# EMISSION FACTOR DOCUMENTATION FOR

# AP-42 SECTION 1.8

# BAGASSE COMBUSTION IN SUGAR MILLS


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# 1. INTRODUCTION

The document "Compilation of Air Pollutant Emission Factors" (AP-42) has been published by the U.S. Environmental Protection Agency (EPA) since 1972. Supplements to AP-42 have been routinely published to add new emission source categories and to update existing emission factors. AP-42 is routinely updated by EPA to respond to new emission factor needs of EPA, State, and local air pollution control programs and industry.

An emission factor relates the quantity (weight) of pollutants emitted to a unit of activity of the source. The uses for the emission factors reported in AP-42 include:

1. Estimates of area-wide emissions;
2. Emission estimates for a specific facility; and
3. Evaluation of emissions relative to ambient air quality.

The purpose of this report is to provide background information from over 12 test reports to support revision of emission factors for bagasse combustion in sugar mills.

Including the introduction (Chapter 1), this report contains five chapters. Chapter 2 gives a description of the use of boilers for bagasse combustion in the sugar cane industry. It includes a characterization of the industry, an overview of the different process types, a description of emissions, and a description of the technology used to control emissions resulting from bagasse-fired boilers. Chapter 3 is a review of emissions data collection and analysis procedures. It describes the literature search, the screening of emission data reports, and the quality rating system for both emission data and emission factors. It also describes particle size determination and particle size data analysis methodology. Chapter 4 details pollutant emission factor development. It includes the review of specific data sets, the results of data analysis, and the data base protocol. Chapter 5 presents the AP-42 Section 1.8.

## 2. INDUSTRY DESCRIPTION

Bagasse is a solid waste product associated with sugar mills. Previously, bagasse was burned as means of solid waste disposal. However, as the cost of fuel oil, natural gas, and electricity have increased, the definition of bagasse has changed from refuse to a fuel. Currently, most bagasse is burned as a fuel, not as the incineration of refuse.[1] In at least one mill, bagasse is sent to an adjacent chemical production plant for use in making furfural; the bagasse residue is returned as fuel for generating steam for both facilities.[2]

### 2.1 CHARACTERIZATION OF THE INDUSTRY[1,2,3]

As of 1980, there were approximately 185 bagasse-fired boilers operating in Florida, Louisiana, Texas, and Hawaii. Bagasse boilers ranged in capacity from approximately 4.4 to 230 MW (15 to 800 million Btu/hr) heat input, or approximately 3,400 to 210,000 kg/hr (7,500 to 460,000 lb/hr) steam output. Between 1982 and 1990, new capacity was expected to be installed at an average rate of four to five bagasse-fired boilers per year, due primarily to growth in boiler capacity expected in Florida and to the replacement of older boilers with new ones in other areas.

The U.S. sugar cane industry is located in the tropical and subtropical regions of Florida, Texas, Louisiana, Hawaii, and Puerto Rico. The sugar cane growing season is approximately 6 months in Louisiana, 12 months in Florida and Texas, and about 2 years in Hawaii. Except in Hawaii, where raw sugar production takes place year round, sugar mills operate seasonally, from 2 to 5 months per year.

### 2.2 PROCESS DESCRIPTION[1,2,3,4]

Sugar cane is a large grass that has a bamboo-like stalk, grows 2.5 to 4.5 meters (8 to 15 feet) high, and contains a large amount of sucrose in the stalk. Different varieties occur throughout the tropical and semitropical regions of the world; they are the results of diverse soil conditions, climates, and modes of cultivation.

#### 2.2.1 Harvesting Methods

Only the stalk contains sufficient sucrose for processing into sugar. All other parts of the sugar cane (i.e., leaves, top growth and roots) are termed "trash". The objective of harvesting is to deliver the sugar cane to the mill with a minimum of "trash" or other extraneous material. The cane is normally burned in the field to remove a major portion of the "trash" and to control insects and rodents. Cane burning is especially prevalent in areas where labor is expensive. The stalk is not injured by burning but the rate of deterioration is increased.

Three general methods of harvesting are most common:

1. Hand Cutting: Involves laborers who cut the cane close to the ground and then top it just above the highest colored joint and thus remove much of the unburned trash.

2. Machine Cutting: Attempts to do the same type of bottom and top cutting as by hand but normally leaves more "trash" on the stalk and gathers more mud and dirt.

3. Mechanical Raking: A labor-saving harvesting method that pushes down the cane rather than cutting it. Trash, dirt, mud, rocks and scrap metal are carried to the mill along with the cane.

Variations in the above procedures are the rule, not the exception. Therefore, the cane that is delivered to a particular mill will vary in "trash" and dirt content depending on which plantation the cane is grown and the weather conditions. State-to-state variations in the "trash" and dirt content of delivered cane are large. The general practice in Florida is hand or machine cutting, with many plantations cutting the stalks into 30- to 45-centimeter (12- to 18-inch) pieces. Louisiana uses machine cutting almost entirely. Hawaii uses mostly mechanical raking. Thus, the cane as delivered to the mills in Hawaii normally contains much more trash, dirt, rocks, mud, and scrap metal than the cane delivered to the mills in Florida.

