	Hi-Energy Cyclone	6,000	8,000	3,369	600	2,415	1,208	7,592	24,150
Bean Conditioning	Hi-Energy Cyclone	6,000	8,000	3,369	600	1,935	967	6,871	19,350
Dehulling and Screen	FF	10,000	8,000	5,033	1,000	2,560	1,280	9,873	25,600
Meal Dryer									
Primary Control	Hi-Energy Cyclone	10,000	8,000	5,033	1,000	2,830	1,415	10,278	28,300
Secondary Control	Wet Scrubber	10,000	8,000	2,496	1,000	4,120	2,060	9,676	41,200
Meal Cooler	Hi-Energy Cyclone	20,000	8,000	6,697	2,000	4,976	2,488	16,161	49,760
Hull Toaster	Hi-Energy Cyclone	10,000	8,000	5,033	1,000	2,833	1,416	10,282	28,330
Hull Grinder	FF	5,000	8,000	2,120	500	1,600	800	5,020	16,000
Truck Loadout	FF	5,000	2,500	793	500	1,652	826	3,771	16,520
Boxcar Loadout	FF	10,000	2,500	1,171	1,000	2,580	1,290	6,041	25,800
Hopper Car Loadout	FF	10,000	2,500	1,171	1,000	2,580	1,290	6,041	25,800
Total				55,584	20,830	52,825	26,412	155,651	528,250

a/ Includes cost of truck shed - $10,350
b/ Includes cost of 2-track unloading shed - $24,260

Plant Capacity - 1,000 tons/24 hr
Storage Capacity - 3,500,000 bu
Operate - 8,000 hr/year

Table 228. MODEL NEW PLANT FOR SOYBEAN PROCESSING

Case 2 - Alternate Controls

Operation	Selected Device	Model Plant Control and Cost Estimate: Air Flow (cfm)	Oprn. (hr/year)	Electrical ($/year)	Maintenance ($/year)	Depreciation ($/year)	Capital Charges ($/year)	Annualized Cost ($/year)	Installed Cost ($)
Truck Receiving[a]	Cyclone	12,250	2,500	1,104	613	2,645	1,323	5,685	26,450
Car Receiving[b]	Cyclone	25,000	2,500	2,090	1,250	5,140	2,570	11,050	51,400
Handling and Transfer	Cyclone	25,000	8,000	6,680	1,250	4,560	2,280	14,770	45,600
Scale and Garner	Cyclone	10,000	2,500	738	500	1,500	750	3,488	15,000
Drying (Capacity: 1,000 bu/hr)	Self Cleaning Screen	30,000	6,000	1,000	2,400	2,000	1,000	6,400	20,000
Cracking Mills	Cyclone	10,000	8,000	4,026	500	1,630	820	6,976	16,300
Flaking	Hi-Energy Cyclone	6,000	8,000	3,369	600	2,415	1,208	7,592	24,150
Bean Conditioning	Hi-Energy Cyclone	6,000	8,000	3,369	600	1,935	967	6,871	19,350
Dehulling and Screen	Cyclone	10,000	8,000	4,026	500	1,760	880	7,166	17,600
Meal Dryer Primary Control	Hi-Energy Cyclone	10,000	8,000	5,033	1,000	2,830	1,415	10,278	28,300
Secondary Control	Wet Scrubber	10,000	8,000	2,496	1,000	4,120	2,060	9,676	41,200
Meal Cooler	Hi-Energy Cyclone	20,000	8,000	6,697	2,000	4,976	2,488	16,161	49,760
Hull Toaster	Hi-Energy Cyclone	10,000	8,000	5,033	1,000	2,833	1,416	10,282	28,330
Hull Grinder	Cyclone	5,000	8,000	1,696	250	1,010	505	3,461	10,100
Truck Loadout	Cyclone	5,000	2,500	634	250	1,062	531	2,477	10,620
Boxcar Loadout	Cyclone	10,000	2,500	937	500	1,780	890	4,107	17,800
Hopper Car Loadout	Cyclone	10,000	2,500	937	500	1,780	890	4,107	17,800
Total				49,865	14,713	43,976	21,993	130,547	439,760

a/ Includes cost of truck shed - $10,350
b/ Includes cost of 2-track unloading shed - $24,260

Plant Capacity - 1,000 tons/24 hr
Storage Capacity - 3,500,000 bu
Operate - 8,000 hr/year

Primary Device	Total Annualized Cost ($/year)	Total Installed Cost ($)
Case 1 - (Fabric filters)	155,650	528,250
Case 2 - (Cyclones)	130,550	439,760

However, the control systems associated with the cracking, dehulling and screening, and hull toasting and grinding are actually product recovery systems rather than pollution control systems. In keeping with actual plant practice, the costs for these systems probably should not be attributed to pollution control costs. With this revision, the total investment costs for pollution control and associated annual costs would be:

Primary Device	Total Annualized Cost ($/year)	Total Installed Cost ($)
Case 1 - (Fabric filters)	120,798	434,020
Case 2 - (Cyclones)	102,662	367,430

This consideration reduces investment costs and annual operating costs 17% and 22%, respectively, in both Case 1 and Case 2.

Credits for Dust Control

The dust that is collected in the soybean receiving, storage, and cleaning operations would have some value if it could be added to the hulls stream and blended with the hulls. However, since the hulls themselves are blended with the soybean meal to produce products of different protein content, the exact value of the hull stream is difficult to define. This uncertainty coupled with the lack of data on emission factors precluded estimation of the potential positive impact of the dust control system.

Financial Statements

An income statement and balance sheet for the model soybean processing plant are presented in Tables 229 and 230. Separate statements were developed for the operation of the model plant without and with the two alternative pollution control systems.

Table 229. INCOME STATEMENT FOR MODEL NEW SOYBEAN MILL
(1973)

	Without Controls		Case 1 - Best Controls			Case 2 - Alternate Controls		
			Control Costs	With Controls		Control Costs	With Controls	
	($000)	Percent	($000)	($000)	Percent	($000)	($000)	Percent
Sales								
Cost of Materials	73,444	100.0		73,444	100.0		73,444	100.0
Soybeans	66,667	90.8		66,667	90.8		66,667	90.8
Other Materials	2,656	3.6		2,656	3.6		2,656	3.6
Wages	528	0.7		528	0.7		528	0.7
Cost of Goods Sold	69,851	95.1		69,851	95.1		69,851	95.1
Gross Income	3,593	4.9		3,593	4.9		3,593	4.9
Expenses								
Administration	383	0.5		383	0.5		383	0.5
Other Expenses	748	1.0	76	824	1.1	65	813	1.1
Depreciation	400	0.6	53	453	0.6	44	444	0.6
Interest	600	0.8	26	626	0.9	22	622	0.8
Total Expenses	2,131	2.9	156	2,287	3.1	131	2,262	3.1
Net Income Before Taxes	1,462	2.0	-156	1,306	1.8	-131	1,331	1.8
Net Income/Ton Processed	$4.39			$3.92			$3.99	
% Net Income/Net Worth	13.2%			11.8%			12.0%	
% Net Income/Total Assets	6.6%			5.9%			5.9%	

Table 230. BALANCE SHEET FOR MODEL NEW SOYBEAN MILL
(1973)

	Without Controls		Case 1 - Best Controls			Case 2 - Alternate Controls		
			Control Costs	With Controls		Control Costs	With Controls	
	($000)	Percent	($000)	($000)	Percent	($000)	($000)	Percent
Assets								
Current Assets								
Receivables	4,246	19.2		4,246	18.7		4,246	18.7
Inventory	7,216	23.6		7,216	31.8		7,216	31.8
Other Current	2,059	9.3		2,059	9.1		2,059	9.1
Total Current Assets	13,521	61.1		13,521	59.6		13,521	59.6
Fixed Assets								
Structure and Building	2,085	9.4		2,085	9.2		2,085	9.2
Machinery and Equipment	4,720	21.3	528	5,248	23.1	440	5,160	22.8
Total Depreciable	6,805	30.7	528	7,333	32.3	440	7,245	32.1
Other Fixed	1,820	8.2		1,820	8.0		1,820	8.0
Total Fixed Assets	8,625	38.9	528	9,153	40.4	440	9,065	40.1
Total Assets	22,146	100.0	528	22,674	100.0	440	22,586	100.0
Liabilities								
Accounts Payable	2,036	9.2		2,036	9.0		2,036	9.0
Short-Term Notes	2,154	9.7		2,154	9.5		2,154	9.5
Other Current	1,526	6.9		1,526	6.7		1,526	6.7
Total Current Liabilities	5,716	25.8		5,716	25.2		5,716	25.2
Long-Term Debt	5,357	24.2	528	5,885	26.0	440	5,797	25.7
Total Liabilities	11,073	50.0	528	11,601	51.2	440	11,513	51.0
Net Worth	11,073	50.0		11,073	48.8		11,073	48.8
Total Liabilities and Net Worth	22,146	100.0	528	22,674	100.0	440	22,586	100.0

The monthly average price of soybeans reached all-time highs in 1973. In developing the income statement presented in Table 229, soybeans were assumed to be selling at $6/bu and the processing margins were assumed to be 61¢/bu. Processing margins are the differences between prices of soybeans and prices for equivalent quantity of oil and meal.

Soybean cash prices in January 1973 were around $4/bu, rose to over $11/bu in June 1973, and were at $5.80/bu the last week in December 1973. Soybean processing margins increased from 21¢/bu in September 1972 to $1.07 in January 1973. The 61¢/bu value was the average season margin as reported in the April 1973 Fats and Oils Situation.[26/]

A summary of the income statement in Table 229 shows the following financial impact:

	Pollution Control and Product Recovery Equipment			
	Net Income Without Controls ($/cwt)	Net Income With Controls ($/cwt)	Reduction ($/cwt)	Reduction (%)
Case 1 - Best controls	4.39	3.92	0.47	10.7
Case 2 - Alternate controls	4.39	3.99	0.40	9.1

The reduction in net income from Case 1 controls is 16% less than the reduction from Case 2.

These costs were computed assuming all the equipment listed in Tables 227 and 228 were considered as pollution control. If, as mentioned previously, the cracking, dehulling and screening, and hull toasting and grinding equipment are classified as product recovery devices, the income before taxes without and with pollution control would be affected as follows:

	Pollution Control Equipment Only			
	Net Income Without Controls ($/cwt)	Net Income With Controls ($/cwt)	Reduction ($/cwt)	Reduction (%)
Case 1 - Best controls	4.28	3.92	0.36	8.4
Case 2 - Alternate controls	4.28	3.99	0.29	6.8

The cost of plant and equipment shown in the balance sheet (Table 230) was calculated from book value of fixed assets as reported in the 1970 Annual Survey of Manufacturers[15/] assuming an 8.5% yearly inflation in construction costs between 1970 and 1973.

For the selected model plant, the addition of pollution control and product recovery equipment increases the investment cost per ton of daily capacity (1,000 tons/day) in total plant and equipment as follows:

	Pollution and Product Recovery Equipment			
	Plant Investment Without Controls ($/ton)	Plant Investment With Controls ($/ton)	Increase ($/ton)	Increase (%)
Case 1 - Best controls	6,805	7,333	528	7.8
Case 2 - Alternate controls	6,805	7,245	440	6.5

If the product recovery equipment is included in the original investment cost, then the construction costs will be as follows:

	Pollution Control Equipment Only			
	Plant Investment Without Controls ($/ton)	Plant Investment With Controls ($/ton)	Increase ($/ton)	Increase (%)
Case 1 - Best controls	6,899	7,333	434	6.3
Case 2 - Alternate controls	6,877	7,245	368	5.4

Economic Impact of Control Systems on Industry

New Plants - The financial impact of pollution control equipment on the model plant is summarized in Table 231. Separate analyses were made to determine the impact at 1970 and 1973 price levels of: (1) pollution control and product recovery equipment, and (2) pollution control equipment only. In the latter case, the equipment on the cracking, dehulling and screening, and hull toasting and grinding operations was not considered as control equipment. At first quarter 1973 price levels, the investment in control

Table 231. ECONOMIC IMPACT OF CONTROLS APPLIED TO MODEL SOYBEAN MILL

	Pollution Control & Product Recovery Equipment				Pollution Control Equipment Only			
	Case 1 (Fabric Filter)		Case 2 (Cyclone)		Case 1 (Fabric Filter)		Case 2 (Cyclone)	
	1970	1973[a]	1970	1973[a]	1970	1973[a]	1970	1973[a]
Control Investment	$413,571	$528,250	$344,288	$439,760	$339,794	$434,020	$287,661	$367,430
Percent of Plant and Equipment	7.8%	7.8%	6.5%	6.5%	6.3%	6.3%	5.3%	5.4%
Percent of Dollar Sales	1.2%	0.72%	1.0%	0.60%	1.0%	0.59%	0.86%	0.50%
Per Ton of Soybean Production	$1.24	$1.58	$1.03	$1.32	$1.02	$1.30	$0.86	$1.10
Annual Control Operating Costs	$121,860	$155,651	$102,205	$130,547	$ 94,573	$120,798	$ 79,720	$101,827
Percent of Net Worth	1.7%	1.4%	1.4%	1.2%	1.3%	1.1%	1.1%	0.92%
Percent of Total Assets	0.85%	0.70%	0.72%	0.59%	0.66%	0.85%	0.56%	0.46%
Percent of Dollar Sales	0.36%	0.21%	0.31%	0.18%	0.28%	0.16%	0.24%	0.14%
Per Ton of Soybean Production	36.6¢	46.7¢	30.7¢	39.2¢	28.4¢	36.2¢	23.9¢	30.5¢

a/ First quarter 1973 average prices.

and recovery equipment is 0.72% (Case 1) and 0.6% (Case 2) of dollar sales. The corresponding annual costs are 0.21% (Case 1) and 0.18% (Case 2) of dollar sales.

The elimination of the product recovery equipment from the pollution control costs reduces the control investment figures and the annual control cost even more. In this case, the capital investment at first quarter 1973 prices is about 0.59% (Case 1) and 0.50% (Case 2) of dollar sales and the annual costs are 0.16% (Case 1) and 0.14% (Case 2).

Existing Plants - To determine the economic impact of installing the "best" control systems on existing plants, it is necessary to take into account the current level of control on existing plants. Table 232 presents the current status of control at soybean plants as determined from emission inventory questionnaires submitted by 42 individual plants. As seen in this table, current plants are quite well-controlled in the processing section. However, in most cases, they are not equipped with best control devices as specified in Case 1. An analysis of existing plant controls indicates that an average existing plant will have to spend about 68% of the cost required for the installation of best control systems on a new plant.

Alternate (Case 2) controls will require expenditures which are about 52% of new plant control system costs. These cost data, along with the financial impact figures for the industry are presented in Table 233.

The major assumptions made in determining these costs are as follows:

1. The cost to install control equipment on an existing plant which does not have pollution controls is 120% of the cost required for a new plant. The increased costs reflect the fact that additional installation charges will be incurred on an existing or older plant.

2. Existing plants which already have adequate control equipment or specific operations will not incur any additional charges.

3. The pollution control equipment specifications for the model plant was used as the average for the existing plants in the industry and the controls on the surveyed plants were used as an industry average.

4. The maintenance and electrical expenses for a new fabric filter system will be 50% and 80%, respectively, of the expense required for an existing cyclone system.

