AP-42 Section 9.7
Reference 2
Report Sect. 2
Reference 1

EPA-600/2-78-004a
January 1978

Environmental Protection

EPA Tests identified here
1) EMB 72-MM-19, 11/74
2) EMB 72-MM-16, 11/74
3) EMB 72-MM-23, 11/74

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EPA-600/2-78-004a
January 1978
NTIS PB 280024/AS
11.95

SOURCE ASSESSMENT: COTTON GINS

by

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FOREWORD

When energy and material resources are extracted, processed, converted, and used, the related pollutional impacts on our environment and even on our health often require that new and increasingly more efficient pollution control methods be used. The Industrial Environmental Research Laboratory - Cincinnati (IERL-Ci) assists in developing and demonstrating new and improved methodologies that will meet these needs both efficiently and economically.

This report contains an assessment of air emissions from cotton gins. The study was conducted to provide EPA with sufficient information to decide whether additional control technology needs to be developed for this emission source. Further information on this subject may be obtained from the Food and Wood Products Branch, Industrial Pollution Control Division.

David G. Stephan
Director
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Cincinnati

PREFACE

The Industrial Environmental Research Laboratory (IERL) of the U.S. Environmental Protection Agency (EPA) has the responsibility for insuring that pollution control technology is available for stationary sources to meet the requirements of the Clean Air Act, the Federal Water Pollution Control Act, and solid waste legislation. If control technology is unavailable, inadequate, or uneconomical, then financial support is provided for the development of the needed control techniques for industrial and extractive process industries. Approaches considered include: process modifications, feedstock modifications, add-on control devices, and complete process substitution. The scale of the control technology programs ranges from bench- to full-scale demonstration plants.

IERL has the responsibility for developing control technology for a large number of operations (more than 500) in the chemical and related industries. As in any technical program, the first step is to identify the unsolved problems. Each of the industries is to be examined in detail to determine if there is sufficient potential environmental risk to justify the development of control technology by IERL. This report contains the data necessary to make that decision for cotton ginning.

Monsanto Research Corporation has contracted with EPA to investigate the environmental impact of various industries that represent sources of emissions, in accordance with EPA's responsibility, as outlined above. Dr. Robert C. Binning serves as Program Manager in this overall program, entitled "Source Assessment," which includes the investigation of sources in each of four categories: combustion, organic materials, inorganic materials, and open sources. Dr. Dale A. Denny of the Industrial Processes Division at Research Triangle Park serves as EPA Project Officer for this series. This study of cotton gins was initiated by IERL-Research Triangle Park in April 1975; Mr. Edward Wooldridge served as EPA Task Officer. The project was transferred to the Industrial Pollution Control Division, IERL-Cincinnati, in October 1975. Mr. Thomas N. Sargent initially served as EPA Task Officer at Cincinnati. Dr. H. Kirk Willard replaced Mr. Sargent and served as EPA Task Officer through completion of the study.

ABSTRACT

This report summarizes the assessment of air emissions from cotton gins. The study was completed to provide EPA with sufficient information to determine whether additional control technology needs to be developed for this emission source.

Cotton gins are used to separate cotton fibers from cottonseed and trash. During the 1976 crop year, 2.30 x 10^6 metric tons of lint cotton were ginned in 18 southern and western states.

Particulates composed of cotton dust, cotton lint, fine-leaf trash, and other trash are released to the atmosphere during each step of the ginning process. Emissions are enhanced because materials are handled by air conveying systems. The average particulate emission for the entire ginning process is 3.14 g/kg of cotton ginned. = 6.28 lb/ton 1.57 lb/bale

Potential environmental effects from ginning were assessed by determining the source severity at a typical plant boundary. Severity is defined as the ratio of the ground level particulate concentration to a reduced threshold limit value. Source severities for nine individual emission points at a typical gin ranged from 1 to 40, while the severity for one other point was less than 0.01.

All cotton gins in the United States use a combination of cyclones, separators, condensers, and inline filters to separate cotton and trash from the conveying air stream and to reduce air emissions. The emission factor of 3.14 g/kg is therefore a controlled emission factor. Additional controls are not normally used by the industry.

This report was submitted in partial fulfillment of Contract 68-02-1874 by Monsanto Research Corporation under the sponsorship of the U.S. Environmental Protection Agency. This report covers the period April 1975 to August 1977, and the work was completed as of August 1977.

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FIGURES

FIGURES (continued)

TABLES

TABLES (continued)

ABBREVIATIONS AND SYMBOLS

a_i -- standard deviation of A_i
A_i -- average emission factor from the ith cotton gin
CO -- carbon monoxide
e -- 2.72
F -- hazard factor for an emission species
h -- stack height, m
LD_{50} -- dose that is lethal to 50% of a test population
N -- total number of gins
OES -- optical emission spectrography
Q -- mass emission rate, g/s
S -- source severity
t -- averaging time
t_o -- short-term averaging time
TLV -- threshold limit value
$\bar{u}$ -- national average wind speed (4.5 m/s)
π -- 3.14
χ -- ground level concentration of a pollutant
$\bar{\chi}$ -- time-averaged ground level concentration of a pollutant
χ_{max} -- maximum ground level concentration of a pollutant
$\bar{\chi}_{max}$ -- time-averaged maximum ground level concentration of a pollutant

CONVERSION FACTORS AND METRIC PREFIXES[a]

CONVERSION FACTORS

To convert from	to	Multiply by
Degree Celsius (°C)	Degree Fahrenheit	$t_F^\circ = 1.8\ t_C^\circ + 32$
Kilogram (kg)	Pound-mass (pound mass avoirdupois)	2.204
Kilogram (kg)	Ton (short, 2,000 pound mass)	1.102×10^{-3}
Kilogram/meter^3 (kg/m^3)	Pound-mass/foot^3	6.243×10^{-2}
Kilometer^2 (km^2)	Mile^2	3.860×10^{-1}
Meter (m)	Foot	3.281
Meter (m)	Mile	6.215×10^{-4}
Meter^3 (m^3)	Foot^3	3.531×10^{1}
Metric ton	Pound	2.205×10^{3}
Radian (rad)	Degree	5.730×10^{1}
Second (s)	Minute	1.667×10^{-2}

METRIC PREFIXES

Prefix	Symbol	Multiplication factor	Example
Kilo	k	10^3	2 kg = 2×10^3 grams
Milli	m	10^{-3}	2 mg = 2×10^{-3} gram
Micro	μ	10^{-6}	2 μm = 2×10^{-6} meter

[a]Standard for Metric Practice. ANSI/ASTM Designation: E 380-76$^{\varepsilon}$, IEEE Std 268-1976, American Society for Testing and Materials, Philadelphia, Pennsylvania, February 1976. 37 pp.

SECTION 1

INTRODUCTION

Cotton gins are used to separate cotton fibers (lint) from the cottonseed and to remove trash from the lint. During the ginning process, cotton dust consisting of dirt, fine-leaf and other trash, and lint are emitted into the atmosphere. The emission of cotton dust and lint is enhanced because the ginning operation uses air to handle the seed cotton, lint cotton, cottonseeds, and trash. Thus, gins require cyclones, separators, and condensers to separate the transported material from the conveying air.

Emissions from the ginning process are dependent on the ginning rate and seed cotton trash content. The major factor affecting seed cotton trash content is the method of harvesting. The two primary harvesting methods are machine stripping and machine picking.

The potential environmental impact of atmospheric emissions from cotton gins has been investigated and is summarized in this report. Sources of emissions, their characteristics, and the process variables that affect the quantity of emissions are identified. Emissions produced from ginning cotton harvested by the two primary methods are considered. Air pollution control measures employed at cotton gins are also described.

SECTION 2

SUMMARY

In the 1976 crop year, 10.58×10^6 bales of cotton, representing 2.30×10^6 metric tons[a] of lint cotton, were ginned at 2,771 cotton gins spanning 18 southern and western states. Texas ginned more cotton (31.3%) than any other state and contained the largest number (29.2%) of active cotton gins. California and Mississippi ranked second and third, ginning 23.6% and 10.9% of the total and containing 8.2% and 14.0% of the active gins, respectively.

In this study, atmospheric emissions from cotton ginning were investigated. This included emissions associated with unloading of the seed cotton from the trailers, cleaning it, separating the lint from the seeds, and cleaning and baling the lint. Emissions from transporting seed cotton to the gin and from the processing of cottonseeds to produce cottonseed oil or meal were not considered.

In order to assess the potential environmental impact of cotton ginning, a representative gin was defined as one having the characteristics shown in Table 1.

TABLE 1. CHARACTERISTICS OF REPRESENTATIVE COTTON GINS

Annual production	914 metric tons/yr or 4,200 bales/yr
Average production capacity	1,481 kg/hr or 6.8 bales/hr
Operating period	10 hr/day, 6 days/wk, 10 wk/yr, 600 hr/yr
Location	In a county having a population density of 12 persons/km^2

Particulates composed of dust, fine-leaf trash, lint, and other trash are generated during each step of the ginning process. The emission of cotton dust is enhanced because seed cotton, lint cotton, seed, and trash are handled almost exclusively by air conveying systems. As a result, each ginning process step requires a cyclone, separator, or condenser to separate the product or trash from the conveying airstream and discharge the air to the atmosphere.

[a] 1 metric ton = 10^6 grams; conversion factors and metric system prefixes are presented in the prefatory pages.

Table 2 summarizes the emission factors at various points in a representative cotton gin. The emission factors were calculated from source test data gathered at six gins and representing about 2,000 source test measurements. Plume dispersion calculations were used to determine $\bar{\chi}_{max}$, the maximum 24-hr average ground level cotton dust concentration downwind from a gin, which is also included in Table 2. The source severity, S, for cotton dust emissions from gins is defined as the ratio of $\bar{\chi}_{max}$ to a hazard factor, F, which consists of a modified threshold limit value (i.e., $0.2 \text{ mg/m}^3 \cdot 8/24 \cdot 1/100$) containing an exposure factor and a safety factor. Initial calculations revealed that $\bar{\chi}_{max}$ occurs within 25 m of each source, which is well within the boundaries of a typical cotton gin. Therefore, the ground level dust concentration at the property line (204 m from each source) was used to calculate the source severity values at various emission points, as summarized in Table 2.

TABLE 2. EMISSION FACTORS AND SOURCE SEVERITIES FOR COTTON DUST EMISSIONS FROM A REPRESENTATIVE COTTON GIN

Emission point	Stack height, m	Emission factor,[a] g/kg	$\bar{\chi}_{max}$,[b] μg/m^3	Source severity[b]
Unloading fan	5.2	0.305 ± 0.109	8.2	12
No. 1 dryer and cleaner	5.2	0.258 ± 0.042	6.9	10
No. 2 dryer and cleaner	5.2	0.160 ± 0.068	4.3	6
Trash fan for extractors	5.2	0.027 ± 0.010	0.7	1
Overflow fan	5.2	0.246 ± 0.010	6.6	10
No. 1 lint cleaner condenser	2.4	0.942 ± 0.087	26.6	40
No. 2 lint cleaner condenser	2.4	0.277 ± 0.067	7.8	12
Mote fan	5.2	0.262 ± 0.012	7.0	10
Battery condenser	2.4	0.337 ± 0.057	9.5	14
Master trash fan	16.0	0.330 ± 0.067	<0.01	<0.01
TOTAL	_[c]	3.144 ± 0.197	_[c]	_[c]

[a] Emission factors calculated from 2,000 source test measurements.

[b] At property line, 204 m from emission source.

[c] Column not additive.

The mass of cotton dust emitted in each of the 18 ginning states was calculated. Cotton dust emission contributions did not exceed 0.82% of any state's particulate burden and averaged 0.15% for 18 ginning states. On a national basis, emissions from cotton gins in 1976 represented 0.04% of the total annual particulate emissions.

The affected population was defined as the number of persons living in the area around the gin where the time-averaged ground level concentration ($\bar{\chi}$) of emissions divided by the hazard factor is greater than 1.0. Plume dispersion calculations indicate that $\overline{\chi}$ is greater than or equal to 1.0 between the gin property line (204 m from emission source) and 4.1 km from the gin. Within the annular area, the affected population is 576 persons based on an average population density of 12 persons/km^2.

All cotton gins in the United States use a combination of cyclones, separators, condensers, and inline filters to separate the product and trash from the conveying air stream and to reduce air emissions. Approximately 80% of the gins use covered condenser drums instead of inline filters.

The trend in the cotton ginning industry is to replace the smaller gins (less than 7 bales/hr) with large centralized ones (greater than 10 bales/hr). Cotton production is expected to grow at a rate of about 2% to 5% for the next 3 years. Therefore, the emissions should increase by 2% to 5% over the same period. As the price of petroleum continues to increase, the increased cost of synthetic fibers is creating a renewed demand for natural fibers.

SECTION 3

SOURCE DESCRIPTION

GENERAL DESCRIPTION

The Bureau of the Census, U.S. Department of Commerce, reports that 10.58×10^6 bales of cotton representing 2.30×10^6 metric tons were ginned in the United States during the 1976 crop year (August 1976 through February 1977) (1). This production rate represents a 27.5% increase over the amount ginned in 1975, but an 8.3% decrease from the amount ginned in 1974, and an 18.5% decrease from that ginned in 1973. Cotton was ginned in 18 southern and western states. Five states--Arizona, Arkansas, California, Mississippi, and Texas--ginned 81.5% of the total quantity ginned. The geographical distribution of cotton ginned in 1976 is shown in Figure 1.

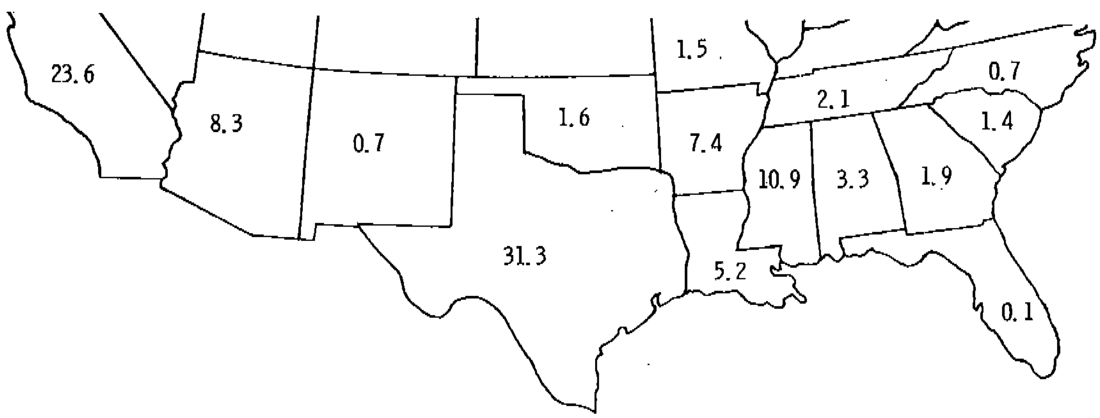

Figure 1. Percent distribution of cotton ginned in 1976.

The emissions discussed in this report include those from unloading the seed cotton at the gin, cleaning it, separating the lint from the seeds, and cleaning and baling the lint. Emissions from transporting the seed cotton to the gin and from the production of cottonseed oil or meal are excluded.

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(1) Cotton Ginning in the United States, Crop of 1976. U.S. Department of Commerce, Bureau of the Census, Washington, D.C., June 1977. 19 pp.

The quantity of cotton ginned, the number of active and idle gins, and the average production statistics for gins in the 18 cotton-producing states are given in Table 3. Texas gins more cotton (31.3%) than any other state and contains the largest number (29.2%) of active cotton gins. California and Mississippi rank second and third, ginning 23.6% and 10.9% of the total and containing 8.2% and 14.0% of the active gins, respectively.

The cotton ginning season usually begins in mid-July in southern Texas and lasts through January in northern Texas and central California (Figure 2). In 1976, 90.0% of the cotton in the United States was ginned in the 3-month period between October 1 and December 31 (1). However, the length of any given season is completely dependent upon weather conditions during the growing and harvesting season. If the summer months are especially dry or if the early portion of the winter is especially wet, the length of the season will be significantly shorter, ending as soon as early December.

TABLE 3. GINNINGS OF COTTON BY STATE, 1976 (1)

State	Cotton ginned: Equivalent 217-kg bales	Cotton ginned: Weight ginned, metric tons	Percent of total ginned	Number of gins: Active	Number of gins: Idle	Average number of bales per gin[a]	Average net weight of bale, kg
Alabama	351,131	76,450	3.3	153	45	2,295	224.2
Arizona	873,083	190,092	8.3	112	10	7,795	221.7
Arkansas	779,744	169,769	7.4	312	66	2,499	223.1
California	2,492,764	542,735	23.6	228	8	10,933	222.4
Florida	2,612[b]	569	<0.1	2	2	1,306	230.3
Georgia	196,529	42,789	1.9	105	38	1,872	227.3
Kentucky	2,612[b]	569	<0.1	0	1	0	[c]
Louisiana	555,135	120,866	5.2	122	21	4,550	222.8
Mississippi	1,147,891	249,923	10.9	388	48	2,958	224.3
Missouri	161,681	35,203	1.5	97	12	1,667	219.3
Nevada	2,612[b]	569	<0.1	1	0	2,612	225.9
New Mexico	73,253	15,949	0.7	46	12	1,592	223.0
North Carolina	73,695	16,045	0.7	56	21	1,316	224.6
Oklahoma	174,969	38,095	1.6	95	10	1,842	220.0
South Carolina	144,202	31,396	1.4	99	39	1,457	222.4
Tennessee	225,774	49,156	2.1	145	33	1,557	220.1
Texas	3,316,268	722,032	31.3	809	122	4,099	222.0
Virginia	2,613[b]	569	<0.1	1	0	2,613	219.6
United States	10,576,568	2,302,776	100	2,771	488	3,817	222.5

[a]Number of running bales divided by the number of active gins.

[b]Estimated values because figures were not released to avoid disclosure of information for individual gins.

[c]Not available.

Two basic types of cotton are grown in the U.S.: picker-harvested (65%) and stripper harvested (35%). Picker-type cotton grows on a taller plant than the stripper type and is harvested with a spindle picker machine. This machine removes cotton from the bur with rotating spindles, leaving unopened bolls on the plant and collecting relatively few leaves, burs, and other trash. The smaller, stripper-type cotton plant is grown in the more arid, irrigated

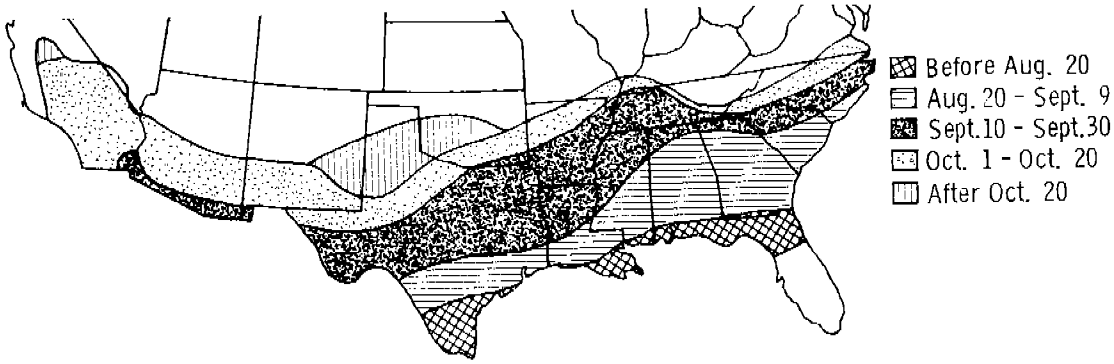

Figure 2. Usual start of cotton harvest.

areas of Texas, Oklahoma, and eastern New Mexico (Figure 3) (2). Here yields are relatively low and production costs must be kept at a minimum. Mechanical strippers are used to harvest this cotton. These machines strip away both open bolls (with their burs) and unopened bolls, collecting leaves, burs, sticks, rocks, and soil in the process. As a result, stripper-type cotton arriving at the gin contains as much as six times more trash than picker-type cotton (3).

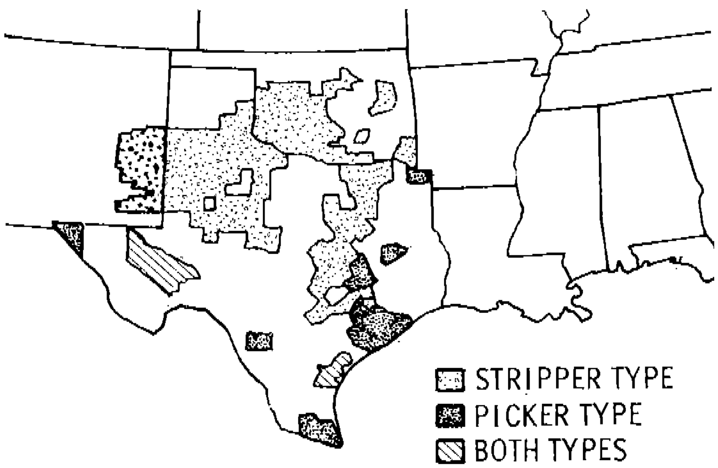

Figure 3. Predominant types of cotton planted in Texas, Oklahoma, and New Mexico (2).