### 2.2.2 Cleaning and Milling

The cane is transported to the mill as soon as possible after harvesting to prevent loss of sugar content. After delivery to the mill, the cane is prepared prior to extraction of the juice. This preparation varies from mill to mill but usually involves washing the cane to remove the "trash" and dirt, chopping, then crushing. Mills that normally handle dirty cane tend to wash the incoming cane much more than other mills. Some mills have large electromagnets to remove scrap metal that is inadvertently brought into the plant with the cane. In general, the mills in Hawaii wash their cane through an involved series of sprays and baths while also separating out large objects. The mills in Florida, where hand-cutting is normally used, may spray only a small amount of water to wash the mud off during the rainy season. Labor-saving harvesting methods tend to result in more capital expenditures and more water usage for washing. Figure 2-1 shows a typical process diagram for a sugar cane mill. The milling portion of the plant consists of up to seven individual mills, each of which has three grooved rolls. Juice is extracted by passing the chopped and crushed cane through the series of mills. About 90 to 95 percent of the available sucrose is extracted from the cane. The remaining cane is called "bagasse" and consists of matted cellulose fibers and fine particles. It is normally used in the boilers for fuel, but it may be used to produce other products such as paper, wallboard, and furfural.

### 2.2.3 Fuel Characteristics

Bagasse is a fuel of varying composition, consistency, and heating value. These characteristics depend on the climate, type of soil upon which the cane is grown, variety of cane, harvesting method, amount of cane washing, and the efficiency of the milling plant. In general, bagasse has a heating value between 1,600 and 2,200 kcal/kg (3,000 and 4,000 Btu/lb) on a wet, as-fired basis. Most bagasse has a moisture content between 45 and 55 percent by weight. The lower bagasse moisture contents are generally found in Hawaii. The sulfur and nitrogen contents of bagasse are generally near or below 0.1 weight percent with ash contents generally less than 2 weight percent, as fired. Table 2-1 shows a typical bagasse composition for a Florida sugar mill.

### 2.2.4 Boiler Types

Fuel cells, horseshoe boilers, and spreader stoker boilers are used to combust bagasse. Horseshoe boilers and fuel cells differ in the shapes of their furnace area but in other respects are similar in design and operation. In these boilers (most common among older plants), bagasse is gravity-fed through chutes and piles up on a refractory hearth. Primary and overfire combustion air flows through ports in the furnace walls; burning begins on the surface pile. Many of these units have dumping hearths that permit ash removal while the unit is operating.

In more-recently built sugar mills, bagasse is burned in spreader stoker boilers. Bagasse feed to these boilers enters the furnace through a fuel chute and is spread pneumatically or mechanically across the furnace, where part of the fuel burns while in suspension. Simultaneously, large pieces of fuel are spread in a thin, even bed on a stationary or moving grate. The flame over the grate radiates heat back to the fuel to aid combustion. The combustion area of the furnace is lined with heat exchange tubes (waterwalls). Figure 2-2 shows a schematic of a representative bagasse-fired spreader stoker boiler with a steam generating capacity of approximately 52,000 kg/hr (115,000 lb/hr).

## 2.3 EMISSIONS

### 2.3.1 Combustion Theory[1]

The complete combustion of bagasse can be thought of as occurring in two stages: primary and secondary combustion. Primary combustion refers to the physical and chemical changes occurring on the fuel bed. It consists of drying, devolatilization, ignition, and burning of the bagasse. Secondary combustion refers to the oxidation of the gases and particulate matter released by primary combustion. Secondary combustion is aided by high temperature, sufficient air and turbulence in the gas stream. The turbulence must be intense and last long enough to ensure adequate mixing at elevated temperatures.

Time, temperature, turbulence, and air require a delicate balance for complete combustion. A disturbance in one or more of these variables can reduce combustion efficiency and result in measurable increases in emissions of carbon monoxide (CO) and other organic compounds (i.e., the products of incomplete combustion). As a class, these organic compound emissions are generally measured either as volatile organic compounds (VOCs) or total organic compounds (TOCs).

### 2.3.2 Boiler Operating Procedures[2]

Boiler operating procedures can influence uncontrolled emissions from bagasse-fired boilers. First, like other waste-fired boilers, bagasse boilers may use auxiliary fuels for start-up. Because fuel oil is usually the start-up fuel, the initial sulfur dioxide ($SO_2$) and nitrogen oxides ($NO_x$) emissions are higher than when bagasse alone is fired. The duration of startup is typically up to 8 hours. During this period, particulate matter (PM) emissions may increase due to poor combustion conditions in the boiler while it is cold. In most areas, bagasse boilers are started up once at the start of the harvest season and are not shut down until the end of the season, unless it is absolutely necessary.

In Hawaii, the boilers are operated differently in that they are shut down on weekends unless they are cogenerating electricity. For economic reasons, cogeneration boilers typically operate continuously nearly year round. Also, bagasse-fired boilers in Hawaii are generally more efficient than in other areas due to lower fuel moisture contents, larger boiler sizes, and the placement of the stoker feed system higher above the grate to increase suspension burning.

