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Raw Cane Sugar Industry

Environmental Engineerig Inc.

USEPA

July 1971

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environmental engineering, inc.

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Reference 3
Report Sect.
Reference

DRAFT

BACKGROUND INFORMATION FOR ESTABLISHMENT OF

NATIONAL STANDARDS OF PERFORMANCE

FOR NEW SOURCES

RAW CANE SUGAR INDUSTRY

Contract No. CPA 70-142
Task Order No. 9c

Prepared for

Industrial Standards Branch
Division of Applied Technology
Office of Air Programs
Environmental Protection Agency
Raleigh, North Carolina

by

Environmental Engineering, Inc.

July 15, 1971

DRAFT

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NATIONAL STANDARDS OF PERFORMANCE

RAW CANE SUGAR INDUSTRY

1.0 INTRODUCTION

Carbohydrates such as sugar and starch serve as one of the principal energy foods for man. In fact, it is estimated that sugar supplies man with nearly fifteen percent of the energy required for his existence. In nature, sugar is found in a number of foods. In our modern society, however, most of the sugar which is utilized is refined from sugar beets or sugar cane. This working document will concern itself with the production of raw sugar from sugar cane. The process of extracting raw sugar from cane consists essentially of the chemical engineering unit operations of maceration, extraction, clarification, filtration, evaporation, crystallization and centrifugation. Raw sugar mills generally are found in the immediate vicinity of the sugar cane growing areas, thus most of the sugar mills in the world are found in a belt between latitude 30° South and 30° North. In the United States, the majority of these mills are located in Florida, Hawaii, Louisiana, and Puerto Rico. A small industry is developing in the southern part of Texas. Except in Hawaii, where raw sugar production takes place year round, the industry is seasonal with seasons ranging from two months in Louisiana to four or five months in the other areas.

In 1970, it is estimated that about 11 million tons of refined sugar were utilized in the United States. This quantity of refined sugar requires the production of about 11.8 million tons of raw sugar. Approximately 30 percent of the sugar production came from domestic sugar beets; 29 percent came from domestic sugar cane, and the remainder came from overseas sources. About one third of the sugar consumed annually in the United States is sold for household use. The remainder goes to institutions and to food processors. The food processors, who use more than half of all the sugar utilized, include bottlers, bakers, and confectioners, plus miscellaneous uses. The non-food uses of sugar are very few and represent only a small amount of the total consumption.

Mainland production of sugar cane in the United States takes place in Louisiana, Florida, and Texas(1). The industry in Louisiana is located in twenty of the south-central parishes where approximately 43 raw sugar mills are in operation. The season normally extends from October 1 through December 15. In Florida, the production of sugar cane is concentrated in the area around the southern part of Lake Okeechobee approximately 40 miles west of West Palm Beach. Nine raw sugar mills are located in this area and operation normally extends from about November 15 to about March or April 15. In Texas*, sugar cane production is just getting under way and no raw sugar mills are yet in operation. Other domestic production(1) is on four of the principal islands of Hawaii where about 25 raw

*Texas has applied for a quota to produce 100,000 tons per year starting in 1973-74.

sugar mills are located. In Hawaii, production is continuous throughout the year. In Puerto Rico, there are about 15 raw sugar mills scattered around the island. Production in recent years is declining.

The sugar industry is a highly regulated industry(2). Since 1934 it has operated on a quota system. The basis of marketing allotment for mainland cane, domestic sugar beets, domestic cane, and overseas sources is the consumption estimate fixed by the Secretary of Agriculture each year. New amendments to the Sugar Act are expected in 1971, to extend the Act for 3 or more years. Among other changes, the 1971 Amendments* allocate 62 percent of sugar production to domestic sources and shift about 300,000 tons per year of cane sugar production from the Virgin Islands and Puerto Rico to Florida and Louisiana.

The processing of sugar cane to produce raw sugar in itself is an insignificant source of emissions to the atmosphere. The process, however, uses large quantities of steam which usually are generated on site. To avoid a tremendous solid waste disposal problem, and with the present economic balance of the industry, much of the bagasse which results from processing is burned in boilers to produce the necessary process steam. Bagasse has a rather low heat value, is fibrous in nature, and contains substantial moisture. Thus particulate emissions from the furnaces under the boilers can be significant. Special problems in control of these emissions are encountered due to the nature of the resulting fly ash.

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*As of the date of this report, the Amendments had not been passed by Congress.

2.0 PROCESS DESCRIPTION

The raw material for this industry is sugar cane, a member of the grass family. Sugar cane has a bamboo-like stalk, grows to a height of 8 to 15 feet, and contains 10 to 15 percent of sucrose by weight. A number of varieties of sugar cane have been developed to meet the demands of the various growing conditions throughout the world. The growing season is 6 to 7 months in Louisiana, 9 to 12 months in Florida, and about two years in Hawaii. Harvesting is done by hand with machetes or, in those places where it is feasible, by mechanical cutters. The cane is usually burned in the field to remove trash and control insects and rodents. Harvested cane must be processed in less than 24 to 60 hours to avoid rapid inversion of the sucrose into glucose and fructose.

The raw sugar industry actually begins with delivery of the cane from the field. The cane usually is first washed to remove mud and trash, then chopped into small pieces and crushed in preparation for removing the juice. Figure 1 shows a generalized flow diagram of a typical process for the production of raw sugar from sugar cane(3).

Efficient milling is the key to a good economic balance in raw cane sugar production. The milling plant consists of a series of three to seven individual mills, each of which consists of three grooved rolls operating with heavy pressure. Juice is extracted from the cane by passing the crushed cane through the milling

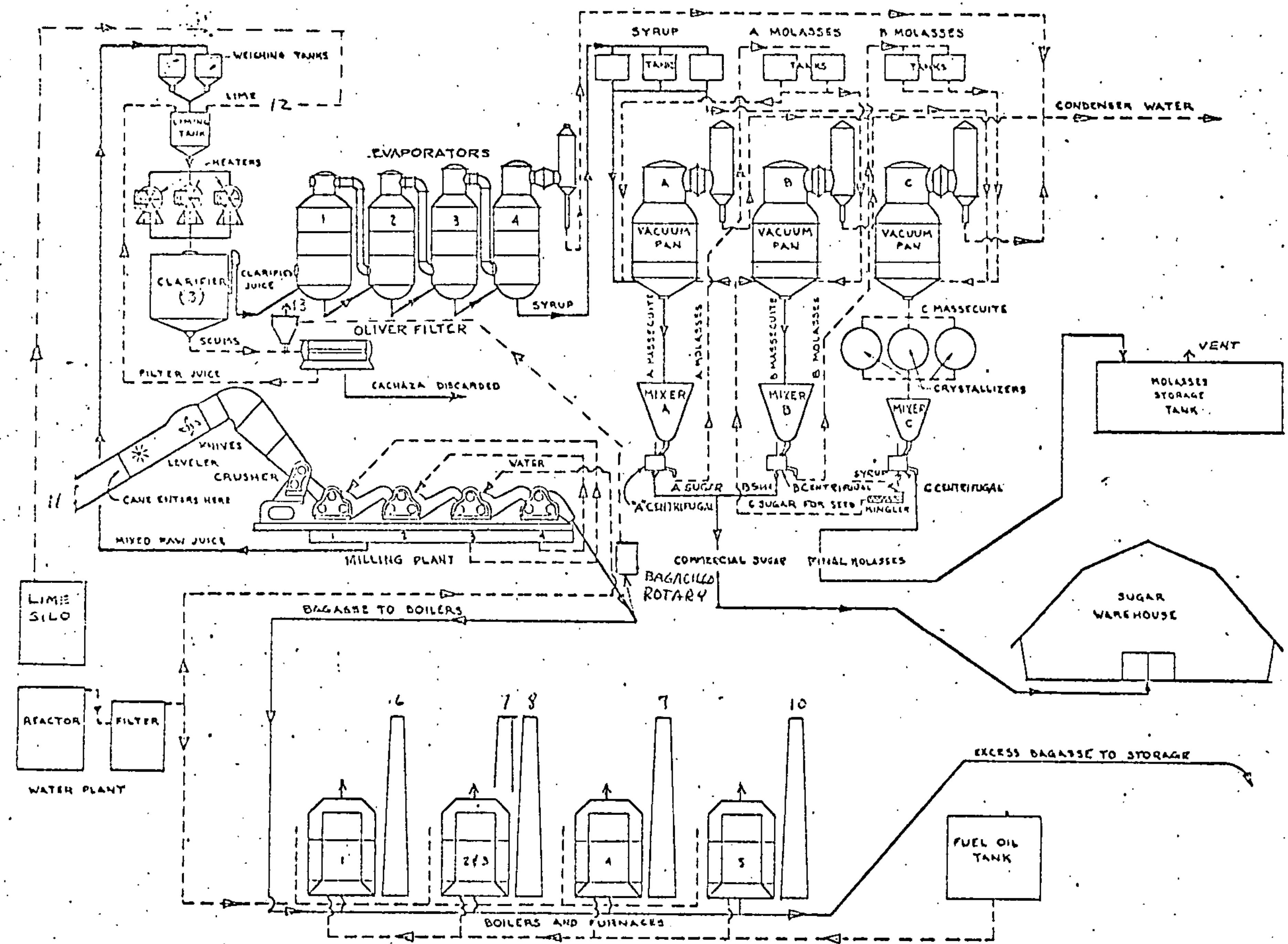

FIGURE 1 - TYPICAL FLOW DIAGRAM FOR A MILL PRODUCING RAW SUGAR FROM CANE.