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(2) Texas Cotton Review, 1973-74. The Univeristy of Texas, Natural Fiber Economic Research. Research Report No. NFFPC-NFER-UT-104-74 (PB 235 388), Austin, Texas, July 1974. 143 pp.

(3) Pendleton, A. M., and V. P. Moore. Ginning Cotton to Preserve Fiber Quality. Publication No. ESC-560. U.S. Department of Agriculture, Federal Extension Service, Washington, D.C., September 1967. 19 pp.

In spite of the numerous varieties of cotton grown across the U.S., there is little variation in the basic cotton ginning procedures. The five basic ginning steps include the 1) unloading system, 2) seed cotton drying and cleaning system, 3) overflow system, 4) lint cotton cleaning and handling system, and 5) battery condenser and baling press. The largest variation in gin design is the amount of equipment used in each of the five process steps. For example, stripper gins use more equipment for seed cotton cleaning than picker gins.

There are numerous process steps that remove trash from the cotton and exhaust pneumatic conveying air to the atmosphere. Pneumatic conveying systems are used throughout the gin to 1) convey seed cotton from trucks, trailers, or storage; 2) operate cotton conditioners or dryers; 3) supply necessary volumes of air to the gin stand and lint cleaner; 4) convey cotton from point to point in the ginning system; and 5) convey seed, hulls, and trash. Numerous separators, cyclones, and condensers are used to separate the cotton, trash, and seed from the conveying system.

PROCESS DESCRIPTION

A detailed flow diagram of a typical cotton ginning process for picker-type cotton is shown in Figure 4. Gins designed for stripper-type cotton contain additional equipment such as an airline cleaner and another stick extractor. Each of the five ginning steps and associated equipment are described in detail below.

Unloading System

Trucks and trailers transport seed cotton from the field to the gin. Pneumatic systems equipped with telescoping intake tubes suck the seed cotton from the vehicles and convey it to a separator and feed control unit. The screen assembly in the separator removes the seed cotton from the conveying air, permitting it to fall to the feed control unit. The conveying air flows through the screen and from the separator to a cyclone system where it is cleaned and discharged to the atmosphere. The feed control unit serves to 1) minimize chokages in seed cotton cleaners, 2) provide an even flow of cotton to the dryers and cleaners for efficient operation, and 3) decrease time loss between bales.

Gins that handle stripper-harvested cotton and other seed cotton that contains high quantities of trash install a green boll trap and airline cleaner either before or after the separator and feed control unit. The green boll trap is an inertial separator that removes unopened cotton bolls and other heavy foreign matter. Airline cleaners permit both air and seed cotton to pass entirely through the cleaner. In this respect they differ from gravity cleaners. Airline cleaners are used to remove sand from seed cotton and to break the bolls before cleaning. Trash collected from these two units together with the trash collected by the

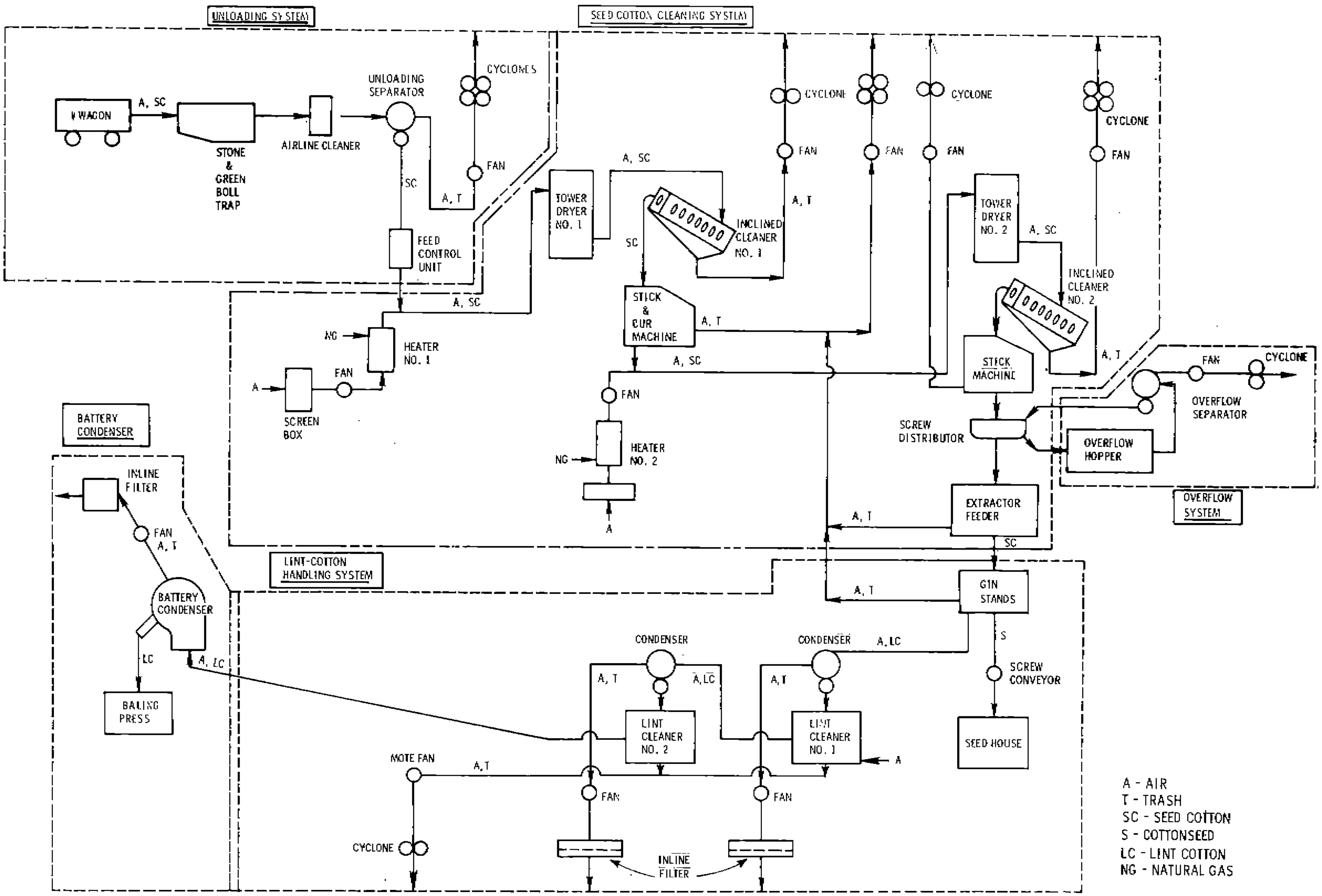

Figure 4. Flow diagram of the cotton ginning process.

cyclones is transported pneumatically or by screw conveyors to the trash disposal area.

Seed Cotton Cleaning System

Seed cotton is subjected to three basic conditioning processes before it enters the gin stand for separation of lint from the seed: drying, cleaning, and extracting. The basic difference between cotton ginning procedures lies in this process category. While the gins use basically the same equipment, they vary in the placement and number of the units within the conditioning process. To insure adequate conditioning, cotton gins use two similar conditioning systems, in series (Figure 4).

The key to preserving quality during ginning is proper moisture content of the fiber. The higher the moisture content, the more resistant the fibers are to breakage when subjected to the stresses of processing. However, the lower the moisture content, the easier it is to separate the trash from the fiber, and the more efficient the gin cleaning machines will be.

Cotton dryers are designed to reduce the moisture content of the seed cotton to an optimum level of 6.5% to 8.0% (3). There are several types of cotton dryers on the market, but all are variations of the tower dryer. Heated air conveys the seed cotton through the tower dryer at about 600 m/min, giving an exposure time of 10 s to 15 s. The temperature of the heated conveying air ranges from 180°C at the inlet of the dryer to 65°C at the discharge end. Heaters for gin drying systems use natural gas, propane, butane, and propane-butane mixtures for fuel (3, 4).

A push-pull high pressure fan system conveys seed cotton through the tower dryer to the cleaner system. The seed cotton cleaners serve the dual purpose of first opening the cotton or breaking up large wads and, second, removing fine foreign matter such as leaf trash, sand, and dirt from the seed cotton. The seed cotton cleaner consists of revolving spiked drums or cylinders, turning at about 400 rpm, that convey the cotton over a series of grid rods or screens. This process agitates the cotton, allowing the fine foreign matter to fall through the screen or grid opening (Figure 5). The capacity of these cleaners ranges from 6 to 12 bales/hr depending on the width. The cleaners may be used in a horizontal position or inclined at an angle of 0.52 rad (30°). The majority (more than 80%), referred to as "inclined cleaners," are installed at an angle to conserve space (3).

The large particles of foreign matter are removed from the seed cotton under an entirely different principle referred to as

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(4) Handbook for Cotton Ginners. Agriculture Handbook No. 260. U.S. Department of Agriculture, Agriculture Research Service, Washington, D.C., February 1964. 121 pp.

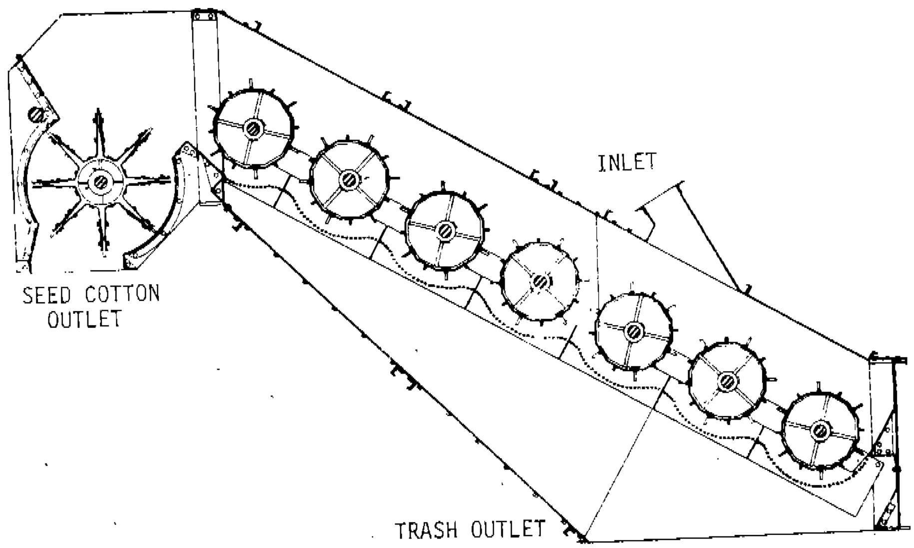

Figure 5. Inclined cleaner (3).

"extracting." The extractor, commonly called a stick machine, is used to remove large particle trash such as sticks, stems, and burs from the seed cotton.

Because of the differences in trash content of the seed cotton, the combination of extracting equipment used is the primary difference between a gin processing picker-harvested cotton and one processing stripper-harvested cotton. A gin processing picker-type cotton uses a stick and green leaf extractor and an extractor-feeder. Because of the relatively larger amounts of trash and burs encountered, gins processing stripper-type cotton use a combination of a bur machine, stick machine, and extractor-feeder.

The bur machine, used by gins in Texas, Oklahoma, and New Mexico that process stripper-harvested cotton, removes the burs from the seed cotton. The bur trash is pneumatically conveyed to the trash storage area, and the seed cotton falls into the stick machine. The latter machine removes other large trash particles consisting of sticks, leaf trash, and stems. This machine is replacing the less efficient bur machine in gins where cotton is not stripped.

Seed cotton issues from the extractor unit and is pneumatically conveyed through the second conditioning system, consisting of a tower dryer, inclined cleaner, stick machine, distributor, and extractor-feeder. If the seed cotton has a moisture content less than 6.5%, the tower dryer is replaced by a moisture addition unit (5).

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(5) Feairheller, W. R., and D. L. Harris. Particulate Emission Measurements from Cotton Gins, J. G. Boswell Co., El Rico #9, Corcoran, California. EMB Project Report No. 72-MM-19, U.S. Environmental Protection Agency, November 1974. 424 pp.

In general (more than 60% of the gins), the trash from the extractors is combined in a common high-pressure pneumatic system and sent to a bank of cyclones. The trash collected in the cyclones is carried (by screw or pneumatic convection) to the trash storage area. The trash from each of the inclined cleaners is separately conveyed pneumatically to its own cyclone system. The trash collected by these cyclones is also conveyed to the trash storage area (Figure 4).

Overflow System

Seed cotton issues from the second inclined cleaner into a screw conveyor distributor. This distributor apportions the seed cotton to the extractor-feeders at a rate controlled by the gin stand capacity. When the flow of seed cotton from the screw distributor exceeds the total intake rates of the extractor-feeders, the excess seed cotton flows into the overflow hopper.

A pneumatic system picks up seed cotton from the overflow hopper as required by the extractor-feeder. A separator removes the seed cotton from the conveying air, dropping it back into the screw distributor and discharging the air into a bank of cyclones.

Lint Cotton Handling System

The gin stand, which is the heart of the gin, embodies the basic ginning principle that has remained unchanged since its invention by Eli Whitney in 1792. Basically, it consists of saws turning between ribs. The saw teeth pass between the ribs at the ginning point approximately parallel to the rib face to avoid a shearing action that would cut the fibers (Figure 6). Cotton enters the gin stand through a huller front which performs some cleaning action (Figure 7). The saw grasps the locks of cotton, drawing them through a widely spaced (50 mm) set of "huller ribs" that strip off hulls and sticks, allowing them to fall out of the machine.

The locks are drawn into the roll box from the huller ribs, where the removal of the fibers from the seeds takes place. As the seeds are cleaned, they slide down the face of the ginning rib and fall out the bottom of the gin stand to be conveyed to the seed house by a screw conveyor or pneumatic system. The lint is removed from the saw by a blast of air or a brush. This process is known as "doffing." The lint is then conveyed by air to the lint cleaning system for final cleaning and combing before baling.

The lint cotton from the gin stand is removed from its low pressure conveying air stream by a condenser that forms the lint into a batt. This batt is fed into the first set of lint cleaners, where saws comb the lint cotton and remove leaf particles, grass, and motes (immature seeds with short, immature fibers attached). A lint cleaner is shown in Figure 8. The lint cleaning saw, a cylinder covered with a continuous ribbon saw, rotates at

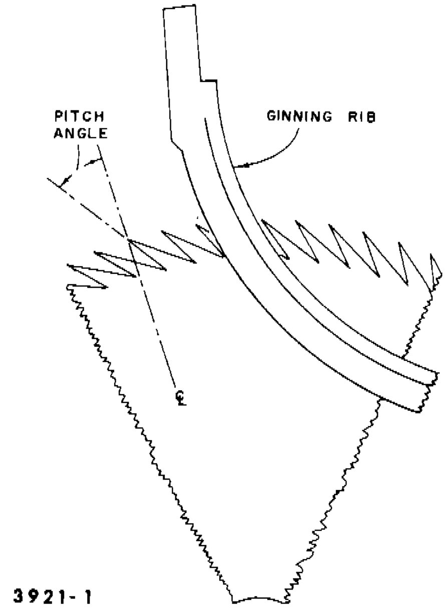

Figure 6. The ginning rib-saw relationship at the point where ginning takes place (3).

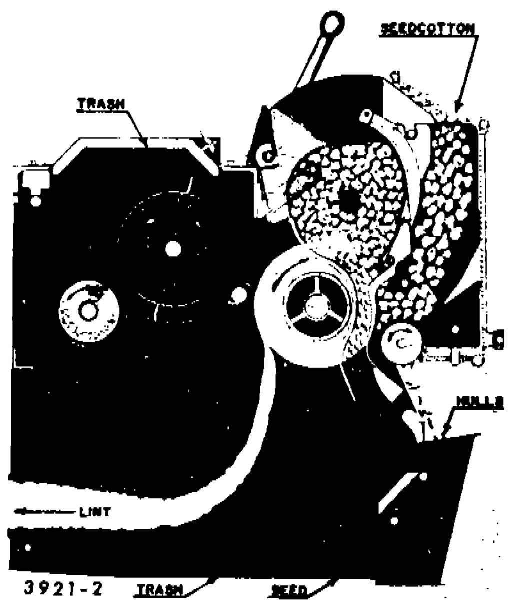

Figure 7. The gin stand (3).

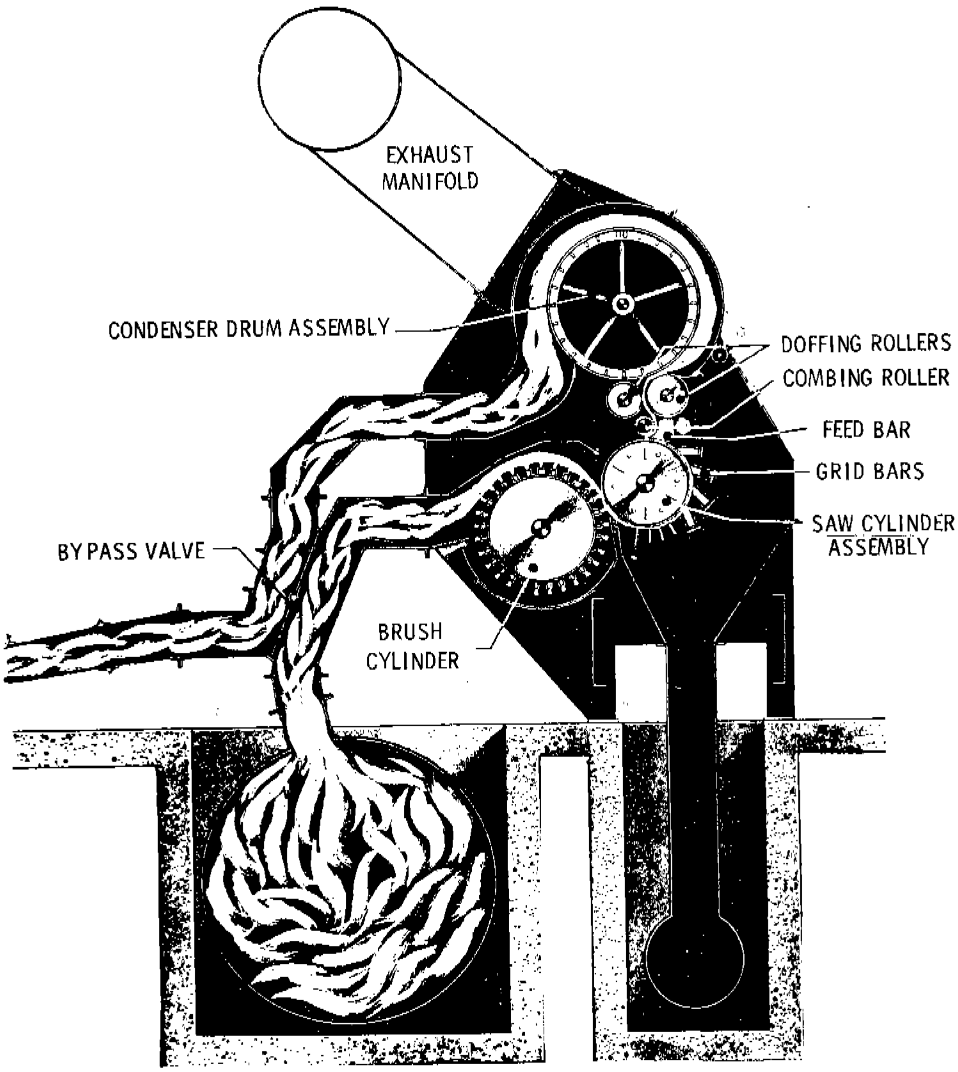

Figure 8. Unit saw-type cleaner (4).

about 1,000 rpm. The cleaned lint is removed from the saw by a brush that also provides the air to convey the lint to the second set of lint cleaners.

The low pressure air discharged from each lint cleaner condenser passes through an inline filter for lint fly removal before being exhausted to the atmosphere. The trash collected from both sets of lint cleaners is combined in a pneumatic system and conveyed by a mote fan to a set of cyclones.

Battery Condenser and Baler

Lint cotton is pneumatically conveyed by low pressure fans from the lint cleaning system to a battery condenser. The battery condenser contains a condenser drum covered with a screen that separates the lint cotton from the conveying air. The conveying air is discharged through an inline filter before being exhausted to the atmosphere.

The batt of lint cotton is then fed into the baling press, which packs it into uniform bales of cotton.

MATERIAL FLOW

The quantity of material flowing through a cotton gin depends on the gin's capacity, the rate at which the seed cotton is harvested and transported to the gin, and the type of cotton. It takes more (47%) stripper-type seed cotton than picker-type cotton to produce a bale of lint cotton because of the relative trash contents of the two types of seed cotton (Table 4) (6, 7). The values in Table 4 also show the breakdown of seed cotton in terms of lint, seed, and trash content. Figures 9 and 10 further illustrate the compositions of picker-type and stripper-type seed cotton.