Second, most bagasse boilers may cofire an auxiliary fuel (normally fuel oil or natural gas) at times to produce the total energy needed for the facility to sustain good combustion with wet bagasse. As is the case during startup, combined oil and bagasse firing will increase $SO_2$ and $NO_x$ emissions. Auxiliary fuel is used whenever additional heat input is required. If the supply of bagasse to the boiler is interrupted, auxiliary fuel will be used to provide up to 100 percent of the heat input of the boiler. During these periods, $SO_2$ and $NO_x$ emissions will increase. Facilities burning bagasse normally attempt to keep auxiliary fuel use to a minimum for economic reasons. Typically, less than 15 percent of the total annual fuel heat input into the boiler comes from fossil fuels. Bagasse-fired boilers in Hawaii which cogenerate electricity generally fire the largest amounts of fossil fuels because they are operated outside of the harvest season.

If boilers are undersized, soil brought in with the cane can become physically entrained by the high velocity of the combustion gases.[1] Soil characteristics such as particle size can affect the magnitude of PM emissions from the boiler. Mill operation can also influence the bagasse ash content by not properly washing and preparing the cane.

## 2.4 CONTROL TECHNOLOGY[1,2,3]

The primary emissions of concern for bagasse-fired boilers are particulates. Currently, there are four basic control devices used to reduce particulate emissions: (1) mechanical collectors (or cyclones), (2) wet scrubbers, (3) fabric filters, and (4) electrostatic precipitators. Before 1970, few bagasse-fired boilers were controlled with devices other than mechanical collectors. With the passage of more stringent air emission standards, wet scrubbers have become more common in Texas, Louisiana, and Florida.

Mechanical collectors, or cyclones, use centrifugal separation to remove PM from flue gas streams. At the entrance of the cyclone, a spin is imparted to the particle-laden gas. This spin creates a centrifugal force which causes the PM to move away from the axis of rotation and towards the walls of the cyclone. Particles which contact the walls of the cyclone tube are directed to a dust collection hopper where they are deposited.

In a typical single cyclone, the gas enters tangentially to initiate the spinning motion. In a multitube cyclone (or multiclone), the gas approaches the entrance axially and has the spin imparted by a stationary "spin" vane that is in its path. This allows the use of many small, higher efficiency cyclone tubes operating parallel to the gas flow stream, with a common inlet and outlet header.

One variation of the multitube cyclone is to place two similar mechanical collectors in series. This system is often referred to as a dual or double mechanical collector. The collection efficiency of the dual mechanical collector is theoretically improved over that of a single mechanical collector.

Mechanical collectors have been reported to have PM collection efficiencies of 20 to 60 percent. Particulate emissions from bagasse-fired boilers are considered to be abrasive and can cause erosion within the mechanical collector. Such erosion reduces PM collection efficiency over time unless corrective maintenance procedures are employed.

A wet scrubber is a collection device which uses an aqueous stream or slurry to remove particulate and/or gaseous pollutants. There are three basic mechanisms involved with collecting particulate matter in wet scrubbers: interception, inertial impaction, and diffusion of particles on droplets. The interception and inertial impaction effects dominate at large particle diameters; the diffusion effects dominate at small particle diameters.

Wet scrubbers are usually classified by energy consumption (in terms of gas-phase pressure drop). Low-energy scrubbers, represented by spray chambers and towers, have pressure drops of less than 1 kPa (5 inches of water). Medium-energy scrubbers such as impingement scrubbers have pressure drops of 1 to 4 kPa (5 to 15 inches of water). High-energy scrubbers such as high- pressure-drop venturi scrubbers have pressure drops exceeding 15 inches of water. Greater removals of PM are usually achieved with higher-energy scrubbers.

Currently the most widely used wet scrubbers for bagasse-fired boilers are impingement and venturi scrubbers. An impingement scrubber (also known as an orifice, self-induced spray, or entrainment scrubber) features a shell that retains liquid so that gas introduced to the scrubber impinges on and skims over the liquid surface to reach the gas exit duct. Atomized liquid is entrained by the gas and acts as a particle collecting and mass transfer surface. Particle collection results from inertial impaction caused by both the gas impinging on the liquid surface and by the gas flowing around the atomized drops.

In a typical venturi scrubber, the particle-laden gas first contacts the liquor stream in the core and throat of the venturi section. The gas and liquid streams then pass through the annular orifice formed by the core and throat, atomizing the liquid into droplets which are impacted by particles in the gas stream. Impaction results mainly from the high differential velocity between the gas stream and the atomized droplets. The droplets are then removed from the gas stream by centrifugal action in a cyclone separator and (if present) a mist eliminator section.

Wet scrubbers have reported PM collection efficiencies of 90 percent or greater. Operational problems can occur with wet scrubbers due to clogged spray nozzles, sludge deposits, dirty recirculation water, improper water levels, and unusually low pressure drops. The spray impingement scrubber is in greater use due to lower energy requirements and less operating and maintenance problems.

Gaseous emissions (e.g., $SO_2$, $NO_x$, CO, and organics) may also be absorbed to a significant extent in a wet scrubber. In addition, alkali compounds are sometimes utilized in the scrubber to prevent low pH conditions. If carbon dioxide-generating compounds (such as sodium carbonate or calcium carbonate) are used, carbon dioxide ($CO_2$) emissions will increase.