Table 232. POLLUTION CONTROLS OF EXISTING SOYBEAN PLANTS
(SURVEY OF 42 PLANTS)

Operation	Quantity	No. of Plants	Cyclone % Control[a]	Cyclone No. of Plants	Fabric Filters % Control[a]	Fabric Filters No. of Plants	Other Devices % Control[a]	Other Devices No. of Plants	Total % With Control
Receiving (bu/yr)									
Hopper	79,835,000	32	> 0.2	1	> 8.4	6	0	0	~ 50.0[b]
Boxcar	60,262,000	33	6.4	3	40.0	6	0	0	46.4
Truck	158,403,000	42	7.9	4	46.9	13	0	0	54.8
Barge	14,754,000	3	0.0	0	0.0	0	0	0	0
Total	313,254,000	42	> 5.3		> 33.6		0		~ 50.0
Handling (bu/yr)									
Transfer	313,254,000	42	20.6	8	56.2	16	0.2	1	77.0
Garner and Scale	271,415,000	32	16.9	4	54.9	13	0	0	71.8
Legs	313,254,000	42	22.6	9	60.6	17	2.2	1	85.4
Tripper	196,938,000	26	20.0	3	48.7	9	0	0	68.7
Drying (bu/yr)	208,922,000	27	3.6[d]	2	0	0	38.9[e]	9	42.5
Bean Preparation (tons/yr)									
Cracking	7,790,000	41	63.3	25	32.2	9	0	0	95.5
Hull Grinder	7,722,000	38	62.2	23	35.6	10	0	0	97.8
Bean Conditioning	7,790,000	41	72.1	28	6.9	2	0	0	79.0
Flaking	7,766,000	40	91.9	34	3.7	1	0	0	95.6
Meal Finishing (tons/yr)									
Dryer	7,419,000	37	61.5	21	0	0	0	0	61.5
Cooler	7,718,000	40	85.6	31	8.7	3	0	0	94.3
Bulk Loading[c]	Unknown	41	5.0	2	32.0	13	0	0	37.0

a/ Percent control is the percentage of the total quantity for the operation which is controlled by the specific device.
b/ Assumed value of 50%, some plants may be using choke unloading.
c/ Percent control based on number of plants rather than quantity loaded.
d/ Control device assumed to be Wiedenmann Screen Kleen or Carter-Day Day-Vac Units.
e/ Control device assumed to be screen house.

Table 233. CONTROLS APPLIED TO EXISTING SOYBEAN PROCESSING PLANTS

	Average per Establishment		Total for Industry[a/]	
	Case 1 ($)	Case 2 ($)	Case 1 ($)	Case 2 ($)
Investment for control equipment	359,000	230,000	46,670,000	29,900,000
Annual control costs	87,600	48,900	11,388,000	6,357,000
Annual cost per bushel of soybeans crushed			1.47¢	0.82¢

a/ Assumes 130 plants.

In 1973, soybean plants processed an estimated 775 million bushels of soybeans for $4.3 billion in sales. Using these data, the investment costs for installation of control equipment on existing plants would be 1.1% of dollar sales (Case 1) and 0.7% in Case 2.

Price Elasticity - As a general rule, the price of soybean oil and meal tends to reflect the changes in the cost of soybeans; however, these products must remain competitively priced. Soybean meal is the major source of high-protein feed and increasingly is being used in edible soy products. Soybean oil is used in salad and cooking oils, shortening, margarine and in a variety of industrial products. Since 1960, the domestic use and export of both soybean meal and oil have increased at a rate of more than 5% annually, and according to projections of the Economic Research Service[26/] this growth will continue through 1985.

Considering the current demand from soybean products, the price increases which could result from the installation of best controls will probably be passed on to the consumer. The estimated 0.6% increase in price of product to the consumer resulting from pollution controls is small when compared to the 100% and greater price increases which have occurred since 1972.

Industry Structure - Regulations requiring installation of controls on new plants will have no significant impact on the industry structure. The economics of scale for new plants will be changed because the same basic control equipment is required for grain receiving and handling operations regardless of plant size. The resulting increase in investment required for an economical new plant will tend to limit the number of small firms in the industry.

Control regulations for existing plants will have a greater impact than new plant regulations. Because of the economics of scale for the control equipment, the small existing plant will be most severely affected. However, as a result of increasing demand for soybean products, it is unlikely that any existing plants will be forced to go out of business because of control regulations.

CORN WET MILLING

Description of Model Plant

Figure 63 and Figure 64 summarize the characteristics of the new model plant for corn wet milling. Figure 63 presents a simplified flow sheet of the processes in the plant. The specific processes shown in this figure depict the general spectrum of operations conducted at a corn wet milling plant. A given plant may not have all the operations shown in Figure 63 or it might have additional processes for refining dextrose. Figure 64 illustrates the processing operations in a corn wet milling plant which were judged to require the installation of pollution control systems. The control device(s) judged to represent the best demonstrated technology are also shown. An alternate set of control devices which substitute cyclones for the fabric filters will also be analyzed.

The processing capacity for the model plant is 30,000 bu/24-hr day, and the plant is assumed to operate 8,000 hr/year. The yearly processing rate is, therefore, 10 million bushels.

Control Equipment Costs

A summary of the control equipment and associated costs required for the model plant is presented in Table 234 (Case 1) and Table 235 (Case 2). For each operation an estimate is given for the investment cost required for the control devices, as well as estimates for the total annual costs including electrical charges, maintenance expenses, depreciation expenses and capital charges.

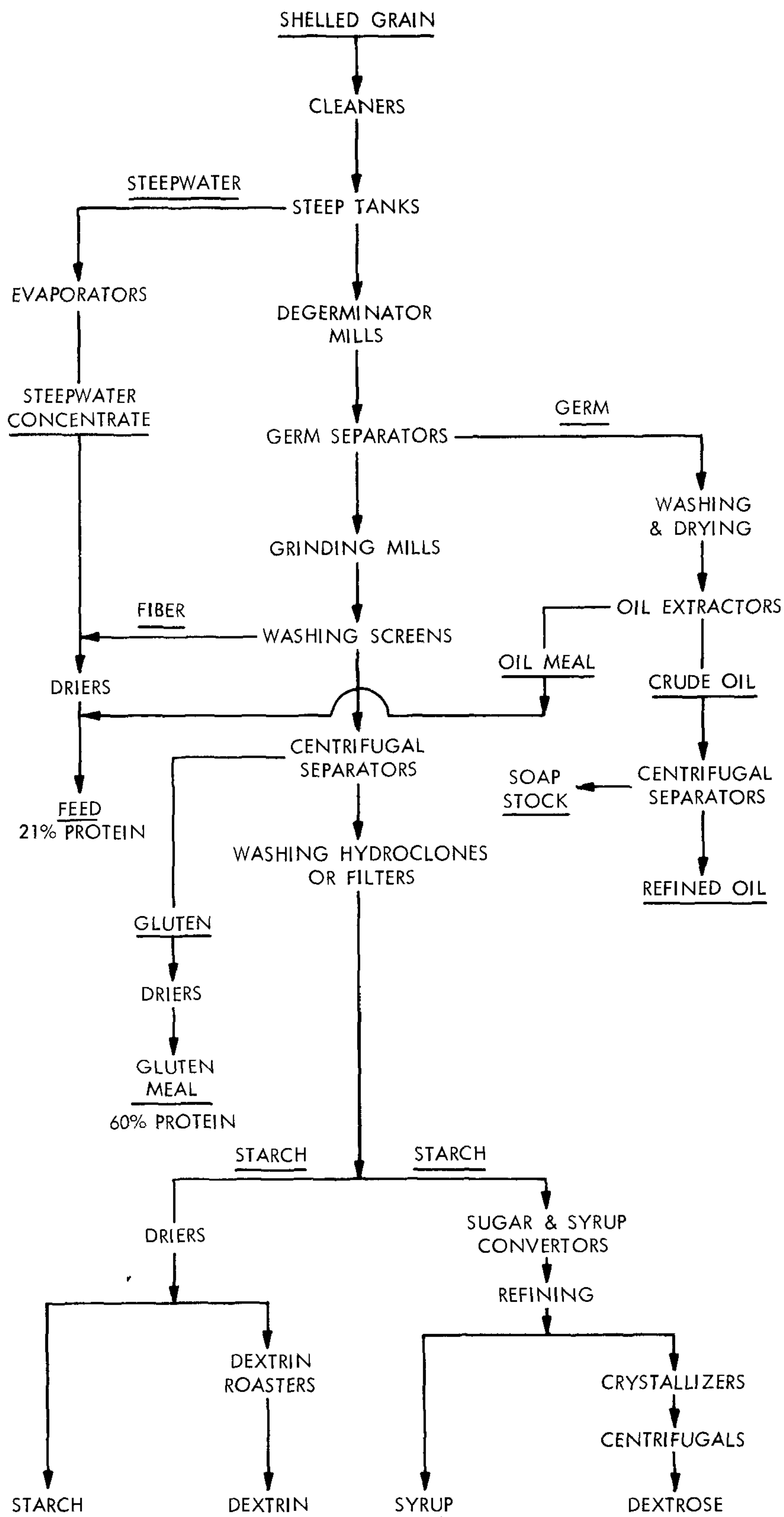


Figure 63. Simplified flow diagram of corn wet milling plant.

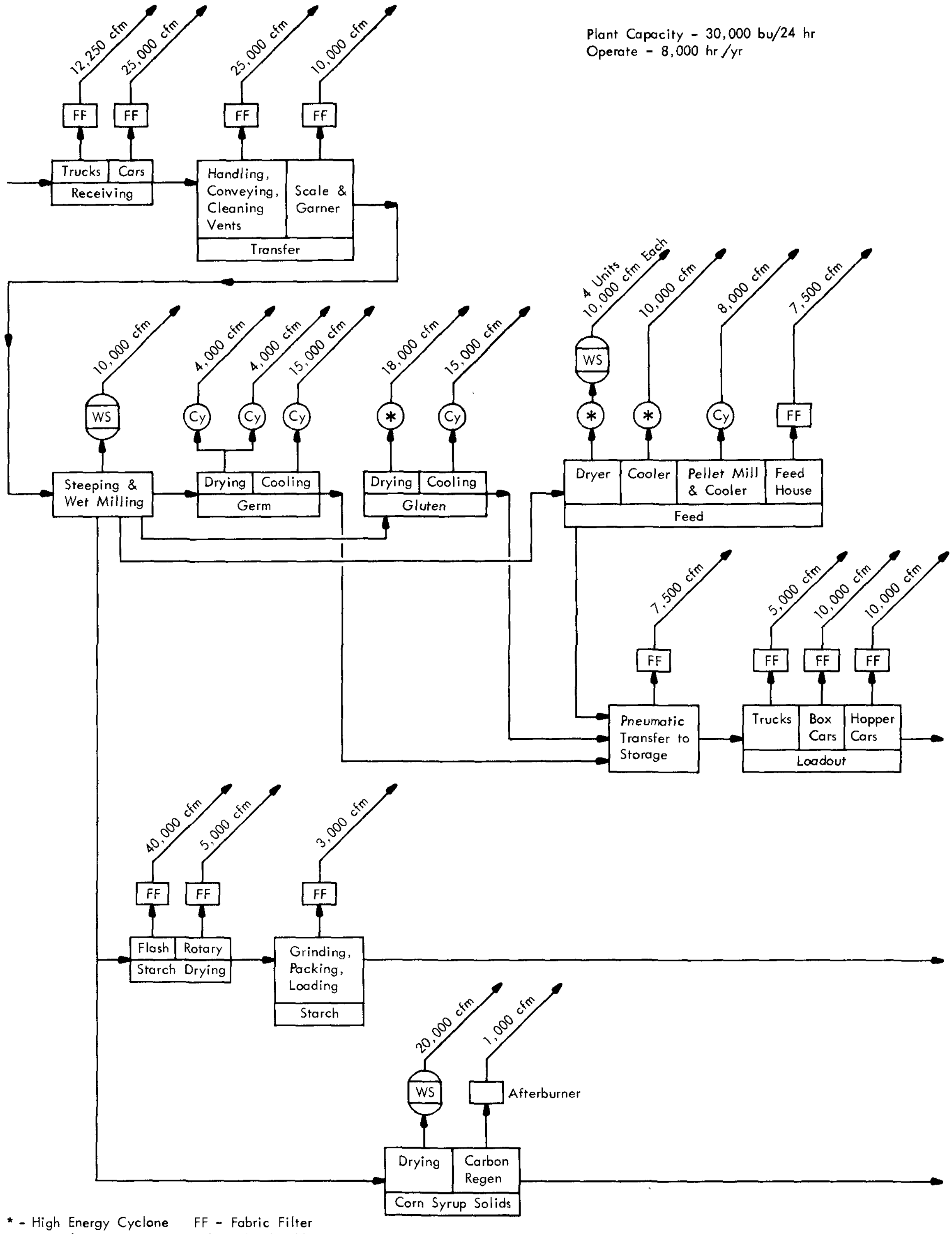


Figure 64. Model new corn wet milling plant.

Table 234. MODEL PLANT FOR NEW CORN WET MILLING

Case 1 - Best Controls

	Model Plant Control and Cost Estimate								
Operation	Selected Device	Air Flow (cfm)	Oprn. (hr/year)	Electrical ($/year)	Maintenance ($/year)	Depreciation ($/year)	Capital Charges ($/year)	Annualized Cost ($/year)	Installed Cost ($)
Truck Receiving[a/]	FF	12,250	2,500	1,380	1,230	3,564	1,782	7,956	35,640[a/]
Railroad Car Receiving[b/]	FF	25,000	2,500	2,613	2,500	6,515	3,258	14,886	65,150[b/]
Handling and Transfer	FF	25,000	8,000	8,350	2,500	5,935	2,968	19,753	59,350
Scale and Garner	FF	10,000	2,500	923	1,000	2,300	1,150	5,373	23,000
Separation Process									
Steeping and Wet Milling	Scrubber	10,000	8,000	4,201	1,000	4,700	2,350	12,251	47,000
Germ Drying	Hi-Energy Cyclone	8,000[c/]	8,000	1,664	800	2,288	1,144	5,896	22,880
Germ Cooling	↓	15,000	8,000	5,024	1,500	3,732	1,866	12,122	37,320
Gluten Drying	↓	18,000	8,000	9,609	1,800	4,600	2,300	18,309	46,000
Gluten Cooling	↓	15,000	8,000	5,024	1,500	3,732	1,866	12,122	37,320
Feed Drying									
Primary Control	↓	40,000[d/]	8,000	21,631	4,000	9,650	4,825	40,106	96,500
Secondary Control	Scrubber	40,000	8,000	12,480	4,000	7,020	3,510	27,010	70,200
Feed Cooling	Hi-Energy Cyclone	10,000	8,000	5,033	1,000	2,700	1,350	10,083	27,000
Pellet Milling and Cooling	↓	8,000	8,000	1,664	800	2,288	1,144	5,896	22,880
Feed House	Filter	7,500	8,000	3,369	750	2,434	1,217	7,765	24,340
Pneumatic Transfer of Germ, Gluten and Feed	Filter	7,500	8,000	2,912	750	2,245	1,122	7,029	22,450
Dry Starch Grinding and Transfer	Filter	3,000	8,000	1,705	300	1,313	656	3,974	13,130
Starch Drying									
Flash	Filter	40,000	8,000	12,500	4,000	6,460	3,230	26,210	64,600
Rotary	Filter	5,000	8,000	2,120	500	1,655	828	5,103	16,550
Corn Syrup Solids Drying	Scrubber	20,000	8,000	6,240	2,000	5,540	2,770	16,550	55,400
Carbon Regeneration	After-burner	1,000	2,000	187[e/]	100	1,706	853	2,846	17,060
Truck Loadout	Filter	5,000	2,500	793	500	1,652	827	3,772	16,520
Boxcar Loadout	Filter	10,000	2,500	1,170	1,000	2,580	1,290	6,040	25,800
Hopper Car Loadout	Filter	10,000	2,500	1,170	1,000	2,580	1,290	6,040	25,800
Total				111,777	34,530	87,189	43,596	277,092	871,890

a/ Includes cost of shed - $10,350.
b/ Includes cost of shed for 2-track unloading - $24,260.
c/ Two 4,000 cfm high-energy cyclones in parallel.
d/ Four 10,000 cfm high-energy cyclones in parallel.
e/ Includes cost of natural gas.