TABLE 4. PROPORTION OF LINT, SEEDS, AND TRASH IN DRY SEED COTTON (6, 7)

Component	Machine-picked	Machine-stripped
Weight of dry seed cotton required to produce a 227-kg bale of lint cotton:		
Range, kg	635 to 900	900 to 1,100
Average, kg	680	1,000
Lint content, kg	227	227
Percent of seed cotton	33	23
Seed content		
Range, kg	320 to 450	340 to 450
Average, kg	360	410
Percent of seed cotton	54	41
Trash content		
Range, kg	45 to 115	320 to 545
Average, kg	90	360
Percent of seed cotton	13	36
Composition, %		
Burs	35	65
Sticks	15	15
Leaf and dirt	50	20

(6) Survey of Particulate Emissions, Frisby-Bell Cotton Gin, LaVilla, Texas, April 1 to August 31, 1971. Texas Air Control Board, Austin, Texas, September 1971. 31 pp.

(7) Durrenberger, C. Cotton Gin Report. Texas Air Control Board, Austin, Texas, May 31, 1974. 50 pp.

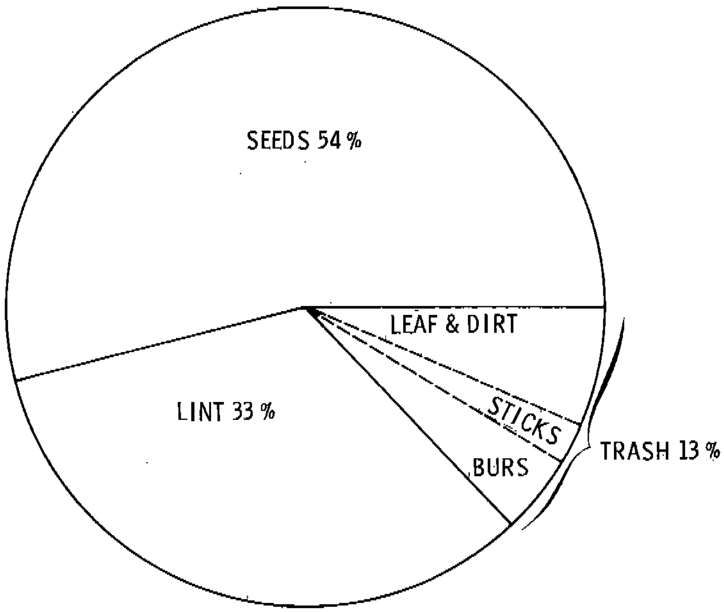

Figure 9. Average composition of dry, picker-harvested seed cotton.

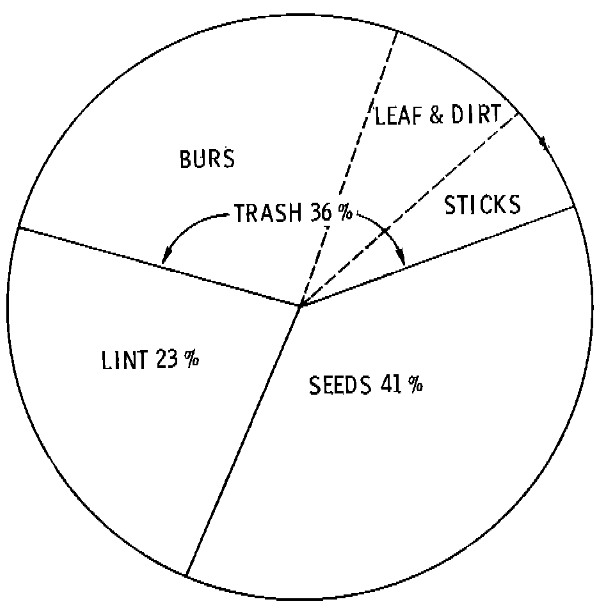

Figure 10. Average composition of dry, stripper-harvested seed cotton.

Machine-stripped cotton contains an average of four times more trash than machine-picked cotton. A 10-bale/hr gin will produce 900 kg/hr of trash when ginning machine-picked cotton and 4,000 kg/hr of trash when ginning machine-stripped cotton. The particle size distribution of gin trash is given in Table 5 (8, 9).

TABLE 5. PARTICLE SIZE DISTRIBUTION OF GIN TRASH

Particle size, μm	Percent by weight		
	Stripper trash (8)	Picker trash (8)	Picker trash (9)
>3,300	67.5	49.8	N.A.[a]
420 to 3,300	27.2	42.3	N.A.
74 to 420	4.5	5.7	N.A.
<74	0.8	2.2	N.A.
>150	N.A.	N.A.	96.7
50 to 150	N.A.	N.A.	0.5
25 to 50	N.A.	N.A.	1.1
10 to 25	N.A.	N.A.	1.0
5 to 10	N.A.	N.A.	0.3
0 to 5	N.A.	N.A.	0.4
TOTAL	100	100	100

[a]Not applicable; not measured in the original report.

Approximately 90% to 99% of the trash is removed from the seed cotton during the entire ginning process (10). A bur machine removes 7% to 12% of the total trash in picker-type seed cotton. It is about 75% efficient at removing burs and 35% efficient at removing sticks. The stick and green leaf machine is 13% to 20% efficient at removing total trash content of picker-type cotton (personal communication, Mr. Garner, USDA Cotton Ginning Research Laboratory, Stoneville, Mississippi, May 6, 1975). At one gin processing stripper harvested cotton, 98% of the burs, 95% of the

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(8) Baker, R. V., and V. L. Stedronsky. Gin Trash Collection Efficiency of Small Diameter Cyclones. Publication No. ARS 42-133, U.S. Department of Agriculture, Washington, D.C., July 1967. 16 pp.

(9) McCaskill, D. L., and R. A. Wesley. Tests Conducted on Exhausts of Gins Handling Machine Picked Cotton. The Cotton Gin and Oil Mill Press. September 5, 1970. 12 pp.

(10) Criteria for a Recommended Standard - Occupational Exposure to Cotton Dust. Publication No. (NIOSH)75-118, U.S. Department of Health, Education, and Welfare, Washington, D.C., 1974. 159 pp.

sticks, and 57% of the fine trash were removed before the distributor (11).

The trash collected by all cyclone systems at a gin is pneumatically conveyed by a master trash fan to a trash disposal area. A cyclone system separates the conveying air from the trash and drops the trash into a storage bin. A 1965 survey revealed that 37% of the cotton gins in the U.S. incinerated the trash, 59% returned the trash to the land, and 5% disposed of the trash by other methods (12). However, the Clean Air Act of 1970 bans open incineration of cotton gin wastes except for a few isolated cases under EPA supervision (13).

The number of fans required and the amount of air moved during ginning vary with the size of the plant and with the method of harvest. The number of fans also depends on the types of equipment used and their arrangement in the ginning sequence.

The amount of air moved per fan by high pressure fans handling seed cotton and trash ranges from 57 to 312 m^3/min. The number of fans required varies from 10 in the 6-bale/hr gin designed for machine-picked cotton to 24 in the 36-bale/hr gin for machine-stripped cotton. More fans and greater air volumes are required for gins processing machine-stripped cotton because they must handle more material to produce a bale of lint as a result of the higher trash content of this cotton type.

Discharges from these fans carry varying amounts of dust, trash particles, and lint into the atmosphere. Dry cyclones, inline filters, and condenser coverings are used by all gins to reduce these emissions.

During the growing season, cotton crops are sprayed with all types of pesticides; e.g., fungicides, herbicides, insecticides, miticides, fumigants, defoliants, and desiccants. Pesticide residues can accumulate on and in the cotton plant and cotton boll.

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(11) Parnell, C. B., Jr., and R. V. Baker. Particulate Emissions of a Cotton Gin in the Texas Stripper Area. Production Research Report No. 149, U.S. Department of Agriculture, Agricultural Research Service, Washington, D.C., May 1973. 18 pp.

(12) Pendleton, A. M. Current Gin Trash Disposal Practices. In: Control and Disposal of Cotton-Ginning Wastes. Publication No. 999-AP-31, U.S. Department of Health, Education, and Welfare, Public Health Service, Cincinnati, Ohio, 1967. pp. 39-44.

(13) Wilmot, C. A., Z. M. Looney, and O. L. McCaskill. The Cost of Air Pollution Control to Cotton Ginners. Publication No. ERS-536, U.S. Department of Agriculture, Economic Research Service, Washington, D.C., February 1974. 35 pp.

Therefore, the cotton dust and lint emitted during the ginning process may contain trace quantities (less than 1%) of these pesticides.

The quantities of pesticides used and the areas treated with these pesticides in 1971 are given in Table 6 (14).

To date, the Environmental Protection Agency has banned the pesticides aldrin, dieldrin, DDT, chlordane, heptachlor, 2,4-D, and 2,4,5-T. Further tests are being conducted on the environmental effects of the fungicide ethylenebisdithiocarbamate. EPA has confirmed that methyl parathion, parathion, malathion, phorate, and demeton are fully suitable substitutes for certain uses of DDT (15).

GEOGRAPHIC DISTRIBUTION

The number of active cotton gins in each of the 18 ginning states is shown in Figure 11. For illustrative purposes, the geographical location of the 502 counties in the U.S. containing active cotton gins is shown in Figure 12. Figure 13 shows the 100 leading cotton ginning counties and illustrates the four major cotton producing regions. These 100 counties gin 81.5% of the cotton and contain 60.8% (1,686) of the active cotton gins (1).

The population densities of the 445 ginning counties and the number of active gins located in these counties are given in Table 7. The table shows that the majority (75.7%) of the counties containing gins have population densities less than 20 persons/km^2 and contain 66.7% of the active gins.

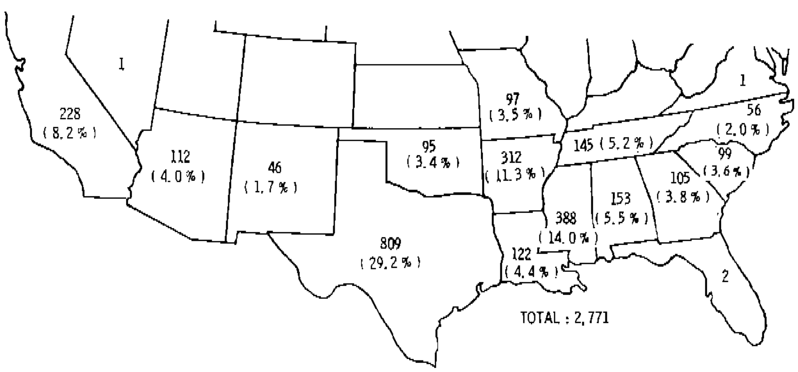

Figure 11. Number of active cotton gins, 1976 (1).

(14) Andrilenas, P. A. Farmer's Use of Pesticides in 1971. . . Quantities. Agricultural Economic Report No. 252, U.S. Department of Agriculture, Economic Research Service, Washington, D.C., July 1974. 56 pp.

(15) Gibney, L. EPA Seeks Substitutes for Banned Pesticides. Chemical and Engineering News, 53(23)15-16, June 9, 1975.

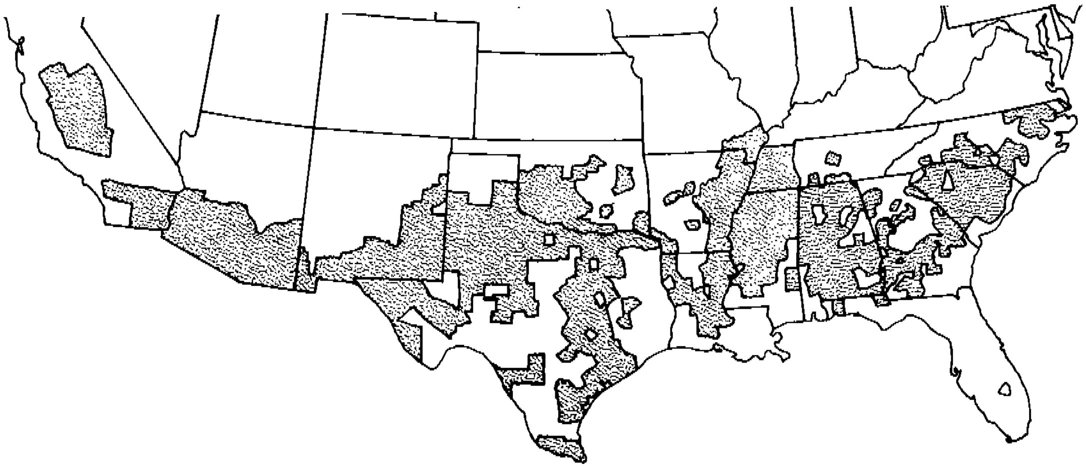

Figure 12. Geographical location of active cotton gins by county, 1976.

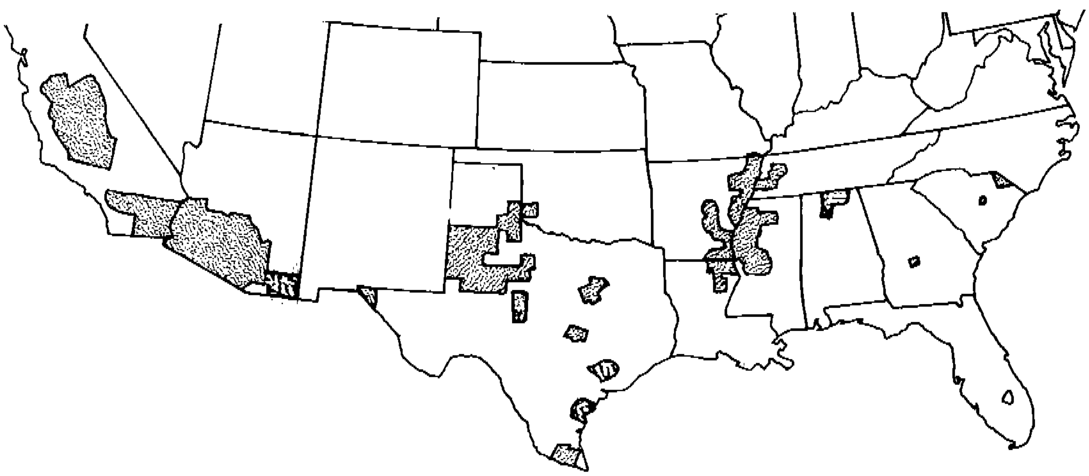

Figure 13. Leading 100 cotton ginning counties, 1976.

TABLE 6. APPLICATION OF PESTICIDES TO COTTON CROPS IN 1971 (14)

Type of pesticide	Quantity applied to cotton crops (active ingredients), metric tons	Treated area, km²
Inorganic fungicides:		
Copper sulfate	11.8	210.4
Organic fungicides:		
Dithiocarbamates		
Zineb	5.4	24.3
Others	15.4	93.1
Phthalimides		
Captan	2.3	36.4
Dinocap, dodine, quinones	6.8	109.3
Phenols	33.6	295.4
Other organics	24.5	566.6
Total fungicides (excluding sulfur)	99.8	1,335.5
Sulfur	6,839.4	2,699.3
Total fungicides	6,939.2	4,034.9
Inorganic herbicides	252.7	1,072.5
Organic herbicides:		
Arsenicals	3,433.3	16,685.8
Phenoxys:		
2,4-D	1.8	20.2
Other phenoxys	27.7	1,161.5
Phenyl ureas:		
Diuron	257.6	3,140.5
Linuron	24.0	890.3
Fluometuron	1,512.3	17,021.7
Other phenyl ureas	19.1	234.7
Amides:		
Alanap	1.8	68.8
Alachlor	1.8	8.1
Other amides	85.3	437.1
Carbamates	1.4	72.8
Dinitro group	173.3	1,036.0
Triazines	365.6	4,524.6
Other organics:		
Trifluralin	2,061.2	27,535.8
Nitralin	226.8	2,088.2
Dalapon	8.2	89.0
Norea	383.8	1,695.7
Others	57.6	1,817.1
Total herbicides	8,895.1	79,600.4
Inorganic insecticides	31.3	93.1
Synthetic organic insecticides:		
Organochlorines:		
Strobane	98.0	72.8
DDT	5,968.5	9,644.0
Endrin	484.4	1,060.3
Dieldrin	29.5	704.2
Toxaphene	12,751.6	13,253.9
Organophosphorus:		
Disulfoton	102.1	2,238.0
Bidrin	352.9	7,272.5
Methyl parathion	10,427.4	25,836.0
Parathion	1,161.2	2,760.0
Malathion	303.9	1,104.8
Trichlorofon	65.3	773.0
Azinphosmethyl	130.6	481.6
Phorate	45.4	736.6
Ethion	2.7	121.4
Others	733.5	4,921.1
Carbamates:		
Carbaryl	550.7	987.5
Methomyl	18.1	339.9
Others	16.8	267.1
Other synthetic organics	0.9	97.1
Total insecticides	33,274.7	73,655.4
Miticides:		
Dicofol	85.7	955.1
Chlorobenzilate	11.3	206.4
Omite	2.7	44.5
Others	28.1	457.3
Fumigants:		
Dibromochloropropane	95.7	97.1
Telone	279.4	56.7
Others	152.9	934.9
Defoliants and desiccants:		
Arsenic acid	2,744.7	3,731.3
DEF and folex	2,269.8	14,723.0
Others	2,810.1	4,188.7
Total miscellaneous pesticides	8,480.5	25,394.9
TOTAL PESTICIDES	57,589.5	182,685.6

TABLE 7. POPULATION DENSITIES OF COTTON GINNING COUNTIES CONTAINING ACTIVE COTTON GINS

State	Population density: 0 to 5 persons/km^2		5 to 20 persons/km^2		20 to 50 persons/km^2		50 to 100 persons/km^2		100 to 200 persons/km^2		>200 persons/km^2		Total No. of counties with active gins	Total No. of active gins
	No. of ginning counties	No. of active gins	No. of ginning counties	No. of active gins	No. of ginning counties	No. of active gins	No. of ginning counties	No. of active gins	No. of ginning counties	No. of active gins	No. of ginning counties	No. of active gins		
Alabama	0	0	32	71	10	54	4	27	1	1	0	0	47	153
Arizona	5	60	2	9	1	43	0	0	0	0	0	0	8	112
Arkansas	0	0	26	176	5	132	0	0	1	4	0	0	32	312
California	0	0	6	153	2	75	0	0	0	0	0	0	8	228
Florida	0	0	2	2	0	0	0	0	0	0	0	0	2	2
Georgia	0	0	35	83	9	21	1	1	0	0	0	0	45	105
Louisiana	0	0	16	87	2	24	1	9	1	2	0	0	20	122
Mississippi	1	2	44	287	8	97	1	2	0	0	0	0	54	388
Missouri	0	0	5	44	3	53	0	0	0	0	0	0	8	97
New Mexico	8	31	1	15	0	0	0	0	0	0	0	0	9	46
North Carolina	0	0	6	10	9	37	4	8	1	1	0	0	20	56
Oklahoma	9	30	12	60	3	5	0	0	0	0	0	0	24	95
South Carolina	0	0	13	30	13	61	2	5	2	3	0	0	30	99
Tennessee	0	0	15	91	4	48	0	0	0	0	1	6	20	145
Texas	49	280	43	326	14	111	2	65	2	25	1	2	116	809
Others	1	1	1	1	0	0	0	0	0	0	0	0	2	2
TOTAL	73	404	264	1,445	83	761	15	117	8	36	2	8	445	2,771

SECTION 4

EMISSIONS

EMISSION CHARACTERISTICS

Selected Emission Species

Particulates composed of dust, fine-leaf trash, lint, and other trash are generated during each step of the cotton ginning process. The emission of cotton dust is enhanced because seed cotton, lint cotton, seed, and trash are handled almost exclusively by air conveying systems. As a result, each ginning process step requires a cyclone, separator, or condenser to separate the product or trash from the conveying air and discharge the air to the atmosphere. Gins use 10 to 24 cyclones, depending on ginning capacity.

Emissions from the unloading fan, inclined cleaners, trash fan, and overflow system consist of dust and fine-leaf trash. Emissions from the gin stand, lint cleaner condensers, mote fan, and battery condensers contain lint fly and cotton dust.

The threshold limit value (TLV®) established by the American Conference of Governmental Industrial Hygienists for nonlint cotton dust is 0.0002 g/m^3 of air (16). The acute local, acute systemic, and chronic local inhalation toxic hazard rating for cotton dust is moderate (17).

Cotton dust emissions from gins may also contain trace quantities (less than 1%) of pesticides, defoliants, and desiccants. The predominant pesticides sprayed on cotton fields in 1971 were DDT, toxaphene, and methyl parathion (Table 6). To reduce the amount of green leaves and stems on the stalk where harvesting is to be done with a spindle picker, a chemical defoliant is applied to cotton fields when 60% of the bolls are open. Defoliation also

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(16) TLVs® Threshold Limit Values for Chemical Substances and Physical Agents in the Workroom Environment with Intended Changes for 1976. American Conference of Governmental Industrial Hygienists, Cincinnati, Ohio, 1976. 94 pp.

(17) Sax, N. I. Dangerous Properties of Industrial Materials, Third Edition. Reinhold Book Corp., New York, New York, 1968. p. 591.

reduces the population of insects that feed on the green cotton leaves in the late season. The predominant (greater than 90%) defoliants used in 1971 were sodium chlorate and tributylphosphorotrithioites (DEF and Folex).

When stripper machine harvesting is to be done before frost, a chemical desiccant is applied to the field to reduce the moisture content of the leaves and stems. Cotton desiccation is primarily used in the uplands of Central Texas and the Blackland area and nonirrigated areas of South Texas. The predominant desiccants used on cotton crops are arsenic acid and paraquat. The TLV's for the pesticides, defoliants, and desiccants applied to cotton are shown in Table 8.