Fabric filtration is not currently being used to a significant extent for controlling PM emissions from bagasse-fired boilers in the U. S. The relative cost and the fire danger is generally given as the reason for not using fabric filtration.

Relative costs are also the primary reason why electrostatic precipitators are not being applied to bagasse-fired boilers in the U.S. to a significant extent. Electrostatic precipitators are being applied successfully to both wood waste combustion and municipal waste incineration. The similarities between bagasse combustion, wood waste combustion, and municipal waste incineration suggest that the application of electrostatic precipitators is possible.

## TABLE 2-1. TYPICAL FLORIDA MILL BAGASSE COMPOSITION[5]

| Parameter | Weight Percent, As Fired |
|---|---|
| Proximate Analysis | |
| Moisture | 58.7 |
| Ash | 0.8 |
| Volatile Matter | 35.8 |
| Fixed Carbon | 4.7 |
| | |
| Ultimate Analysis | |
| Carbon | 19.2 |
| Hydrogen | 2.6 |
| Sulfur | <0.1 |
| Ash | 0.8 |
| Nitrogen | 0.15 |
| Oxygen (By Difference) | 77.1 |
| | |
| Heating Value | 7,620 kJ/kg (3,280 Btu/lb) |

REFERENCES FOR CHAPTER 2


1. Potential Control Strategies for Bagasse Fired Boilers, EPA Contract No. 68-02-0627, Engineering-Science, Inc., Arcadia, CA, May 1978.

2. Background Document: Bagasse Combustion in Sugar Mills, EPA-450/3-77-077, U. S. Environmental Protection Agency, Research Triangle Park, NC, January 1977.

3. Nonfossil Fuel Fired Industrial Boilers - Background Information, EPA-450/3-82-007, U. S. Environmental Protection Agency, Research Triangle Park, NC, March 1982.

4. A Technology Assessment of Solar Energy Systems: Direct Combustion of Wood and Other Biomass in Industrial Boilers, ANL/EES-TM--189, Angonne National Laboratory, Argonne, IL, December 1981.

5. Emission Test Report For the Talisman Sugar Corporation, Belle Glade, Florida, EPA Contract No. 68-02-1406, Engineering-Science, Inc., McLean, VA, January 1976.

*(Figure Missing 3/17/99)*

Figure 2-2. Typical Spreader Stoker Boiler Used For Bagasse Combustion[3]

*(Figure Missing 3/17/99)*

Figure 2-1. Typical Sugar Cane Mill Process Diagram[1]

# 3. GENERAL DATA REVIEW AND ANALYSIS PROCEDURES

## 3.1 LITERATURE SEARCH AND SCREENING

The first step of this investigation involved a search of available literature relating to criteria and noncriteria pollutant emissions associated with bagasse combustion in sugar mills. This search included the following sources:

- AP-42 background files,
- Files and dockets maintained by the Emission Standards Division of OAQPS for relevant NSPSs and NESHAPs,
- "Locating and Estimating" reports available through EPA's Clearinghouse for Inventories and Emission Factors (CHIEF) web site,
- PM-10 "gap filling" documents in the OAQPS library,
- Publications available through EPA's Control Technology Center,
- Reports and project summaries from EPA's Office of Research and Development,
- Control Techniques Guideline documents generated by the Emission Standards Division of OAQPS,
- Information in the Air Facility System (AFS) of EPA's Aerometric Information Retrieval System (AIRS),
- Handbook of Emission Factors, Parts I and II, Ministry of Health and Environmental Protection, The Netherlands,
- EPA's CHIEF and National Air Toxics Information Clearinghouse (NATICH),
- EPA databases, including SPECIATE, XATEF, and TSAR,
- Various EPA contractor reports, and
- In-house files maintained the Contractor.

To reduce the large amount of literature collected to a final group of references pertinent to this report, the following general criteria were used:

1. Emissions data must be from a primary reference:

a. Source testing must be from a referenced study that does not reiterate information from previous studies.

b. The document must constitute the original source of test data. For example, a technical paper was not included if the original study was contained in the previous document. If the exact source of the data could not be determined, the document was eliminated.

2. The referenced study must contain test results based on more than one test run.

3. The report must contain sufficient data to evaluate the testing procedures and source operating conditions (e.g., one-page reports were generally rejected).

A final set of reference materials was compiled after a thorough review of the pertinent reports, documents, and information according to these criteria.

## 3.2 EMISSION DATA QUALITY RATING SYSTEM[1]

As part of the Contractor's analysis of the emission data, the quantity and quality of the information contained in the final set of reference documents were evaluated. The following data were always excluded from consideration.

1. Test series averages reported in units that cannot be converted to the selected reporting units;

2. Test series representing incompatible test methods (i.e., comparison of EPA method 5 front-half with EPA method 5 front- and back- half);

3. Test series of controlled emissions for which the control device is not specified;

4. Test series in which the source process is not clearly identified and described; and

5. Test series in which it is not clear whether the emissions were measured before or after the control device.

Data sets that were not excluded were assigned a quality rating. The rating system used was that specified by the OAQPS for the preparation of AP-42 sections. The data were rated as follows:

A--Multiple tests performed on the same source using sound methodology and reported in enough detail for adequate validation. These tests do not necessarily conform to the methodology specified in either the inhalable particulate (IP) protocol documents or the EPA reference test methods, although these documents and methods were certainly used as a guide for the methodology actually used.