plant. Water and weak juices may be added to help in the extraction. By spraying warm water on the fiber blanket in the last mill and using a portion of the expressed juices in each preceding mill, about 90 to 95 percent of the available sucrose is removed from the cane. The spent cane is known as "bagasse" and contains 3 to 5 percent sucrose plus fibers and about 50 percent moisture. About 30 percent of the weight of cane entering the milling operation may end up as bagasse. Bagasse is usually used in boilers for fuel, but it may be used to produce paper, wall board, livestock bedding, livestock food, or furfural. The use of bagasse as fuel will be discussed in more detail later.

The juice which results from the milling operation is dark, turbid, and has a pH of 4.7 to 5.5. The juice is usually clarified by the addition of lime and heat. The clarification, which is also known as "defacation", coagulates the colloidal matter, precipitates some of the impurities, and changes the pH to more neutral. After addition of the lime and heating, the juice is discharged into a clarifier from which the settled material is discharged to a rotary drum, or plate and frame press, filter. Prior to filtration, the muds may be mixed with some of the finest particles of bagasse in order to improve filtration. The mud cake from the filter is known as "cachaza" and is usually used for fertilizer on the cane fields. The filtered juice is usually returned to process through the lime tank.

The clarified juice from the clarifier contains about 85 percent water. It is evaporated to about 35 or 40 percent water by multiple effect evaporators. The product of this evaporation is called "meladura". The thickened juice, having a pale yellow color, is next transferred to a series of single effect evaporators known as vacuum pans. Here the thick syrup is evaporated to a predetermined degree of supersaturation. The syrup is shock seeded by the addition of powdered sugar and sugar crystals build around the sugar nuclei. At the optimum point, the pan is filled with sugar crystals and molasses containing about 10 percent water. This mixture is known as "massecuite", and is dumped into a mixer or crystallizer followed by a mixer in which it is cooled slightly to complete crystallization. The discharge of the massecuite from the pan is called a strike. The accumulated massecuite is discharged from the mixer into a centrifuge which separates the molasses and the sugar crystals. The crystals, which are known as raw sugar, are light brown in color and contain approximately 97 to 99 percent sucrose. The syrup which results from centrifugation may be retreated in additional vacuum pans to obtain additional crops of sugar. The syrup which results from the second centrifuge may be treated further or may be sold as high grade molasses. The sugar which results from the third centrifuge is usually used as seed and the syrup which results is known as black strap molasses.

Most of the power used in the mill is provided by steam turbines or electric motors. In addition, large quantities of steam are required for processing. Steam and electricity are usually produced on the mill site using a variety of fuel. One of the most frequently used fuels, either alone or in conjunction with oil or gas, is bagasse.

Approximately 11 to 15 percent of the weight of the original cane is fiber. Thus the quantities of bagasse which result from raw sugar production is tremendous, and would represent a substantial solid waste disposal problem. By-product recovery from bagasse has been developed to a limited extent, but the economics of the various recovery processes are not favorable at this time. The by-product uses of bagasse have been mentioned previously. Thus much of the bagasse is still used for fuel. It is a fuel of varying composition and heat value, depending upon such factors as season of the year, moisture content, variety of cane, and the type of soil upon which it is grown. On the average, bagasse will contain about 50 percent moisture by weight and have an average fuel value of about 2,800 to 3,900 Btu per pound. As a rule of thumb, one pound of bagasse as fed to the furnace will produce about 2 pounds of steam. Burning bagasse is difficult at best, but it does eliminate what would otherwise be a significant solid waste disposal problem. Almost all bagasse burning boilers utilize a supplemental fuel such as fuel oil or gas. Some mills already are abandoning bagasse as the primary fuel and sending it for by-product recovery. At some point in the future, it is possible that little or no bagasse will be used as fuel in the industry.

More complete descriptions of the process and flow diagrams may be found in Shreve's Chemical Process Industries[4] and the publications of Keller[5], and Pace [6, 7].

3.0 EMISSIONS FROM RAW CANE SUGAR MILLS

The processing of sugar cane to produce raw sugar in itself is an insignificant source of emissions into the atmosphere. The movement of trucks on unpaved mill yards and once-a-week or so filling of lime silos occasionally result in particulate emissions which are only of very localized effect and are readily controlled by good housekeeping. The occasional cleaning of heat exchanger tubes by boiling with muriatic acid releases some acid fumes which are noticeable only to the extent of 8 or 10 feet from the vent. Infrequent odors of carmelized sugar from a strike, and ethanol from the molasses storage tanks late in the season, usually are not noticed beyond the mill buildings themselves.

The related activity of steam generation by bagasse-burning boilers is a source mainly of particulate emission. Sulfur dioxide may be, and nitrogen dioxide is, emitted in quantities related to the type and quantity of fuel and auxiliary fuel used. The isolated location of most sugar mills, surrounded by large acreage of cane fields, tends to minimize any adverse effect of furnace emissions.

As indicated earlier, bagasse is a fuel of varying composition and heating value. It can probably best be described as fibrous in nature with the fiber length determined by the crushing and maceration stages of processing. Almost all bagasse-burning furnaces utilize fuel oil for supplemental fuel. Microscopic examination of the resulting flyash shows generally elongated particles of burned, partially charred, or unburned fibrous material. The specific gravity has not been determined, but observations lead to a value of less than one. During source sampling in the 1969-70 Florida season, samples were collected for particle sizing. Using Martin's Diameter as the basis for classification, the following summary may be considered typical (all percentages are expressed as weight percentage of particles exceeding the stated size):

PARTICLE SIZE, μ	WEIGHT PERCENT
5	98.7 - 100.0
10	96.3 - 99.3
20	84.3 - 99.2
50	66.3 - 91.0
80	60.4 - 86.8
100	33.6 - 79.8
200	13.0 - 50.0
500	2.4 - 22.0

One mill in Florida uses as fuel the residue resulting from the production of furfural from bagasse. This material is more granular than fibrous, but the particle size distribution was found to be similar except for slightly lower percentages in the sizes above 50μ.

During the same season, 26 boilers were tested at eight mills in Florida. The procedure used was that specified by the State of Florida (essentially WP Bulletin 50) using an alundum thimble as the collector. During sampling, all boilers were operated within the range of the top 25 percent of boiler steam production recorded during the preceding season. In most cases, Bunker C fuel oil was required as auxiliary fuel to reach this capacity. The following summarizes the information reported to the state control agency:

	MAXIMUM	MINIMUM	AVERAGE
Solid fuel delivery rate, lbs/hour, dry	29,200	6,000	15,500
Particulate emission rate, lbs/hour	713	49	199
Particulate emission rate, lbs/1000 lbs dry fuel	53.5	3.2	14.6

These results include those from four mills which utilize multiclone collectors and four which do not. Results for individual mills probably may be obtained from the state agency or from the individual mills whose Presidents are noted in the listing in Appendix A.

Emissions of sulfur oxides and nitrogen oxides have not been measured but were calculated for the applications to the State of Florida for a Permit to Operate these sources.

An ambient air study in the cane growing area of Florida (See Appendix B) indicates that although combustion product particulates are emitted into the atmosphere of a three-county area from bagasse-burning boilers, cane field burning and wildfires, the quality of the air is very good. The annual geometric mean of suspended particulates is less than 41 micrograms per cubic meter with very low sulfur dioxide concentrations. During the cane harvesting and processing season, the geometric mean was 39 compared with 44 during the non-harvesting season.