In experimental toxicology, it is common practice to determine the quantity of poison per unit of body weight (of an experimental animal) that will have a fatal effect. The values are expressed as milligrams of poison per kilogram of body weight. A commonly used concentration figure is the amount of poison that will kill one-half of a group of experimental animals. This is known as the LD_{50} test (Lethal Dose--50%). When TLV's are not available, LD_{50} values can be used to estimate the relative toxicity of a chemical.

Emission Factors

The numerous exhaust points at a gin can be arranged into 10 emission source categories based on specific ginning operations (Figure 14). Conveying air transports the seed cotton, lint cotton, and seed from one process step to the next. In addition, trash is conveyed away from each process step by air. Cyclones and inline filters are used to remove the air from the trash. The trash is then conveyed by air or screw conveyors to the trash hopper, and the conveying air is discharged to the atmosphere. Cyclone exhausts are located 4 m to 15 m above the ground and inline filter and condenser exhausts are located 1.5 m to 5.0 m above the ground (personal communication, C. B. Parnell, Jr., Texas Agricultural Extension Service, Texas A&M University, College Station, Texas) (18).

Fugitive dust emissions result when the trash hoppers are emptied into trucks. During ginning periods, the trash hoppers are emptied from one to four times a day (6).

A literature search of both public and private information sources revealed six sets of reliable source test data. The data were judged reliable based on the gin sampled, sampling methods employed,

(18) Taylor, M., M. Preusse, D. Johnson, and R. Wallis. Particulate Survey of Cotton Gin Operations, Lubbock and Lubbock County, December 1971-January 1972. Texas State Department of Health, Air Pollution Control Services, Austin, Texas, December 1972. 19 pp.

TABLE 8. TLV's OF PESTICIDES APPLIED TO COTTON CROPS (16, 17)

Type of pesticide	TLV, mg/m^3 [a]	Acute oral LD_{50}, mg/kg
Inorganic fungicides:		
Copper sulfate	1.0	300
Organic fungicides:		
Dithiocarbamates		
Zineb	(5.0)	>5,200
Phthalimides		
Captan	(5.0)	9,000
Dinocap, dodine, quinones	0.4	
Phenols	19.0	
Organic herbicides:		
Arsenicals	0.5	
Phenoxys		
2,4-D	10.0	300 to 1,000
Phenyl ureas:		
Diuron	(5.0)	3,400
Linuron	(5.0)	1,500 to 4,000
Fluometuron	(5.0)	8,900
Amides:		
Alanap	(5.0)	8,200
Alachlor	(5.0)	1,200
Carbamates, see insecticides		
Dinitro groups	(0.1)	10 to 60
Triazines	(5.0)	3,000 to 5,000
Other organics:		
Trifluralin	(10.0)	>10,000
Nitralin	(5.0)	2,000
Dalapon	(1.0)	970
Norea	(5.0)	2,000
Synthetic organic insecticides:		
Organochlorines:		
Strobane	0.5	220
DDT	1.0	113 to 118
Endrin	0.10	5 to 17.8
Dieldrin	0.25	46
Toxaphene	0.5	80 to 90
Organophosphorus:		
Disulfoton	(0.1)	12.5
Bidrin	(0.1)	15 to 22
Methyl parathion	0.2	14 to 24
Parathion	0.1	3.6 to 13
Trichlorfon	(1.0)	560 to 630
Azinphosmethyl	0.2	11 to 13
Phorate	(0.1)	1.1 to 2.3
Ethion	(0.1)	27 to 65
Carbamates:		
Carbaryl	5.0	500 to 850
Methomyl	(0.1)	17
Miticides:		
Dicofol	(1.0)	809
Chlorobenzilate	1.0	960
Omite	(5.0)	2,200
Fumigants:		
Dibromochloropropane	(0.1)	173
Telone	(0.1)	250 to 500
Defoliants and desiccants:		
Arsenic acid	0.25	48 to 100
DEF	(1.0)	350
Folex	(5.0)	1,272
Sodium chloride	(5.0)	1,200

[a] Values in parentheses are assumed TLV's based on their LD_{50}'s according to the following schedule:

TLV = 0.1 if LD_{50} <300 mg/kg
TLV = 1.0 if 300 <LD_{50} <1,000 mg/kg
TLV = 5.0 if 1,000 <LD_{50} <10,000 mg/kg
TLV = 10.0 if LD_{50} >10,000 mg/kg

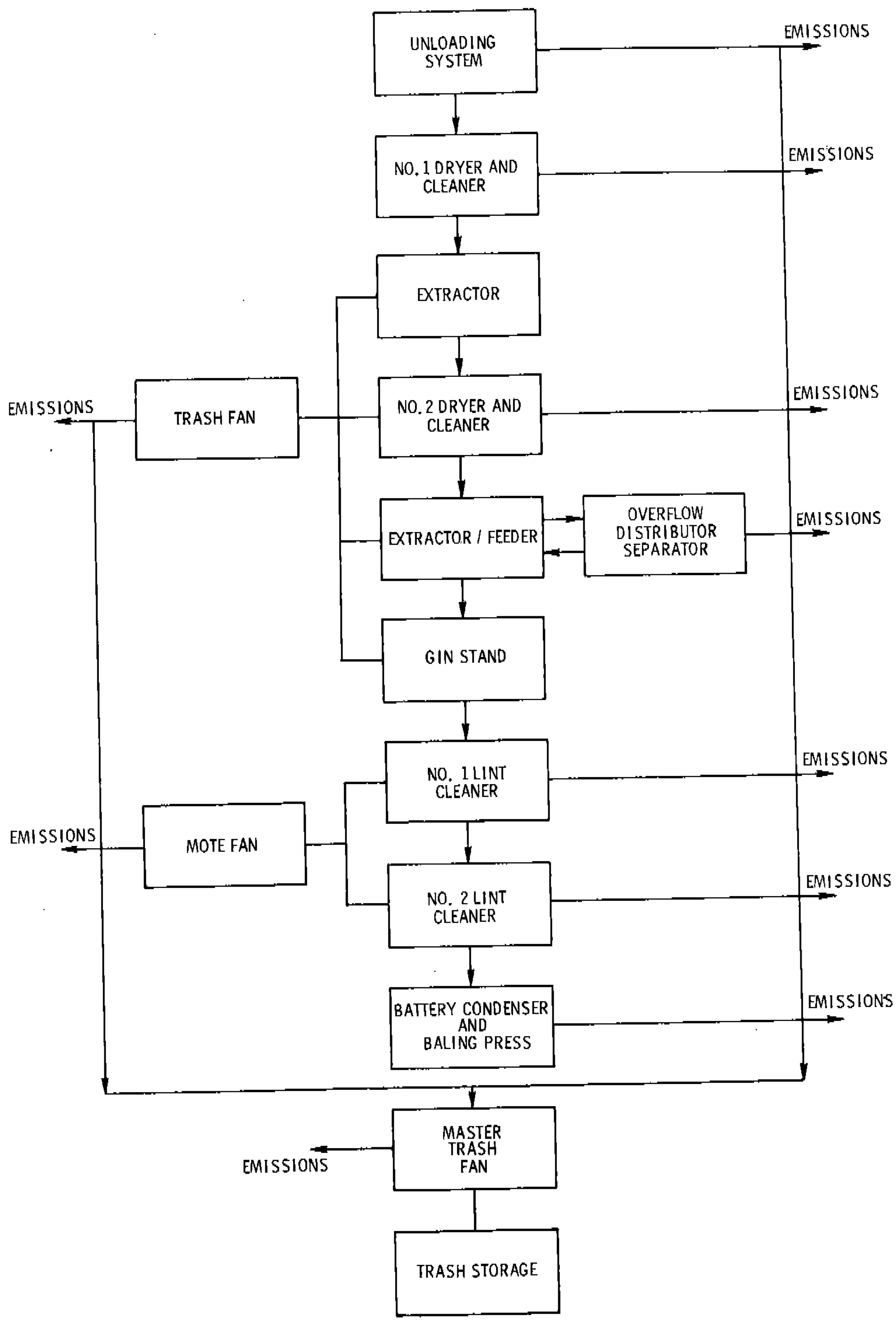

Figure 14. Typical ginning operation.

the number of samples collected, and the standard deviation of the emission averages at each source. Gins A and B (Appendix) were USDA research cotton gins equipped with the best ginning and control equipment and operating with maximum efficiency. Gin C was sampled by a private consulting company as requested by the Texas Air Control Board for the purposes of collecting data and developing source sampling procedures applicable to agricultural processing industries. Gins D, E, and F were sampled by Monsanto Research Corporation in order to determine emissions from cotton gins equipped with the best available air pollution control equipment.

Before sampling at each gin, all cyclone, inline filters, condenser, and wet scrubber exhausts were equipped with stack extensions, as required by EPA stack sampling procedures. The sampling ducts were sized so as not to affect the back pressure (and control efficiency) of the control devices. All sampling tests were conducted under isokinetic conditions. In addition, samples were collected only when the exhaust air had been used to actively convey materials within the ginning system.

Stripper-Harvested Cotton--

Table 9 lists emission factors for gins processing stripper-harvested cotton, the results of emission test data from Gin A. The raw data and a description of Gin A are presented in Appendix A. This gin is equipped with cyclones and inline filters on all the fan exhausts.

TABLE 9. EMISSION FACTORS FOR BEST AVAILABLE CONTROLLED COTTON-DUST EMISSIONS FROM A COTTON GIN PROCESSING STRIPPER-HARVESTED COTTON AT A RATE OF 10 BALES/HR

	Test cottons[a]							
	Early season		Midseason		Late season		Extremely dirty	
Emission source	g/kg	Percent of total	g/kg	Percent of total	g/kg	Percent of total	g/kg	Percent of total
Unloading fan	0.455 ± 0.105	22.2	0.351 ± 0.209	10.5	0.664 ± 0.150	15	3.454 ± 0.55	41.7
No. 1 dryer and cleaner	0.102 ± 0.010	5	0.357 ± 0.049	10.6	0.349 ± 0.033	7.9	0.843 ± 0.067	10.2
No. 2 dryer and cleaner	0.058 ± 0.005	2.8	0.135 ± 0.017	4	0.152 ± 0.018	3.4	0.264 ± 0.027	3.2
Trash fan for extractors[b]	-		-		-		-	
Overflow fan and distributor	0.191 ± 0.073	9.3	0.303 ± 0.010	9	0.103 ± 0.009	2.3	0.167 ± 0.018	2
No. 1 lint cleaner condenser	0.736 ± 0.096	35.8	1.229 ± 0.113	36.7	2.219 ± 0.385	50.2	2.377 ± 0.315	28.7
No. 2 lint cleaner condenser	0.106 ± 0.009	5.2	0.166 ± 0.017	5	0.189 ± 0.038	4.3	-[c]	
Mote fan	0.177 ± 0.015	8.6	0.247 ± 0.024	7.4	0.279 ± 0.043	6.3	0.462 ± 0.035	5.6
Battery condenser	0.154 ± 0.026	7.5	0.155 ± 0.020	4.6	0.144 ± 0.021	3.3	0.200 ± 0.017	2.4
Master trash fan	0.076 ± 0.012	3.7	0.410 ± 0.062	12.2	0.323 ± 0.030	7.3	0.520 ± 0.066	6.3
TOTAL	2.055 ± 0.164	100	3.353 ± 0.254	100	4.422 ± 0.421	100	8.287 ± 0.643	100

[a]Average trash content of the four test cottons is 24.74%, 28.80%, 29.80%, and 36.49%, respectively.

[b]Combined with master trash system.

[c]No sample.

Approximately 1,100 source test samples were collected from 10 emission points at this gin (11). All emission values not falling within plus or minus three standard deviations were rejected before the calculation of the final average and standard deviation. The uncertainty values on the emission factors are 95%

confidence limits calculated from the individual source measurements.

As Table 9 indicates, the emission factors are greatly influenced by the trash content of the seed cotton. The longer the open boll remains on the cotton plant, the more trash it accumulates. A threefold increase in the total emission factor was experienced when the trash content was increased from 24.74% to 38.25%. A linear regression analysis of the total emission factor as a function of trash content yielded a zero order correlation coefficient of 0.989 and a standard error of the estimate equal to 1.64 (Figure 15) (11).

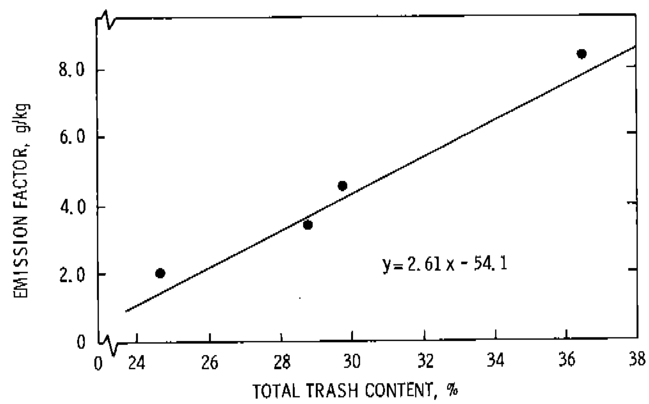

Figure 15. Effect of trash content on emission factor (11).

The extremely dirty seed cotton (test 4) was a result of an improperly adjusted mechanical stripper harvester. A mechanical defect allowed the stripper mechanism to descend so low that large amounts of loose soil were picked up and mixed with the seed cotton. These emission values are included to indicate maximum dust emission factors from a gin processing stripper-harvested cotton.

A further illustration of the variation in emission factors as a result of fluctuations in seed cotton trash contents is given in Table 10. The ranges of total emission factors and trash contents were obtained by summing the averages minus the confidence limits and the averages plus the confidence limits.

TABLE 10. RANGE OF TOTAL EMISSION FACTORS AS RELATED TO TRASH CONTENT OF THE SEED COTTON (11)

	Test cottons							
	Early season		Midseason		Late season		Extremely dirty	
Item	Low	High	Low	High	Low	High	Low	High
Emission factor, g/kg	1.70	2.40	2.83	3.87	3.69	5.15	7.19	9.38
Trash content, %	23.34	26.11	27.82	29.78	28.41	31.20	34.73	38.25

Emission factors can also be influenced by the use of field extraction harvesting units. These harvesters remove trash from the seed cotton as it is harvested. Emission tests conducted on field extracted stripper-type cotton showed a decrease in the total emission factors ranging from 1% to 36% (Figure 16) (11).

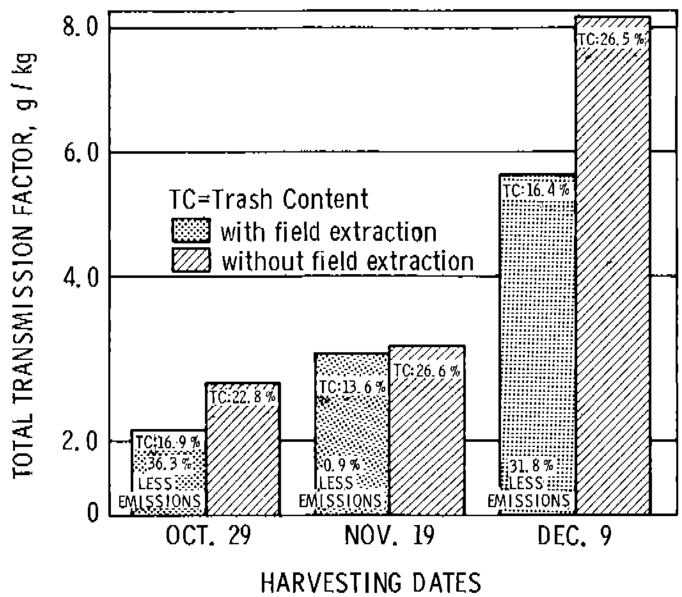

Figure 16. Effect of field extraction of trash on emission factors (11).

Other tests were conducted at Gin A to determine the effect of ginning feed rate on the emission rate. A statistical analysis of these data concluded that the slower feed rates resulted in a significantly greater emission rate. The results of this test are shown in Figure 17.

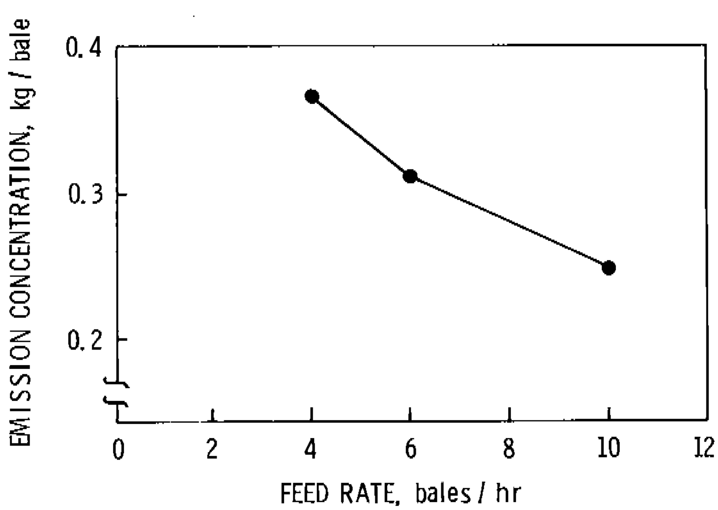

Figure 17. Effect of feed rate on emission concentration (11).

Picker-Harvested Cotton--

Emission factors for gins processing picker-harvested cotton are given in Table 11. These values were determined by averaging the appropriate emission factors from the source test data for Gins B through F. The raw data and a description of each gin are given in Appendix A. Each of these gins is equipped with cyclones and inline filters or condenser drum coverings on all the fan exhausts.

TABLE 11. EMISSION FACTORS FOR CONTROLLED COTTON DUST EMISSIONS FROM A COTTON GIN PROCESSING PICKER-HARVESTED COTTON AT A RATE OF 10 BALES/HR

Emission source	Emission factor, g/kg			Percent of total
	High[a]	Low	Average	
Unloading fan	1.34	0.032	0.259 ± 0.079	8.8
No. 1 dryer and cleaner	0.690	0.005	0.158 ± 0.068	5.4
No. 2 dryer and cleaner	0.73	0.003	0.185 ± 0.135	6.3
Trash fan for extractors	0.198	0.006	0.052 ± 0.028	1.8
Overflow fan[b]	0.303	0.103	0.19 ± 0.019	6.5
No. 1 lint cleaner condenser	2.784	0.127	0.655 ± 0.132	22.3
No. 2 lint cleaner condenser	1.122	0.072	0.388 ± 0.134	13.2
Mote fan	0.385	0.162	0.277 ± 0.05	9.5
Battery condenser	1.05	0.110	0.519 ± 0.114	17.7
Master trash fan	0.816	0.034	0.250 ± 0.12	8.5
TOTAL	9.418	0.654	2.933 ± 0.302	100

[a]Based on largest single emission factor reported from the gins sampled.

[b]Estimated emission factor based on the average of the emission factors for stripper-harvested cotton because no source test measurements were made from this source for picker-harvested cotton.

The uncertainty values associated with each emission factor were calculated from the standard deviations of the averages reported from each gin's source test measurements and computed in the following manner:

$$\frac{1}{N}\sum_{i=1}^{N}\left(A_i \pm a_i\right) = \frac{1}{N}\sum_{i=1}^{N}\left(A_i\right) \pm \frac{1}{N}\left[\sum_{i=1}^{N}\left(a_i\right)^2\right]^{\frac{1}{2}}$$

where A_i = the average emission factor from the ith gin
a_i = the standard deviation of A_i

The emission factors in Table 11 indicate that 62.7% of the emissions from gins processing picker-harvested cotton are from the lint-handling system. As with stripper-harvested cotton, there is a large variation in emission factors as a result of fluctuating ginning rates and varying trash contents of the seed cotton. Picker-harvested seed cotton contains 5% to 15% trash.

Tests were conducted at the U.S. Cotton Ginning Research Laboratory, Stoneville, Mississippi, over a 3-yr period to determine both the collection efficiency and the emission particle size distribution of cyclones (19). The results indicated that a sharp decrease in collection efficiency took place when the recommended inlet velocity of 914 m/min was exceeded. The total collection efficiency varied from 99.884% to 99.946% by weight, with an average value of 99.927% by weight.

The particle size analysis of the emissions showed that 90% of the particles emitted from the cyclone were smaller than 8 μm (Figure 18). The coefficient of determination for the curve fit was 0.990.