B--Tests that were performed by a generally sound methodology but lack enough detail for adequate validation.

C--Tests that were based on an untested or new methodology or that lacked a significant amount of background data.

D--Tests that were based on a generally unacceptable method but may provide an order-of-magnitude value for the source.

The following criteria were used to evaluate source test reports for sound methodology and adaquate detail:

1. Source operation. The manner in which the source was operated is well documented in the report. The source was operating within typical parameters during the test.

2. Sampling procedures. The sampling procedures conformed to a generally acceptable methodology. If actual procedures deviated from accepted methods, the deviations are well documented. When this occurred, an evaluation was made of the extent such alternative procedures could influence the test results.

3. Sampling and process data. Adequate sampling and process data are documented in this report. Many variations can occur unnoticed and without warning during testing. Such variations can include wide deviations in sampling results. If a large spread between test results cannot be explained by information contained in the test report, the data are suspect and are given a lower rating.

4. Analysis and calculations. The test reports contain original raw data sheets. The nomenclature and equations used were compared to those (if any) specified by EPA to establish equivalency. The depth of review of the calculations was dictated

by the reviewer's confidence in the ability and conscientiousness of the tester, which in turn was based on factors such as consistency of results and completeness of other areas of the test report.

## 3.3 PARTICLE SIZE DETERMINATION

There is no one method which is universally accepted for the determination of particle size. A number of different techniques can be used which measure the size of particles according to their basic physical properties. Since there is no "standard" method for particle size analysis, a certain degree of subjective evaluation was used to determine if a test series was performed using a sound methodology for particle sizing.

For pollution studies, the most common types of particle sizing instruments are cyclones and cascade impactors. Traditionally, cyclones have been used as a preseparator ahead of a cascade impactor to remove the larger particles. These cyclones are of the standard reverse-flow design whereby the flue gas enters the cyclone through a tangential inlet and forms a vortex flow pattern. Particles move outward toward the cyclone wall with a velocity that is determined by the geometry and flow rate in the cyclone and by their size. Large particles reach the wall and are collected. A series of cyclones with progressively decreasing cut-points can be used to obtain particle size distributions.

Cascade impactors used for the determination of particle size in process streams consist of a series of plates or stages containing either small holes or slits with the size of the openings decreasing from one plate to the next. In each stage of an impactor, the gas stream passes through the orifice or slit to form a jet that is directed toward an impaction plate. For each stage, there is a characteristic particle diameter that has a 50 percent probability of impaction. This characteristic diameter is called the cut-point ($D_{50}$) of the stage. Typically, commercial instruments have six to eight impaction stages with a backup filter to collect those particles which are either too small to be collected by the last stage or which are re-entrained off the various impaction surfaces by the moving gas stream.

## 3.4 EMISSION FACTOR QUALITY RATING SYSTEM

The quality of the emission factors developed from analysis of the test data was rated utilizing the following criteria:

A--Excellent: Developed only from A-rated test data taken from many randomly chosen facilities in the industry population. The source category is specific enough so that variability within the source category population may be minimized.

B--Above average: Developed only from A-rated test data from a reasonable number of facilities. Although no specific bias is evident, it is not clear if the facilities tested represent a random sample of the industries. As in the A-rating, the source category is specific enough so that variability within the source category population may be minimized.

C--Average: Developed only from A- and B-rated test data from a reasonable number of facilities. Although no specific bias is evident, it is not clear if the facilities tested represent a random sample of the industry. As in the A-rating, the source category is specific enough so that variability within the source category population may be minimized.

D--Below average: The emission factor was developed only from A- and B-rated test data from a small number of facilities, and there is reason to suspect that these facilities do not represent a random sample of the industry. There also may be evidence of variability within the source category population. Limitations on the use of the emission factor are noted in the emission factor table.

E--Poor: The emission factor was developed from C- and D-rated test data, and there is reason to suspect that the facilities tested do not represent a random sample of the industry. There also may be evidence of variability within the source category population. Limitations on the use of these factors are always noted.

The use of these criteria is somewhat subjective and depends to an extent on the individual reviewer. Details of the rating of each candidate emission factor are provided in Chapter 4 of this report.

REFERENCES FOR CHAPTER 3

1. Technical Procedures for Developing AP-42 Emission Factors and Preparing AP-42 Sections, Office of Air Quality Planning and Standards, U.S. Environmental Protection Agency, Research Triangle Park, NC, March 1992.


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## 4. POLLUTANT EMISSION FACTOR DEVELOPMENT

This chapter describes the test data and methodology used to develop pollutant emission factors for bagasse combustion in sugar mills.

### 4.1 REVIEW OF SPECIFIC DATA SETS

A total of 12 references were documented and reviewed during the literature search. These references are listed at the end of this chapter. The source data for this revision included emission data from the January 1977 version of AP-42 Section 1.8.

The following efforts were made to ensure that the selection and rating of the reference documents did not introduce bias in the data. The majority of references used (75 percent) were compliance test reports. Given the impetus for compliance testing, these reports would be expected to characterize facilities with various levels of maintenance, operation, and control. Twenty-five percent of the references used in this report were classified as research or special study tests. In some cases, it could be reasoned that such studies would involve testing of facilities with above average maintenance, operation, and control and would, therefore, not be representative of the industry. Rather than downgrade the ratings for these references, each reference was considered on its own merit.