Plant Capacity - 30,000 Bu/24 Hr/Day

Table 240. WET CORN MILLS, POLLUTION CONTROLS ON EXISTING PLANTS, SURVEY OF 13 PLANTS

Operation	Quantity	Number Plants	Cyclone % Control[a/]	Cyclone No. Plants	Fabric Filter % Control[a/]	Fabric Filter No. Plants	Wet Scrubber % Control[a/]	Wet Scrubber No. Plants	Other Devices % Control[a/]	Other Devices No. Plants	Total % With Control
Receiving (1,000 bu/year)											
Hopper	54,163	10	0		56.8	6	14.4	1	0		71.2
Boxcar	116,930	11	0		57.5	6	0		0		57.5
Truck	45,001	8	4.4	1	81.8	5	0		0		86.2
Total	228,534	13	0.9	1	64.4	8	3.4	1	0		63.3
Handling (1,000 bu/year)											
Transfer	220,734	12	23.1	3	76.9	9	0		0		100.0
Garner & scale	215,034	12	17.5	2	35.9	5	3.6	1	0		57.0
Legs	228,534	13	22.4	3	51.2	7	3.4	1	0		77.0
Tripper	220,734	12	23.1	3	61.4	6	0		0		84.5
Cleaning (1,000 bu/year)	228,534	13	39.9	4	56.7	8	3.4	1	0		100.0
Dryers (tons/year)											
Gluten	290,284	12	81.6	8	3.4	1	15.0	3	0		100.0
Feed	1,180,779	12	80.3	8	4.7	1	15.0	3	0		100.0
Germ	235,900	9	67.1	5	0		23.2	3	9.7	1	100.0
Starch Production (tons/year)											
Dryer[b/]	1,692,654	12	41.5	5	15.2	4	43.3	6	0		100.0
Grinder	1,501,157	10	11.0	1	89.0	9	0		0		100.0
Bagging	1,692,654	12	0		100.0	12	0		0		100.0
Bulk Shipping	1,692,654	12	0		93.6	11	6.4	1	0		100.0
Corn Syrup & Dextrins (ton/year)											
Dryer[b/]	1,189,768	10	1.2	1	39.3	5	48.0	5	0		88.5

a/ Percent control is the percentage of the total quantity for the operation which is controlled by the specified device.
b/ Values for the wet scrubber and fabric filter were evenly divided if both were used.

The electrical expense was determined from the hourly operating expense as quoted by the equipment manufacturers and the hours per year which the device would be required to operate. The operational hours per year which are listed in Tables 234 and 235 were estimated from an analysis of (1) the operational requirements and capacities of each device, and (2) the volume of material which would be processed by each operation.

For the two specified pollution control systems, the corn wet milling plant would require estimated investment costs and annual operating costs as follows:

	Total Annualized Cost ($/year)	Total Installed Cost ($/year)
Case 1 - Best controls	277,092	871,890
Case 2 - Alternate controls	264,110	827,250

These figures represent the investment necessary to purchase and install the control equipment for a new corn wet milling plant based upon the specifications of the model plant.

These figures actually overstate the costs associated with pollution control equipment. The cyclone system on the germ, gluten, and feed dryers and the fabric filter systems on the starch dryer, grinder, and various pneumatic transfer lines are actually product recovery devices. As such, the costs of these devices should not be attributed to pollution control. With this revision, the total investment costs and annual costs for pollution control are reduced as follows:

	Pollution Control Equipment Only	
	Total Annual Cost ($)	Total Installed Cost ($)
Case 1 - Best controls	170,465	589,780
Case 2 - Alternate controls	157,483	545,140

The elimination of the product recovery equipment reduces the control investment by 32.4% in Case 1 and 34.1% in Case 2. The annual cost is reduced by 38.5% in Case 1 and 40.4% in Case 2.

Credits for Dust Control

There are a number of control credits or positive impacts which could result from the installation of high-efficiency pollution control equipment on corn wet milling plants. The most obvious benefit would be increased recovery of both intermediate and final products. An analysis of the positive impact for the total model plant was precluded because of two factors: (1) emission factor data for many sources in a corn wet milling plant are not available, and (2) the value of several intermediate product streams is not known.

An indication of the positive impact from dust control in the corn receiving, cleaning and storage segment of the plant is shown in Table 236.

In developing the data in this table, it was assumed that the recovered material could be sold at a value of \$40/ton. Under the assumed conditions, the value of the material recovered in this portion of the plant might account for up to 10% of the annual control costs for pollution control and product recovery equipment, and 16% of annual costs if product recovery equipment is excluded. The value of the recovery material can fluctuate over time and the positive impact would vary accordingly.

Financial Statements

To determine the financial impact of air pollution control costs upon corn wet milling plants, an income statement and balance sheet were developed for the model plant. Separate financial statements were developed for the operation of the model plant both without and with the two alternative pollution control systems. These statements were compared to determine the impact of the control equipment on the financial condition of new plants.

The income statements were developed using the 1967 Census of Manufacturers,[15/] 1970 Annual Survey of Manufacturers,[16/] and individual company statements as reported in Standard and Poor's and Moody's. The resulting income statements are presented in Table 237 and summarized as follows:

Table 236. POTENTIAL POSITIVE IMPACT OF DUST CONTROL IN GRAIN RECEIVING, CLEANING, AND STORAGE SECTION OF MODEL CORN WET MILLING PLANT

				Value Recovered as Percent of Annual Cost			
				Pollution Control and Product Recovery Equipment		Pollution Control Equipment Only	
Assumed Recovery of Grain Dust (lb/ton of grain handled)	Grain Handled (ton/year)	Total Dust Recovered (tons)	Value of Dust[a/] Recovered ($)	Case 1 (%)	Case 2 (%)	Case 1 (%)	Case 2 (%)
1	280,000	140	5,600	2.0	2.1	3.3	3.6
2		280	11,200	4.0	4.2	6.6	7.1
3		420	16,800	6.1	6.4	9.9	10.7
4		560	22,400	8.1	8.5	13.1	14.2
5		700	28,000	10.1	10.6	16.4	17.8

a/ Assumed that recovered material could be sold at a value of $40/ton, which was the average price of screenings during April 1973.

Table 237. INCOME STATEMENT FOR NEW MODEL CORN WET MILL (1970)

	Without Controls		Case 1 - Best Controls			Case 2 - Alternate Controls		
	Without Controls		Control Costs	With Controls		Control Costs	With Controls	
	($000)	Percent	($000)	($000)	Percent	($000)	($000)	Percent
Sales	41,000	100.0		41,000	100.0		41,000	100.0
Cost of Materials	23,650	57.7		23,650	57.7		23,650	57.7
Wages and Benefits	5,530	13.5		5,530	13.5		5,530	13.5
Cost of Goods Sold	29,180	71.2		29,180	71.2		29,180	71.2
Gross Income	11,820	28.8		11,820	28.8		11,820	28.8
Expenses								
Administration	2,680	6.5		2,680	6.5		2,680	6.5
Other Expenses	3,510	8.6	146	3,656	8.9	140	3,650	8.9
Depreciation	1,760	4.3	87	1,847	4.5	83	1,843	4.5
Interest	1,370	3.3	44	1,414	3.4	41	1,411	3.4
Total Operating Expenses	9,320	22.7	277	9,597	23.4	264	9,584	23.4
Net Income Before Taxes	2,500	6.1		2,223	5.4		2,236	5.5
Net Income/Bushel Processed	$0.25			$0.22			$0.22	
% Net Income/Net Worth	12.5%			11.1%			11.2%	
% Net Income/Total Assets	6.2%			5.4%			5.5%	

	Pollution Control and Product Recovery Equipment			
	Net Income Without Controls (¢/bu)	Net Income With Controls (¢/bu)	Reduction (¢/bu)	Reduction (%)
Case 1 - Best controls	25.0	22.2	2.8	11.2
Case 2 - Alternate controls	25.0	22.4	2.6	10.4

If the cyclone systems on the germ, gluten and feed dryers, and the fabric filter systems on the starch dryer, grinder and various pneumatic transfer lines are considered to be a product recovery system, rather than for pollution control, then the impact of pollution control regulations on net income before taxes will be:

	Pollution Control Equipment Only			
	Net Income Without Controls (¢/bu)	Net Income With Controls (¢/bu)	Reduction (¢/bu)	Reduction (%)
Case 1 - Best controls	23.9	22.2	1.7	7.1
Case 2 - Alternate controls	23.9	22.4	1.5	6.3

Even this latter case overstates the impact of pollution control equipment on the model plant because no credit has been given for the recovery of material from the corn receiving, cleaning and storage segment of the plant. The maximum credit of $28,000 as shown in Table 236, would result in even less of a reduction in profitability as shown below:

	Pollution Control Equipment Only With Control Credits			
	Net Income Without Controls (¢/bu)	Net Income With Controls (¢/bu)	Reduction (¢/bu)	Reduction (%)
Case 1 - Best controls	23.9	22.5	1.4	5.9
Case 2 - Alternate controls	23.9	22.6	1.3	5.6

The balance sheets for the model plant are presented in Table 238. The effect upon new plant construction cost expressed as dollars per bushel capacity per 24-hr day is shown below:

	Pollution and Product Recovery Equipment			
	Investment Costs Without Controls ($/bu)	Investment Costs With Controls ($/bu)	Increase ($/bu)	Increase (%)
Case 1 - Best controls	1,019	1,048	29	2.8
Case 2 - Alternate controls	1,019	1,047	28	2.7

If the control devices described as product recovery systems are eliminated from the control costs, then the construction costs would be as follows:

	Pollution Control Equipment Only			
	Investment Costs Without Controls ($/bu)	Investment Costs With Controls ($/bu)	Increase ($/bu)	Increase (%)
Case 1 - Best controls	1,028	1,048	20	1.9
Case 2 - Alternate controls	1,029	1,047	18	1.8

The financial impact of pollution control equipment, both including and excluding product recovery equipment, is summarized in Table 239. The annual control costs for pollution control and product recovery equipment are 0.7% of dollar sales at 1970 prices. If product recovery equipment is eliminated, the annual cost in both Case 1 and Case 2 are 0.4% of dollar sales. The inclusion of control credits from dust collection in the grain receiving, cleaning, and storage operations (see Table 236) would further reduce the financial impact of pollution control equipment.

Table 238. BALANCE SHEET FOR NEW MODEL CORN WET MILL
(1970)

	Without Controls		Case 1 - Best Controls			Case 2 - Alternate Controls		
	Without Controls		Control Costs	With Controls		Control Costs	With Controls	
	($000)	Percent	($000)	($000)	Percent	($000)	($000)	Percent
Assets								
Current Assets								
Receivables Net	3,870	9.7		3,870	9.5		3,870	9.5
Inventory	3,770	9.4		3,770	9.2		3,770	9.2
Other Current Assets	1,790	4.5		1,790	4.4		1,790	4.4
Total Current Assets	9,430	23.6		9,430	23.1		9,430	23.1
Fixed Assets								
Structure and Building	10,210	25.5		10,210	25.0		10,210	25.0
Machinery and Equipment	19,710	49.3	872	20,582	50.3	827	20,537	50.3
Total Depreciable Assets	29,920	74.8	872	30,792	75.3	827	30,747	75.3
Other Fixed Assets	660	1.6		660	1.6		660	1.6
Total Fixed Assets	30,580	76.4	872	31,452	76.9	827	31,407	76.9
Total Assets	40,010	100.0	872	40,882	100.0	827	40,837	100.0
Liabilities								
Accounts Payable	1,210	3.0		1,210	3.0		1,210	3.0
Short-Term Notes	730	1.8		730	1.8		730	1.8
Other Current Liabilities	2,100	5.3		2,100	5.1		2,100	5.1
Total Current Liabilities	4,040	10.1		4,040	9.9		4,040	9.9
Long-Term Debt	15,960	39.9	872	16,832	41.2	827	16,787	41.1
Total Liabilities	20,000	50.0	872	20,872	51.1	827	20,827	51.0
Net Worth	20,010	50.0		20,010	48.9		20,010	48.9
Total Liabilities and Net Worth	40,010	100.0	872	40,882	100.0	827	40,837	100.0

Table 239. IMPACT OF BEST CONTROL APPLIED TO MODEL NEW CORN WET MILLING PLANT

	Pollution Control and Product Recovery Equipment		Pollution Control Equipment Only	
	Case 1	Case 2	Case 1	Case 2
Control Investment	$871,900	$827,250	$589,780	$545,140
Percent of Investment for New Plant and Equipment	2.9%	2.7%	2.0%	1.8%
Percent of Dollar Sales	2.1%	1.9%	1.4%	1.2%
Per Bushel of Corn Processed Per Year	8.72¢	8.27¢	5.90¢	5.45¢
Annual Control Operating Costs	$277,100	$264,110	$170,465	$157,483
Percent of Net Worth	1.4%	1.3%	0.85%	0.78%
Percent of Total Assets	0.68%	0.64%	0.42%	0.38%
Percent of Dollar Sales	0.68%	0.64%	0.42%	0.38%
Per Bushel of Corn Processed	2.77¢	2.64¢	1.70¢	1.57¢

Economic Impact of Control Systems on Industry

New Plants - Costs associated with installation of pollution control equipment will have a small impact on new plants (see Table 239). The investment in control equipment is not great enough in comparison to total plant investment to have a significant impact. Furthermore, new plants recently completed or currently under construction are equipped with high-efficiency systems both for improved product recovery and pollution control.

Existing Plants - If the best control systems were applied to existing plants, the impact would still be small. As shown in Table 240, with the exception of the grain receiving and handling segments, existing plants are already controlled to a high degree. It is possible that some of the older plants might be phased out of operation sooner than normal if the best control systems had to be applied to all existing plants. Since all but one of the companies in this industry are integrated, it is difficult to assess the likelihood of plant closings. However, no changes in industry structure or ownership patterns are anticipated.

Price Elasticity

It is difficult to determine whether increases in costs resulting from pollution control equipment would be passed on to the consumer. In the past, whenever feasible, prices for bulk corn product shipments to industrial users tend to promptly reflect variations in costs. However, full adjustments cannot always be made readily, since prices would then be out of line with those for competing products. For example, dextrose (corn sugar) must sell at least a cent a pound below cane sugar to compete with it at all, and corn syrup prices are similarly restricted. Corn feeds are priced to compete with other feeds, and starch competes with tapioca from foreign sources.

In sum, profits of the industry are affected by corn production, corn costs,and production and related prices of competing products. Profit margins may vary widely from product to product and from year to year, since the above factors are largely outside the control of the corn refiner.

Table 235. MODEL PLANT FOR NEW CORN WET MILLING

Case 2 - Alternate Controls

Operation	Selected Device	Air Flow (cfm)	Opra. (hr/year)	Electrical ($/year)	Maintenance ($/year)	Depreciation ($/year)	Capital Charges ($/year)	Annualized Cost ($/year)	Installed Cost ($)
				Model Plant Control and Cost Estimate					
Truck Receiving[a]	Cyclone	12,250	2,500	1,104	613	2,645	1,323	5,685	26,450[a]
Railroad Car Receiving[b]	Cyclone	25,000	2,500	2,090	1,250	5,145	2,573	11,058	51,450[b]
Handling and Transfer	Cyclone	25,000	8,000	6,680	1,250	4,560	2,280	14,770	45,600
Scale and Garner	Cyclone	10,000	2,500	738	500	1,500	750	3,488	15,000
Separation Process									
Steeping and Wet Milling	Scrubber	10,000	8,000	4,201	1,000	4,700	2,350	12,251	47,000
Germ Drying	Hi-Energy Cyclone	8,000[c]	8,000	1,664	800	2,288	1,144	5,896	22,880
Germ Cooling		15,000	8,000	5,024	1,500	3,732	1,866	12,122	37,320
Gluten Drying		18,000	8,000	9,609	1,800	4,600	2,300	18,309	46,000
Gluten Cooling		15,000	8,000	5,024	1,500	3,732	1,866	12,122	37,320
Feed Drying									
Primary Control		40,000[d]	8,000	21,631	4,000	9,650	4,825	40,106	96,500
Secondary Control	Scrubber	40,000	8,000	12,480	4,000	7,020	3,510	27,010	70,200
Feed Cooling	Hi-Energy Cyclone	10,000	8,000	5,033	1,000	2,700	1,350	10,083	27,000
Pellet Milling and Cooling		8,000	8,000	1,664	800	2,288	1,144	5,896	22,880
Feed House	Filter	7,500	8,000	3,369	750	2,434	1,217	7,770	24,340
Pneumatic Transfer of Germ, Gluten and Feed	Filter	7,500	8,000	2,912	750	2,245	1,122	7,029	22,450
Dry Starch Grinding	Filter	3,000	8,000	1,705	300	1,313	656	3,974	13,130
Starch Drying									
Flash	Filter	40,000	8,000	12,500	4,000	6,460	3,230	26,190	64,600
Rotary	Filter	5,000	8,000	2,120	500	1,655	828	5,103	16,550
Corn Syrup Solids Drying	Scrubber	20,000	8,000	6,240	2,000	5,540	2,770	16,550	55,400
Carbon Regeneration	After-burner	1,000	2,000	187[e]	100	1,706	853	2,846	17,060
Truck Loadout	Filter	5,000	2,500	793	500	1,652	827	3,772	16,520
Boxcar Loadout	Filter	10,000	2,500	1,170	1,000	2,580	1,290	6,040	25,800
Hopper Car Loadout	Filter	10,000	2,500	1,170	1,000	2,580	1,290	6,040	25,800
Total				109,108	30,913	82,725	41,364	264,110	827,250

a/ Includes cost of shed - $10,350
b/ Includes cost of shed for 2-track unloading - $24,260
c/ Two 4,000 cfm high-energy cyclones in parallel
d/ Four 10,000 cfm high-energy cyclones in parallel
e/ Includes cost of natural gas

Plant Capacity - 30,000 bu/24-hr day

CHAPTER 5

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CHAPTER 6

AIR POLLUTION EPISODE PROCEDURES

INTRODUCTION

Exposure of the general population to high concentrations of air pollutants, due to the occurrence of stagnant air masses, constitutes an air pollution episode. Temperature inversions, which severely reduce the effective volume of air available for pollutant dispersion, are generally responsible for the stagnant air masses.[1/]

The exposure to high levels of pollutant concentrations has been associated with both increased death rates and increased treatment of patients with respiratory ailments as well as various non-health related effects such as visibility reduction and vegetation damage. Because of these effects, the federal government's Environmental Protection Agency (EPA) has required that the states implement a plan to prevent air pollution concentrations from reaching detrimental levels. Since episodes are generally of short duration, (1/2 day to 1 or 2 days), these temporary control strategies or plans require a rapid, short-term reduction in the quantity of pollutants emitted.