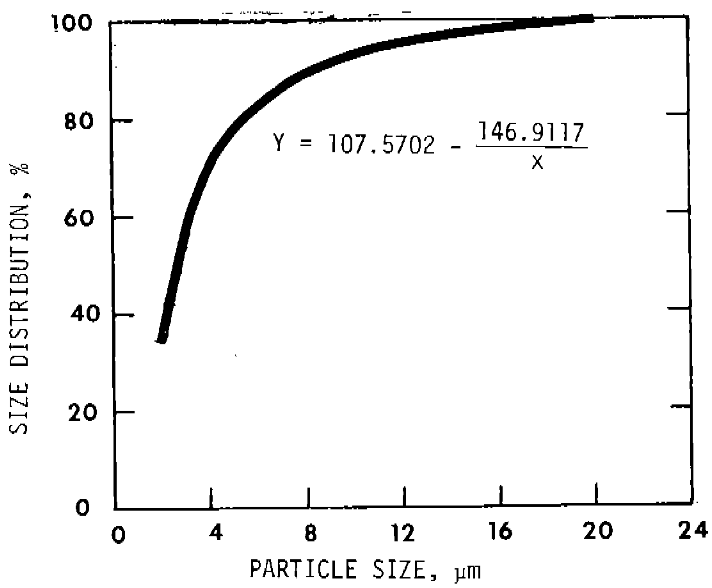

Figure 18. Composite of accumulative particle size distribution (19).

One factor that affects the emissions is the maintenance of the air pollution control equipment. Source tests on a 1.5 m skimmer at a gin processing picker-harvested cotton found significantly larger emissions as the unit got increasingly dirty (6). Initial samples from the skimmer yielded an average emission factor of 2.35 g/kg. Later resampling of the same unit under similar conditions resulted in an average emission factor of 8.6 g/kg. After the skimmer was dismantled and the trash lines were cleaned, resampling indicated an average emission factor of 0.77 g/kg.

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(19) Wesley, R. A., W. D. Mayfield, and O. L. McCaskill. An Evaluation of the Cyclone Collector for Cotton Gins. Technical Bulletin No. 1439, U.S. Department of Agriculture, Washington, D.C., January 1972. 13 pp.

Pesticides and Trace Elements--

Pesticide residues may accumulate on cotton plants, cotton bolls, and topsoil. Therefore, trace quantities of these pesticides may be found in the cotton dust and lint emitted during the ginning process.

Samples of unprocessed picker-harvested seed cotton and trash were collected at Gins E and F for pesticide analysis. The seed cotton was collected at the trailer before ginning.

Trash samples were collected from the bottom discharges of the cyclones from the green leaf and stick extractor, gin stand and mote chamber, gravity-type cleaner, and trash house. The samples were analyzed at the EPA Pesticides Monitoring Laboratory in Bay St. Louis, Mississippi, under the direction of Dr. Han Tai. The results of this analysis are given in Table 12 (20, 21).

TABLE 12. PESTICIDE ANALYSIS OF SEED COTTON AND TRASH (20, 21)

	Sample concentration, ppm by wt					
		Trash				
Compound	Seed cotton	Green leaf and stick extractor	Gin stand and mote chamber	Gravity-type cleaner	Trash house	Minimum detectable limit ppm by wt
p,p'-DDT	4.57	10.1	17.2	53	19.5	0.01
o,p-DDT	0.54	1	2	5.94	3.57	0.01
p,p'-TDE[a]	0.19	0.21	0.78	2.60	2.08	0.01
p,p'-DDE[a]	0.31	0.45	1	3.91	1.61	0.01
Toxaphene	6.16	25.9	27.9	136	22.5	0.1
DEF	0.09	0.17	0.17	0.7	_[b]	0.05
Methyl parathion	0.09	0.17	0.06	0.10	0.33	0.05
Endrin	0.01	_[b]	_[b]	_[b]	<0.01	0.01

[a]Degradation product of DDT. [b]No sample collected.

Pesticide emission factors are given in Table 13. They were calculated based on the assumption that the pesticide concentration in the cyclone emissions is the same as the concentration in

(20) Feairheller, W. R., and D. L. Harris. Particulate Emission Measurements from Cotton Gins, Delta and Pine Land Co., Scott, Mississippi. EMB Project Report No. 72-MM-16, U.S. Environmental Protection Agency, Research Triangle Park, North Carolina, November 1974. 239 pp.

(21) Feairheller, W. R., and D. L. Harris. Particulate Emission Measurements from Cotton Gins, Bleckley Farm Service Co., Cochran, Georgia. EMB Project Report No. 72-MM-23, U.S. Environmental Protection Agency, Research Triangle Park, North Carolina, November 1974. 265 pp.

TABLE 13. PESTICIDE EMISSION FACTORS

	Emission factor, µg/kg							
	No. 1 dryer and cleaner		No. 2 dryer and cleaner		Mote fan		Trash house	
Compound	Stripper cotton[a]	Picker cotton	Stripper cotton[a]	Picker cotton	Stripper cotton[a]	Picker cotton	Stripper cotton[a]	Picker cotton
p,p'-DDT	3.6	1.6	7.2	9.8	4.2	4.8	8	4.9
o,p-DDT	0.4	0.2	0.8	1.1	0.5	0.6	1.5	0.9
p,p'-TDE[b]	0.07	0.03	0.4	0.5	0.2	0.2	0.9	0.5
p,p'-DDE[b]	0.2	0.07	0.5	0.7	0.2	0.3	0.7	0.4
Toxaphene	9.2	4.1	18.4	25.2	6.9	7.7	9.2	5.6
DEF	0.06	0.03	0.09	0.1	0.04	0.05	_[c]	_[c]
Methyl parathion	0.06	0.03	0.01	0.02	0.01	0.02	0.1	0.08
Endrin	_[c]	_[c]	_[c]	_[c]	_[c]	_[c]	<0.01	<0.01

[a]Used midseason emission factors from Table 9. [b]Degradation product of DDT.

[c]No sample collected.

the trash from the bottom discharge of the cyclone. The emission factors were calculated by multiplying the pesticide concentration by the particulate emission factors for the appropriate emission source for both stripper- and picker-harvested cotton.

Arsenic concentrations ranging from 0.15% to 0.22% of the net particulate emissions have been measured downwind from a gin in Texas processing stripper-harvested cotton that had been desiccated with arsenic acid (7, 22). Using the total emission factors from Table 9 for stripper-harvested cotton yields arsenic emission factors ranging from 0.004 g/kg to 0.017 g/kg. Further studies at this gin found arsenic concentrations of 0.2% in cotton plant leaves, 0.07% in the burs, and none detected in the lint.

Arsenic concentrations in particulate emissions from the exhaust of the unloading fan cyclones at a gin processing picker-harvested cotton ranged from 0.009% to 0.012% (21). The cotton being processed was treated with an arsenic-based herbicide early in the growing season. The unloading fan emission factors in Table 11 yield an average arsenic emission factor of 0.0003 g/kg.

A trace element analysis of the particulate emissions from the exhaust of the unloading fan cyclone was also conducted (21). Two particulate samples were analyzed for trace elements by optical emission spectrography (OES). The data are shown in Table 14. Results are given in parts per million by weight. Analysis by OES is intended only for screening to determine what elements are present and their approximate concentrations.

(22) Cuffe, S. T., and J. C. Knudson. Considerations for Determining Acceptable Ambient and Source Concentrations for Particulates from Cotton Gins. In: Control and Disposal of Cotton-Ginning Wastes. Publication No. 999-AP-31, U.S. Department of Health, Education, and Welfare, Public Health Service, Cincinnati, Ohio, 1967. pp. 79-90.

TABLE 14. TRACE ELEMENT ANALYSIS OF PARTICULATE EMISSIONS FROM THE UNLOADING FAN AT A GIN PROCESSING MIDSEASON, PICKER-HARVESTED COTTON (21)

Element	Concentration in dust, ppm by wt
Antimony	$<4,700$
Arsenic	$<1,400$
Barium	$<6,400$
Beryllium	<17
Boron	$<2,800$
Cadmium	$<1,700$
Calcium	$<226,000$
Chromium	<810
Copper	$<3,900$
Iron	$<23,000$
Lead	$<1,300$
Lithium	$<3,600$
Magnesium	$<12,800$
Manganese	$<1,310$
Nickel	$<1,200$
Potassium	$<38,000$
Silicon	$<113,000$
Silver	<180
Sodium	$<400,000$
Strontium	$<1,050$
Tin	$<1,200$
Vanadium	<600
Zinc	$<4,700$

REPRESENTATIVE COTTON GIN

Though there are about 2,771 active cotton gins in the United States, there is very little variation in the basic ginning processes (Figure 4) (1). The major differences between individual gins are their ginning capacities and operating periods.

Cotton gins vary in capacity from 1 to 36 bales/hr. The geographical distribution of cotton gins in 1970 with respect to ginning capacity is shown in Table 15 (13). The smaller gins (less than six bales/hr) are located predominantly in the Southeast and Midsouth, while the majority of the gins in the Southwest and West have ginning capacities between 7 and 10 bales/hr.

Table 15 indicates that 66% of the gins have a capacity of 8 bales/hr or less. Plotting the distribution in this table on probability graph paper yields a mean gin capacity of 6.8 bales/hr.

TABLE 15. DISTRIBUTION OF GIN BATTERIES BY CAPACITY IN BALES/HR FOR EACH STATE, REGION, AND UNITED STATES, 1970 (13)

State and region	Capacity in bales/hr									
	6 or below	7 and 8	9 and 10	11 to 13	14 to 17	18	19 to 21	22 to 25	36	Total[a]
	Number of gin batteries									
North Carolina	89	16	0	5	0	1	0	0	0	111
South Carolina	119	45	4	20	5	1	0	0	0	194
Georgia	106	64	6	21	3	3	0	0	0	203
Alabama	153	72	5	25	8	0	1	0	0	264
Southeast	467	197	15	71	16	5	1	0	0	772
Mississippi	201	161	23	61	22	28	1	6	0	503
Tennessee	142	49	3	12	1	1	0	0	0	208
Missouri	54	43	7	10	1	1	0	0	0	116
Arkansas	216	135	23	29	8	8	0	2	0	421
Louisiana	51	54	17	21	4	8	2	2	0	159
Midsouth	664	442	73	133	36	46	3	10	0	1,407
Texas	154	467	294	146	71	25	10	7	0	1,174
Oklahoma	44	43	17	17	7	3	2	0	0	133
Southwest	198	510	311	163	78	28	12	7	0	1,307
New Mexico	12	22	6	8	2	0	0	0	0	50
Arizona	2	27	61	13	3	7	0	0	0	113
California	0	48	115	49	25	8	2	10	1	258
West	14	97	182	70	30	15	2	10	1	421
TOTAL	1,343	1,246	581	437	160	94	18	27	1	3,907

[a]Totals do not agree with census figures because both active gins and those idle gins considered likely to operate again are included here.

The length of the ginning season extends from August through January, but individual gins operate only during a small portion of the season. Ginning periods range from 8 to 24 hr/day, 5 to 7 days/wk, and 5 to 20 wk/yr. The results of an EPA-sponsored survey illustrating operating schedules in 1974 (Table 16) (23) indicate that the average gin operates approximately 10 hr/day, 6 days/wk, and 10 wk/yr for a total of 600 hr/yr.

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(23) LeSourd, D., and F. K. Zada. Final Report - Capital and Operating Cost Study of Model Cotton Gin Plants with Pollution Control Systems. RTI Project No. 41U-762-7, Research Triangle Institute, Research Triangle Park, North Carolina, and PEDCo-Environmental Specialists, Inc., Cincinnati, Ohio, May 1974. 221 pp.

TABLE 16. NUMBER OF GINS, BY SIZE AND NORMAL OPERATING SCHEDULE (23)

Capacity in bales/hr	Number of plants	No. plants built last 5 yr	Normal operating schedule: Hr/day: Up to 8	8½ to 12	12½ to 18	18½ to 23	24	Days/wk: 5 or less	5½ to 6	7	Wk/yr: 5 or less	6 to 10	11 to 15	16 to 20	Over 20
1 to 4	52	1	2	36	9	1	2	5	33	9	5	17	22	7	1
5 to 9	151	3	0	67	28	3	34	1	68	65	8	51	65	19	0
10 to 14	50	5	0	18	5	2	18	2	16	23	1	19	24	3	0
15 to 19	17	0	0	5	3	2	7	0	4	12	0	7	5	3	1
20 to 24	1	1	0	0	0	1	0	0	1	0	0	1	0	0	0
25 to 29	1	1	0	0	0	0	1	0	0	1	0	1	0	0	0
30 to 34	4	0	0	1	0	0	2	0	0	4	0	2	1	1	0
TOTAL	276	11	2	127	45	9	64	8	122	114	14	98	117	33	2

This operating period and the ginning capacity of 6.8 bales/hr yield an annual production rate of 4,080 bales/yr of cotton. In comparison, the average production rate reported by the U.S. Bureau of the Census for the 1976 cotton year is 3,734 bales/yr-gin of cotton (1).

The trend in the ginning industry is toward large gins with production capacities greater than 18 bales/hr and continuous operation for 7 days/wk, 12 to 20 wk/yr.

All cotton gins use high efficiency (greater than 99%), small diameter (less than 0.96 m) cyclones on all fan exhausts, except at the lint cleaner condenser and battery condenser exhaust. Cyclone exhausts are located 4 m to 15 m above the ground, with an average emission height of 5.2 m.

Approximately 80% of the active gins either use or are in the process of adding screen coverings to their condenser drums in order to reduce emissions. These screen coverings are about 94% efficient at collecting lint fly and particles greater than 125 µm and 5% efficient for particles less than 125 µm, yielding a total collection efficiency, by weight, of 36% to 42%. The remaining gins (20%) have installed inline filters on their condenser exhausts. These units are 99% efficient at collecting lint fly and 70% efficient for dust, yielding a total collection efficiency of 87% (9, 11) (personal communication, C. B. Parnell, Jr., Texas Agricultural Extension Service, Texas A&M University, College Station, Texas). Inline filters and condenser exhausts are located 1.5 m to 5.0 m above the ground, with an average emission height of 2.4 m.

Cotton dust emission factors at individual gins vary widely, from about 0.6 g/kg to 9.5 g/kg, depending on the ginning rate and seed cotton trash content. Evaluation of the emission factors in Tables 9 and 11 indicates that while stripper-harvested cotton contains relatively more trash than picker-harvested cotton, the average total emission factors for gins handling these two types of cotton differ by only 13.3%. Therefore, the average total emission factor of 3.144 ± 0.197 g/kg for typical controlled emissions will be used to define a representative cotton gin. The emission factors for each emission source within a gin are given in Table 17. The values were calculated by averaging the appropriate emission factors for midseason-harvested stripper cotton and the average values for picker cotton.

TABLE 17. EMISSION FACTORS FOR A REPRESENTATIVE COTTON GIN

Emission source	Emission factor, g/kg
Unloading fan	0.305 ± 0.109
No. 1 dryer and cleaner	0.258 ± 0.042
No. 2 dryer and cleaner	0.160 ± 0.068
Trash fan for extractors	0.027 ± 0.010
Overflow fan	0.246 ± 0.010
No. 1 lint cleaner condenser	0.942 ± 0.087
No. 2 lint cleaner condenser	0.277 ± 0.067
Mote fan	0.262 ± 0.012
Battery condenser	0.337 ± 0.057
Master trash fan	0.330 ± 0.067
TOTAL	3.144 ± 0.197

The masses of cotton dust emitted from gins in the 18 cotton-ginning states are given in Table 18 (24). These values were calculated by multiplying the average total cotton dust emission factor (3.144 g/kg) by the quantity of cotton ginned in each state.

The contribution of cotton dust particulate emissions to each state's total annual particulate emissions is also shown in Table 18. The maximum, minimum, and average gin emission contributions are 0.82%, less than 0.01%, and 0.15%, respectively. On a national basis, emissions from cotton gins in 1976 represented 0.04% of the total annual particulate emissions.

As indicated from data in Table 7, 94.2% of all cotton gins are located in counties with fewer than 50 persons/km^2. In addition, 74.7% of the counties containing cotton gins have a population density lower than 11 persons/km^2. Furthermore, 50% of the cotton gins are located in counties with a population density less than 12 persons/km^2. A value of 12 persons/km^2 will therefore be used to represent the population density around a representative gin.

(24) National Emission Report - 1972. Publication No. EPA-450/2-74/012, U.S. Environmental Protection Agency, Washington, D.C. June 1974. 422 pp.

TABLE 18. MASS OF COTTON DUST EMITTED IN THE UNITED STATES

State	Quantity ginned in 1976, metric tons	Mass of emissions from gins,[a] metric tons/yr	Total state particulate emissions (24), metric tons/yr	Contribution from gins, %
Alabama	76,450	240	1,178,643	0.02
Arizona	190,092	598	72,685	0.82
Arkansas	169,769	534	137,817	0.39
California	542,735	1,706	1,006,452	0.17
Florida	569	2	226,460	<0.01
Georgia	42,789	135	404,574	0.03
Kentucky	569	2	546,214	<0.01
Louisiana	120,866	380	380,551	0.10
Mississippi	249,923	786	168,355	0.47
Missouri	35,203	110	202,435	0.05
Nevada	569	2	94,040	<0.01
New Mexico	15,949	50	102,785	0.05
North Carolina	16,045	50	481,017	0.01
Oklahoma	38,095	120	93,595	0.13
South Carolina	31,396	98	198,767	0.05
Tennessee	49,156	155	409,704	0.04
Texas	722,032	2,270	549,399	0.41
Virginia	569	2	477,794	<0.01
TOTAL U.S.	2,302,776	7,240	17,872,000	0.04

[a]Based on a representative gin emission factor of 3.144 g/kg.

EFFECT ON AIR QUALITY

In order to determine the effect of cotton gin emissions on air quality, the source severity, S, is defined as:

$$S = \frac{\bar{\chi}_{max}}{F} \tag{1}$$

where $\bar{\chi}_{max}$ = a time-weighted, 24-hour average of the maximum downwind ground level concentration of the emission species

$$F = TLV\ (8/24)(1/100) \tag{2}$$

where TLV = threshold limit values for the emission species
8/24 = normalizes the factor to a 24-hr/day exposure
1/100 = safety factor

For criteria pollutants, the 24-hr primary ambient air standard is substituted for F.

The value of $\bar{\chi}_{max}$ is calculated from the following equation (25):

$$\bar{\chi}_{max} = \chi_{max}\left(\frac{t_o}{t}\right)^{0.17} \quad (3)$$

where χ_{max} = maximum ground level concentration of the emission species (calculated from Equation 4)

t_o = short-term averaging time

t = averaging time

$$\chi_{max} = \frac{2\ Q}{\pi e \bar{u} h^2} \quad (4)$$

where Q = emission rate, g/s
π = 3.14
e = 2.72
$\bar{u}$ = average wind speed, m/s
h = stack height, m

The equation for χ_{max} (Equation 4) is derived from the general plume dispersion equation for an elevated source and gives the ground level concentration directly downwind from the source under U.S. average atmospheric stability conditions (25). A wind speed of 4.5 m/s is used for $\bar{u}$.

For a 24-hr time-weighted ground level concentration, the values of time for t_o and t (Equation 3) are 3 min and 1,440 min, respectively. Therefore, Equation 3 reduces to:

$$\bar{\chi}_{max} = \chi_{max}\left(\frac{3}{1,440}\right)^{0.17} = (0.35)\chi_{max} \quad (5)$$

Values of $\bar{\chi}_{max}$ and S for representative cotton gins emitting cotton dust are shown in Table 19, based on the TLV for cotton dust of 0.2 mg/m^3 (16). A representative gin is defined as producing 4,080 bales/yr (888 metric tons/yr), operating 600 hr/yr, and having a total emission factor of 3.144 ± 0.395 g/kg. The value of S for each possible pesticide emission (Table 13) was less than 0.01.

Because of low emission heights (5.2 m for cyclones and 2.4 m for inline filters), the values of $\bar{\chi}_{max}$ occur within 25 m of the source. This distance is well within the property lines of a typical gin. The Handbook for Cotton Ginners (4) recommends a gin yard design of 305 m x 427 m for minimum safe distances between buildings for fire protection. The radius of a circle of equal

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(25) Turner, D. B. Workbook of Atmospheric Dispersion Estimates. Publication No. 999-AP-26, U.S. Department of Health, Education, and Welfare, Public Health Service, Cincinnati, Ohio, May 1970. 84 pp.

TABLE 19. SOURCE SEVERITY FOR CONTROLLED COTTON DUST EMISSIONS FROM A REPRESENTATIVE COTTON GIN

Emission source	Stack height, m	At χ_{max}: $\bar{\chi}_{max}$, μg/m³	At χ_{max}: Source severity, S	At property line[a]: $\bar{\chi}_{max}$, μg/m³	At property line[a]: Source severity, S
Unloading fan	5.2	84.4	127	8.3	12
No. 1 dryer and cleaner	5.2	71.4	107	6.9	10
No. 2 dryer and cleaner	5.2	44.3	66	4.3	6
Trash fan for extractors	5.2	7.5	11	0.7	1
Overflow fan	5.2	68.1	102	6.6	10
No. 1 lint cleaner condenser	2.4	122.4	184	26.6	40
No. 2 lint cleaner condenser	2.4	36	54	7.8	12
Mote fan	5.2	72.5	109	7	10
Battery condenser	2.4	43.8	66	9.5	14
Master trash fan	16	9.6	14	<0.01	<0.01

[a]Property line 204 m from source.

area for this gin yard is 204 m. Therefore, the ground level cotton dust concentration at the property line (204 m from the source), calculated from the general plume dispersion equation (25), is used for χ_{max} (and $\bar{\chi}_{max}$). The values of $\bar{\chi}_{max}$ and the corresponding values of S are also given in Table 19.