The original group of 12 documents was reduced to a final set of primary references utilizing the criteria outlined in Chapter 3. Two reference documents (References 10 and 11) were not used because significant quantities of fuel oil were co-fired with bagasse during the testing period.

The following is a discussion of the data contained in each of the primary references used to develop candidate emission factors. Emission factor calculations were made in terms of weight of pollutant per weight of steam produced. These terms were selected based on the consideration that most sugar mills monitor the amount of steam produced by their boilers but do not monitor the amount of bagasse fired.[12] It should be noted that the terms "controlled" and "uncontrolled" in this discussion are indicative of the location at which the measurements were made relative to a control device operating to remove a specific pollutant(s). For example, particulate matter emissions measured downstream of a cyclone are considered to be controlled emissions. However, nitrogen oxides emissions measured at the same location are considered to be uncontrolled emissions because a cyclone is not operated to remove nitrogen oxides from a flue gas stream.

A summary of the total particulate matter and particulate matter less than 10 microns (PM-10) emissions data discussed below is contained in Table 4-1. Table 4-2 presents a summary of emissions data for $CO_2$, $NO_x$, and polycyclic organic matter (POM). Table 4-3 summarizes the data presented in Tables 4-1 and 4-2.

4.1.1 References 1 Through 7

References 1 through 7 were PM compliance test performed on eight different bagasse-fired boilers. Two boilers were tested at the same site in Reference 1. Data from Boiler No. 3 at this site were not considered for emission factor development because oil was co-fired with bagasse during the test at a rate of 8 percent of heat input. For Boiler No. 4 at this site, and all other boilers tested in References 1 through 7, bagasse represented 100 percent of the boiler fuel.

Testing results were presented in these references for PM and $CO_2$. These data were obtained with EPA Method 5 and a continuous emission monitor, respectively. A rating of A was assigned to the data in each of these tests.

4.1.2 Reference 8

Reference 8 was a test performed by an EPA contractor on three bagasse-fired boilers at the same site. The objective of the test was to support development of emission factors for AP-42. Flue gases from Boilers No. 1 and 2 were ducted to Stack OA; flue gas from Boiler No. 3 were ducted to Stack OB. Separate measurements were collected for pollutants at each stack, forming two sets of emissions data.

Testing results were presented for controlled emissions of PM, $CO_2$, $NO_x$, and POM. EPA Method 5 was used to collect PM and POM data; only the quantities collected in the probe and filter were reported as PM. Samples of POM were collected on a Tenax plug and then analyzed using a gas chromatograph. EPA Method 7 was followed for sampling and analyzing for $NO_x$. Data for $CO_2$ were collected with a continuous emission monitor during the PM testing. A rating of A was assigned to the emissions data from both stacks.

### 4.1.3 Reference 9

Reference 9 was a test performed by an EPA contractor on a single bagasse-fired boiler. The test was conducted to gather emissions data from a well-controlled source that could be used for the development of new source performance standards. Of the three test runs conducted on the subject boiler, bagasse alone was fired during Runs 2 and 3. During Run 1 a small amount of oil was also burned with the bagasse. Only the results from Runs 2 and 3 were used to calculate emission factors for bagasse combustion.

Controlled emissions data were collected for PM, PM-10, $NO_x$, and $CO_2$. EPA Method 5 was used to collect PM data. Particle size distribution data were collected with an Anderson sampler. Data for $CO_2$ and $NO_x$ were collected using EPA Methods 3 and 5, respectively. A rating of A was assigned to the emissions data from this test.

### 4.1.4 Reference 12

Reference 12 was the 1977 Background Document for bagasse combustion in sugar mills (see Appendix A). This report contained test results for nine bagasse-fired boilers operating with no PM control equipment. Four of these data sets were excluded because either the boiler co-fired oil with bagasse or the data were of questionable quality. The remaining uncontrolled PM data were assigned a B rating in light of the overall uncontrolled PM emission factor rating of C in this report. The overall C rating indicates the emission factor was developed from A- and B-rated data; since the rating was not specified in the report, a conservative rating of B was assigned.

## 4.2 RESULTS OF DATA ANALYSIS

Most bagasse boilers have limited monitoring of operating parameters. Typically, the steam production rate is measured and recorded but the amount of bagasse fired is not directly measured.[2] As a result, the compliance test reports discussed above generally contain steam production data but not bagasse feedrate data. In developing pollutant emission factors for bagasse boilers, emission rates were expressed in terms of lb pollutant/1000 lb steam (or g pollutant/kg steam), consistent with the best available measure of process operating rate.

4.2.1 Total Particulate Matter Emissions Data

An uncontrolled PM emissions factor was determined from the data contained in Reference 12. For the test data utilized, the boilers ranged in size from 14,000 to 120,000 kg steam/hr (30,000 to 270,000 lb steam/hr).