4.0 CONTROL TECHNOLOGY AVAILABLE FOR NEW PLANTS

Since the only noticeable sources of atmospheric emissions from raw cane sugar production are the bagasse-burning boilers, most of the operating variables applicable to control from similar combustion sources should be effective. Unfortunately, there is little control possible on fuel composition and rate of production of fuel. Also, there is little correlation between steam demand and bagasse production in a time reference. Cane milling frequently is dictated by natural factors not under the control of the mill. An increase in milling and raw sugar production requires an increase in steam production which precedes the availability of bagasse from the milling. Other than the use of add-on control hardware, the mills which appear to be the most successful in reducing total particulate emissions have one or more furnaces operated at reasonably steady conditions to carry the base load plus others to accept surges.

The flyash resulting from bagasse burning has characteristics similar to the emissions from the bark boilers used in the wood pulp and other forest products industries. Similar approaches have been used in hardware for emissions control. In describing applicable hardware, it is essential to differentiate between "available technology" and that which is in the R & D stages. For the purpose of this report, available technology is that which has been proven in practice by full-scale operation for at least a year on the same unit processes in the same industry here or abroad. The most modern mills at present use small-diameter mechanical collectors such as multiclones. When in good condition, these have a weight efficiency of 60 to 75 percent. Materials of construction, routine inspection, and maintenance are of considerable importance in maintaining the efficiency due mainly to the erosive nature of the flyash. It also has been observed that reinjection of flyash has an adverse effect on emissions.

One mill in Cuba several years ago was reported[8] to have unsuccessfully attempted the application of an electrostatic precipitator to a bagasse boiler.

Schaffer[9], who has designed a number of the more recently constructed raw sugar mills, has an unproven theory that raising the arch of the firebox several feet will drastically reduce particulate emissions.

The Florida Sugar Cane League, cooperating with the Florida Department of Air and Water Pollution Control, in attempting to further reduce particulate emissions from the boilers has undertaken several R & D studies. Under contract with Environmental Engineering, Inc., and David B. Smith Engineers, Inc., several pilot plant studies were begun. In January 1970, a wet scrubbing unit of 2500 CFM capacity was installed and operated at two Florida mills. The unit was equipped to operate as a cyclonic scrubber or a venturi scrubber so that the particulate removal efficiency of both methods could be investigated. An insulated duct was installed to withdraw stack gas, under isokinetic conditions, at a point prior to the stack breeching. The amount of gas withdrawn during pilot plant operation amounted to about 4 to 6 percent of the total gas flow. In both cases, the gas flow had already been passed through multiclones. Various liquid/gas ratios, liquid pressures, and total pressure drops were investigated. When operated as a Venturi scrubber, with results extrapolated to full scale, weight efficiencies of 98 to 99 percent were achieved. When operated as a Cyclonic scrubber, with results extrapolated to full scale, weight efficiencies of 91 to 98 percent were achieved. The cyclonic results were achieved at a total energy input of 20 - 25 percent of the venturi results. Arrival of the end of the processing season halted further work on this unit.

In November or December, 1970, a pilot unit Cyclonic scrubber was installed at one Florida mill to investigate problems of day-to-day operation and treatment of the resulting wastewater. Problems revealed included carryover of a discoloring mist, rapid erosion of stainless steel nozzles and resultant drastic lowering of efficiency, wet steam plume, and wastewater treatment difficulties. Continuing the planned program, a full-scale unit will be installed for investigation on a furnace at the Clewiston mill of the U.S. Sugar Corporation during the 1971-72 season.

In January, 1971, a pilot unit "shave-off" mechanical collector was installed at another Florida mill. Results were encouraging and a full-scale version is planned for a furnace at the Sugar Cane Growers Cooperative of Florida during the 1971-72 season.

5.0 RAW CANE SUGAR MILLS UTILIZING BEST EMISSION CONTROL TECHNOLOGY

In Section 4 of this report, "available technology" was defined. By this definition, best available technology for control of particulate emissions for bagasse-burning boilers is a small-diameter mechanical collector such as the multiclone. When in good condition, without flyash reinjection, these have a weight efficiency of 60 to 75 percent.

The selection of best controlled plants was made on the basis of those installations which have such units installed. In Florida these mills are the Clewiston and the Bryant mill of U. S. Sugar Corporation, the mill of Sugar Cane Growers Cooperative of Florida, Inc., and the mill of the Atlantic Sugar Association. Emissions stated in units such as lbs/1000 lbs dry fuel are lower than for uncontrolled sources. Total mass emission rates may be higher than for uncontrolled sources of lower steam production. Actual emission data may be obtained from officials of the companies involved as indicated in Appendix A. Little in the way of reliable cost information is available from the companies.

Generally, the mills in Louisiana and Hawaii are older than those in Florida. Only some of their newer boilers reportedly are equipped with mechanical collectors. Some Louisiana mills ship all of their bagasse to wall board plants and use oil or gas as fuel.

Information on results of full-scale installations of other types of collectors will not be available until at least the completion of the 1971-72 Florida season.

6.0 SPECIFIC REGULATIONS CURRENTLY PERTAINING TO EMISSIONS FROM RAW CANE SUGAR MILLS

Raw cane sugar mills operate at present in the states of Hawaii, Florida and Louisiana. No regulations specifically for particulate emissions from bagasse-burning boilers are in existence in any of these states. General regulations, of course, are applicable to bagasse-burning boilers in each instance.

All three states[10,11,12] have similar regulations on visible emissions. Louisiana's is typical of these and indicates that visible emissions from combustion sources shall not be darker than 2 on the Ringelman scale, except during start-up, soot blowing, etc., when 2 may be exceeded for not more than 5 minutes in any consecutive 60-minute period.

In Louisiana, a general emission limitation for particulate matter is hinted at without providing any specific values. It states:

> "To aid in controlling the overall level of suspended particulate matter in the atmosphere, air pollution control facilities should be installed whenever possible, and where installed on a property shall be used whenever emissions of particulate matter are being made which can be controlled by the facilities, even though the ambient air quality standards in affected areas are not exceeded."

Florida has a process weight chart which has been conceded by the State not to be applicable to bagasse-burning boilers. At present, no specific regulations are so applicable, but general philosophy is that best available technology must be applied. It is our understanding that when best available technology is defined and identified, specific emission limitations will be prepared.

Hawaii has a specific limitation for emission of particulate matter which states that emissions from combustion sources must be limited to 0.85 lbs/1000 lbs of exhaust gases adjusted to 50 percent excess air, except that for new installations dust collection equipment is required which has an efficiency of not more than 85 percent. In addition, Hawaii prohibits the emissions of soot and fumes which are detrimental to the property, health, comfort, or safety of people, or which create a nuisance.

Correspondence with officials of the State of Hawaii reveals that they are uncertain as to whether any changes will be made in their air control regulations which may be applicable to bagasse-burning boilers.

8.0 PRODUCTION AND GROWTH OF THE RAW CANE SUGAR INDUSTRY

As indicated previously, the sugar industry is a highly regulated industry which operates on a quota system. The basis of marketing for all sources of sugar is the consumption estimate fixed by the Secretary of Agriculture each year. A new amendment to the Sugar Act is considered by the Congress about every four years. Since the political maneuvering at both the state and federal level is virtually unpredictable, projections of production by area are hazardous except where other factors impose limitations.

At the present time it is estimated that mills in Florida and Louisiana have about 10 to 15 percent unused capacity. Puerto Rico is believed to have somewhat more unused capacity and Hawaiian mills an unknown amount, but in each instance other factors limit the availability of cane for grinding. Louisiana has a number of small and inefficient mills which probably will be shut down or consolidated with other mills in the future.

Other than possibly one or two new mills in each of the mainland cane producing areas in the next decade most of the increase in production probably will be accomplished by expansion of existing or consolidated facilities.

Figure 2 portrays actual and projected domestic raw cane sugar production from 1940 to 1980. The solid lines are historical data[13, 14] with some of the fluctuations smoothed out. "Total Domestic" is the sum of the individual curves and the straight line drawn through the curve is a line of best fit which roughly parallels U. S. population. The dashed lines are projections based on information developed by Francis C. Schaffer[9]. Both Hawaii and Puerto Rico have limitations on available land imposed by an increasing population and the island geography. Louisiana has a limitation imposed by the short growing season. Florida, it is estimated, can grow enough cane to produce one million tons of raw sugar per year. New sugar cane growing areas are expected to be developed in Texas, Arizona, and California.