Another measure of the potential environmental impact is the population that may be affected by emissions from a typical cotton gin. The affected population is defined as the number of persons living in the area around a gin where the time-averaged ground level concentration ($\bar{\chi}$) divided by F is greater than 1.0. Because the compactness of cotton-ginning operations at a gin, the total emission factor of 3.144 g/kg and the dominant stack height of 5.2 m were used to calculate the affected population. Plume dispersion calculations show the two locations downwind from the gin where $\bar{\chi}/F$ exceeds 1.0 (Figure 19). For $\bar{\chi}/F$ greater than or equal to 1.0, the values of x_1 and x_2 are 12 m and 4,113 m. Since a gin is located a distance of 204 m from the gin property line, the resulting area circumscribed by the annulus from 204 m to 4,113 m gives an affected population of 576 persons based on an average population density of 12 persons/km².

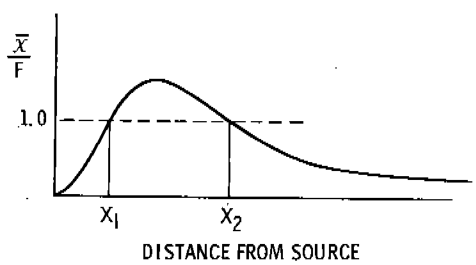

Figure 19. General distribution of $\bar{\chi}/F$ as a function of distance from the source, showing the two general roots to the plume dispersion equation.

SECTION 5

CONTROL TECHNOLOGY

STATE OF THE ART

Numerous devices are used at cotton gins to reduce particulate emissions. Air pollution control equipment currently employed includes cyclones, filters, and wet scrubbers.

Cyclones

The cyclone is used at all cotton gins to collect dust and trash from the conveying air and to reduce particulate emissions (26). The number of cyclones recommended for a gin ranges from 10 for a 6-bale/hr gin processing picker-harvested cotten to 24 for a 36-bale/hr gin processing stripper-harvested cotton (13). More cyclones are required for a gin processing stripper-harvested cotton because of the relatively high quantities of trash in the stripper cotton.

The majority (greater than 90%) of the cyclones used at gins are the small-diameter (less than 0.96 m), high-efficiency (greater than 99% for particles greater than 125 μm) type developed by the Atomic Energy Commission (13). Relative dimensions for this type of cyclone are critical for satisfactory operation (Figure 20). An 0.86-m diameter has been recommended as the optimum for high efficiency cyclones (13). In addition, the air inlet velocity must be approximately 914 m/min, and the air volume must not exceed 85 m^3/min (4). The back pressure for these cyclones ranges from 996 Pa to 1,245 Pa (4 in. to 5 in. of water). The calculated pressure drop for cyclones designed for an inlet velocity of 914 m/min is 1,071 Pa (4.3 in. of water) (13).

When the volume of air exceeds 84 to 130 m^3/min, two or more cyclones are used in parallel. Cyclone banks consists of a single, double, or quadruple arrangement of cyclones. Single cyclones handle up to 85 m^3/min, double cyclones handle up to 170 m^3/min, and quadruple cyclone sets handle up to 311 m^3/min.

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(26) Moore, V. P., and O. L. McCaskill. Evaluation of Abatement Methods Applicable to Cotton Gins. In: Industrial Air Pollution Control, Noll, K. E., and J. R. Duncan (eds.). Ann Arbor Science Publishers, Inc., Ann Arbor, Michigan, 1974. pp. 229-240.

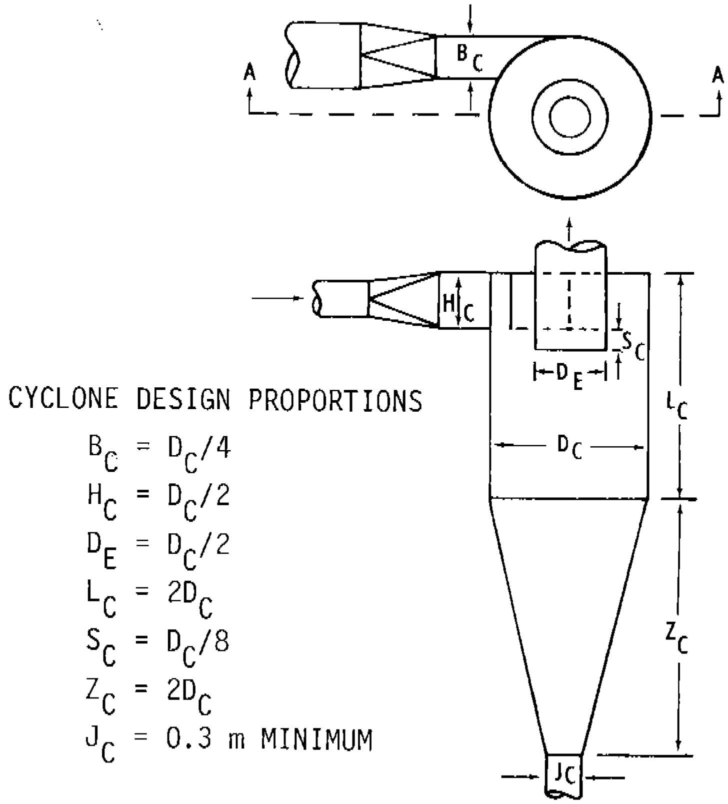

Figure 20. Relative dimensions for a small-diameter, (<96 m) high-efficiency (>99%) cyclone (13).

Tests were conducted in 1972 at the U.S. Cotton Ginning Laboratory, Stoneville, Mississippi, to determine the collection efficiency of the small-diameter (less than 0.96 m), high-efficiency (greater than 99% for particles less than 125 μm) cyclone (19). The cyclone was designed according to Figure 20 with a 0.41-m diameter and an inlet velocity of 914 m/min. The results showed that there was a sharp decrease in collection efficiency when the recommended inlet velocity of 914 m/min was exceeded. The total collection efficiency varied from 99.884% to 99.946% by weight. A composite of all data indicated that the cyclone operated at an average collection efficiency of 99.927% by weight.

Earlier reports indicate that for a small-diameter cyclone with a 0.76-m diameter, the total particulate collection efficiency was 99.94% by weight on large trash removed from stripper-harvested cotton when the cyclone operated with an inlet velocity of approximately 914 m/min (8). Other source test data measured cyclone particulate collection efficiencies ranging from 83% to 99.9% by weight (21).

Filters

Filters are installed at about 20% of gins, nationwide, to collect lint fly and small amounts of dust on low-pressure, high-volume air discharges following condensers. These filters may be of a fixed-screen or revolving-screen design. Essentially, a filter of this type consists of a fine mesh filtering screen mounted in an enclosed housing. The screen may be of stainless steel or Monel bolting cloth with about 50% open area. Foreign matter such as lint fly and leaf trash accumulates on the screen surface during the collection sequence and acts as a filter to catch finer dust particles.

Three basic types of inline filters are used at cotton gins. The first design, developed in 1964, is a fixed concave screen inline air filter with a revolving wiping brush (Figure 21) (27). The dust and lint-laden air passes into the filter screen. When the back pressure of the unit reaches a preset level, a motor is activated that causes the brush to revolve and clean the screen.

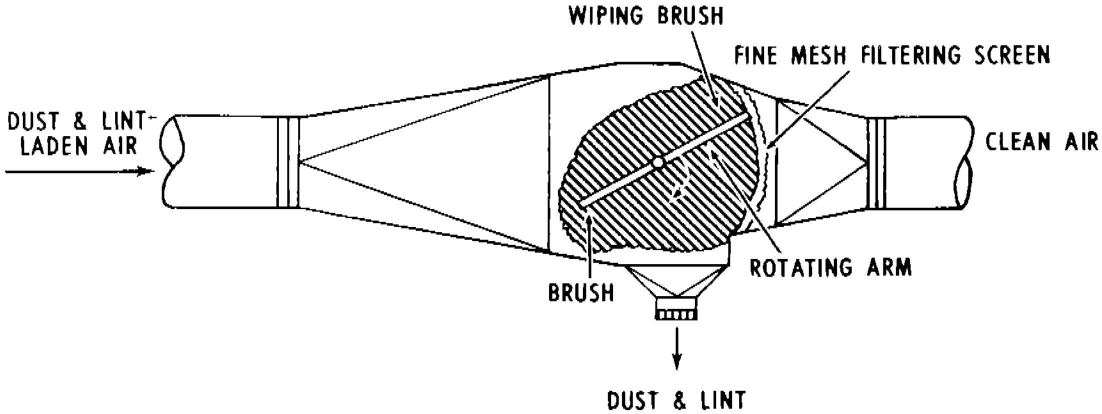

Figure 21. Fixed-screen inline filter with revolving wiping brush (13).

The second type of inline filter is similar in design to the first, except that it uses a screen-covered revolving drum with a fixed wiping brush (Figure 22) (13).

A new, simpler design is a round inline filter with a fixed, flat (horizontal) screen and a radial wiping arm (Figure 23) (28). This filter is less expensive than the others because it requires no scaffolding and is easier to construct. In comparative tests,

(27) Alberson, D. M., and R. V. Baker. An Inline Air Filter for Collecting Cotton Gin Condenser Air Pollutants. Publication No. ARS 42-103, U.S. Department of Agriculture, Washington, D.C., September 1964. 16 pp.

(28) Parnell, C. B., Jr., and R. V. Baker. Application and Design of Round Air Filters for Axial-Flow Fan Exhausts of Cotton Gins. In: Proceedings of First Annual Symposium on Air Pollution Control in the Southwest, Cooper, H. B. H., Jr., and J. M. Hughes (eds.), Texas A&M University, College Station, Texas, November 1973. pp. 168-188.

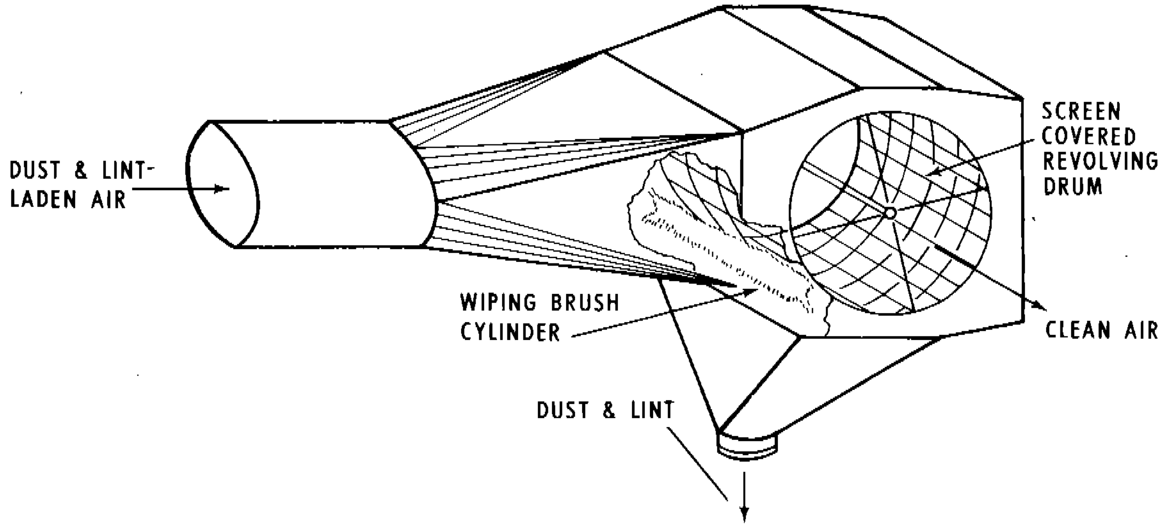

Figure 22. Revolving-screen inline filter with fixed wiping brush (13).

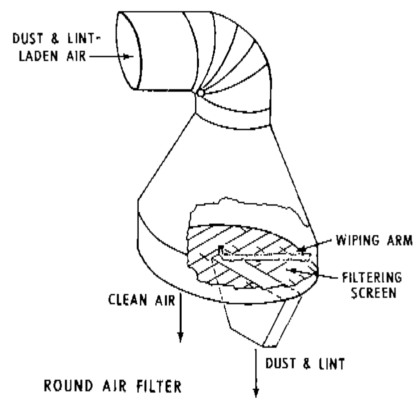

Figure 23. Horizontal-round inline filter with radial wiping arm (13).

all three types of filters had collection efficiencies of about 99% for lint fly and overall collection efficiencies of 80% on stripper-harvested cotton.

Studies at the USDA Ginning Research Laboratory indicate that lint fly emissions can also be reduced by covering the condenser drum with fine screen wire (0.5-mm to 1.9-mm openings), as shown in Figure 24 (13). This design reduced the lint fly and dust concentration in the exhaust air from 0.12 to 0.05 g/m^3 when the drum was covered with 70-mesh (210-μm openings) cloth. When the condenser was covered with perforated metal having 8.4-mm diameter openings and a 20% open area in lieu of the conventional covering material, the dust concentration was reduced from 0.12 g/m^3 to 0.07 g/m^3 of exhaust air (26).

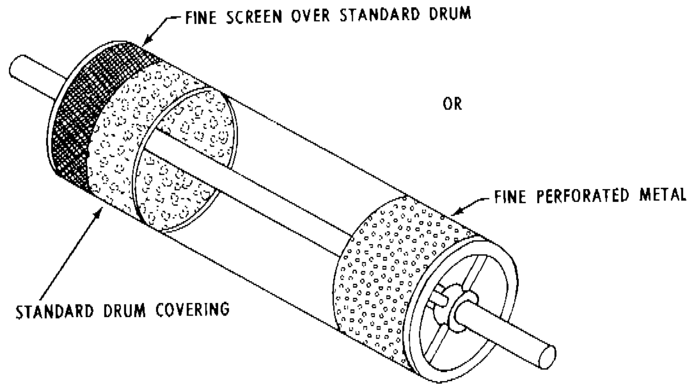

Figure 24. Standard condenser drum covering overlaid with fine screen or fine perforated metal (13).

Approximately 80% of the country's active gins either use covered condensers or are installing them in order to reduce lint fly emissions (personal communication, C. B. Pernell, Jr., Texas Agricultural Extension Service, Texas A&M University, College Station, Texas). Covering a condenser drum costs about $300, whereas installed inline filters cost about $2,000 each.

Wet Scrubbers

To date, less than five cotton gins use wet scrubbers. The J. G. Boswell Company Gin, El Rico #9, uses air/water spray scrubbing chambers on the exhaust outlets of the battery condensers and on the exhaust from all six lint cleaners. Two skimmer-spray column combinations are used to control the exhaust emissions from the two inclined cleaners, two overflow separators, two moisture-conditioning hoppers, and the extractor feeders.

Results of source test data at this gin found that the particulate collection efficiency of the lint cleaner wet scrubber ranged from 74.1% to 96.2%, with an average value of 83% by weight (5). The skimmer and spray column combinations yielded collection efficiencies ranging from 98.3% to 99.8%, with an average value of 99.1% by weight.

Cost Overview

Recent studies have evaluated the economic impact of retrofitting cotton gins with air pollution control equipment. Estimates for the cost of installing small-diameter, high-efficiency cyclones and inline air filters, plus the cost of overhead storage hoppers and trucks for hauling trash, range from about $24,000 for a 6-bale/hr gin designed for machine-picked cotton to over $53,000 for a plant capable of ginning 36 bales of stripper-harvested cotton/hr (13).

If all active gins in the United States were compelled to install cyclones on all fan exhausts, inline filters on all condenser exhausts, and a secondary collection system, and haul the accumulated trash to an approved site away from the plant, the resulting total investment would exceed \$100 million (13). Annual costs under these conditions, including depreciation, interest, taxes, insurance, maintenance, extra energy, and hauling expenses, would exceed \$28.5 million. This amounts to about \$2.33/bale, based on a 12.8×10^6-bale crop.

The purpose of a second study was to develop capital and operating costs for three model cotton gins (23), including costs for three alternative pollution control systems and their impact on the ginning cost. A summary of these cost data is given in Table 20. The assumptions used to derive the cost values are listed in Table 21. The cost of retrofitting these three gins ranges from \$0.47 to \$2.37/bale (13).

FUTURE CONSIDERATIONS

The installation of small-diameter, high-efficiency cyclones on all exhaust high pressure fans and of inline filters on low pressure condenser exhausts would reduce particulate emissions from cotton gins. Maintenance of the cyclones and inline air filters is a major factor affecting the performance of each device. Each gin should take extra precautions to insure that the cyclone discharge lines do not clog. Further work on the design of cyclone discharge systems would help to control emissions.

Source test data indicate that field extraction of trash can reduce emissions by 1% to 35% (11). This procedure is not widely practiced to date.

Other suggestions for reducing emissions from gins include: 1) operate cyclones only at their design capacities and install additional cyclones if the present ones are overloaded, 2) insure that the machine harvesting equipment is properly adjusted so that it does not pick up soil in the harvesting process, and 3) shelter the trash hopper system when the hopper dumps into the hauling truck.

TABLE 20. SUMMARY OF COST DATA FOR MODEL COTTON GIN PLANTS

Cost factor	Without pollution control systems	With pollution control systems I[a]	II[b]	III[c]
Model Plant A, 10 bales/hr:				
Capital cost	$339,788	$ 360,265	$ 384,584	$ 426,497
Ginning cost/yr	157,592	162,852	168,275	176,838
Ginning cost/bale	25.02	25.84	26.80	28.07
Cost of controls/bale		0.82	1.78	3.05
Model Plant B, 24 bales/hr:				
Capital cost	517,086	550,674	612,069	669,424
Ginning cost/yr	377,578	389,301	406,459	416,348
Ginning cost/bale	14.98	15.45	16.13	16.52
Cost of controls/bale		0.47	1.15	1.54
Model Plant C, 40 bales/hr:				
Capital cost	978,044	1,025,558	1,114,180	1,183,726
Ginning cost/yr	522,990	538,671	561,168	599,654
Ginning cost/bale	16.14	16.62	17.32	18.51
Cost of controls/bale		0.48	1.18	2.37

[a]With high-efficiency cyclones and inline filters.

[b]With high-efficiency cyclones and wet scrubbers.

[c]With baghouses.

TABLE 21. DESIGN BASIS FOR MODEL COTTON GIN PLANTS (23)

Location	Southeastern-South Central region of the United States
Type of cotton ginned	Upland cotton
Method of harvesting	Machine picked
Density of bale of ginned cotton	224 kg/m^3
Rated capacities:	
Model Plant A	Ten 227-kg bales of cotton/hr
Model Plant B	Twenty-four 227-kg bales of cotton/hr
Model Plant C	Forty 227-kg bales of cotton/hr
Equipment utilization factor[a]	75%
Operating schedule:	
Model Plant A	One 12-hr shift, 7 days/wk, 70 days/yr
Model Plant B	Two 10-hr shifts, 7 days/wk, 70 days/yr
Model Plant C	Two 12-hr shifts, 7 days/wk, 45 days/yr
Plant costs	Based on proposals prepared by manufacturers of cotton gin equipment
Operating costs	
Supervision and labor:	Industry's practices and wage structure
Maintenance[b]	Industry's average $/bale
Utilities[b]	Industry's average $/bale
Bags and ties	Industry's average $/bale
Trash disposal	Based on $4.4/metric ton ($4/ton) of trash[c]
Interest on borrowed capital	Based on 7% interest rate
Depreciation[d]	Industry's allowable depreciation rates
Property tax	Assumed 2% of capital investment
Insurance	Assumed 1% of capital investment
Pollution control systems:	
System I	High-efficiency (small-diameter) cyclones on high-pressure system and inline filters on low-pressure system
System II	High-efficiency (small-diameter) cyclones on high-pressure system and wet scrubbers on low-pressure system
System III	Baghouses (fabric filters)
Ginning costs	For the purpose of this study, costs of hauling in the seed cotton, hauling out the seeds and the ginned cotton, and warehousing are not considered as part of the ginning operation but as related services for which separate charges are levied.

[a]Defined as the average hourly production rates during the ginning season, divided by the hourly rated capacity of the gin plant.

[b]Based on figures obtained from cotton gin equipment manufacturer.

[c]Estimate based on figures from "What We Know About Pollution Control." Published by Texas Cotton Ginners Association.

[d]Based on figures obtained from cotton gin equipment manufacturer.

SECTION 6

GROWTH AND NATURE OF THE INDUSTRY

PRESENT TECHNOLOGY

There is very little variation in the equipment used at different cotton gins. The primary difference is in the placement of equipment and duct work. For example, one gin may include the trash from the gin stands with the trash from the extractors. Other gins may include the gin-stand trash with that from the condensers or mote fan. Additionally, some (less than 30%) gins employ three seed-cotton cleaning stages instead of two.

A smaller difference in process description is in the amount of air required to process stripper-harvested cotton as opposed to picker-harvested. Gins processing stripper-harvested cotton require about 20% more air because of the higher trash content in the seed cotton (13).

EMERGING TECHNOLOGY

Because of regulations in the 1970 Clean Air Act, all ginning states have banned the incineration of gin trash. Gins now must have trash houses where the trash is stored until enough accumulates to fill a truck. During the ginning season, the trash house is emptied from one to four times daily, and extra precautions must be taken to insure that this dumping of the trash bin does not become another source of particulate emissions.