EPISODE CRITERIA

Episode avoidance plans are required to incorporate at least two alert stages of episode criteria and define the preventive action to be taken at these alert stages. The EPA, however, has recommended the following five criteria that trigger the emergency action plans:[2/]

1. Forecast - National Weather Service and/or local weather services forecast stagnant atmospheric conditions. An Air Stagnation Advisory (ASA) may be issued.

2. "Alert" - The alert level is that concentration of pollutants at which first-stage control actions are to begin. An alert will be declared when any one of the following ambient air levels is reached at any monitoring site:

SO_2 - 800 μg/m^3 (0.3 ppm), 24-hr average.

Particulate - 3.0 COHs or 375 μg/m^3, 24-hr average.

SO_2 and particulate combined - product of SO_2 ppm, 24-hr average, and COHs equal to 0.2 or product of SO_2 - μg/m^3, 24-hr average, and particulate μg/m^3, 24-hr average equal to 65 x 10^3.

CO - 17 mg/m^3 (15 ppm), 8-hr average.

Oxidant (O_3) - 200 μg/m^3 (0.1 ppm), 1-hr average.

NO_2 - 1,130 μg/m^3 (0.6 ppm), 1-hr average; 282 μg/m^3 (0.15 ppm), 24-hr average.

and meteorological conditions are such that the pollutant concentrations can be expected to remain at the above levels for 12 or more hours, or increase, or in the case of oxidants, the situation is likely to reoccur within the next 24 hr unless control actions are taken.

3. "Warning" - The warning level indicates that air quality is continuing to degrade and that additional control actions are necessary. A warning will be declared when any one of the following levels is reached at any monitoring sites:

SO_2 - 1,600 μg/m^3 (0.6 ppm), 24-hr average.

Particulate - 5.0 COHs or 625 μg/m^3, 24-hr average.

SO_2 and particulate combined - product of SO_2 μg/m^3, 24-hr average and COHs equal to 0.8; or product of SO_2 μg/m^3, 24-hr average and particulate μg/m^3, 24-hr average equal to 261 x 10^3.

CO - 34 mg/m^3 (30 ppm), 8-hr average.

Oxidant (O_3) - 800 μg/m^3 (0.4 ppm), 1-hr average.

NO_2 - 2,260 μg/m^3 (1.2 ppm), 1-hr average; 565 μg/m^3 (0.3 ppm), 24-hr average.

and meteorological conditions are such that pollutant concentrations can be expected to remain at the above levels for 12 or more hours, or increase, or in the case of oxidants, the situation is likely to reoccur within the next 24 hr unless control actions are taken.

4. "Emergency" - The emergency level indicates that air quality is continuing to degrade to a level that should never be reached and that the

most stringent control actions are necessary. An emergency will be declared when any one of the following levels is reached at any monitoring site:

SO_2 - 2,100 μg/m^3 (0.8 ppm), 24-hr average.

Particulate - 7.0 COHs or 875 μg/m^3, 24-hr average.

SO_2 and particulate combined - product of SO_2 ppm, 24-hr average and COHs equal to 1.2: or product of SO_2 μg/m^3, 24-hr average and particulate μg/m^3, 24-hr average equal to 393 x 10^3.

CO - 46 mg/m^3 (40 ppm), 8-hr average.

Oxidant (O_3) - 1,200 μg/m^3 (0.6 ppm), 1-hr average.

NO_2 - 3,000 μg/m^3 (1.6 ppm), 1-hr average; 750 μg/m^3 (0.4 ppm), 24-hr average.

and meteorological conditions are such that this condition can be expected to continue for 12 or more hours, or in the case of oxidants, the situation is likely to reoccur within the next 24 hr unless control actions are taken.

5. "Termination" - Once declared, any status reached by application of these criteria will remain in effect until the criteria for that level are no longer met. At such time, the next lower status will be assumed.

It should be made clear that an alert, warning, or emergency can be declared on the basis of deteriorating air quality alone; an ASA need not have been issued. The appropriate episode status should be declared when any monitoring site records ambient pollution concentrations above those designated in the criteria. The criteria should be applied to individual monitoring sites and not to area-wide air quality.

SPECIFIC EPISODE PLAN RESPONSIBILITIES

The states must provide emergency episode action plans as part of their implementation plans. Part 420.16 of Title 42, (2) cites, in part, the following implementation plan requirements:

> "For the purpose of preventing air pollution emergency episodes, each plan for a Priority I region shall include a contingency plan which shall, as a minimum, provide for taking any emission control actions necessary to prevent ambient pollutant concentrations at any location in such region from reaching levels

which would constitute imminent and substantial endangerment to the health of persons, which levels shall be prescribed by the Administrator.

Each contingency plan shall (1) specify two or more stages of episode criteria such as those set forth in Appendix L to this part or their equivalent, (2) provide for public announcement whenever any episode stage has been determined to exist, and (3) specify emission control actions to be taken at each episode stage..."

In Priority I regions, all portions of the contingency plan must be presented; in Priority II regions only Parts 1 and 2 must be developed. In addition to these general emission control actions, a large number of states are requiring that individual pollutant sources develop emergency action plans for the reduction of emissions during episodes.

The following is quoted from an emergency action plan document developed for one of the states:3/

"154.X3 Emission Control Action Programs"

"(1) Any person responsible for the operation of a source of air contaminant which emits 0.25 tons/day or more of air contaminants for which air standards have been adopted shall prepare emission control action programs, consistent with good industrial practice and safe operating procedures, for reducing the emission of air contaminants into the outdoor atmosphere during periods of an AIR POLLUTION ALERT, AIR POLLUTION WARNING, and AIR POLLUTION EMERGENCY. Emission control action programs shall be designed to reduce or eliminate emissions of air contaminants into the outdoor atmosphere in accordance with stated objectives...

"(2) Emission control action programs as required under Section 1 shall be in writing and show the source of air contamination, the approximate amount of reduction of contaminants, the approximate time required to effect the program, a brief description of the manner in which the reduction will be achieved during each stage of an air pollution episode, and such other information as the Department shall deem pertinent.

"(3) During a condition of AIR POLLUTION ALERT, AIR POLLUTION WARNING, and AIR POLLUTION EMERGENCY emission control action programs as required by Section 1 shall be made available on the premises to any person authorized to enforce the provisions of the Department's emergency procedure.

"(4) Emission control action programs as required by Section 1 shall be submitted to the Department upon request within 30 days of the receipt of such request; such emission control action programs shall be subject to review and approval by the Department. If, in the opinion of the Department, such emission control action programs do not effectively carry out the (stated) objectives,...the Department may disapprove said emission control action programs, state its reason for disapproval and order the preparation of amended emission control action programs within the time period specified..."

EMISSION CONTROL STRATEGIES

The percent of emissions contributed by the grain and feed industry in any region will, of course, vary widely and must be determined through an emission inventory. The emission contribution of a specific plant is of primary importance to an air pollution control agency when developing emission reduction plans for episodes.

Ideally, a table identifying the actions which must be taken for each unit operation within the grain handling and processing industry at each episode level could be prepared. However, two factors mitigate against establishing such a general control strategy. First, the emergency plan must be tailored for each region. For example, cessation of unloading activities at a small feed manufacturing operation during an alert stage may have no significant impact on ambient air concentrations if the major source of particulate pollution is an adjacent steel mill or cement plant. The second factor is the varying degree of air pollution control employed at different plants. Again there may be no detectable improvement in air quality if a well-controlled truck unloading operation (e.g., one having a three-sided enclosure, good dust pickup systems and a fabric filter for emission control) is shut down.

Thus, in developing the emergency episode control plan, it is necessary to have a reasonably complete area-wide emissions inventory and emission factors for specific processes to be able to compute the percent reduction in emissions attainable through various control strategies.

The method of reducing ambient air concentrations caused by manufacturing or processing industries generally consists of curtailing, postponing, or deferring production and operations, or temporary alteration of the manufacturing process involved. Due to the close relationship between various processes in a grain plant, any curtailment in one process will inevitably result in some curtailment of another process.

The exact plan to be implemented at any given facility will depend on the process layout and material flow, storage capacities at critical points in the process flow, steam and/or heating requirements, and the degree of existing control on a specific process. The following sections present examples of the types of controls that can be implemented at various grain and feed industry operations.

Grain Elevator Operations

Particulate emissions are the only significant pollutants from grain elevator operations. The most practical method of reducing emissions is to reduce processing throughput rates and/or halt some operations. Many alternatives are available. At some elevators, only processes without fabric filter control systems might be shut down or curtailed or some other combination of process curtailment could be developed to reduce emissions (e.g., all poorly controlled loading and unloading operations could be discontinued). A final step would be to halt all operations. A complete curtailment of all operations requires less than 30 min to implement.

Feed Manufacturing

Particulate emissions from grain unloading, and from cyclone vents or pellet coolers and pneumatic transfer lines are the primary emission problem associated with feed manufacture. These emissions may be reduced by curtailing process throughput in various steps. Grain handling and transfer and bulk product loading, which may account for 50% of particulate emissions, are the most obvious processes which should be curtailed. Total shutdown of a feed mill could be accomplished in about 1 hr.

Soybean Processing

Particulates emitted from soybean receiving and drying, dehulling, and meal drying and cooling are the emissions of primary concern from soybean processing plants.

Curtailment of grain unloading and drying operations could be the first step in a particulate emission reduction plan and would require about 30 min. Other operations could continue to operate until all previously stored material was exhausted. The second phase of the emission reduction plan could consist of halting all processing steps. An exact reduction plan will, of course, depend on the process layout and material flow and storage capacities.

Wet Corn Milling

Particulates from grain receiving, drying and cooling of gluten and feed, and starch drying are the emissions of primary concern from wet corn milling. Emissions of sulfur oxides from steeping and wet milling operations are minor.

Curtailment of corn receiving operations could constitute the initial emission reduction step. Reducing the throughput rate of various processing operations such as the drying and cooling of germ, gluten and feed, and drying of starch could constitute step two of the particulate reduction plan. Other operations could continue to the extent that the curtailment of these operations would allow. Final action would be complete shut down of all processing. Again, an exact reduction plan will depend on the process layout and material flow and storage capacities.

Dry Milling of Wheat, Rice and Corn

Particulate emissions from the receiving, cleaning, and drying operations present the most serious emission problem in dry milling. The actual milling operations (e.g., break rollers, sifters, purifiers) and product loading operations are also potential emission sources. However, these sources are usually well controlled.

Curtailment of grain unloading operations can constitute the initial emission reduction stage. Step 2 could be the curtailment of drying and cleaning operations. Maximum reduction would come from complete shutdown of all processing, including load-out, although this latter operation is usually well controlled. The exact reduction plan will depend on the process layout and material flow and storage capacities.

Alfalfa Dehydrating

Unlike all the other grain and feed industry processes, the major particulate emission sources from alfalfa dehydrating are the various cyclone separators, not receiving and handling.

Plans for curtailment of particulate emissions would necessarily involve cut-backs in throughput rates, instead of initial shutdowns of selected operations, since the alfalfa dehydrating process involves a continuous flow system. Throughput rates would be reduced at increments commensurate with the severity of the episode state. In an episode plan, ultimate reduction would be obtained by complete plant shutdown.

UNIQUE PROBLEMS ENCOUNTERED IN EPISODE CONTROL PLANS

Short term, emergency type emission control actions present some unique problems for the grain and feed industry. Foremost among these problems is the dependence of one processing step on another. The curtailment of one process will cause the eventual curtailment of many subsequent processing steps, although these subsequent processing steps may not be significant sources of emissions.

Another potential problem is the spoilage of raw grains. Corn, soybeans, and other high moisture content grains are dried soon after receipt to prevent deterioration. Thus, spoilage could occur if drying operations are curtailed for more than a day or so.

A similar risk applies to grain which must be kept in trucks, railroad cars, or barges due to curtailment of receiving operations. The length of time that a shipment can be stored without drying will vary widely with the moisture content, ambient temperature, and degree of bacterial infestation. Storage beyond 1-3 days is probably not desirable in most cases.

EPISODE CONTROL COSTS

Extraordinary control costs are not generally incurred during implementation of episode controls. The largest cost is, of course, lost production. If an episode occurs during a peak production period, the lost time will be difficult to regain. During nonpeak production periods, lost time can be regained by scheduling extra shifts or extra days of work. An added cost for premium labor rates for overtime work will be incurred.

CHAPTER 6

REFERENCES

1. Guide for Air Pollution Episode Avoidance. Environmental Protection Agency, Office of Air Programs, Research Triangle Park, North Carolina. June 1971. OAP Publication No. AP-76.

2. Requirements for Preparation, Adoption and Submittal of Implementation Plans. Federal Register, Vol. 36, No. 158, Saturday, August 14, 1971.

3. Emergency Procedures for Prevention of Air Pollution Episodes - State of Wisconsin. Environmental Protection Agency, Office of Air Programs, Research Triangle Park, North Carolina. Contract No. 68-02-0044, Task Order No. 3. December 1971, by PEDCo-Environmental Specialists, Inc.

CHAPTER 7

SOURCE SURVEILLANCE AND MONITORING

INTRODUCTION

Little monitoring or sustained surveillance of atmospheric emissions has been done at grain handling and processing operations. Opacity readings of visible emissions, and adherence to equipment specifications and prescribed operating procedures have been used to control atmospheric emissions. Occasionally, ambient air near grain handling facilities has been monitored to assess the impact of emissions and fugitive dust. The limited emission testing which has been done has followed conventional procedures which use dry filtration techniques to determine particulate concentrations.

In the following sections the source test and ambient air monitoring procedures generally used are reviewed. Recommended test practices are also identified.

EMISSION MEASUREMENTS

Source Testing Procedures

Recent source sampling conducted or funded by EPA has been accomplished using EPA recommended procedures. Sampling traverse points were selected according to Method 1 of the Federal Register[3/] and samples were collected in accordance with procedures outlined in Method 5 of Federal Register.[5/] Figure 65 illustrates the EPA particulate sampling train.