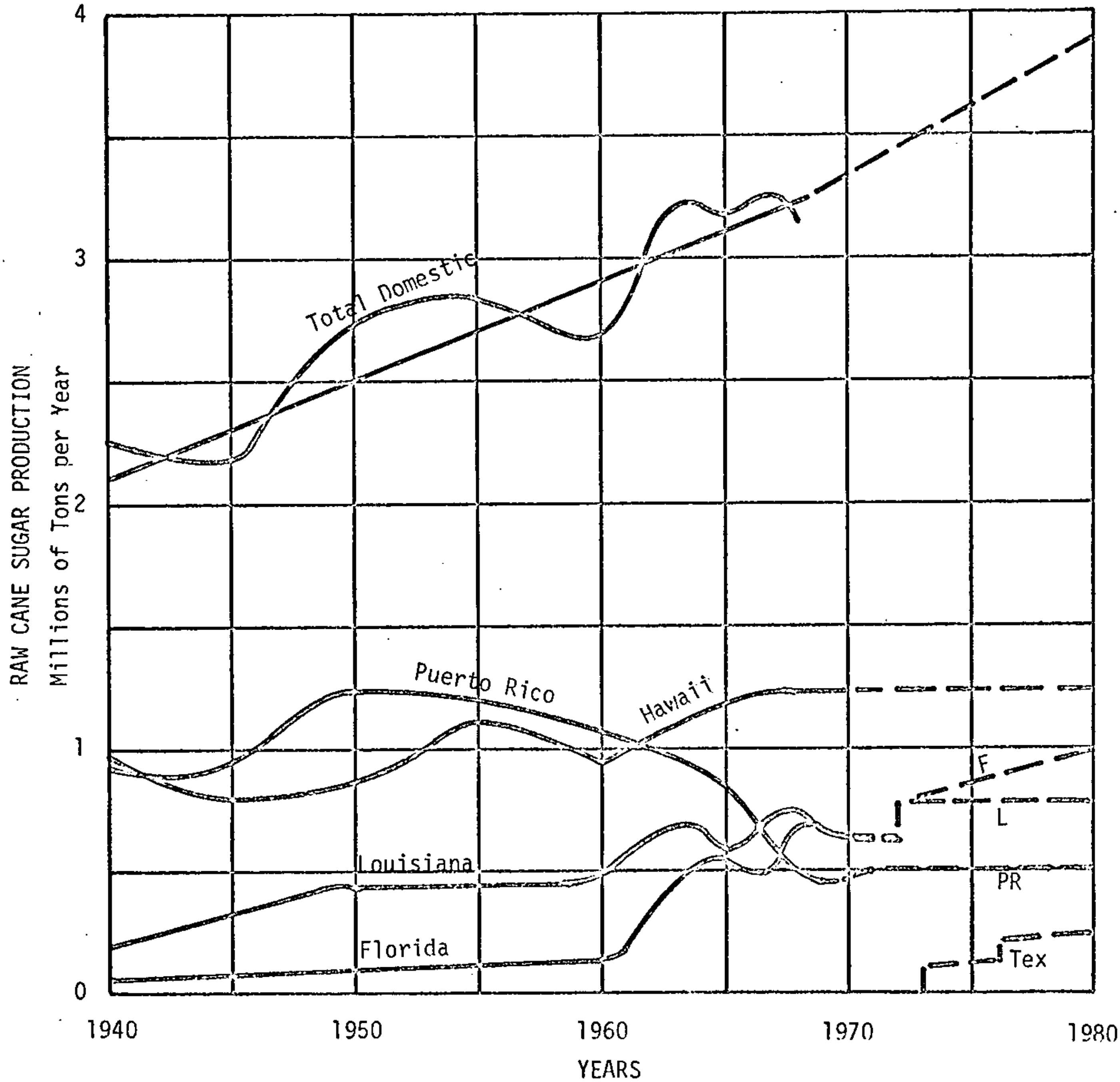

FIGURE 2 - ACTUAL AND PROJECTED PRODUCTION OF RAW CANE SUGAR IN THE U.S.(1940-80)

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APPENDIX A

Listing of

Producers[14]
Producers Associations
Consultants
Research Institutes

RAW CANE SUGAR PRODUCERS

Florida

Company Name & Address	Factory Location
Atlantic Sugar Association Post Office Box 370 Belle Glade, Florida 33430 S. N. Knight, Sr., President	15 miles east of Belle Glade
Florida Sugar Corporation Post Office Box 1001 Belle Glade, Florida 33430 Frank L. Froment, President	11 miles east of Belle Glade
Glades County Sugar Growers Cooperative Association Post Office Box 727 Moore Haven, Florida 33471 Luis deArmas, Manager	Moore Haven, Florida
Osceola Farms Company Post Office Box 679 Pahokee, Florida 33476 Rafael Fanjul, General Manager	7 miles east of Canal Point, Florida, on Route 98
South Puerto Rico Sugar Company Okeelanta Division Post Office Box 86 South Bay, Florida 33493 Arthur Kirstein, President	South Bay, Florida
Sugar Cane Growers Cooperative of Florida Post Office Box 426 Belle Glade, Florida 33430 George H. Wedgworth, President	Belle Glade, Florida
Talisman Sugar Corporation Post Office Box 814 Belle Glade, Florida 33430 W. D. Pawley, President	17 miles south of South Bay, Florida
United States Sugar Corporation Post Office Drawer 1207 Clewiston, Florida 33440 John B. Boy, President	Clewiston, Florida Bryant, Florida

RAW CANE SUGAR PRODUCERS

Hawaii

Company Name and Address	Factory Location
Alexander & Baldwin, Ltd. Post Office Box 3440 Honolulu, Hawaii 96801 A. C. Wilcox, President	Hawaiian Commercial and Sugar Company Puunene, Maui 96784
	Kahuku Plantation Co. Kahuku, Oahu 96731 E.B. Holroyde, President
	McBryde Sugar Company, Ltd. Eleele, Kauai 96705 E.B. Holroyde, President
Amfac, Inc. Post Office Box 3230 Honolulu, Hawaii 96801	Kekaha Sugar Company, Ltd. Kekaha, Kauai 96752 Karl H. Berg, President
	Lihue Plantation Co., Ltd. Lihue, Kauai 96766 K.H. Berg, President
	Oahu Sugar Company, Ltd. Waipahu, Oahu 96797 Karl H. Berg, President
	Puna Sugar Company, Ltd. Keaau, Hawaii 96749 Karl H. Berg, President
	Pioneer Mill Company, Ltd. Lahaina, Maui 96761 Karl H. Berg, President
Bishop Trust Company, Ltd. Honolulu, Hawaii 96802	Gay & Robinson Makaweli, Kauai 96769

Company Name and Address	Factory Location
C. Brewer & Company, Ltd. Post Office Box 3470 Honolulu, Hawaii 96801 Boyd MacNaughton, President	Hawaiian Agricultural Co. Pahala, Hawaii 96777 Ernest A. Smith, Manager
	Hutchinson Sugar Co., Ltd. Naalehu, Hawaii 96772 J. C. Stopford, President
	Kilauea Sugar Company, Ltd. Kilauea, Kauai 96754 James C. Stopford, President
	Mauna Kea Sugar Co., Inc. Hilo, Hawaii 96720 Boyd MacNaughton, Chairman
	Olokele Sugar Company, Ltd. Kaumakani, Kauai 96747 James C. Stopford, President
	Paauhau Sugar Company, Ltd. Paauhau, Hawaii 96775 James Stopford, President
	Pepeekeo Sugar Company Pepeekeo, Hawaii 96783 James C. Stopford, President
	Wailuku Sugar Company Wailuku, Maui 96793 James C. Stopford, President
Castle & Cooke, Inc. Post Office Box 2990 Honolulu, Hawaii 96802 Malcolm MacNaughton, President	Kohala Sugar Company Hawi, Hawaii 96719 Henry B. Clark, Jr., President
	Waialua Sugar Company, Inc. Waialua, Oahu 96791 H. B. Clark, Jr., President