The Occupational Safety and Health Administration is requiring gins to reduce the amount of suspended particulate matter in the rooms of the gin to 1.0 mg/m^3 (29). This ruling means that room ventilation systems will be installed, thus requiring more cyclones or inline filters.

The most significant trend in the ginning industry is to fewer, larger gins (13). While cotton acreage and the production have been declining generally, the older, low-capacity (6 bales/hr) gins are being replaced by higher-capacity (greater than

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(29) General Industrial Occupational Safety and Health Standards. 29 CFR 1910.1000, U.S. Department of Labor, Occupational Safety and Health Administration, Washington, D.C., January 1976.

10 bales/hr) plants. The trend to fewer plants could be accelerated by imposed air pollution control regulations. The cost of installing additional air pollution control devices is prohibitive for low-volume, older gins.

INDUSTRY PRODUCTION TRENDS

As previously mentioned, there is a slow downward trend in the production of cotton. As illustrated in Figure 25, there is a wide fluctuation in the amount of cotton ginned from year to year because of fiber demand and weather conditions.

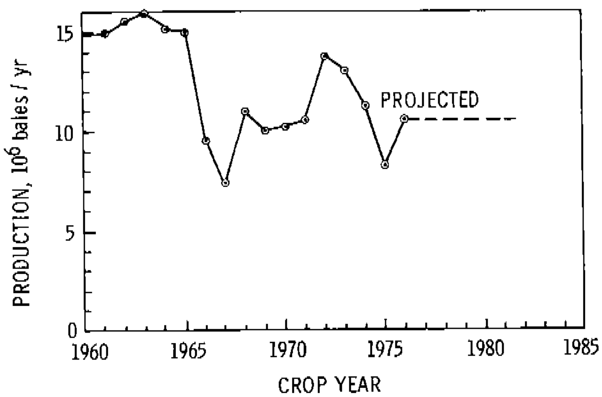

Figure 25. Trend in cotton production (1).

In addition, there is a definite decrease in the number of active cotton gins (Figure 26). The trend is toward fewer, but larger capacity, continuous gins.

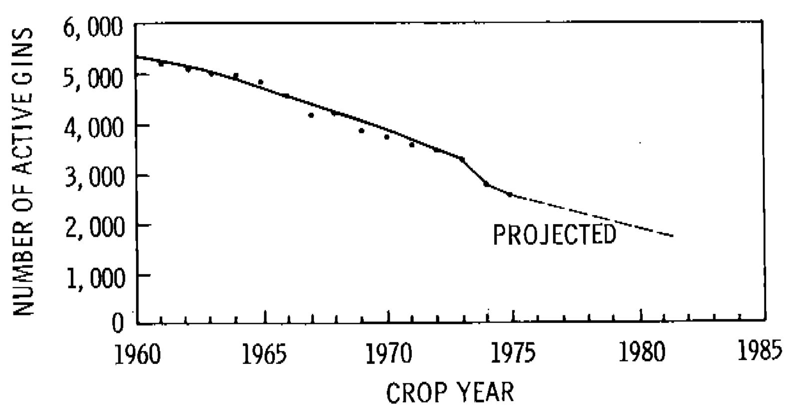

Figure 26. Trend in the number of active gins (1).

The projection for 1980 is the production of 13 x 10^6 bales of lint cotton by 2,318 active gins (23). This projection represents a 2% to 5% increase in production over the next 5 years. As the price of petroleum continues to rise, the increased cost of synthetic fibers is creating a renewed demand for natural fibers.

SECTION 7

UNUSUAL RESULTS

Emissions from the incineration of gin trash (sticks, stems, leaves, burrs, and dirt) are discussed separately because it is a practice that is rapidly being phased out. Before the 1970 Clean Air Act, a large portion (more than 35%) of the gins disposed of gin trash by open burning or by incineration in teepee burners (12). These incineration methods are relatively inefficient and result in plumes with an opacity reading more than 40% and numerous complaints from residents near the gin. After the passage of the Act and its amendments, open burning of gin trash was outlawed in all ginning states except Arkansas and in certain isolated areas in west Texas having high incidence of Verticillium Wilt (Table 22).

State air pollution control regulations also limited the opacity of the plume from teepee burners and other incinerators to Ringelmann 1 or 2, depending on the state. This requirement is virtually impossible for teepee burners to meet, and the majority of such burners were subsequently shut down.

Table 22 indicates that less than 133 gins are still allowed to use teepee burners. In the states of Alabama, Arkansas, and Louisiana, the state air pollution control authorities have granted compliance variances and allowed gins to use teepee burners. However, plans are being formulated by these states to phase out these incinerators in the next 2 to 5 years.

In all cotton ginning states, incineration of gin trash is permitted provided that it is carried out in multiple chamber incinerators and that the emissions meet the state standards. Few (less than 10) gins are equipped with this type of incinerator because of the higher capital cost as compared to land disposal methods. However, these gins are experimenting with recovering the heat from these incinerators and using it to dry the seed cotton. This concept would reduce natural gas fuel costs, thus reducing the cost of the incinerator. Safety problems associated with the air-to-air heat exchanger and in choosing the proper design characteristics have slowed down industrial acceptance of this concept.

Because a few teepee burners are still in use, emission factors are developed in this section. A teepee burner or incinerator, shown schematically in Figure 27, is a conical-shaped steel shell

TABLE 22. SUMMARY OF AIR POLLUTION REGULATIONS CONCERNING INCINERATION OF GIN TRASH

State	Open burning permitted	Number of gins using teepee burners
Alabama	No	<20
Arizona	No	0
Arkansas	Yes	66
California	No	0
Georgia	No	1[a]
Louisiana	No	45[b]
Mississippi	No	0
New Mexico	No	0
North Carolina	No	1[c]
Oklahoma	No	0
South Carolina	No	0
Tennessee	No	0
Texas	No[d]	0

[a] Approved by Georgia Environmental Protection Division.

[b] Granted a variance to burn by Louisiana Air Control Division.

[c] Meets all North Carolina emissions regulations.

[d] Open burning temporarily permitted in certain areas of west Texas with high incidence of Verticillium Wilt.

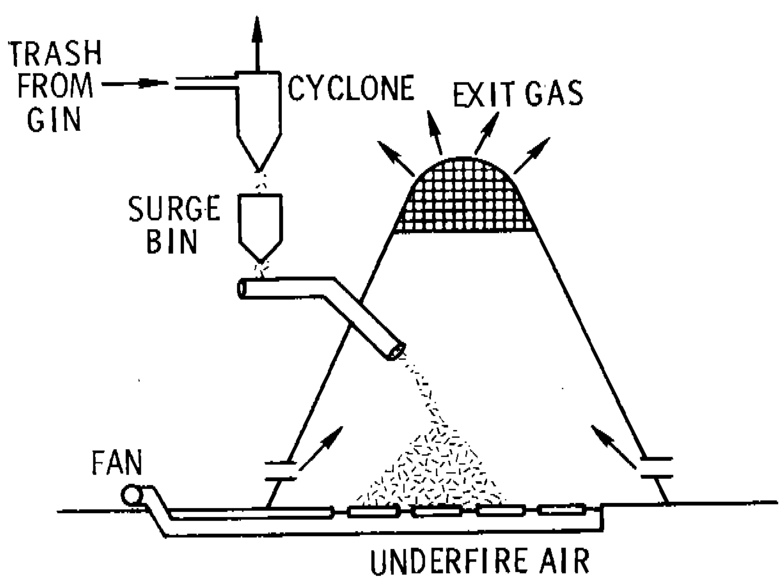

Figure 27. Optimum design teepee incinerator.

with the base diameter approximately equal to the height and topped with a dome-shaped, spark-arrester screen. Cotton gin trash is pneumatically conveyed to a cyclone where the trash is separated from the air stream. The trash falls either directly into the incinerator or first into a surge bin where it is discharged at a controlled rate into the incinerator.

Several teepee modifications have been suggested to reduce smoke and air emissions. Some of these modifications include radial forced air injection, continuous feeding, the elimination of as many openings and cracks as possible, adequate but controlled underfire air supply, damper at the top, and maintenance of an exit gas temperature between 370°C and 480°C regulating air flow rate (30, 31). The most critical of these factors appears to be the level of maintenance on the incinerator. It is not uncommon for teepee burners to have missing doors and numerous holes in the shell, which result in excessive combustion air, low burning temperatures, and, therefore, higher emission rates of combustible pollutants.

No stack test data are reported in the literature for emissions from teepee burners at cotton gins. However, several stack tests have been conducted on teepee burners burning wood waste. The emission factors shown in Table 23 are a result of extensive tests made on a well-maintained teepee burner at Forest Research Laboratory at Oregon State University burning wood waste (30). The emission factors shown should represent best case values for teepee burners at cotton gins. Hydrocarbon emission species include polynuclear hydrocarbons such as benzo(a)pyrene, pyrene, perylene, anthanthrene, and fluoranthene. Emissions of pesticides, defoliants, and dessicants can also be expected if these materials have been applied to the cotton.

Using the emission factors in Table 23, the source severity and values of $\bar{\chi}_{max}$ can be calculated for a typical cotton gin. Since only gins that process picker-harvested cotton are allowed to incinerate their waste, the average trash generation rate of 90 kg/bale will be used to calculate trash quantities. The values of $\bar{\chi}_{max}$ and S are given in Table 24 for a stack height of 10 m.

The mass of emissions from teepee burners in those states still allowing the practice are given in Table 25.

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(30) Kim, B. C., R. B. Engdahl, E. J. Merzey, and R. B. Landrigan. Preliminary Report on Screening Study for Background Information and Significant Emissions from Major Incineration Sources. Batelle, Columbus Laboratory, Columbus, Ohio, May 25, 1973. pp. 74-98.

(31) Kreichelt, T. E. Air Pollution Aspects of Teepee Burners Used for Disposal of Municipal Refuse. Publication No. 999-AP-28, U.S. Department of Health, Education, and Welfare, Public Health Service, Cincinnati, Ohio, September 1966. 35 pp.

TABLE 23. EMISSION FACTORS FOR A TEEPEE BURNER BURNING WOOD WASTE (30)

Exit gas temperature, °C	Emission factor, g/kg of waste charged[a]		
	Particulate	CO	Hydrocarbons
200	8 (3.5)[b]	30	2.3
425	2 (0.5)	10 (65)	0.3 (5.5)

[a]Based on a wood waste with a moisture content of 50%.
[b]Data in parentheses are those given in Reference 32.

TABLE 24. ESTIMATED SOURCE SEVERITY AND $\overline{\chi}_{max}$ FOR EMISSIONS FROM A TEEPEE BURNER AT A TYPICAL COTTON GIN

Exit gas temperature, °C	$\overline{\chi}_{max}$, μg/m³			Source severity, S		
	Particulate	CO	Hydrocarbon	Particulate	CO	Hydrocarbon
200	250	930	70	1.2	0.02	0.4
425	60	310	9	0.3	0.008	0.06

TABLE 25. ANNUAL MASS OF EMISSIONS FROM TEEPEE BURNERS

State	For exit gas temperature, °C	Mass of emissions, metric tons/yr		
		Particulate	CO	Hydrocarbons
Alabama	200	47	176	14
	425	12	59	2
Arkansas	200	155	582	45
	425	39	194	6
Louisiana	200	106	397	30
	425	26	132	4

(32) Compilation of Air Pollution Emission Factors, Second Edition, Publication No. AP-42, U.S. Environmental Protection Agency, Research Triangle Park, North Carolina, April 1973. pp. 2.3-1 to 2.3-3.

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2. Texas Cotton Review, 1973-74. The University of Texas, Natural Fiber Economic Research. Research Report No. NFFPC-NFER-UT-104-74 (PB 235 388), Austin, Texas, July 1974. 143 pp.

3. Pendleton, A. M., and V. P. Moore. Ginning Cotton to Preserve Fiber Quality. Publication No. ESC-560. U.S. Department of Agriculture, Federal Extension Service, Washington, D.C., September 1967. 19 pp.

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APPENDIX

DATA USED TO CALCULATE COTTON DUST EMISSION FACTORS

This appendix presents the raw data used to establish the emission factors given in Section 4 and describes the six cotton gins where the source test data were collected.

GIN A

The particulate emission factors for a gin processing stripper-harvested cotton were obtained from source test data collected during the 1970 crop year at the USDA South Plains Cotton Ginning Research Laboratory, Lubbock, Texas (11). Figure A-1 is a flow diagram of the ginning process showing the 10 sampling locations (exhausts). The source tests were made to determine the total particulate emission rates, to obtain estimates of emission rates for field extracted and nonfield extracted cottons, and to evaluate the effects of different feed rates on the emission rates.

A switch relay system was designed into the sampling system so that all exhausts could be sampled simultaneously and only when the air emitted had been used to actively convey material within the ginning system. In order to sample under isokinetic conditions, ductwork was attached to the top of each elevated cyclone, connected to an inverted U-shaped duct, and extended down to ground level, the shape resembling a candy cane. High-volume samplers with voltage transformers (to control the sampling flow rate) and inclined glass manometers were used to sample each exhaust.

Approximately 1,100 glass fiber filters were used to collect samples. All data not falling within plus or minus three standard deviations were rejected before calculating the final average and standard deviations. It was assumed that there was an external error associated with any value outside this range.

The emission factors calculated from this set of source test data were presented in Table 9 (Section 4). Emission tests were conducted for cotton harvested during four periods; early season (first week in November), midseason (mid-November), late season (late November), and extremely dirty cotton (late November). The extremely dirty cotton was the result of an improperly adjusted mechanical stripper that collected loose soil along with the cotton.

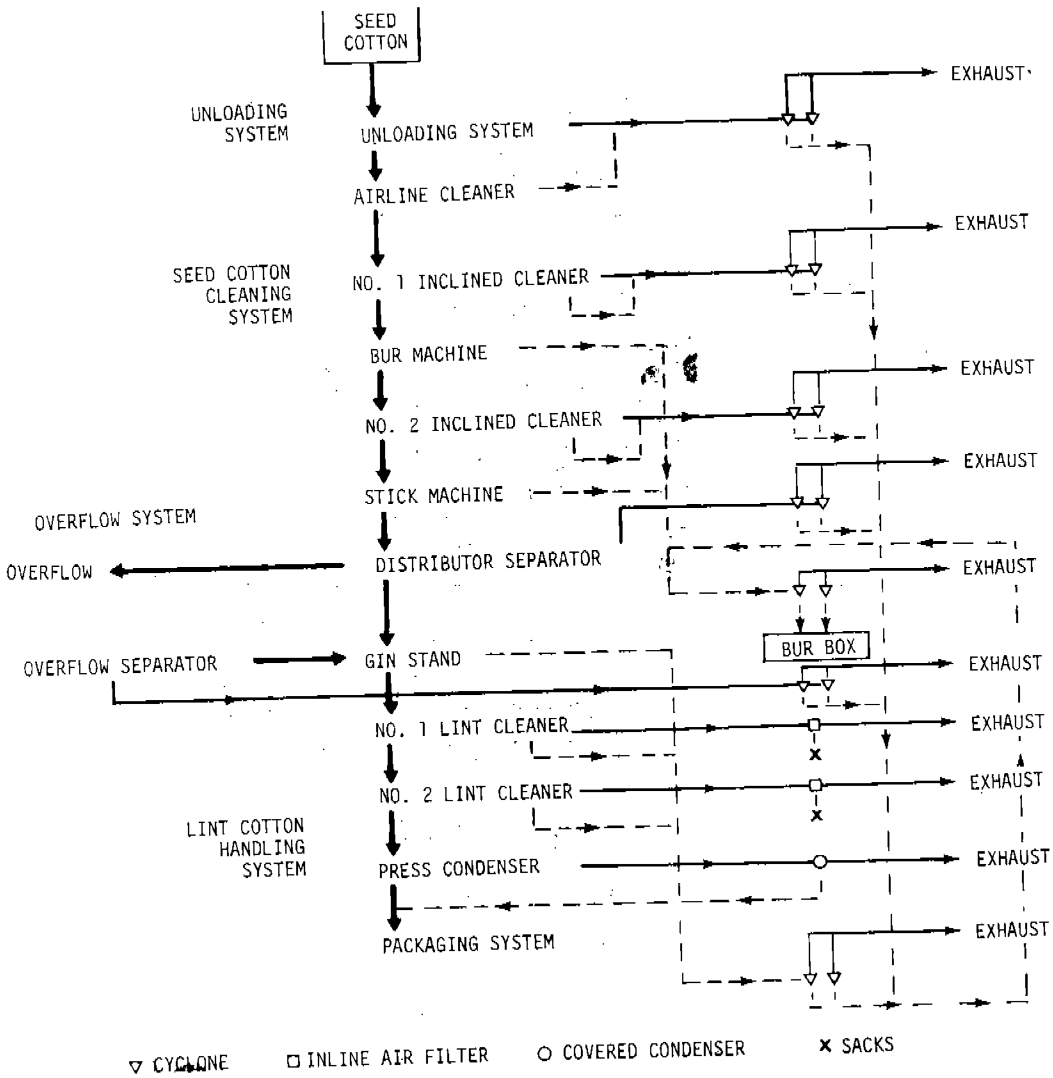

Figure A-1. Cotton ginning system showing the 4 subsystems and 10 exhausts that were sampled (11).

GIN B

The particulate emission factors for gins processing picker-harvested cotton were obtained by averaging the appropriate emission factors for Gins B through F. These emission factors are given in Table A-1. Standard deviations or accuracy values were not reported for these emission factors.

Gin B is the USDA Cotton Ginning Research Laboratory, Stoneville, Mississippi (9). Source tests were conducted during the 1969 crop year. Isokinetic sampling was conducted in the same manner as that used at Gin A. A process flow diagram and the eight source sampling locations for this gin are shown in Figure A-2.

Fifty samples were collected from each exhaust between October 3 and November 17, 1969, while 100 bales of machine-picked cotton

TABLE A-1. SUMMARY OF SOURCE TEST DATA FROM GINS PROCESSING PICKER-HARVESTED COTTON[a]

Emission source	Average emission factor, g/kg, and controls sampled					
	Gin B (9)	Gin C (6)	Gin D (8) 20	Gin E (22) 21	Gin F (23) 5	Average
Unloading fan	0.228 Cyclone (2)[b]	0.359 ± 0.199 Skimmer	0.248 ± 0.057 Cyclone (4)	0.203 ± 0.069 Cyclone (4)		0.259 ± 0.079
No. 1 dryer and cleaner	0.012 Cyclone (2)	0.234 ± 0.190 Cyclone (4)	0.204 ± 0.073 Cyclone (4)	0.181 ± 0.025 Cyclone (2)	Wet scrubber	0.158 ± 0.068
No. 2 dryer and cleaner	0.008 Cyclone (2)	0.086 ± 0.020 Cyclone (4)			0.462 ± 0.270 Skimmer and spray column	0.185 ± 0.135
Trash fan	0.013 Cyclone (2)	0.048 ± 0.037 Cyclone (2)		0.095 ± 0.043 Cyclone (2)		0.052 ± 0.028
Overflow fan						0.19 ± 0.019[c]
No. 1 lint cleaner condenser	0.531 Standard drum covering	0.768 ± 0.104 Skimmer	0.667 ± 0.243 Inline filter		0.0191 ± 0.0078[d] Wet scrubber	0.655 ± 0.132
No. 2 lint cleaner condenser	0.158 Standard drum covering	0.475 ± 0.197 Cyclone (2)	0.532 ± 0.182 Inline filter		0.0127 ± 0.0037[d] Wet scrubber	0.388 ± 0.134
Moto fan	0.271 100 x 100 Mesh filter on drum				0.282 ± 0.05 Cyclone (2)	0.277 ± 0.05
Battery condenser	0.222 Standard drum covering	0.314 ± 0.289 Skimmer	0.63 ± 0.075 Inline filter	0.87 ± 0.17 Inline filter	0.392[d] Wet scrubber	0.519 ± 0.114
Master trash fan		0.218 ± 0.250 Cyclone (4)		0.282 ± 0.016 Cyclone (1)		0.250 ± 0.12

[a] Blanks indicate data not available. [b] Number in parentheses indicates the number of cyclones. [c] Estimated from stripper-harvested cotton emissions.
[d] Not used to calculate the average.