Controlled PM emission data were divided into the two categories of cyclone-controlled and wet scrubber-controlled emissions. Mechanical collector-controlled data included controlled emissions from both single cyclone and multiple cyclone (or multiclone) collectors. In the case of mechanical collector-controlled emissions, References 7 and 8 contained useful data. For both of these references, PM emissions were reported on a pounds of pollutants per hour basis. Steam flow rates were also reported on a pounds per hour basis. Emission factors were calculated by dividing the PM emission rate by the steam flow rate to yield factors expressed in pounds of PM per 1,000 pounds of steam or grams of PM per kilogram of steam. Similar conversion calculations were executed for the other emission factors discussed in this section.

Test averages for Reference 9 were based on the results of two runs (as discussed above); test results for both stacks in Reference 8 were based on three runs. The three boilers tested in these references were all spreader stoker units and ranged in size from 110,000 to 130,000 kg steam/hr (240,000 to 280,000 lb steam/hr).

References 1, 2, 3, 4, 5, 6, and 9 contained useful data for boilers equipped with wet scrubbers. Of the seven boilers tested, two were horseshoe boilers and the remainder were spreader stoker boilers. These boilers ranged in size from 57,000 to 142,000 kg steam/hr (125,000 to 312,000 lb steam/hr).

Wet scrubber-controlled emission factors were calculated manually and with a computer spreadsheet program from data expressed in other terms. In most cases, it was necessary to convert from emission data expressed in lb PM/million Btu to lb PM/1,000 lb steam, or gram PM/kg steam, using the conversion factors discussed in Section 4.3.1. A summary of all available PM emission factors is shown in Table 4-1.

4.2.2 Particle Size Data

Only a controlled PM-10 emission factor could be determined from the data contained in the reference documents described above. Reference 9 contained useful particle size distribution data collected downstream of a wet scrubber operating on a 70,000 kg steam/hr (150,000 lb steam/hr) spreader stoker boiler. The emission factor shown in Table 4-1 corresponds to the fraction of total PM collected below an average 10.55 micron particle size.

4.2.3 Nitrogen Oxides Data

Data for determining an uncontrolled $NO_x$ emission factor were taken from References 8 and 9. These data were collected on three spreader stoker boiler ranging in size from 70,000 to 130,000 kg steam/hr (150,000 to 280,000 lb steam/hr). Although PM emissions from these boilers were controlled by mechanical collectors and wet scrubbers, no specific control systems for reducing $NO_x$ emissions were reported to be in operation.

The emission factors were determined from the test data by manual and spreadsheet calculations. Table 4-2 presents a summary of $NO_x$ emission factors, as well as emission factors for $CO_2$ and POM.

4.2.4 Carbon Dioxide Data

References 1 through 9 were used to develop an uncontrolled emission factor for $CO_2$. Of the 10 boilers tested, two were horseshoe boilers and the remainder were spreader stoker boilers. These boilers ranged in size from 57,000 to 142,000 kg steam/hr (125,000 to 312,000 lb steam/hr). Although PM emissions from these boilers were controlled by mechanical collectors and wet scrubbers, no specific control systems for reducing $CO_2$ emissions were reported to be in operation.

4.2.5 Polycyclic Organic Matter Data

References 8 and 9 were used for the development of an uncontrolled emission factor for POM. These test data included two spreader stoker boiler operating at 110,000 to 130,000 kg steam/hr (240,000 and 280,000 lb steam/hr). Although PM emissions from these boilers were controlled by mechanical collectors and wet scrubbers, no specific control systems for reducing POM emissions were reported to be in operation.  However, a portion of the total POM emissions may have been in the form of POM condensed on PM.  In this case, PM emission controls may have provided some reduction of POM emissions.

## 4.3 PROTOCOL FOR DATA BASE

### 4.3.1 Engineering Methodology

Using the criteria discussed in Section 3.2, two reports representing two source tests were rejected.  The remaining nine reports representing 10 source tests were thoroughly reviewed to establish a data base for the pollutants discussed above.

Data rating forms (see Appendix B) were created to facilitate the evaluation of exclusion criteria, methodology/detail criteria, and data rating criteria.  These forms were completed for each reference to document the rationale for either excluding the reference from emission factor development consideration or for including the reference and assigning ratings to relevant source test data.

The emission data from source test reports were averaged as the arithmetic mean of different sampling runs prior to inclusion in the data base.  Test programs at most facilities consisted of three sampling runs conducted during distinct time periods under normal operating conditions for the systems tested.

Due to the variety of formats used to report units of measure at different bagasse-fired boilers, the emission data required some processing to standardize the units of measure prior to calculation of emission factors.  Average emission factors were then calculated in terms of g/kg of steam or lb/1,000 lb steam for all pollutants based on the arithmetic average of collected data.  The list of conversion factors used in the test data processing are included in Table 4-4.

In many cases it was necessary to convert data expressed in terms of lb pollutant/million Btu or ppmv to lb pollutant/1,000 lb steam.  Based on the information contained in References 1 through 9, this conversion was made using an average bagasse heating value of 3,500 Btu/lb (wet, as fired) and an average steam/feed ratio of 2 lb steam produced per pound of bagasse fired.  In addition, an

F-Factor of 9,230 dscf/million Btu at 0 percent oxygen ($O_2$) was utilized.[13] This factor was adjusted to other $O_2$ flue gas concentrations using the equation

$$F = 9{,}230 \text{ dscf}/10^6 \text{ Btu } [20.9/(20.9\text{-}\%O_{2d})]$$

where $\%O_{2d}$ is the flue gas $O_2$ content measured on a dry basis. Emission data expressed as lb pollutant/1,000 lb steam are equivalent to data expressed as gram pollutant/kg steam.