Company Name and Address	Factory Location
Theo H. Davies & Company, Ltd. Post Office Box 3020 Honolulu, Hawaii 96802	Hamakua Mill Company Paauilo, Hawaii 96776 Leon A. Thevenin, Manager
	Honokaa Sugar Company Haina, Hawaii 96709 M. H. Pickup, President
	Laupahoehoe Sugar Company Papaaloa, Hawaii 96780 M. H. Pickup, President
Grove Farm Company, Inc. Puhi, Kauai 96766	Grove Farm Company, Inc. Puhi, Kauai 96766

RAW CANE SUGAR PRODUCERS

Louisiana

Company Name and Address	Factory Location
Albania Sugar Company, Inc. Jeanerette, Louisiana 70544	Jeanerette, Louisiana
Alma Plantation, Ltd. Highway 413 Lakeland, Louisiana 70752 Mrs. Margebelle Stewart, President	Lakeland, Louisiana
J. Aron & Company, Inc. 336 Magazine Street New Orleans, Louisiana 70130 W.B. Burkenroad, Jr., President	Supreme, Louisiana
Billeaud Sugar Factory, Inc. Post Office Box 98 Broussard, Louisiana 70518 P. Lacaze Billeaud, President	Broussard, Louisiana
Breaux Bridge Sugar Coop., Inc. Post Office Box 236 Breaux Bridge, Louisiana 70517 Irving Broussand, President	Breaux Bridge, Louisiana
Wm. T. Burton Industries, Inc. White Castle, Louisiana 70788	(Cedar Grove Mill) White Castle, Louisiana
Caire & Graugnard Post Office Box 7 Edgard, Louisiana 70049	(Columbia Mill) Edgard, Louisiana
Cajun Sugar Cooperative, Inc. Post Office Box 1179 New Iberia, Louisiana 70560 James P. Cross, President	New Iberia, Louisiana
Caldwell Sugars Cooperative, Inc. Post Office Box 226 Thibodaux, Louisiana 70301 Victor F. Bailliet, Chief Executive	Thibodaux, Louisiana

Company Name and Address	Factory Location
Colombia Sugar Company Box 344 Franklin, Louisiana 70538	Franklin, Louisiana
Cora-Texas Manufacturing Co. Post Office Box 248 White Castle, Louisiana 70788 Paul Kessler, President	White Castle, Louisiana
Dugas & LeBlanc Ltd. Paincourtville, Louisiana 70391 Felix H. Savoie, President	(Westfield Mill) Paincourtville, Louisiana
Duhe & Bourgeois Sugar Company Post Office Box 648 Jeanerette, Louisiana 70544	Jeanerette, Louisiana
Evan Hall Sugar Cooperative, Inc. Post Office Box 431 Donaldsonville, Louisiana 70346 James H. Thibaut, President	McCall, Louisiana
Frisco Cane Company, Inc. Reserve, Louisiana 70084	(San Francisco Mill) Reserve, Louisiana
Glenwood Cooperative, Inc. Assumption Parish Napoleonville, Louisiana 70390 John Thibaut, President	Napoleonville, Louisiana
Helvetia Sugar Co-op, Inc. Route 1 Convent, Louisiana 70723 Ernest Martine, President	Convent, Louisiana
Iberia Sugar Cooperative, Inc. Post Office Box 1389 New Iberia, Louisiana 70561 John L. Germany, President	New Iberia, Louisiana
LaFourche Sugar Company Post Office Box 555 Thibodaux, Louisiana 70301 Harvey Peltier, Manager	(Leighton Mill) Thibodaux, Louisiana

Company Name and Address	Factory Location
Harry L. Laws & Company, Inc. Brusly, Louisiana 70719 E. B. Terrill, Jr., President	(Cinclare Mill) Brusly, Louisiana
Levert-St. John, Inc. Route 1, Box 10 St. Martinville, Louisiana 70582 Ramon E. Billeaud, President	(St. John Mill) St. Martinville, Louisiana
Louisiana State Penitentiary Angola Factory Angola, Louisiana 70712	Angola, Louisiana
Louisiana State University Audubon Sugar Factory Baton Rouge, Louisiana 70803	Baton Rouge, Louisiana
Louisa Sugar Cooperative, Inc. Louisa, Louisiana 70553	Louisa, Louisiana
Meeker Sugar Cooperative, Inc. Meeker Rural Station LeCompte, Louisiana 71346 S. C. Bain, President	LeCompte, Louisiana
Milliken & Farwell, Inc. Port Allen, Louisiana 70767 F. Evans Farwell, President	Port Allen, Louisiana
M. A. Patout & Son, Ltd. Route 1, Box 288 Jeanerette, Louisiana 70544 J. Patout Burns, President	(Enterprise Mill) Jeanerette, Louisiana
Poplar Grove Planting & Refining Company, Inc. Port Allen, Louisiana 70767	Port Allen, Louisiana
St. James Sugar Cooperative, Inc. St. James, Louisiana 70086	St. James, Louisiana
St. Mary Sugar Cooperative, Inc. Post Office Box 269 Jeanerette, Louisiana 70544 C. Beverly Causey, President	Jeanerette, Louisiana

Company Name and Address	Factory Location
Savoie Industries Lulu Factory, Inc. Belle Rose, Louisiana 70341 Mrs. S.S. Chancienne, Partner	(Lula Mill) Belle Rose, Louisiana
South Coast Corporation 226 Carondelet Street New Orleans, Louisiana 70130 Sidney J. Menard, President	(Oaklawn Mill) Franklin, Louisiana (Georgia Mill) Mathews, Louisiana (Terrebonne Mill) Montegut, Louisiana (Raceland Mill) Raceland, Louisiana
Southdown Lands, Inc. 1221 Commerce Building Post Office Box 52378 New Orleans, Louisiana 70130	(Southdown Mill) Houma, Louisiana (Greenwood Mill) Thibodaux, Louisiana (Armant Mill) Vacherie, Louisiana
Sterling Sugars, Inc. Post Office Box 572 Franklin, Louisiana 70538 Thomas H. Allen, Exec. V.P.	Franklin, Louisiana
J. Supple's Sons Planting Co., Ltd. Highway 1 Bayou Goula, Louisiana 70716 Edward T. Supple, President	(Catherine Mill) Bayou Goula, Louisiana
Valentine Sugars, Inc. RFD 1 Lockport, Louisiana 70374 Will J. Gibbens, Jr., President	Lockport, Louisiana
Vida Sugars, Inc. Post Office Box 336 Loreauville, Louisiana 70552	Loreauville, Louisiana
A. Wilbert's Sons Post Office Box 540 Plaquemine, Louisiana 70764	(Myrtle Grove Mill) Plaquemine, Louisiana

RAW CANE SUGAR PRODUCERS

Puerto Rico

Company Name & Address	Factory Location
Antonio Roig Sucesores, Inc. Humacao, P.R. 00661	Roig
Asociacion Azucarera Cooperativa Lafayette Arroyo, P.R. 00615	Lafayette
The New Central Aguirre Land Administration of Puerto Rico Aguirre, P.R. 00608	Aguirre Cortada
Central Coloso, Inc. Post Office Box 2912 San Juan, P.R. 00903	Coloso
Central Eureka, Inc. Post Office Box 419 Mayaguez, P.R. 00708	Eureka
Central Igualdad, Inc. Post Office Box 599 Mayaguez, P.R. 00708	Igualdad
Central Mercedita, Inc. Mercedita, P.R. 00715	Mercedita
Central Monserrate, Inc. Box 445 Manati, P.R. 00701	Monserrate
Central San Francisco Box 5 Yauco, P.R. 00768	San Francisco
Cooperative Azucarera Central Juncos Box 519 Juncos, P.R. 00666	Juncos
Land Authority Commonwealth of Puerto Rico Post Office Box 9745 Santurce, P.R. 00908	Cambalache Fajardo

Company Name & Address	Factory Location
Plata Sugar Company, Inc. Post Office Box 228 San Juan, P.R. 00902	Plata
Central Guanica Land Administration of Puerto Rico Ensenada, P.R. 00647	Guanica
Central Roig Refining Company Humacao, P.R. 00661	
Puerto Rican American Sugar Refinery, Inc. Mercedita, P.R. 00715	
Western Sugar Refining Company Box 6 Mayaguez, P.R. 00709	

CANE SUGAR PRODUCERS ASSOCIATIONS

American Sugar Cane League, Inc.
416 Whitney Building
New Orleans, Louisiana 70130

Florida Sugar Cane League, Inc.
Post Office Box 1148
Clewiston, Florida 33440

Hawaiian Sugar Planters Association
Post Office Box 2450
Honolulu, Hawaii 96804

CONSULTANTS

(Air)