Control equipment manufacturers have conducted some emission tests to determine the efficiency of their control equipment. These tests have been conducted largely on grain handling and drying operations. Testing methods for these operations have included various combinations of dry filtering systems as shown in Figure 66. These sampling trains have been adapted from those developed in other industries and have been described, in general, in ASME Power Test Code 27-1957 and more recently in ASTM Procedure 2928-71.[1,2/]

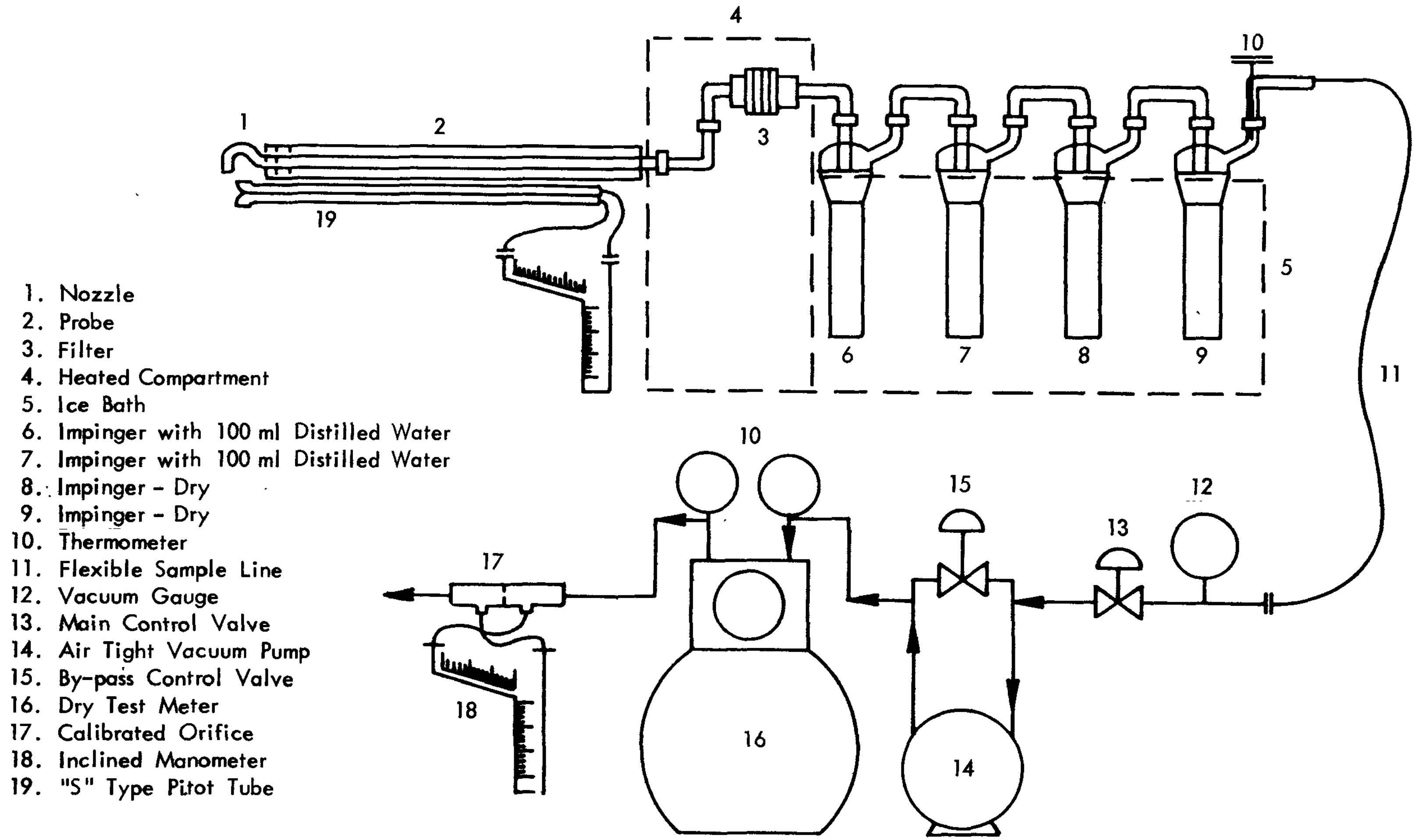

Figure 65. Schematic of EPA particulate sampling train.

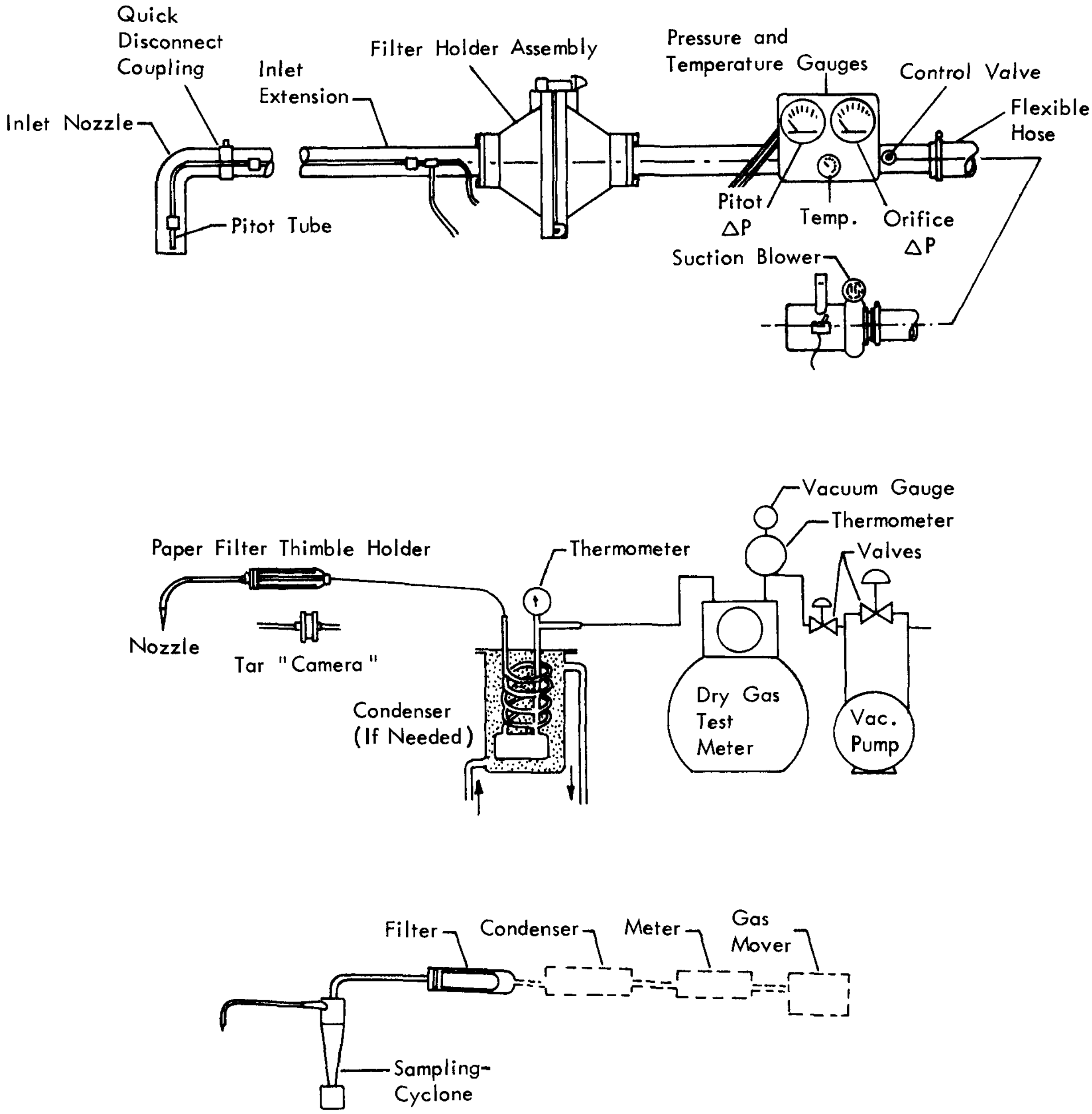

Figure 66. Common particulate sampling trains.

In most cases the sampling trains include a carefully sized sampling nozzle (usually 1/4 in. to 1/2 in. in diameter), a probe to extend the nozzle into the duct, a filtering medium, a gas volume meter or rate meter, and a pump or suction device.

Sampling is generally conducted isokinetically* by measuring the velocities at various points in the ducts, as shown in Figure 67, and then sampling at this same velocity at these points. The actual sampling train, procedure, and filtering medium varies with the tester since there is no industry-wide standard. Filters have included cloth filter bags, alundum thimbles (medium and fine porosity), paper thimbles and flat filters of fiber glass or paper. The collection efficiency of these filtering mediums is not known for grain handling processes. However, due to the relatively large size of the particulate matter, it may be surmised that the filtration efficiency is fairly high in most applications; especially after the first 5 or 10 min of sampling.

Selection of Sampling Sites - The selection of the sampling site will depend on the physical layout of the process equipment and the purpose of the test. If emission rates directly from a process are to be measured, then a site before any control equipment must be used. If atmospheric emissions are to be determined, then a site after any control equipment and near the final duct exit should be selected. Preferably, a sampling site should be located so that the velocity throughout the duct cross section follows a fairly uniform distribution. A section of round duct is preferable to a rectangular duct since there is less fluctuation in velocity across a round duct. In most cases, depending on the gas velocity, a uniform velocity distribution in a circular flue will occur about eight diameters downstream and two diameters upstream from any flow disturbance such as a bend, connection, or change in area. There are times when this arrangement is found, but more often than not compromises must be made and the sampling site is less than ideal. In such cases, the site must have the longest run of straight duct available directly upstream and as little interference from branch ducts, etc., as possible. Figure 68 is a guide for selecting the number of sampling points at various distances from a flow disturbance.

When sampling for a gaseous compound, a single point may usually be used unless there is reason to believe that the gaseous pollutant may not be evenly dispersed within the effluent stream.

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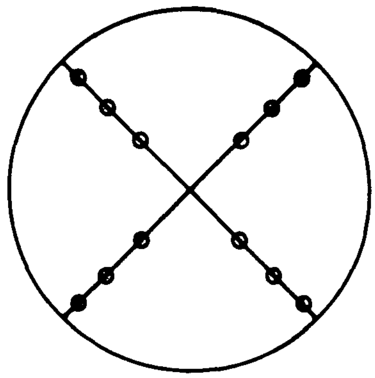
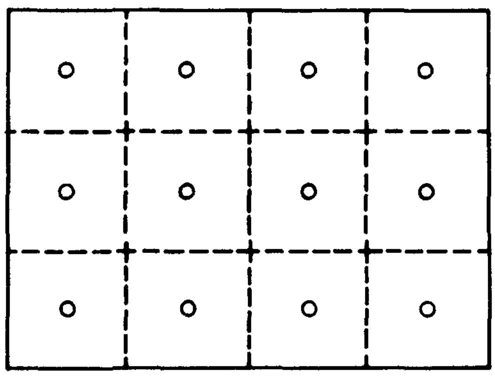
* Velocity in sampling nozzle is equal to velocity of gas in duct at the sampling point.



Cross section of circular stack divided into 12 equal areas, showing location of traverse points at centroid of each area.



Cross section of rectangular stack divided into 12 equal areas, with traverse points at centroid of each area.

Figure 67. Sampling point location layout.[3]

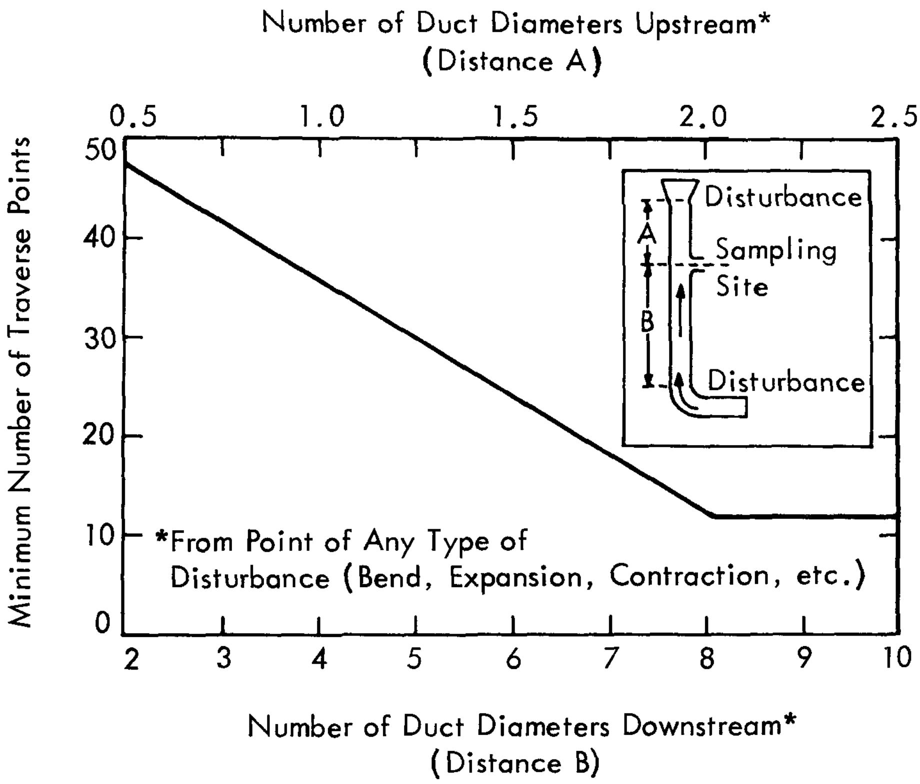


Figure 68. Guide for selecting sampling points.[3/]

Recommended Particulate Sampling Procedure -

General - The large majority of grain handling and processing emission sites should be sampled with the EPA sampling train (EPA Method 5, Figure 65). When large fibers such as beeswings are present in the gas stream or if the process operates only for short time periods (truck and railcar loading or unloading), a high volume sampler should be used with a sampling rate of 15 to 30 ft^3/min. Under heavy dust loading conditions, a cyclone preceding the filter will be required to prevent overloading of the filter.

In all cases a pitot tube should be placed along side the sampling nozzle in order to continuously measure duct gas velocity and allow for maintaining isokinetic sampling rates.

The following general procedure can be used for particulate testing:

1. Select sampling site and number of sampling points.

2. Check all process fans, ducts, and duct openings to insure proper operation.

3. Make preliminary velocity and temperature measurements and make a determination of the stack gas moisture content.

4. Select nozzle size compatible with desired sampling rate, and calculate isokinetic sampling rates.

5. Assemble sampling train.

6. Take initial meter reading and place nozzle at first sampling point.

7. Start isokinetic sampling and continue until all points have been sampled.

8. Record velocity pressure, meter readings, meter temperature, stack gas temperature, and sampling rate (orifice pressure drop) every 5 min or at every sampling point.

9. Upon completion of sampling, carefully remove filter and any loose dust in nozzle and probe. Place dust in labeled, sealed container for later weighing.

Detailed procedures according to the Environmental Protection Agency requirements are presented in References 3 and 5.

Grain dryers - Grain dryers present unique sampling problems due to inaccessibility, large exit surface area, low velocities, and large particle size. Various approaches have been used to solve these problems. In one case a 3-ft by 3 ft square by 3-ft long sheet meter duct was placed tightly against the dryer vent's exit screen at various locations. Sampling was then conducted within this duct at various points according to procedures as described in the previously cited ASME and ASTM procedures. Another procedure utilized a Hi-Vol ambient air sampler system with a 8-1/2 in. by 11 in. rectangular straight duct about 12-in. long mounted on top of the filter. This sampler was located directly against the exit screen at various points to obtain a representative sample. Each point was sampled for 1 to 2 hr.

Still another procedure used in the past, utilizes a large nozzle (3 to 5 in. in diameter) which is placed against the exit screen. Sampling rates in the 15- to 75-cfm range are used and a small fabric bag is used to collect the particulate matter. This filter has a tare weight of about 30 g. Isokinetic sampling is performed with this apparatus at various points on the screen. Flow rates through the sampler are monitored by an orifice.

While no ideal sampling train exists for this application, the following guidelines are recommended for sampling dryer vents.

1. Sample at isokinetic rates with exit velocities from the dryer measured with a velometer or similar low air speed measuring device.

2. Use a high efficiency, low weight, fiber glass filter.

3. Subdivide the exit area into smaller areas approximately 9 ft^2 or smaller in size and sample at the center of each of these areas.

4. Use an orifice in the sampling train to monitor sampling rate.

In most cases, extensive scaffoling, a crane, and complete personal dust protection equipment will be required.

Cyclone outlet ducts - Gas flow in the exit stream from a cyclone forms a tangential pattern with high velocity along the duct wall and low or negative velocity near the center. This tangential flow pattern can be converted to a more uniform pattern by flow straighteners in the duct or by passing the gas through a fan, or other flow disturbance which will break up the tangential pattern. Sampling directly in the cyclone exit should be avoided and flow straighteners may be required to provide an acceptable site.