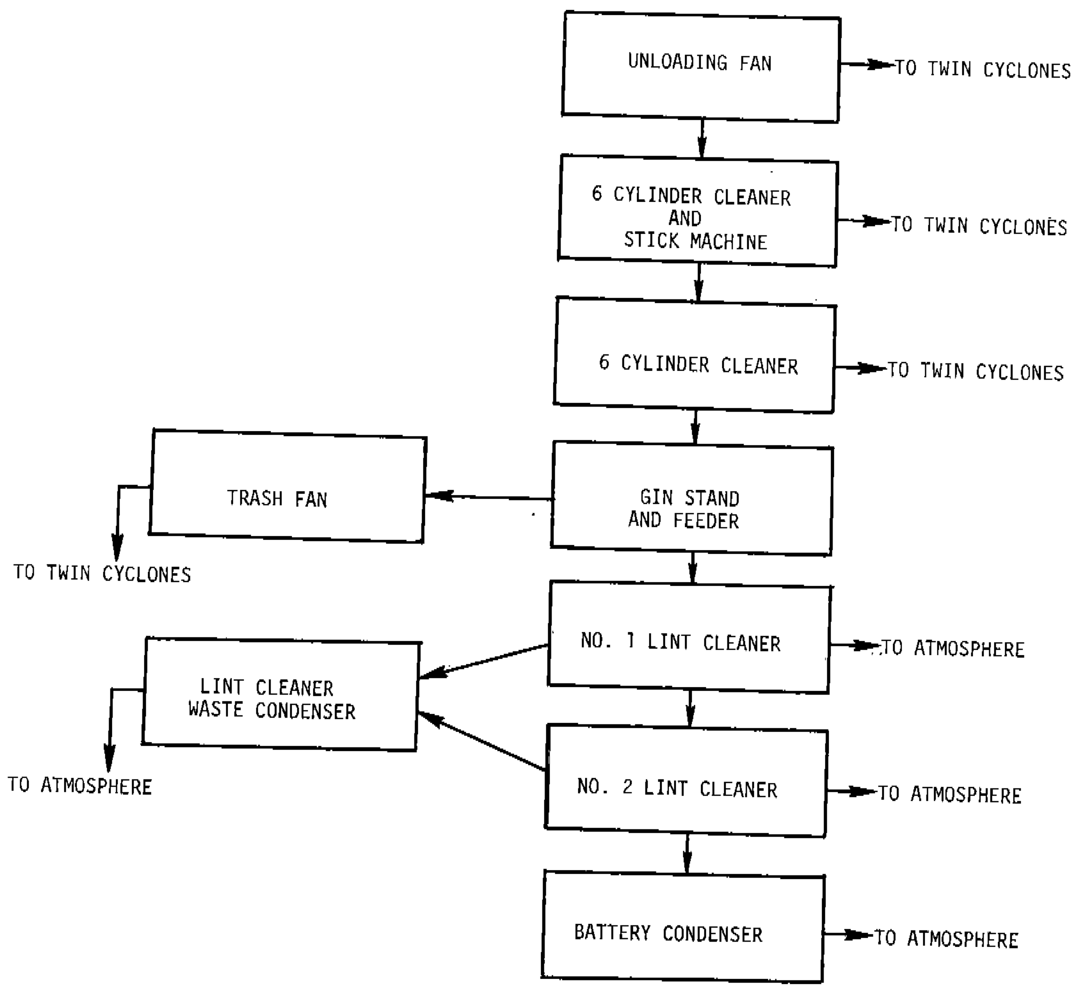

Figure A-2. Flow diagram of Gin B (9).

were being processed. The average trash content of the seed cotton was 7.6% (personal communications, R. A. Wesley and O. L. McCaskill. USDA Cotton Ginning Research Laboratory, Stoneville, Mississippi, June 4, 1975).

GIN C

This gin was sampled by a private consulting firm for the Texas Air Control Board for the purpose of obtaining source test data and establishing test methods applicable to agricultural processing industries (6). The gin is located in South Texas and processes picker-harvested cotton at an average rate of 10.8 bales/hr.

During the 10-day sampling period, 56 samples were taken from eight source locations (Table A-1). Candy-cane-shaped ducting was installed on the exhausts of all cyclones that were sampled in order to insure isokinetic sampling procedures.

GIN D

Gins D, E, and F were sampled by MRC under EPA Contract No. 68-02-0226 for the purpose of obtaining source test data from gins equipped with the best types of pollution control equipment currently available (5, 20, 21).

Emission points on all three gins were equipped with candy-cane-shaped duct extensions to permit isokinetic sampling. Care was taken in the design of the ducting so as not to change the back pressure (and collection efficiency) of each control device.

Gin D is located in Mississippi and processed machine-picked cotton at a rate of about 20 bales/hr. The source test data are summarized in Table A-1. A process flow diagram and the sampling locations are shown in Figure A-3 (20). All emission points at Gin D were equipped with either small-diameter, high-efficiency cyclones or inline filters.

GIN E

This gin is located in Georgia and processed picker-harvested cotton at approximately 9 bales/hr. A process flow diagram for this gin is shown in Figure A-4 (20). All exhaust points were controlled with either small-diameter, high-efficiency cyclones or inline filters.

The source test data are summarized in Table A-1.

GIN F

This gin is located in California and processed picker-harvested cotton at about 10 bales/hr. Figure A-5 shows the process flow diagram (21). Wet scrubbers were used on the outlets of the battery condenser and all six lint cleaners. Two skimmer-spray column combinations were used to control the emissions from the inclined cleaners, overflow separators, moisture conditioning hoppers, and the extractor feeders.

The emissions from this gin were sampled in early December 1972 and the results are summarized in Table A-1.

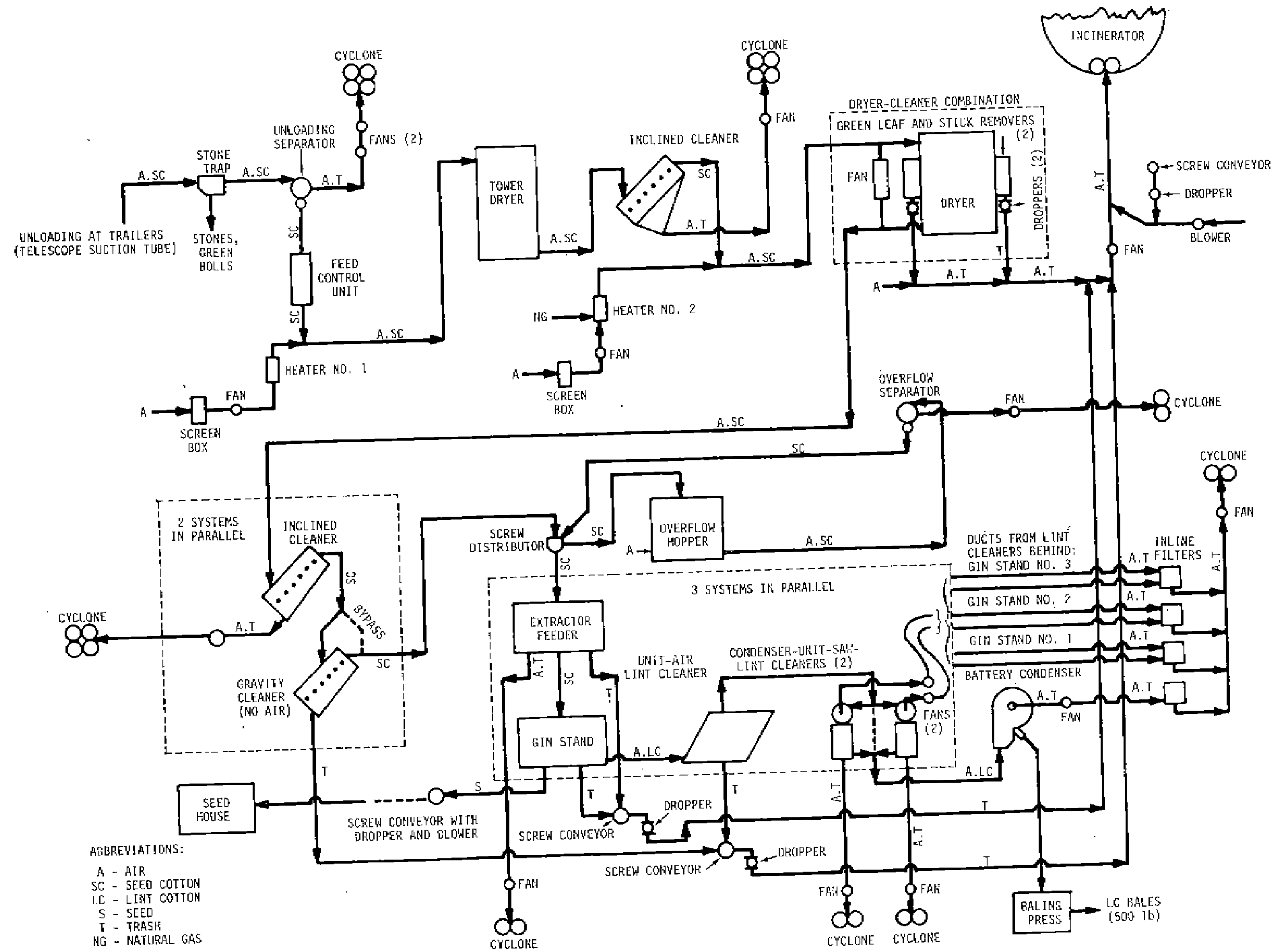

Figure A-3. Flow diagram of Gin D ~~(5)~~.20

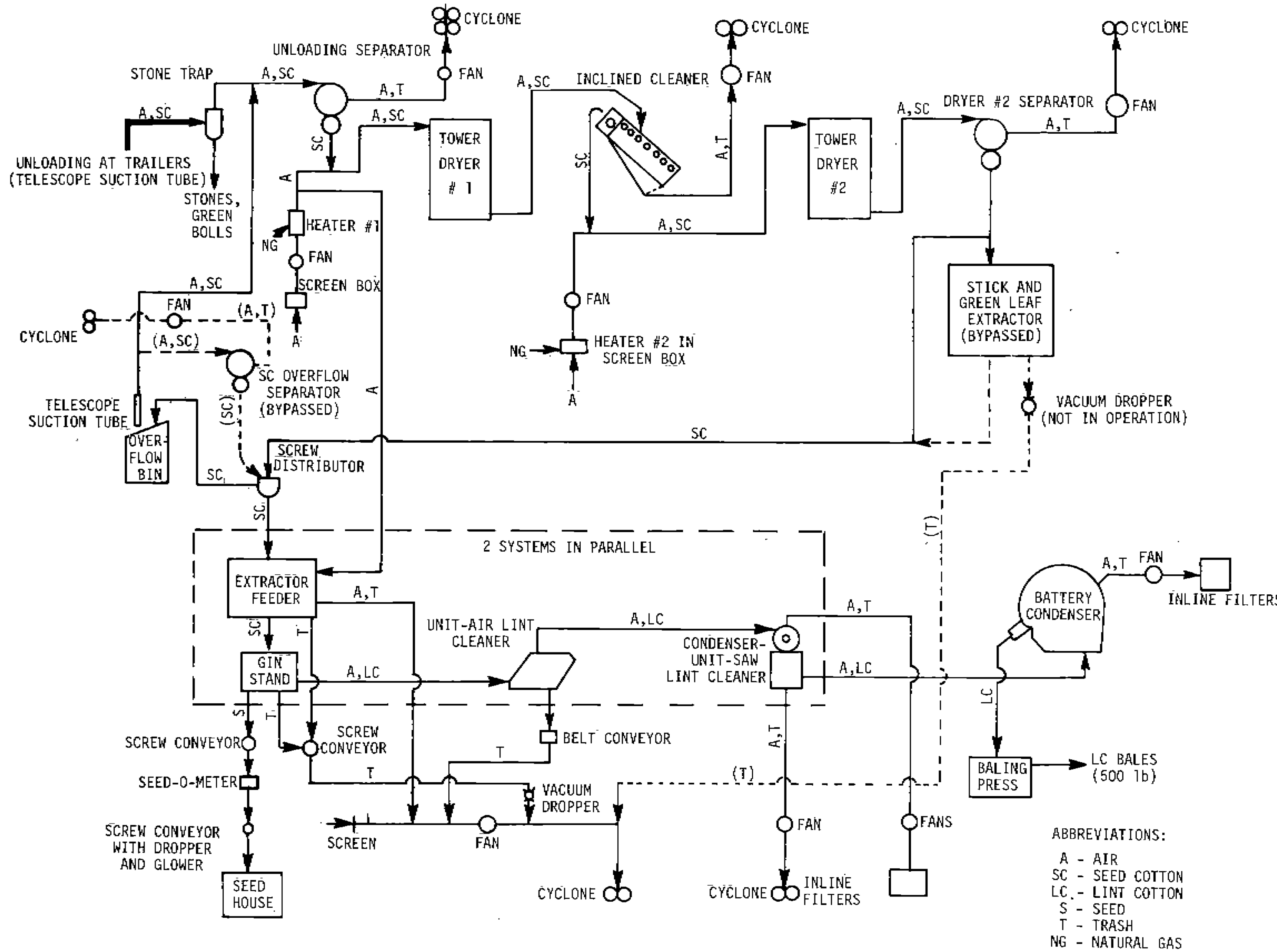

Figure A-4. Flow diagram of Gin E (20).[2/]

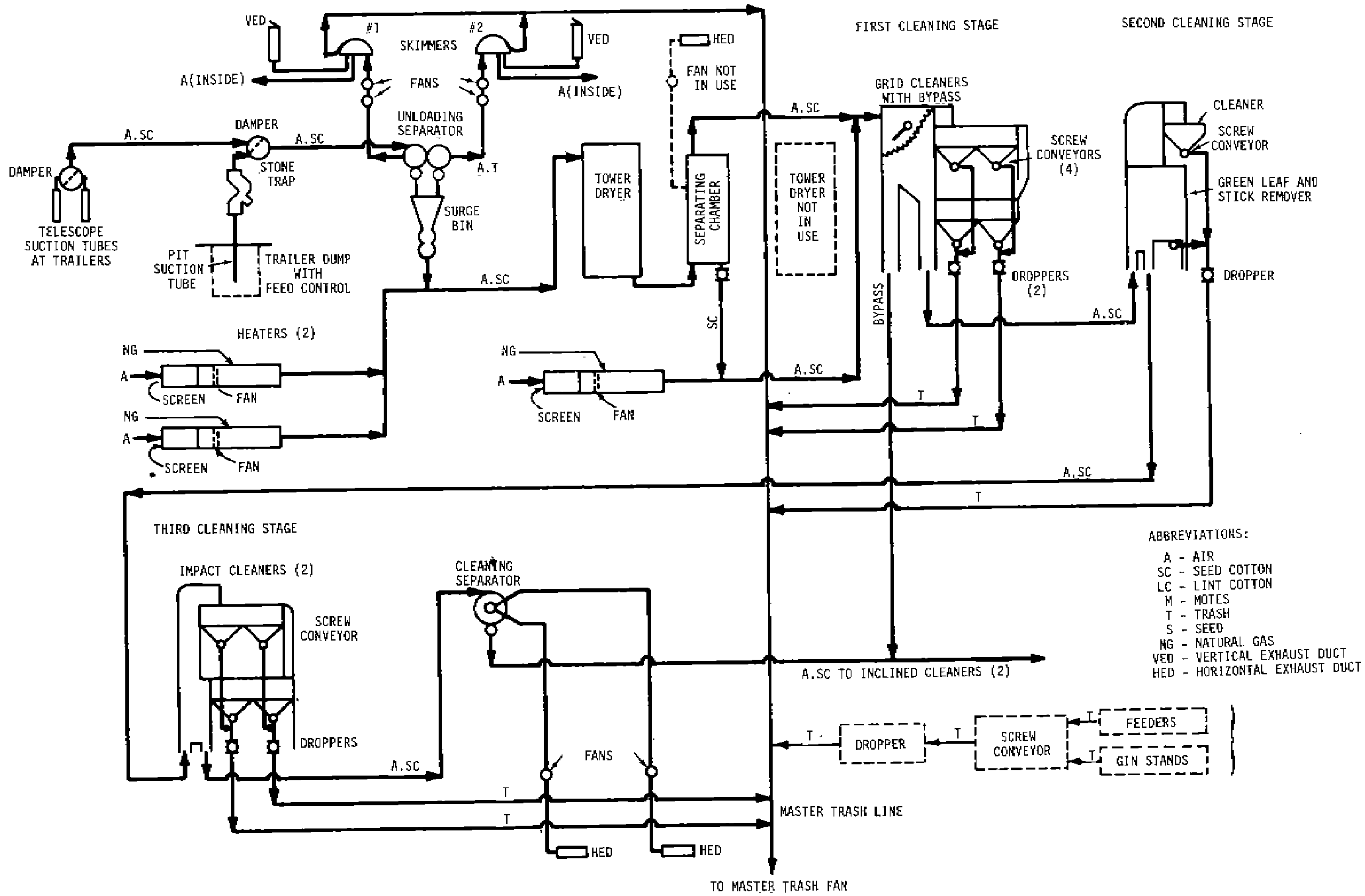

Figure A-5. Flow diagram of Gin F (21).

GLOSSARY

batt: Matting of lint cotton in the condenser drum as the lint is separated from the conveying air.

battery condenser: Final condenser at the gin press that collects lint cotton from air-conveying systems.

bur: Rough casing surrounding the seed cotton before the boll is opened.

candy cane: Ducting attached to the top of an elevated cyclone, then connected to an inverted U-shaped section of duct and finally extended down to the ground--the shape resembling a candy cane.

condenser drum: Device located over a lint cleaner or lint slide that separates the lint cotton from the conveying air stream; device normally consists of a cylinder covered by perforated metal that contains holes about 2.5 mm in diameter.

cotton dust: Dust generated as a result of the processing of cotton fibers combined with naturally occurring materials such as soil, stems, leaves, sticks, bracts, and inorganic matter that may have accumulated on the cotton fibers during the growing or harvesting period.

cylinder cleaner: Machine with rotating cylinders that remove dirt and small trash from the seed cotton but do not remove large trash.

defoliation: Naturally or artificially induced shedding of leaves from the cotton plant; chemicals are normally used to defoliate cotton to aid mechanical harvesting.

desiccation: Killing leaves and reducing the leaf moisture content on the cotton plant with a chemical; leaves do not wilt and fall off plant as in defoliation.

distributor: Device to apportion seed cotton to various machines or gin stands; excess cotton from this device is discharged to the overflow system; a distributor may be of the belt or pneumatic type or equipped with an auger or helical screw.

doffing: Act or process of removing lint cotton from any part of a machine; function can be accomplished with rollers, brushes, or a blast of air.

extractor: Device for removing large trash such as burs, sticks, stems, and leaves from seed cotton; device may accomplish cleaning but should not be confused with a cleaner.

gin stand: Machine that separates the cotton lint from the seed.

inline filter: Device that cleans lint fly and cotton dust from the conveying air before discharging the air to the atmosphere.

lint cleaner: Machine for removing foreign matter from lint cotton.

lint fly: Short (less than 50 μm) cotton fibers emitted from the condensers and mote fan.

mote: Immature cotton seed with short, immature fibers attached.

picker-type harvester: Harvesting machine that removes cotton from the bur with rotating spindles, leaving unopened bolls on the plant.

separator: Inline machine that separates seed cotton from the conveying air.

stick machine: Machine that efficiently removes sticks and green leaves from the seed cotton.

stripper-type harvester: Harvesting machine that pulls or strips all cotton bolls, open and unopen, from the plant; machine also collects relatively large amounts of leaves, sticks, and stems.

TECHNICAL REPORT DATA
(Please read Instructions on the reverse before completing)

1. REPORT NO. EPA-600/2-78-004a	2.	3. RECIPIENT'S ACCESSION NO.
4. TITLE AND SUBTITLE SOURCE ASSESSMENT: COTTON GINS		5. REPORT DATE January 1978 (issuing date)
		6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S) G. D. Rawlings and R. B. Reznik		8. PERFORMING ORGANIZATION REPORT NO. MRC-DA-726
9. PERFORMING ORGANIZATION NAME AND ADDRESS Monsanto Research Corporation 1515 Nicholas Road Dayton, OH 45407		10. PROGRAM ELEMENT NO. 1AB604
		11. CONTRACT/GRANT NO. 68-02-1874
12. SPONSORING AGENCY NAME AND ADDRESS Industrial Environmental Research Laboratory--Cin., OH Office of Research and Development U.S. Environmental Protection Agency Cincinnati, Ohio 45268		13. TYPE OF REPORT AND PERIOD COVERED Task Final, 4/75-11/77
		14. SPONSORING AGENCY CODE EPA/600/12

15. SUPPLEMENTARY NOTES

IERL-Ci project leader for the report is H. Kirk Willard

16. ABSTRACT

This report describes a study of air pollutants from cotton gins. Cotton gins separate cotton fibers from cottonseed and trash. During the 1976 crop year, 2.6×10^6 metric tons of lint cotton were ginned. Particulates composed of cotton dust, cotton lint, fine-leaf trash, and other trash are released to the atmosphere during each step of the ginning process. The average particulate emissions for the entire process is 3.14 g/kg of cotton ginned. Potential environmental effects from ginning were assessed by determining the source severity at a typical plant boundary. Severity is defined as the ratio of the ground level particulate concentration to a reduced TLV. Source severities for nine individual emission points at a typical gin ranged from 1 to 40, while the severity for one other point was less than 0.01. Cotton gins in the United States use a combination of cyclones, separators, condensers, and inline filters to separate cotton and trash from the conveying air stream and to reduce air emissions.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Air Pollution Assessments Cotton Plants Agricultural Machinery	Air Pollution Control Source Assessment Source Severity Cotton Gins	13B

18. DISTRIBUTION STATEMENT Release to Public	19. SECURITY CLASS (This Report) Unlimited	21. NO. OF PAGES 80
	20. SECURITY CLASS (This page) Unlimited	22. PRICE

EPA Form 2220-1 (9-73)

☆ U.S. GOVERNMENT PRINTING OFFICE: 1978— 757-140/6673

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