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2512 S. W. 34th Street
Gainesville, Florida 32601

F. C. Schaffer & Associates, Inc.
185 Bellewood Drive
Baton Rouge, Louisiana 70806

Environmental Engineering, Inc.
2324 S. W. 34th Street
Gainesville, Florida 32601

CANE SUGAR RESEARCH INSTITUTES

Institute of Food and Agricultural Sciences
University of Florida
Everglades Experiment Station
Belle Glade, Florida 33430

Hawaii Sugar Planters Association
Experiment Station
Post Office Box 2450
Honolulu, Hawaii 96804

Audubon Sugar Factory
Louisiana State University
Baton Rouge, Louisiana 70803

International Sugar Research Foundation, Inc.
7316 Wisconsin Avenue
Bethesda, Maryland 20014
(Cane and Beet)

APPENDIX B

STATUS OF AIR QUALITY IN THE SUGAR CANE AREA OF FLORIDA

E. R. Hendrickson, Ph.D., P. E.
Environmental Engineering, Inc.
Gainesville, Florida

INTRODUCTION

Ambient air studies of limited scope plus theoretical emission and dispersion calculations conducted during 1967 and 1968 by personnel of the Palm Beach County Health Department led to the contention that the sugar industry was a major contributer to polluted air in southeast Florida. These calculations led the air pollution control authorities to conclude that the industry was responsible for more than 25 percent of the "total air pollution" and more than 95 percent of suspended particulates. Based on sampling for suspended particulates at 3 stations they concluded that the sugar cane growing area was substantially higher than other areas of Palm Beach County, and that the levels increase significantly during the harvesting season.

Based on the observations which were made, the state pollution control authorities served notice on the 9 operating mills that they were in violation of existing regulations. This action set off a round of source evaluation and the development of an extensive air quality improvement program on the part of the Florida Sugar Cane League, Inc. The source sampling revealed that all boilers in the industry were

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exceeding the existing process weight limitations of the state regulations when burning bagasse. This regulation should not be applied to a combustion source since it originally was developed for application to metallurgical furnace fumes. The application to bagasse boilers represents an arbitrary extrapolation from a completely different type of source, it is not related to reduction of some undesirable condition in the environment, the size of particles emitted from bagasse furnaces is such that they are largely non-respirable, and the majority of the weight of the particles falls out on farmland owned by the growers. These preliminary observations raised doubt as to the validity of the official claims.

The Florida Sugar Cane League, Inc. retained Environmental Engineering, Inc. and David B. Smith Engineers, Inc. as a joint venture to plan and conduct an air quality improvement program. The program included continuation of the bagasse boiler emission evaluation, pilot plant studies of devices for reduction of particulate emissions from the boilers, evaluation of the magnitude of particulate emissions from cane field burning, and an ambient air survey for particulates and sulfur dioxide. Concurrently the Florida Agricultural Experiment Station conducted an evaluation of alternatives to cane field burning. This paper reports the results of the ambient air survey.

PROJECT DESIGN

Working in close coordination with the state and county regulatory agencies, the League developed and implemented a massive ambient air study covering the entire Florida sugarcane growing and processing area. The study which started in September, 1969, and continued through May, 1970, encompassed pre-season, season, and post-season conditions. The major objective of the ambient air study was to evaluate the air quality of the area, including rural as well as populated centers. It also was intended to estimate the influence of sugar harvesting and mill operations on the air quality.

The ambient air survey involved a meterological network, a sampling network for suspended and settleable particulates, a sampling network to monitor sulfur oxides, aircraft sampling, a sub-system for reporting time and location of field burning, and a correlation program.

Meteorological stations in the area were considered to be atypical because of their location and the location of possible obstructions. A site was selected south of Okeelanta which was considered to be more typical of the entire sugarcane growing area. A meteorological station consisting of a recording wind direction and velocity unit was installed at this location. Hourly average figures were tabulated for both wind direction and velocity. Each month a windrose was constructed. Rainfall data were collected from several other meteorological stations in the area.

Thirty-four ambient air sampling sites were selected in the tri-county area. These initially were located on a grid network which was later modified by field investigation. Final location depended on access, site conditions, security, and availability of electricity.

Eight of the sites were in urban areas, located on the rooftops of buildings, and twenty-six were in rural areas on power poles. Figure 1 shows the location of individual stations.

All thirty-four stations were equipped with dustfall buckets to measure the settleable particulate concentration accumulated during a 30-day exposure. The technique used is that essentially described in "Standard Method for Collection and Analysis of Dustfall," ASTM Designation D 1739-62. All samples were analyzed for insoluble particulates and water soluble particulates. The dustfall rate was determined by dividing the container opening area into the weights of soluble and insoluble particulates collected over a period of thirty days. Thirteen representative samples were sent to Walter C. McCrone Associates, Inc., for morphological examination to estimate the portion of each sample which was attributable to cane burning and boiler stack emissions as opposed to other settleable particulate matter. These samples were selected to show conditions during periods of burning and non-burning.

The eight urban stations, plus sixteen of the rural stations were equipped with high-volume samplers which collected suspended particulates during a 24-hour period. The Hi-Vols were operated once every fourth day during the survey period. The procedure used was essentially that described in "Recommended Standard Method for Atmospheric Sampling of Fine Particulate Matter by Filter Media--High-Volume Sampling," APM-2.5, APCA Committee TR-2. The samplers used were Curtin Model 1105-3C which were equipped with a on-off