Factors Affecting Test Results - With care in performing the mechanics of emission testing, errors in determining the dust concentration at a selected point can be minimized. However, other factors exist which can radically affect the test results. To minimize these factors and provide representative data, the following points should be considered before performing the test.

1. Location of a sampling site which provides the most representative conditions of particulate concentration.

2. Operation of the process in a representative manner considering both rate and type of material being processed.

3. Sampling for sufficient time to average out emission changes due to fluctuations in the process rates and composition.

AMBIENT AIR MONITORING

Monitoring of particulate in the ambient air around grain processing installations has proven useful in determining the impact of these facilities on the overall particulate loading. This is possible because grain dust can be distinguished from other types of dust by analyzing for the protein content of the total particulate collected. This procedure will not determine the quantity emitted by a given source within a grain processing facility, but is useful in determining the impact of a total facility.

Ambient air samples are usually taken over a 24-hr period at more than one location and for extended periods of time. The exact sampling procedures to be used can only be determined after a study of the site, the meteorology and the intent of the study. As a minimum, samples should be taken over a 1- to 2-week period at two or three locations. Wind direction and speed should also be monitored during this period. High volume air samplers are used for ambient air studies. Procedures for using these instruments have been standardized, but locating the instruments and establishing a useful program require considerable planning.[4]

CHAPTER 7

REFERENCES

1. American Society of Mechanical Engineers, Power Test Code 27-1957, New York, New York.

2. American Society for Testing and Materials, Standard Method for Sampling Stacks for Particulate Matter - D2928-71, Philadelphia, Pennsylvania.

3. Federal Register, Volume 36, No. 247, Part II, December 23, 1971.

4. Methods of Air Sampling and Analysis, American Public Health Association, Washington, D.C., 1972, p. 365.

5. Federal Register, Volume 36, March 31, 1971.

CHAPTER 8

FIELD SURVEILLANCE AND ENFORCEMENT

INTRODUCTION

The Field Enforcement Officer (FEO), often referred to as the air pollution inspector, performs a vital role in state and local air pollution control programs. He has direct responsibility for surveillance of air pollution emission sources and enforcement of applicable regulations. He is often the only contact between the agency and industry. As the agency's representative he must explain its programs, including such elements as roles of various regulatory agencies, emission regulations, procedures for emergency pollution episodes, and requirements for permits to operate or registration of sources. At times he may be asked to advise on ways to control emissions.

The following sections describe general inspection practices, the equipment with which an FEO performs his daily work and the kinds of records he may be expected to maintain, and specific inspection procedures for major emission sources within the grain handling and processing industries.

INTRODUCTION TO INSPECTION PRACTICES

Chapters 3 and 4 have set forth fundamentals of grain handling and processing industries and equipment of concern to the field enforcement officer. Having become familiar with this material, he may find it valuable as a reference resource, a useful compendium of technical information relating specifically to the work he performs.

The sections that follow are designed as a guide to proficient inspection practices. Although each inspection is, of course, a unique event, certain basics may be cited that apply generally to all such inspections.

Observing the Plant Environment

Before entering the plant premises, evaluate the general plant environment. Note any visible emissions, odors, or dustfall in the surrounding area. Look for possible damage to vegetation and for effects of pollutants on materials and paint. Document all significant observations, noting the date, time of day, and weather conditions (especially wind speed and direction).

Interviewing Plant Personnel

Direct communication with plant personnel can range from formal, scheduled interviews to the informal conversations that usually occur during conduct of an inspection. All such communications can be valuable: they enhance the Field Enforcement Officer's understanding of plant scheduling, operations, problems, and management attitudes. Likewise, they give plant personnel some insight into the mission of the Field Enforcement Officer and the reasons for the inspection.

When inspections are planned, the FEO will usually have arranged an appointment with the plant manager. Sometimes, however, especially on unscheduled visits, an interview with another staff member may be appropriate. In any case, it is important that the FEO state immediately his name, agency affiliation, and the purpose of the visit and show his credentials. Credentials should always be carried whether entering the plant or observing dust on the property of the company. If a violation has occurred or is suspected, he should notify the responsible persons promptly upon entering the plant.

The initial visit to a plant should entail an extensive review of the process equipment, air pollution control equipment, plant layout, operating rates and schedules and monitoring equipment. Subsequent visits require less time, since their primary purpose is to ascertain whether conditions have changed, and if changes have occurred to check their effects on pollutant emissions. It is recommended that the inquiries and discussions be conducted in a quite environment (i.e., office) prior to the actual inspection.

Inspecting Inside the Plant

Since detailed instructions for in-plant inspection are given in subsequent sections, this section emphasizes safety precautions, which must be observed in all types and sizes of facilities. The Enforcement Officer, as representative of his agency is obligated to observe <u>all</u> safety precautions, whether or not they are cited in the regulations of the plant being visited. Ordinarily the FEO should not sign accident waivers when entering a plant. It is a good practice, however, to wear safety shoes, hard hats and safety glasses during an inspection. Many plants require such protection of their employees and visitors. Coveralls or shop coats also come in handy when inspecting the dirty areas of a site.

On the first visit to a plant, the FEO should review all safety rules with plant personnel. Never tour the plant without an escort. Since the FEO will work daily with fans, belt and chain drives, and electrical motors, he should constantly keep in mind the hazards associated with this type of equipment.

FIELD INSPECTION EQUIPMENT

The enforcement officer should carry certain basic equipment and pertinent facility records to properly perform field inspections.

Basic Equipment Needs

Table 241 lists the basic equipment each Field Enforcement Officer should have available to perform his inspections both properly and safely.

Table 241. SOURCE INSPECTION EQUIPMENT

Stack evaluation equipment (Ringelmann chart or opacity guide)
Polaroid camera
Compass
Wind speed indicator
Flashlight
Stop watch
Tape measure
6-Ft rule
Hard hat
Safety glasses
Safety shoes
Manometer or pressure/vacuum gage (0-30 in. Hg and 0.10 in. H_2O)
Velometer

In addition, the officer may need an official vehicle equipped with two-way radios to provide transportation and to facilitate communications.

Field File

The basic forms and records which the Field Enforcement Officer should carry with him on an inspection are listed in Table 242.

Table 242. SOURCE INSPECTION FIELD FILE

Form	Completion
Copy of previous field inspection form and other relevant information such as plant layout, processes, rates, records of malfunctions, etc.	
Copy of code	
Extra copy of regulations for the plant manager	
Emergency episode procedures	
Preinspection sheet or permit	Before inspection
Observation recording form	During inspection
Field inspection form	During inspection
Notice of violation	After inspection (if necessary)

A copy of the permit or preinspection data sheet should be brought into the field in order to verify that current operating practices are in conformance with those stated on the permit. A copy of the local regulations and emergency episode procedures should also be carried. These should be reviewed with the operator to insure that he understands their requirements.

INSPECTION PROCEDURES

The purpose of an inspection by the FEO is to determine whether a source is operating in compliance with applicable emission regulations. Table 243 presents a brief list of emission sources in the grain and feed industry and air pollution control devices used on the sources.

Table 243. AIR POLLUTION CONTROL DEVICES USED IN THE GRAIN PROCESSING INDUSTRY

	Operation	Applicable Control Devices: Control Device	Collection Efficiency Range	Typical Outlet Loading Range (gr/scf)
1.0	ELEVATORS			
1.1	Grain receiving	Cyclone	85-95	0.02-0.09
		High energy, recirculating cyclone	97-99	--
		High velocity filter	95-99	0.005
		Fabric filter	99 +	0.002-0.006
1.2	Grain drying	Screen house		
		Rotary screen - self cleaning		
		Vertical screen - self cleaning		
1.3	Transfer operations	Same as grain receiving		
1.4	Shipping	Same as grain receiving		
2.0	FEED MILLS			
2.1	Receiving	See grain receiving operations for elevators.		
2.2	Grinding system	Product recovery cyclone (Pneumatic conveying from grinder)	99	0.01-0.02[a/]
		Fabric filter	99 +	0.002-0.01[a/]
2.3	Pellet cooler	Cyclone		
		low energy	88-96[a/]	0.02-0.7[a/]
		medium to high energy	98-99[a/]	0.06-0.1[a/]
2.4	Shipping	See shipping operations for elevators		
3.0	ALFALFA DEHYDRATING			
3.1	Dryer	Cyclone	85-98	*0.10-0.30[a/]
		Wet scrubber	21-92[a/]	*0.02-0.09[a/]
3.2	Hammermill	Cyclone	85-98	*0.60-1.6[a/]
		Fabric filter	99 +	
3.3	Pellet mill	Cyclone	85-98	
		Fabric filter	99+	
3.4	Pellet cooler	Cyclone	85-98	0.09-0.24[a/]
		Fabric filter	99+	
4.0	MILLING			
4.1	Receiving	See grain receiving operation for elevators		
4.2	Cleaning house	Cyclones	88-99[a/]	0.03-0.1[a/]
		Fabric filter	99 + [a/]	0.005-0.02[a/]
4.3	Mill house	Cyclone	96-99[a/]	0.04-0.2
		Fabric filter	99 + [a/]	0.005-0.01[a/]
4.4	By-Products Hammermill	Cyclone	95-99[a/]	0.1-2.0

Table 243. (Continued)

Operation	Control Device	Applicable Control Devices: Collection Efficiency Range	Typical Outlet Loading Range (gr/scf)
4.5 Shipping by-products	Cyclone	99+	
	Fabric filter	99+	
Flour	Fabric filter	99+	
5.0 SOYBEAN PROCESSING			
5.1 Receiving	See grain receiving operations for elevators		
5.2 Drying	Screen house	--	0.02-0.05[a]
	Vertical self-cleaning screen	--	0.008[a]
5.3 Processing			
. Cracking mills	Fabric filter	99+	
	Cyclone	95-99[a]	
. Dehulling, conditioning, flaking, cooling, and toasting	Cyclone	88.7-99	
	Wet scrubber		
. Meal drying		99+	
. Meal grinding	Fabric filter	99+	
	Cyclone	98-99[a]	
5.4 Shipping	See shipping operations for elevators		
6.0 WET CORN MILLING			
6.1 Receiving	See grain receiving operations for elevators		
6.2 Drying	See drying operations for elevators		
6.3 Steeping	Packed bed scrubbers	90-99+ for SO_2 control	
6.4 Germ and gluten Drying and cooling and feed and pellet cooling	Medium energy cyclones	80-95	0.145[a]
	High energy cyclones	95-98	
6.5 Feed drying	High energy cyclone	95-98	
	High energy scrubber	98-99	
	Afterburner	99+	
6.6 Feed house aspiration; transfer of germ, gluten, feed, and starch; and starch drying	Low to high energy cyclone	85-98	
	Fabric filter	99+	
	Wet scrubber (starch drying only)	95-99	
6.7 Carbon regeneration furnace	Afterburner	99+	0.145[a]
6.8 Corn syrup solids drying	Low to high energy cyclone	85-98	
	Wet scrubber	99+	
6.9 Product loading	See grain loading operations for elevators		

Table 243. (Concluded)

Operation	Control Device	Applicable Control Devices: Collection Efficiency Range	Applicable Control Devices: Typical Outlet Loading Range (gr/scf)
7.0 RICE MILLING			
7.1 Receiving	See grain receiving operations for elevators		
7.2 Drying	See drying operations for elevators		
7.3 Shellers, paddy separators, hullers brushes, and hull grinders	Cyclone Fabric filter	85-98 99+	
7.4 Loading	See grain loading operations for elevators		

a/ From actual stack test data, EPA Method 5.

The initial decision regarding compliance usually is made either (1) by considering process design and operating characteristics at the time of permit issuance, or (2) by conducting emission stack tests under operating conditions considered representative of the range of normal operation. Thus, when these initial evaluations have been made, the major responsibility of the FEO is to check that the source is still operating either (1) as specified in the permit application, or (2) under the same conditions as when the source satisfactorily passed the emission source tests.

The initial permit review is usually performed by an experienced engineer, although in some agencies it may be performed by a field enforcement officer. The initial permit review is crucial, since it is the foundation for future enforcement actions. The permit must contain certain specific operating and design information to allow meaningful evaluation. If such information is not given on existing permit forms, the FEO should obtain it during his first inspection.

In addition, when checking on permit-related information, the FEO must determine whether the plant is following good operating practices, since improper operation or maintenance can lead to excessive emissions. He must also check operation of the air pollution control equipment to determine whether it attains the specified collection efficiencies. He should also spot-check selected records to determine whether the source has been following good operating practices in the interval between inspections.

Thus, a source inspection should cover the following elements:

1. Determine whether a source is operating in accordance with permit specifications;

2. Determine whether a source is following good operating and maintenance procedures;

3. Spot-check selected records of operation since last inspection to determine whether source has been following good operating procedures;

4. Determine whether the air pollution control equipment is operating properly.

5. Determine whether the facility is in compliance with opacity standards.

The following subsections describe specific inspection procedures for inspecting air pollution control devices and hooding systems. The additional checks which should be made for some of the handling and processing operations are also described.

Inspection of Air Pollution Control Systems

Inspection of Hooding Systems - Check general mechanical conditions of ductwork. Note missing sections and poor hooding configurations for subsequent discussions with plant personnel. Try to observe the effectiveness of each hooding system while it is in operation.

Check the air flow balance of the ductwork system. Note whether ductwork venting new emission sources has been added to existing ductwork. Use a velometer to check the face velocities of the hooding systems. In many plants, the ductwork system will be substantially out of balance and will require major effort by plant personnel to correct this condition. Establish a deadline by which such corrective action will be completed.

Evaluate ductwork configuration. Many plants vent multiple sources to a single collector using dampers to shut off those sources not being used. Such systems can be overloaded at periods of active operation and plant personnel may not be conscientious about adjusting the dampers. Review operating procedures with personnel to verify that they understand the system's operation. If system is inadequate, follow established control agency procedures regarding requirements for affirmative action program (e.g., compliance schedules).

Inspection Points for Cyclones - Check general mechanical condition of exterior of cyclone. Air leaks caused by holes and severe dents will disrupt air flow patterns thereby decreasing collection efficiency.

Check for buildup of dust on cyclone walls and in cone, and observe any dust buildup around the cyclone. If moist air stream is being handled, either back pressure on cyclone or pressure drop across unit can be monitored on air streams susceptible to plugging. Abnormally high pressure drop across cyclones will decrease effectiveness of hooding systems.

Check hopper discharge mechanism. Rotary valve or equivalent should be used to prevent air from entering through hopper discharge.

Inspection Points for Fabric Filters - Check the pressure drop across the filter. High pressure drops (above 6 to 8 in., e.g.) may substantially decrease the efficiency of the hooding and emission containment system, and indicate that either the self-cleaning mechanism is not working properly or that the fabric should be removed for its periodic cleaning.

Observe emissions during regular operation and cleaning cycle. If visible emissions are detected, then fabric is probably torn and should be replaced.

Inspect the inside of the filter housing when the unit is off stream, noting condition of the fabric and operation of internals (e.g., near the top of the bags where they are attached to the housing).

Check frequency of hopper cleaning and determine its adequacy. Plant should have a set schedule for removing collected dust from hoppers.

Note the manner in which hoppers are emptied. Dust should not fall more than a few feet unless a "sock" or other hooding system is used. Review preventative maintenance schedule with plant manager. Plant should have schedules indicating frequency with which filter internals are checked, fabric removed and cleaned, and fabric replaced. Require that such schedules be maintained for each unit and spot check such records during subsequent inspections.

Check the number of sources being vented to each fabric filter. Many plants have a tendency to vent newly hooded emission sources through an existing filter which may cause overloading of the filter. If additional sources have been vented through the filter, the operating permit must be changed and hence re-evaluated.

Inspection of Wet Scrubbers - Check for structural wear from corrosion or erosion.

Check water flow rate and water pressure to the scrubber and compare to design values.

Check pressure drop across unit and compare to design and permit values.

Note if scrubber location and poor insulation would subject unit to freezing.

Review maintenance schedule for cleaning and replacing nozzles. Plant should establish schedule if one not currently existing.

Note the operation of fans and pumps and fraying or excessively worn drive belts.

Inspect the interior of the scrubber to see if there are deposits of materials which could either disturb the flow pattern or cause the unit to plug.

Inspection of Process Operations - In addition to inspecting the hooding and control system as described above, certain other aspects of process operation should also be inspected. These are discussed below for each processing operation, where appropriate.

Grain receiving - Check the enclosure around the unloading operation. Make sure at least one door is closed in unloading areas (three sides closed) to prevent wind action from overcoming collection system.

Check air flow through grate system with velometer. Should be at least 100 ft/min, preferably a minimum of 150 ft/min.

Grain transfer - Check that systems designed to be intervented (such as scale hopper, mixer, and surge hopper) are in good repair.

Check the conveying mechanism, whether mechanical or pneumatic, for tightness.

Check for good "housekeeping practices" such as maintenance of area around transfer points to prevent buildup of grain.

Grain drying - Where screen filters are used, visually check the collecting screen for holes and wear due to cleaning arms, where appropriate. Also check wind shields around unit to determine whether they are effective in preventing air flow disruptions (can only be done on windy day).

Determine whether grain is cleaned before being dried. Cleaning may be necessary to reduce emissions to acceptable level.

Grain loading - Check the enclosure around the loading operation. Check whether operator is covering open areas with tarpaulins, etc., to restrict airborne dust.

Check the conveying mechanism for tightness.

Feed mills - Check general housekeeping.

Wet corn milling - Feed drying - permit may stipulate that unit is required to operate below maximum temperature to minimize "blue haze" emissions. If so, check drier temperature and spot check records of operating temperature for interval between inspections.

Carbon regeneration furnace - check operating temperature of afterburner to ensure that combustion temperature exceeds minimum design temperature.

CHAPTER 9

RECOMMENDATIONS FOR FUTURE PROGRAMS

AREAS OF NEEDED RESEARCH

The areas where additional research appears warranted can be grouped into the following categories:

A. Dust Control Systems

B. Source Testing Methods

C. Emission Factors

D. Financial Data for Industry

E. Health and Welfare Effects of Emissions

The following section presents specific research programs in each of the above categories.

SPECIFIC RESEARCH PROGRAMS

Dust Control Systems

With the exception of a few sources, the technology required to achieve a high degree of control of dust emissions is already available. Only those sources which involve the generation of fugitive dust (e.g., grain receiving and loading and product loading) and some drying or dehydrating operations present problems where additional technology development would seem justified. Containment of the fugitive dust is the principal problem with regard to the former groups of sources. The properties of the effluent stream pose the major difficulties for control of the emissions from drying operations.

Grain loading operations - Control of fugitive dust which is emitted during the loading of grain into rail cars, barges, and ships is a major problem in the industry. Marine loading operations are especially troublesome. Research should be directed to the development and testing of containment methods for all types of loading operations with special emphasis placed on marine loading.

Grain dryer control - Available techniques for the control of particulate emissions from grain dryers should be reviewed in detail to determine avenues for improvement. New techniques for control or changes in dryer configurations to reduce emissions should be investigated.

Source Testing Methods

Grain dryers present unique sampling problems due to inaccessibility, large exit surface area, low velocities, and large particle size of the emitted particulates. Various approaches have been attempted to solve these problems. However, no reliable sampling train exists for this application. A program to upgrade sampling procedures for grain dryers is recommended.

Emission Factors

Meager data are available on emission factors for uncontrolled sources in the grain and feed industry. To evaluate accurately either the environmental or economic impact of air pollution control regulations on the various segments of the grain and feed industry, the emission factors for each major pollution source should be known.

A program to develop emission factors for all major sources of emissions is recommended. Special attention should be directed to plants located in rural areas. Emission factors should be developed as a function of pertinent parameters (e.g., the type of grain handled, moisture content of the grain, and type of equipment used to process grain).

Financial Data

Assessment of the economic impact of air pollution control regulations could be refined with more detailed financial data for certain segments of the grain and feed industry. Many of the dominant firms in the industry are highly integrated corporations, and it is difficult to define the impact of air pollution control activities on this portion of the industry.

A survey, conducted by an independent noninvolved group (e.g., Dun and Bradstreet), would appear to be the most feasible way to obtain the requisite financial information.

Health and Welfare Effects of Emissions

The effect of airborne emissions from grain and feed industry operations on human health and welfare should be defined in more detail. Attention should be focused on synergistic effects produced by interaction with other particulate or gaseous components of atmospheric pollution.

APPENDIX A

HARVESTING TECHNIQUES AND THEIR INFLUENCE ON DUST EMISSIONS AT GRAIN ELEVATORS

Part of the dust emitted during the handling of grain at elevators gets into the grain during the harvesting operation. Very little quantitative data are available relating farming practices to the type and quantity of dust that may be introduced into the harvested grain. During this program, a limited study was conducted to define, at least in general terms, how harvesting techniques may influence the dust content of grain received at elevators. No quantitative data were found, but some qualitative information was obtained as a result of discussions with equipment manufacturers and farmers.

Before discussing harvesting techniques, it should be noted that existing grain standards actually contribute in an indirect way to the dust content of grain delivered to elevators. Current U.S. Grain Standards specify the maximum amount of foreign matter (FM) that may be contained in a specific grain. If a load of grain delivered by the farmer to an elevator exceeds this limit the farmer is penalized by lower price, depending on the excess FM in the grain. However, if the delivered grain exactly meets the FM limit there is no penalty and if the FM is less than the limit, the farmer receives the same price per bushel as he would if the FM were at the limit. Discussions with farmers, elevator operators and USDA representatives indicated that farmers usually try to deliver the grain with near the maximum allowable FM because they are paid on the basis of total weight delivered to the elevator. Elevator operators also try to keep the FM content up for the same reason. It is generally acknowledged that this is a poor practice because the processor eventually has to remove this material and this poor quality does not help our export grain trade. Furthermore, it also hampers air pollution control and elevator housekeeping efforts.

Discussions with industry representatives regarding possible methods of eliminating the practice of maintaining high FM content did not result in very feasible suggestions. One suggestion was that the processor might offer a premium price for low FM content, but it seems doubtful that the processors would institute such a policy. It was also suggested that the government might pay a subsidy for low FM content, but it would also be difficult to have such a policy adopted by Congress.

Since changes in grain standards did not appear to be a viable approach, attention was directed to harvesting techniques and equipment to determine how they might be improved to reduce dirt levels in harvested grain. Grain harvesters or "combines" are quite complex and there are a number of processing operations within the combine that can affect the dust content of the grain.

The basic mechanisms in combines, as described in the manufacturers' literature, are shown in Figure A-1. In the case of corn as an example, the kernel is separated from the cob by the cylinder and concaves. The

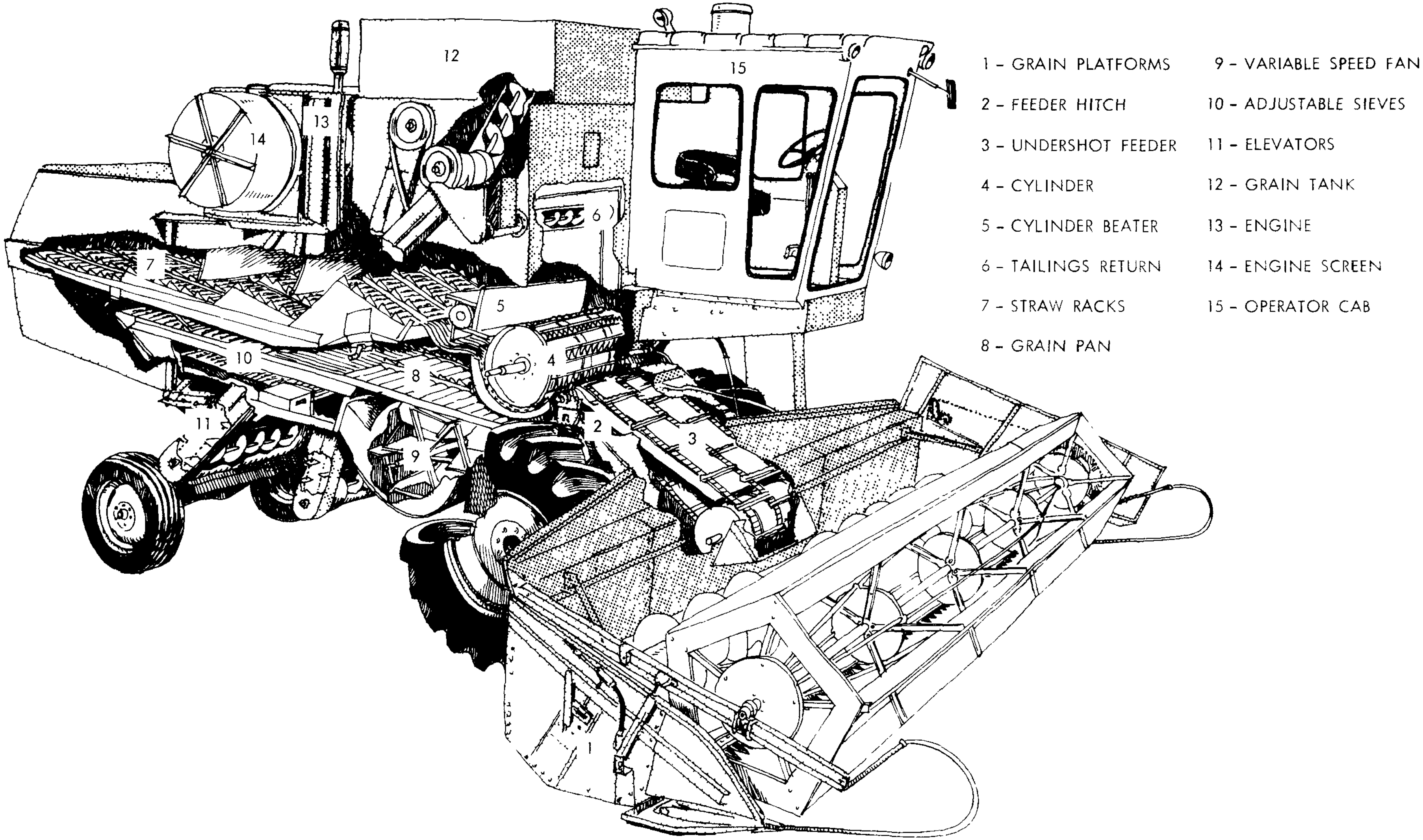


Figure A-1. Cut-away diagram of a combine (grain harvester).

speed of the cylinder is adjustable as is the spacing between the cylinder and concaves. The shelled corn passes through the concaves and the oscillating straw racks onto the two agitating sieves in which the openings are adjustable. A variable speed fan blows air up through the sieves to remove dust and small pieces of leaves, etc. The grain must pass through both sieves, and then is augered up to the grain tank. Adjustment of the fan speed and the speed at which the combine is driven through the field, are probably of primary importance for achieving a clean grain. Our survey of harvesting equipment indicated that all of the combines, except one, had the single variable speed fan. One unit, however, is somewhat different in that it has two fans, the first of which blows air through the grain before it enters the sieves. It would appear that this arrangement might produce a cleaner product.

The manufacturer of the combine having two fans (Allis Chalmers) stated that their newer model (Model L) uses only one fan, but it still has two air discharge ducts so that it operates in the same manner as two fans. However, the new single fan is a transverse flow fan which draws in air along its entire length rather than just from the ends. This provides more even distribution of air. Speed of the fan is constant, but an adjustable inlet vane is used to control air flow. Air discharged from the fan is directed through the grain as it falls toward the shoe assembly (sieves) and a second stream of air flows up through the sieves. The entire shoe assembly, containing the two sieves, oscillates as a unit. Face velocity of the air flowing through the sieves ranges from 500-1,000 fpm when there is no grain on the sieves.

Although the thrashing and cleaning system in the combines has basically remained the same for many years, it was the opinion of the manufacturers that the equipment can provide a very clean grain if it is adjusted properly and is not overloaded. To obtain clean grain, the manufacturers made the following recommendations:

1. Reduce the speed of the combine or harvester.

2. Maintain proper adjustment of fan speed (this fan helps to separate the grain from other components).

3. Maintain proper adjustment of the header (cutting height).

4. Maintain proper adjustment of the cylinder (the cylinder and concaves shell the corn).

5. Maintain proper adjustment of the concaves (inside the cylinder).

6. Keep the screens clean.

Implementation of recommendations such as those presented above would require more time and attention on the part of the farmer or operator of the combine. At present no incentive exists in this regard, except perhaps personal pride of the farmer in producing a clean product, as long as the FM does not exceed the limit set by grain standards. Most spokesmen agree that the FM content can and should be reduced, but no ready solution is apparent. The best solution would seem to be some price compensation to the farmer so that he will make the extra effort to minimize the FM content of his grain during harvesting operations.

APPENDIX B

HEALTH EFFECTS OF EFFLUENTS FROM THE GRAIN AND FEED INDUSTRY

SUMMARY

Airborne grain and feed industry effluents may cause irritation of the skin or eyes. The major health problems, however, are respiratory ailments caused by inhaled particulates of less than 5 μm diameter. High ambient particulate concentrations (> 100 mg/m^3) of grain and feed dust have been reported to cause allergies, asthma, chronic bronchitis, and emphysema. Potentiation is possible if simultaneous exposure to particulates and gaseous pollutants or cigarette smoke occurs.

At normal low ambient particulate concentrations (< 100 $\mu g/m^3$) no evidence exists for adverse effects to healthy people from grain and feed effluents. However, people having preexisting respiratory disorders may be affected or disabled by rapid increases above the seasonal mean concentration of particulate grain dust. There is no evidence to show effects from long term (decades) exposure to low concentrations of grain dust. Grain dust exposure after long term exposure to other industrial dusts may cause gastric cancer. It is not known whether mechanical irritation to the small lung airways, or allergic reaction is the most severe risk.

INTRODUCTION

Airborne effluents from grain and feed industry operations may interact with the human body at the point of contact with the skin, eyes; or they may interact with other sensitive tissues after inhalation. Interior interaction usually begins in the respiratory tract, but may involve the gastrointestinal tract or other bodily organs. These secondary sites of effects usually are irritated by materials cleaned by respiratory defense mechanisms.

Grain and feed effluents may act separately, or in conjunction with other particulate or gaseous components of atmospheric pollution. Individual health, inherited sensitivities, and personal habits (e.g., cigarette smoking) can result in the development of varying degrees of discomfort or illness in different people, even when all are exposed to identical airborne ambient concentrations and types of grain and feed effluents.

EXTERNAL BODY INTERACTIONS

Allergic skin reactions, rashes, and itching patches, can occur from exposure to high concentrations of grain mill dust[1/] or from skin contact with ground flaxseed or linseed.[2/] These skin reactions are produced by all sizes of grain dust. If fungi, molds, or spores from grain and feed effluents come in contact with open cuts on the body, irritation or infection is possible.

Castor bean dust causes irritation of the eyes and initiates tear generation.[3/] One case has been reported of a wheat hair that penetrated the cornea and lodged in the iris.[4/] If grain dust absorbs gaseous or liquid pollutants from the atmosphere, eye irritation may be expected.

INTERNAL BODY INTERACTIONS

The respiratory tract is the major site for health effects resulting from inhaled atmospheric grain and feed effluents. Dust that enters the respiratory tract may be removed by ciliary action, by coughing up and swallowing, or by the activity of pulmonary macrophages. Irritation and allergic effects from dust during its residence time in the body can cause health problems. Very high ambient air dust loadings can slow or overload the removal mechanisms of the respiratory system. Lung defects, either inherited, environmentally induced, or caused by acute and chronic lung diseases, can suppress one or another component of the lung defense mechanisms and enhance disease susceptibility.[6,9/]

There are two clearance mechanisms in the pulmonary air spaces. The fast mechanism removes particles in 1/2-2 hr, while the slow mechanism takes 10-200 hr.[6/] The rate of clearance depends on particle size and concentration. Cleared particles may remain for several days in the gastrointestinal tract before excretion from the body. Little is known about possible gastrointestinal interactions except for a few very special cases.

Clearance from the respiratory system may be impeded by the presence of other particulates or gases. High levels of SO_2 may slow or stop ciliary beat.[6/] Low levels may increase the thickness of the mucus layer so that clearance stops even though cilia beat is unaffected. Increased particulate retention may then approach damaging levels.