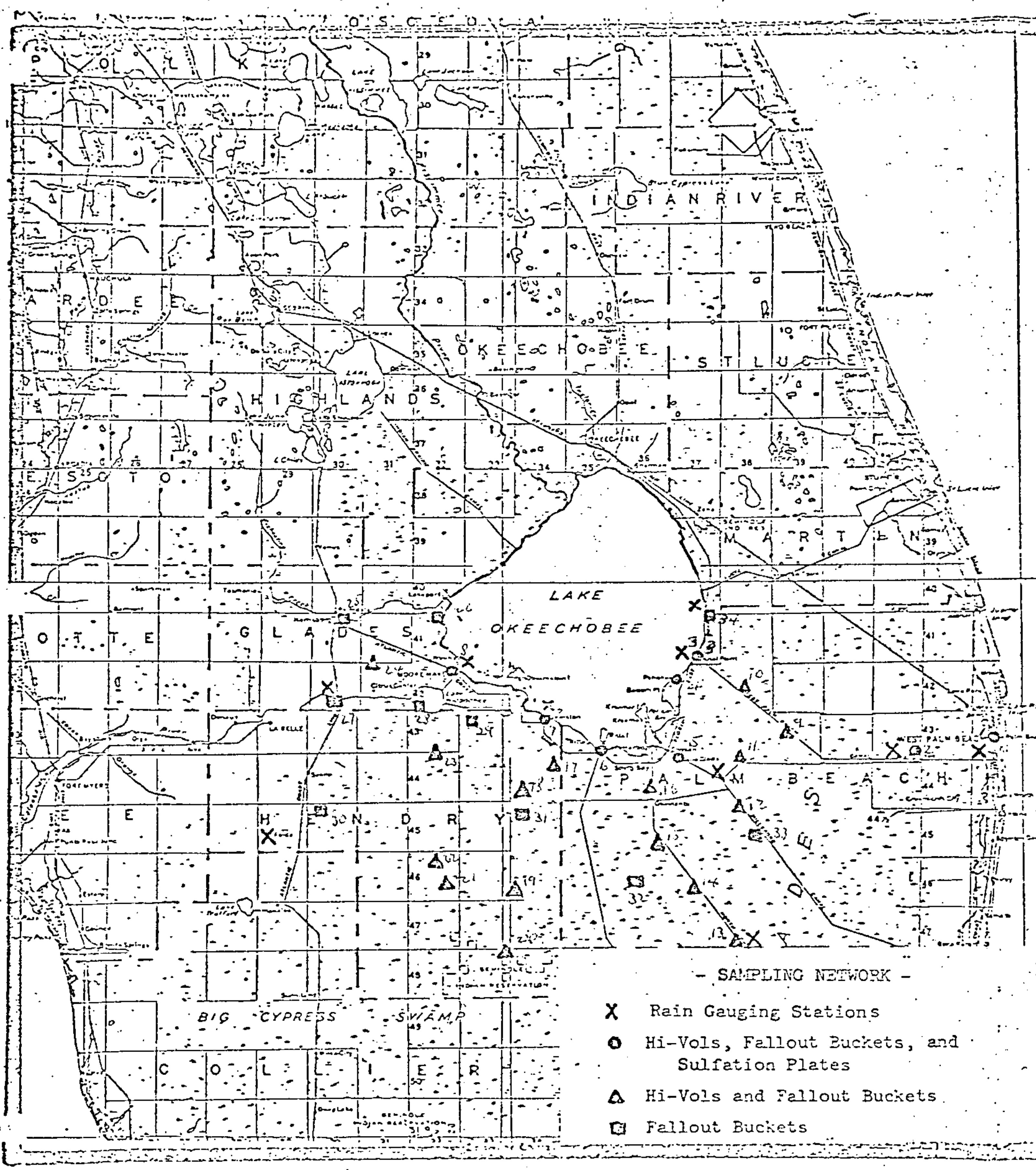


FIGURE 1. STATION LOCATION AND SAMPLING EQUIPMENT

timer and recording flow meter. The flow recorder was calibrated with a certified calibration orifice. Air samples were filtered through a Type A fiberglass filter at a rate of 30 - 50 CFM. The suspended particulate concentration was determined by dividing the filtered particulate weight by the metered air volume. Prior to weighing, filters were equilibrated in a special humidity and temperature controlled room for twenty-four hours. Twenty-three of the high-volume samples collected during the entire season were also subjected to a morphological examination by Walter C. McCrone, Associates, Inc. Those from the eastern part of the county were selected to show influence of west winds.

At the eight urban stations, sulfation rate was also monitored during the survey. The Huey sulfation plate was utilized for this purpose. Exposure was for the same period as the dustfall samplers. At the end of thirty days exposure, the samples were analyzed for the sulfation rate which is related to the sulfur dioxide concentration.

On several occasions, an instrumented airplane traversed the smoke plumes resulting from cane field burning. The instrumentation made it possible to estimate the particle size distribution in the plume at various altitudes and various distances from the burning field. Photographs also were taken of the field which was sampled.

In order to evaluate the different conditions which prevail during the season when burning operations take place, and when burning operations are not conducted, the sampling period started in September and ended in May. Field burning began during the latter half of November and ended about mid-March.

DISCUSSION OF RESULTS

<u>Settleable Particulate Data</u>. Settleable particulate matter usually is considered to be that fraction greater in size than 10 microns. Interpretation of the results of these measurements leaves much to be desired. It is usually considered to be a very gross measure of the general dirtiness of a community. Typical values for U.S. cities range from 10 to 100 tons per square mile per month.

Geometric mean concentrations for all thirty-four stations during the entire sampling period ranged from a low of 5 tons/mi^2/mo to a high of 22 tons/mi^2/mo. Stations were grouped as eastern stations (stations in Palm Beach County) and as western stations (stations in Hendry and Glades counties). The geometric mean values for the entire season were 12 tons/mi^2/mo for eastern stations and 8 tons/mi^2/mo for western stations. The geometric mean value for all stations during the sampling period of September, 1969, through May, 1970, was less than 10 tons/mi^2/mo. Data from the Palm Beach County Health Department indicates that lower concentrations are experienced during the summer months, therefore, the mean value of less than 10 tons/mi^2/mo would probably have been reduced if the summer months would have been included in the sampling period.

Results of the morphological examination revealed that the amount of burned plant material in the samples taken during the burning season ranged between 11 and 47 weight percent. During the season when cane was not being burned, the value ranged from less than 1 to 43 weight percent. The category of "burned plant material" includes not only particulates resulting from cane processing operations, but also particulates from any vegetation which is burned intentionally or accidentally.

The levels observed are generally acceptable in residential areas. Very little data relating to effects as measured by settleable particulates can be found.

Suspended Particulate Data. The category of suspended particulate matter to some extent, is defined by the method of collection and analysis. Using the Hi-vol filter and glass fiber filters, the size range is about 0.1 to less than 100 microns. Suspended particulates, in appropriate concentration, have been related to human health effects, materials damage, and visibility interference. According to the criteria document of the National Air Pollution Control Administration the minimum levels at which adverse effects have been noted include: 80 to 100 micrograms per cubic meter ($\mu g/m^3$) in the presence of sulfation rates exceeding 30 $mg/cm^2/mo.$ - increased death rates for persons over 50 may occur; 60 to 180 $\mu g/m^3$ in the presence of sulfur dioxide and moisture - corrosion of steel and zinc panels occurs at an accelerated rate; about 150 $\mu g/m^3$ (where predominant particle size ranges from 0.2 to 1 micron) and relative humidity is less than 70 percent - visibility may be reduced to as low as 5 miles. All values except that for visibility are annual geometric means. The concentration for visibility is a 24-hour observation.

Observed values in near-urban and urban areas range from about 60 to 200 $\mu g/m^3$ annual geometric mean. Individual 24-hour observations may vary 300 to 700 percent from the mean.

The first field burning began on November 11, 1969, and continued on through March 22, 1970. During this time approximately 138,120 acres of sugar cane was burned. Based upon field burning data, 23 percent of this total acreage was burned on days that suspended particulate samples were being taken. The number of sample days during the time this acreage was burned represented about 25 percent of the total number of days during the entire burning season.

Maximum, minimum, and geometric mean concentrations of the suspended particulate data are shown in Table 1, which includes a differentiation between burning and non-burning conditions. During the burning season the geometric mean concentrations for all twenty-four stations ranged between 22 and 70 $\mu g/m^3$. The range of concentrations for the non-burning season was between 26 and 100 $\mu g/m^3$. The geometric mean concentration of all stations operating during the burning season was 39 $\mu g/m^3$, and during the non-burning season it was 44 $\mu g/m^3$. The range of suspended particulate concentrations in which most burning and non-burning samples fell was between 10 and 50 $\mu g/m^3$ as shown in Figure 2.

As previously mentioned, the stations were separated into eastern and western groups. The geometric mean concentration for suspended particulate in the eastern stations was 48 $\mu g/m^3$, and in the western stations it was 32 $\mu g/m^3$. When all data were evaluated for both burning and

TABLE 1

HI-VOLUME AIR SAMPLER DATA

Sta. No.	Suspended Particulate Concentration, μg/m³ — Burning Season* Max.	Min.	Geo. Mean	No. of Samples	Non-Burning Season** Max.	Min.	Geo. Mean	No. of Samples	Entire Season*** Max.	Min.	Geo. Mean	No. of Samples
1	85	31	56	34	77	40	57	19	85	31	56	53
2	41	8	25	32	40	9	26	22	41	8	25	54
3	177	12	34	34	92	14	33	33	177	12	34	67
4	152	27	70	26	183	18	69	28	183	18	69	54
5	138	15	60	34	112	20	49	32	138	15	54	66
6	56	18	34	23	57	16	28	14	57	16	32	37
7	89	27	50	20	105	25	48	21	105	25	49	41
8	262	13	48	29	99	12	40	29	262	12	44	58
9	133	17	45	32	84	18	59	19	133	17	50	51
10	150	18	68	31	181	25	61	19	181	18	65	50
11	80	19	45	23	102	24	45	18	102	19	45	41
12	129	19	54	29	344	32	100	16	344	19	67	45
13	142	28	70	20	152	33	86	19	152	28	77	39
14	135	21	43	32	100	28	50	16	135	21	46	48
15	130	19	42	33	145	24	50	19	145	19	45	52
16	78	21	37	16	105	27	58	19	105	21	47	35

- continued -

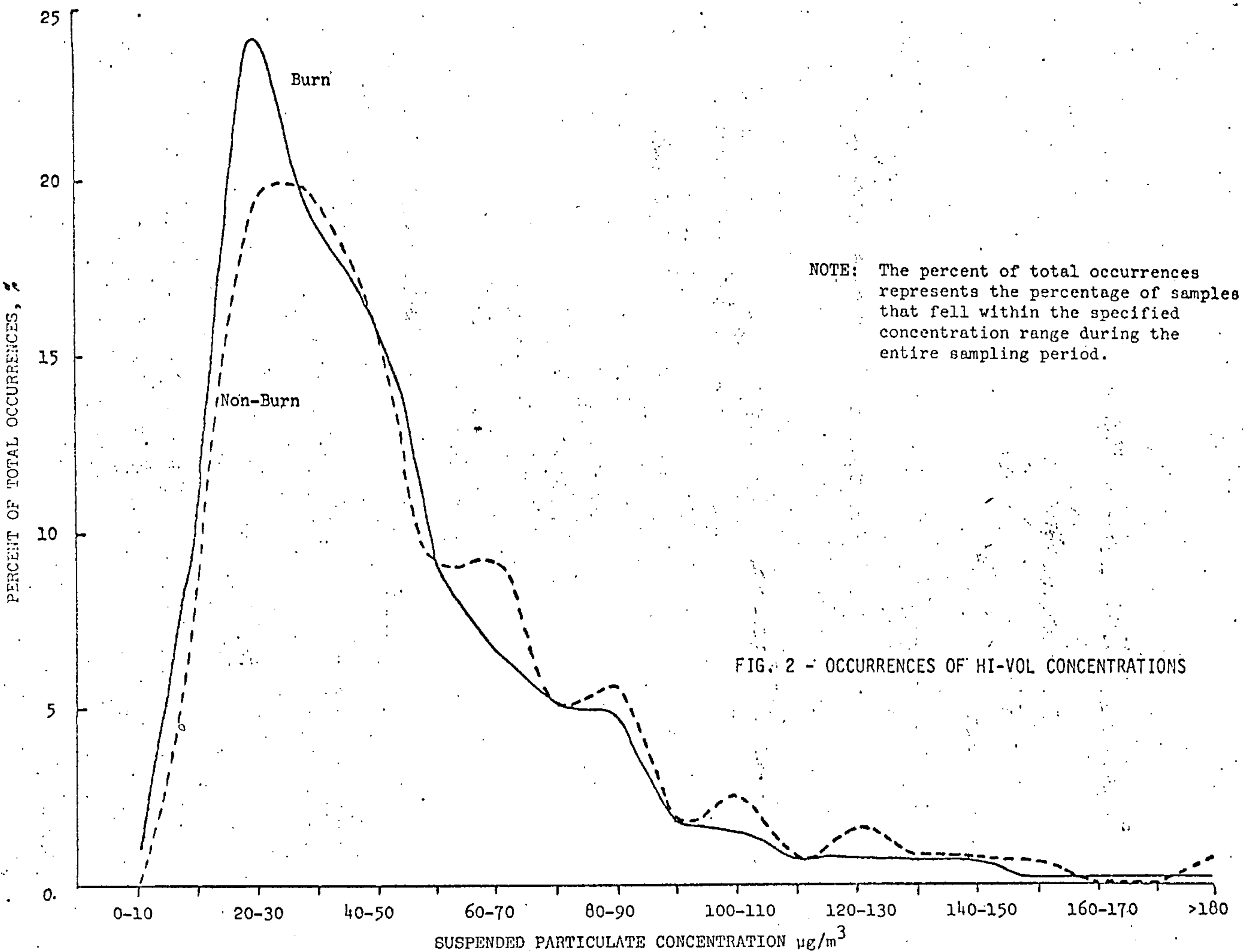
* Nov. 12, 1969, through Mar. 20, 1970
** Sept. 10, 1969, through Nov. 8, 1969, and Mar. 24, 1970, through May 31, 1970
***Sept. 10, 1969, through May 31, 1970

TABLE 1 (CONTINUED)

HI-VOLUME AIR SAMPLER DATA

	Suspended Particulate Concentration, $\mu g/m^3$											
	Burning Season*				Non-Burning Season**				Entire Season***			
Sta. No.	Max.	Min.	Geo. Mean	No. of Samples	Max.	Min.	Geo. Mean	No. of Samples	Max.	Min.	Geo. Mean	No. of Samples
17	100	13	44	22	158	32	73	14	158	13	54	36
18	49	8	27	29	51	14	32	16	51	8	29	45
19	88	18	28	23	47	12	30	18	88	12	29	41
20	51	7	26	33	49	12	30	18	51	7	27	51
21	46	10	22	30	44	10	26	18	46	10	24	48
22	237	8	29	32	550	18	43	18	550	8	33	50
23	48	14	23	29	51	19	28	17	51	14	25	46
24	42	8	25	26	43	12	27	15	43	8	26	41

* Nov. 12, 1969, through Mar. 20, 1970
** Sept. 10, 1969, through Nov. 8, 1969, and Mar. 24, 1970, through May 31, 1970
***Sept. 10, 1969, through May 31, 1970



NOTE: The percent of total occurrences represents the percentage of samples that fell within the specified concentration range during the entire sampling period.

FIG. 2 - OCCURRENCES OF HI-VOL CONCENTRATIONS

non-burning conditions, the geometric mean concentration for the sampling period was 41 $\mu g/m^3$. This value would probably have been reduced if the sampling period had included the summer months, because data from the Palm Beach County Health Department indicates lower concentrations during this period.

Morphological examination of the samples taken during the burning season resulted in observations of 15 to 54 weight percent burned plant material. During the non-burning season the range was 4 to 14 weight percent. Included in these figures were particulates from cane processing operations as well as particulates from any other vegetation burning.

Using data which were collected on wind direction and velocity as well as information on location and duration of burning cane fields, station locations were identified for each day of operation in which three or more were in a narrow sector affected by only one burn or a clustered group of burns. An attempt was made to correlate station location and distance from burn with suspended particulate concentration. No correlation was found.

Since, on any given day of operation, one location may have been exposed to the particulate from several different burns, the total time of possible exposure for each location was calculated. An attempt to relate this information to suspended particulate concentration for each station for each day of operation also resulted in no apparent correlation.

The observed values, when adjusted for the lower concentrations which are said to occur during the summer months, are well below those which are related to any adverse effects on health or materials even in the presence of substantial concentrations of sulfur dioxide. Occasional 24-hour concentrations were noted which would indicate possible interference with visibility. Six of these occasions were noted during the burning season and six during the non-burning season.

Sulfur Oxide Data. The maximum observed sulfation rate outside of West Palm Beach was 3.2 $\mu g\ SO_3/cm^2/day$ and the minimum 0.01. The maximum geometric mean of the sulfation rate that occurred during the sampling period was 0.51 $\mu g\ SO_3/cm^2/day$, and the minimum value was 0.16 $\mu g\ SO_3/cm^2/day$. This is an indication of an extremely low level of sulfur dioxide exposure, far below any adverse health effects even in the presence of particulate matter.

Aircraft Sampling. Several attempts were made to measure the rate of particulate emission from burning cane fields. Transverse and longitudinal paths were followed in each plume. The airplane was equipped with an optical particle counter with which it was possible to measure the number of particles in several discrete size ranges from 0.3 to 7 microns. The data collected were inconclusive.

General observations were that a quantity of large particles fall out on the cane fields as soon as they are released from the thermal updraft. Some large particles were carried to several thousand feet before settling began. The upper air plume contained quantities of micron and sub-micron particles. The rapidity with which the volume of the plume changed made it impossible to obtain significant concentration traverses.

CONCLUSIONS

The results of the most comprehensive evaluation of air quality ever conducted in this area indicate a very good quality of air as measured by some of the common indicators of air pollution. Three of the 34 stations used were in locations common to those of the Palm Beach County Health Department. Data collected by this survey at the common stations compared well with data collected by the Department.

The most important finding was that the average suspended particulate matter concentration during the entire survey was less than 41 $\mu g/m^3$ (annual geometric mean). This represents a very good quality of air which is better than the lowest criteria values developed by NAPCA. Comparison with the NAPCA criteria values is even more favorable when it is considered that the NAPCA values assume the presence of appreciable quantities of sulfur dioxide. The observed SO_2 levels both in this survey and the survey by the Palm Beach County Health Department were very low. SO_2 levels are well below those which indicate impaired air quality according to NAPCA.

Little difference was noted in average values of suspended particulates between the east and west parts of the surveyed area and between urban and rural areas. Little difference also was noted in the weight of material collected by the samplers during periods when the sugar cane fields were being burned and when they were not, although the makeup of the material was different at the two times. The maximum weight percent of the burned vegetation (which may or may not be attributed to cane burning operations) observed at the 34 sampling stations was about 50 percent. The remaining was dust, sand, and other naturally occuring materials. Occasionally excursions to nuisance levels of particulate concentrations were observed both during the period when cane was being harvested and when it was not. These high levels are included in the calculated average concentrations.

The general conclusions which can be drawn for the nine month study is that although the sugar cane industry, along with other natural and man made sources, occasionally may be the cause of nuisance levels of particulate matter and dustfall, the observed air quality in the area is far from being detrimental to the health or property of man.