The extremely toxic effects from inhalation of castor bean dust[3/] have long been known. In addition, the high incidence of respiratory disease among the millers, bakers, grain elevator workers, and dock workers, who are often subject to breathing air of high grain dust concentration, is well known.[1,4,12-16/] Evidence is available which indicates that insects, molds, and fungi associated with grain and feed handling can also cause respiratory ailments.[16-18/]

Highly mechanized, modern grain elevators without adequate dust control equipment can subject workers to 100-400 mg/m^3 of airborne dust.[1,19] This is well above the threshold for known respiratory problems. The dustfall fraction of grain elevator dust may contain 60-90% of organic substances and as much as 3-20% of free silica from the soil fraction. There is no evidence of silicosis from this low concentration of airborne silica. The < 1 μm diameter fraction can be 10-40% of the total number of particles, with the 1-5 μm fraction containing 60-98% and 2-20% being > 5 μm. With application of dust control equipment, the geometric mean particle diameter and the ambient concentration of dust in grain elevators both decrease.

Longer exposure to high concentrations of grain dust increases incidence of coughing, breathlessness, wheezing, grain fever, and dermatitis.[1] Grain molds, or their spores, may be significant in production of cough. Animal tests with high concentrations of sterilized grain dust, however, also resulted in bronchitis.[19] Grain dust alone can cause problems or it can interact with previously existing lung defects or infections. Cigarette smokers or exsmokers are more susceptible to respiratory problems from exposure to grain dust than are nonsmokers.[1] Heavy smokers (more than 20 cigarettes/day) are more susceptible than light smokers.

Evidence of respiratory health effects from ambient concentrations of airborne grain dust at locations well removed from grain and feed facilities is not conclusive. New Orleans asthma was first attributed to products of incomplete combustion originating from city dumps.[20,21] After open burning was curtailed, asthma attacks continued and effluents from a large grain elevator then became suspect.[22,23] The study of patients with respiratory ailments showed that 85% had a positive skin test response to grain elevator dust extracts. Only 43% of the control group showed positive response. While circumstantial evidence pointing to grain dust was accumulated, irrevocable evidence did not result.

A study at the University of Minnesota[24-35] attempted to correlate airborne grain dust from nearby grain handling facilities with the incidence of asthma in asthmatic students. This study included three phases: medical, environmental, and statistical. The medical phase consisted of charting asthma attacks of known asthmatic students. The environmental phase measured meteorological conditions and atmospheric pollutant concentrations. The statistical phase attempted to correlate the environmental and medical factors to determine whether a definite relationship existed between air pollution and allergic diseases.

Dustfall samples yielded an organic fraction of 60% in the immediate vicinity of grain handling and/or processing operations and 20% several miles from the plants.[33] Suspended particulate material was monitored with a high volume sampler and ranged from nearly 240 $\mu g/m^3$ in the immediate vicinity of the plants to about 25% of that concentration when over 1 mile away from the nearest grain handling or processing operation. Note that these ambient concentrations are about 0.1% of the concentrations which have proven to have severe health effects in grain industry workers.[1,19] However, the size distribution of the airborne particulates was such that 99.5% were less than 2 μm diameter and 50% were less than 0.03 μm diameter.[32] These small particles will readily invade and affect the small air spaces in the lungs.

Interactions between atmospheric pollutants and meteorological variables led to difficulty in assigning a definite cause to asthma attacks. However, when the seven originally significant variables[33] were cross correlated and interactions and direct relations were removed, only the meteorological effect from temperature-absolute humidity and the pollution effect from small particulates (< 5 μm diameter) monitored by the smoke spot index remained.[34]

A main conclusion of the University of Minnesota study was that the effect on sensitive individuals caused by even low concentrations of allergic particle pollutants can be quite significant.[34,35]

One report indicates a possible association between having worked in the metal products industry, subsequent exposure to grain dust, and incidence of stomach cancer.[36] No such relation was found if the exposure to grain dust was prior to employment in the metal products industry, or if only grain dust exposure occurred. A possible potentiation and synergistic effect is indicated.

While potentiation and synergistic effects from simultaneous inhalation of particulate dust and gases such as O_3, NO_x, SO_2, etc., have been postulated,[8,9] no evidence exists for such an effect from grain dust. Experimental studies on animals[10] have shown that simultaneous inhalation of NO_2 or SO_2 and silica dust increased the dust retention. This might also occur for grain dust. Respiratory diseases from inhalation of grain dust often take 10 years or longer before well-marked symptoms appear.[12] Dust inhalation is believed to be capable of inducing chronic bronchitis and emphysema even in the absence of allergic sensitivity.[12]

Some evidence indicates that children may have higher susceptibility to a few select grain and feed effluents. Autumn asthmatic attacks in Japan have been attributed to rice pollen.[37] Both skin and inhalation tests with rice pollen on asthmatic children produced positive responses more frequently and with lower concentration than for nonallergic controls. Bronchial asthma also appears to have been induced from feeding soybean milk to infants.[38/]

APPENDIX B

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APPENDIX C

EXAMPLE OF EMISSIONS INVENTORY QUESTIONNAIRE

GRAIN AND FEED INDUSTRY EMISSIONS INVENTORY
QUESTIONNAIRE (SOYBEAN PROCESSING)

I. Plant Identification

1. Parent Corporation Name: ______________________

Mailing Address: ______________________
Street

____
City State Zip

2. Plant or Facility Name: ______________________

Mailing Address: ______________________
Street

____
City State Zip

3. Person to contact regarding information supplied in questionnaire:

Name: ______________________

Title: ______________________

Telephone Number: ______________________

4. What is the normal operating schedule for this plant?

(a) _____Hr/Day (b) _____Day/Week (c) _____Days/Year

5. Would you be willing, on a voluntary basis, to permit access by a contractor of EPA to your plant to conduct stack gas source measurements?

Yes _______

No _______

INSTRUCTIONS FOR RESPONDING TO QUESTIONS ON
GRAIN HANDLING, PROCESSING INFORMATION, AND WASTE DISPOSAL

A. General

Answer all questions for which you have knowledge or information. If certain questions are not applicable to your facility or you have no information, please indicate Not Available or Not Applicable.

B. Specific

Answer questions on grain receiving only if soybeans are the only whole grain handled. Do not answer if soybeans are received from an elevator on the premises which operates as a subterminal or terminal facility handling other grains.

1. Grain Receiving Pattern: Indicate the average number of bushels of soybeans received at plant during each calendar month. Base answer on last 5 years of plant operation.

2. Grain Receiving: List various methods by which grain shipments arrive and approximate amounts received by each method annually. Base answer on last 5 years of plant operation.

3. Grain Unloading: List various methods used for grain unloading and approximate amount unloaded by each method annually. Base answer on last 5 years of plant operation.

4. Grain Drying: List amount of grain dried. Base answer on last 5 years of plant operation.

5. Provide as much detailed information as is available on grain drying equipment.

6. Grain Cleaning: List amount of grain cleaned and method of cleaning (e.g., scalping, aeration, grading shaker screens, etc.). Base answer on last 5 years of plant operation.

7. Refuse Disposal: If you practice on-site refuse disposal, list refuse types and disposal procedures.

8-15. Process Operations: Indicate the general nature of process operations at this plant by answering Questions 8-15.

PLEASE READ INSTRUCTIONS ON PAGE 533
BEFORE COMPLETING THIS SECTION

II. Grain Handling, Processing Information, and Waste Disposal

1. Grain Receiving Pattern:

Month	Soybeans, Bu/Month
January	
February	
March	
April	
May	
June	
July	
August	
September	
October	
November	
December	

2. Grain Receiving:

	Bu/Year
(a) Hopper Bottom Railroad Car	______
(b) Boxcar	______
(c) Truck	______
(d) Barge	______
(e) Other (Describe)	______

3. Grain Unloading:

	Bu/Year
(a) Gravity, Unrestricted to Grate	______
(b) Gravity, Choked-Feed to Grate	______
(c) Mechanical Conveyor	______
(d) Pneumatic Conveyor	______
(e) Dumping Platform (Boxcar)	______
(f) Power Shovel (Boxcar)	______

4. Grain Drying:

	Amount Dried (bu/year)

5. Grain Drying Equipment:

Manufacturer______________________________Date Installed______

Type__________________________Model____________________________

Rated Capacity for Soybeans______Bu/Hr

Water Evaporated__________Lb/Hr

Average Operating Rate________Bu/Hr

Fuel Type____________Rated Capacity____________Btu/Hr

Sulfur Content of Fuel____

Annual Fuel Consumption______________________________________

6. Grain Cleaning:

Method of Cleaning	Amount Cleaned (bu/year)
____________	____________
____________	____________
____________	____________
____________	____________
____________	____________

7. Refuse Disposal:

(a) Kinds and Disposal Method

	Open Burning (lb/year)	Incineration* (lb/year)	Other (lb/year)
(1) Paper, Cardboard	________	________	________
(2) Plastic	________	________	________
(3) Wooden Crates, Lumber	________	________	________
(4) Collected Grain Dust	________	________	________
(5) Other	________	________	________

(b) Incinerator Type

(1) Single Chamber____________

(2) Double Chamber____________

(c) Auxiliary Fuel Consumed in Incineration

(1) Type of Fuel______________________

(2) Amount of Fuel Used______Gal/Year, Ft^3/Year

(3) Sulfur Content of Fuel ______________________

* With gas or oil burner (burning in an enclosure without a burner is classed as "Open Burning").

8. (a) What is rated capacity of plant? _______ Bu/Day

(b) How many bu/year are processed? ________ (5-year average)

9. What type of extraction process is used at this plant?

(a) Expeller or rotary screw pressing ______

(b) Batch type hydraulic pressing_______

(c) Solvent extraction _______

10. If plant utilizes solvent extraction, what type of solvent is used for extraction? __________________________

11. How much solvent is used annually? _____ Gal/Year

12. What type of solvent extractor is used?

13. Are primary solvent recovery condensers vented to a supplementary vent recovery system? If so, indicate type:

(a) Refrigerated vent cooler ______

(b) Mineral oil absorber _______

(c) Activated carbon absorber_____

14. Are meal finishing operations conducted at this plant?

Yes__________ No___________

If answer is Yes, what is annual production of soybean meal?

_________ Tons/Year

15. Are soyflour or soygrits or soyprotein concentrate (i.e., concentrate or isolated) produced at this plant?

Yes__________ No __________

If answer is Yes, what are annual production rates of flour, grits and protein?

(a) Flour____Tons/Year; (b) Soygrits_____Tons/Year; (c) Protein_____Tons/Year

INSTRUCTIONS FOR RESPONDING TO QUESTIONS ON AIR POLLUTION CONTROL EQUIPMENT

I. Extent of Control (Page 539)

Indicate extent to which plant is equipped with dust control systems.

II. Air Pollution Control Systems (Page 541)

Part I - Control Systems and Dust Load

A. General

Describe current air pollution control systems by providing information requested on pages 541 to 542.

B. Specific

1. Indicate grain handling or processing equipment served by each dust control system (e.g., System I - Truck and rail unloading pits, System II - Meal dryer). Attach additional sheets as needed.

2. Indicate type of control device, manufacturer, and model number on each dust control system. If multiple control devices are utilized (e.g., cyclone and fabric filter) on a single source, indicate this fact. Also, provide as much information as is available on the cost of air pollution control equipment in your plant.

3. Provide any information you may have on dust loads into and out of control systems.

Part II - Effluent Properties and Control System Exhaust Configuration

4. Provide any information you may have on the designated chemical and physical properties of the gas stream associated with each control system.

5. Provide as much information as possible regarding points where dust is exhausted to the atmosphere.

PLEASE READ INSTRUCTIONS ON PAGE 538
BEFORE COMPLETING THIS SECTION

III. Air Pollution Control Equipment Information

A. Extent of Control

1. Indicate if the following specific dust sources are ducted to an air pollution control device.

Dust Source	Ducted To Control Device: Yes	No	Type of Air Pollution Control Equipment to Which Source is Ducted: Cyclone	Fabric Filter	Settling Chamber	Other
I. Grain Receiving						
1. Grain Unloading						
a. Truck						
b. Boxcar						
c. Hopper Car						
d. Barge						
2. Grain Cleaning						
3. Grain Dryer						
4. Grain Handling						
a. Conveyor Transfer Points						
b. Garner and Scale						
c. Elevator Leg Vents						
d. Tripper						
II. Bean Preparation						
1. Cracking Mill						
2. Hull Grinder						
3. Cracked Bean Conditioner						
4. Flaking Mill						

III. Air Pollution Control Equipment Information (Concluded)

Dust Source	Ducted To Control Device: Yes	Ducted To Control Device: No	Type of Air Pollution Control Equipment to Which Source is Ducted: Cyclone	Fabric Filter	Settling Chamber	Other
III. Meal Finishing						
1. Dryer						
2. Cooler						
3. Hammer Mill						
4. Screening						
5. Bagging Operation						
6. Bulk Loading						
7. Other (Describe)						
IV. Flour and Protein Production						
1. Flour Mill						
2. Protein Concentrate Dryer						

B. Air Pollution Control Systems

Part I - Control Systems and Dust Load

List each air emission control system concerned with grain handling and soybean processing

System Name ________ ________ ________ ________ ________

A. Grain Handling or Processing Equipment Served by This System

B. Control Equipment or System

a. Primary Control Equipment
   (1) Type (Cyclone, Fabric Filter, Wet Scrubber)
   (2) Manufacturer
   (3) Model No.
   (4) Capital Cost
   (5) Year of Purchase
   (6) Annual Utilities Cost
   (7) Annual Maintenance Cost
   (8) Installation Cost

b. Secondary Control Equipment
   (1) Type (As Above)
   (2) Manufacturer
   (3) Model No.
   (4) Capital Cost
   (5) Year of Purchase
   (6) Annual Utilities Cost
   (7) Annual Maintenance Cost
   (8) Installation Cost

B. Air Pollution Control Systems (Concluded)

System Name ________ ________ ________ ________ ________

C. Dust Load Data

a. Measured
(1) Dust Load to Control Equipment___Lb/Hr
(2) Dust Load from Control Equipment___Lb/Hr

b. Estimated
(1) Dust Load to Control Equipment___Lb/Hr
(2) Dust Load From Control Equipment___Lb/Hr

Part II - Effluent Properties and Control System Exhaust Configuration

System Name _________ _________ _________ _________ _________

A. Effluent Properties

a. Type of Dust Entering Control Equipment
b. CFM Discharged to Atmosphere
c. Particle Size of Dust (Microns), if Known
d. Temperature of Gas Stream
e. Humidity of Gas Stream

B. Control System Exhaust Configuration

a. Exhaust Duct Diameter
b. Height of Exhaust Above Grade
c. Velocity of Exit Gas

IV. Source Test Information

1. Have the emissions from any of the control equipment in your plant been measured by a source test?

Yes____________

No____________

If answer is Yes, please attach copy of test results if available. Also indicate methods used to conduct source test.

2. Do you have any data, obtained by actual measurements at plant, on the chemical and physical properties (i.e., particle size, composition, etc.) of dust emitted from specific equipment in your plant (e.g., grain dryer, meal dryer, cracking roll, flaking roll, etc.)?

Yes____________

No____________

If answer is Yes, please attach copy of data, and if known, indicate method used to sample dust and method used to measure specific properties.

SELECTED WATER
RESOURCES ABSTRACTS

INPUT TRANSACTION FORM

W

Emissions Control in the Grain and Feed Industry,
Volume I - Engineering and Cost Study

Larry J. Shannon, R. W. Gerstle, P. G. Gorman,
D. M. Epp, T. W. Devitt, and R. Amick

Midwest Research Institute
425 Volker Boulevard
Kansas City, Missouri 64110

68-02-0213

This report presents the results of a study of air pollution associated with the grain and feed industry. Specifically, the report discusses the following aspects of the grain and feed industry: operations--type, size, economics, profitability, location; air pollutant emissions--quantity, composition, effects; air pollution control systems--type, efficiency, cost, operation, maintenance; current R&D; current monitoring techniques; best pollution control systems; and economic impact of pollution control systems.

Grain and feed industry
Processes
Air pollution
Emissions
Control systems
Economic impact

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U.S. DEPARTMENT OF THE INTERIOR
WASHINGTON, D.C. 20240

Larry J. Shannon

Midwest Research Institute