Determinations of emission factors were made only when steam production rates were documented or derivable from plant records.

Quality control and quality assurance procedures were used to assure that the data base accurately reflected the reported test data. Each data rating form was checked by a second Contractor staff member to assure accurate documentation of reference exclusion or emission data rating criteria. In addition, manual and spreadsheet calculations were spot checked by a second Contractor staff member to assure accurate documentation of reported emission and process data prior to calculation of overall average emission factors. After emission tables were generated, a final comparison was made between randomly selected test reports, their associated data rating forms, and the produced emission table to assure the quality of the data acquisition and associated calculations.

## REFERENCES FOR CHAPTER 4


1. Particulate Emissions Test Report: Atlantic Sugar Association, Air Quality Consultants, Inc., December 20, 1978.

2. Compliance Stack Test: Gulf and Western Food Products: Report No. 238-S, South Florida Environmental Services, Inc., February 1980.

3. Compliance Stack Test: Gulf and Western Food Products: Report No. 221-S, South Florida Environmental Services, Inc., January 1980.

4. Compliance Stack Test: United States Sugar Corporation: Report No. 250-S, South Florida Environmental Services, Inc., February 1980.

5. Compliance Stack Test: Osceola Farms Company: Report No. 215-S, South Florida Environmental Services, Inc., December 1979.

6. Source Emissions Survey of Davies Hamakua Sugar Company: Report No. 79-34, Mullins Environmental Testing Company, May 1979.

7. Stack Emissions Survey: Honokaa Sugar Company, Kennedy Engineers, Inc., January 19, 1979.

8. Stationary Source Testing of Bagasse Fired Boilers at the Hawaiian Commercial and Sugar Company: Puunene, Maui, Hawaii, EPA Contract No. 68-02-1403, Midwest Research Institute, Kansas City, MO, February 1976.

9. Emission Test Report: U.S. Sugar Company, Bryant, Florida, EPA Contract No. 68-02-2818, Monsanto Research Corporation, Dayton, OH, May 1980.

10. Source Emission Test Report For Riley Stoker Corporation: Particulate Emissions From the Bagasse Fired Boilers at Aguirre, Fajardo and Mercedita, Puerto Rico, Galson Technical Services, East Syracuse, NY, July 1976.

11. Emission Test Report For the Talisman Sugar Corporation, Belle Glade, Florida, EPA Contract No. 68-02-1406, Engineering-Science, Inc., McLean, VA, January 1976.

12. Background Document: Bagasse Combustion in Sugar Mills, EPA-450/3-77-077, U. S. Environmental Protection Agency, Research Triangle Park, NC, January 1977.

13. Nonfossil Fuel Fired Industrial Boilers - Background Information, EPA-450/3-82-007, U. S. Environmental Protection Agency, Research Triangle Park, NC, March 1982.

TABLE 4-1. SUMMARY OF EMISSION FACTORS FOR PARTICULATE MATTER (PM) AND PARTICULATE MATTER LESS THAN 10 MICRONS (PM-10) FROM BAGASSE COMBUSTORS

| Source category/reference/rating | PM, g/kg steam OR lb/1000 lb steam | PM-10, g/kg steam OR lb/1000 lb steam |
|---|---|---|
| Uncontrolled | | |
| 12,b | 7.7 | |
| 12,b | 6.4 | |
| 12,b | 1.8 | |
| 12,b | 1.5 | |
| 12,b | 2.2 | |
| Controlled | | |
| Mechanical collector | | |
| 1,a | 0.50 | |
| 8,a | 4.09 | |
| 8,a | 1.82 | |
| Wet scrubber | | |
| 1,a | 0.46 | |
| 2,a | 0.47 | |
| 3,a | 0.41 | |
| 4,a | 0.25 | |
| 5,a | 0.49 | |
| 6,a | 0.15 | |
| 9,a | 0.36 | 0.34 |

TABLE 4-2. SUMMARY OF CARBON DIOXIDE ($CO_2$), NITROGEN OXIDES ($NO_x$), AND POLYCYCLIC ORGANIC MATTER (POM) FROM BAGASSE COMBUSTORS

| Source category/ reference/rating | $CO_2$, g/kg steam OR lb/1000 lb steam | $NO_x$, g/kg steam or lb/1000 lb steam | POM, g/kg steam or lb/1000 lb steam |
|---|---|---|---|
| After PM control device | | | |
| 1,a | 375 | | |
| 2,a | 367 | | |
| 3,a | 397 | | |
| 4,a | 400 | | |
| 5,a | 373 | | |
| 6,a | 392 | | |
| 7,a | 372 | | |
| 8,a | 476 | 0.43 | 3.1E-4 |
| 8,a | 421 | 0.12 | 1.9E-4 |
| 9,a | 303 | 0.57 | |

TABLE 4-3. SUMMARY OF BAGASSE COMBUSTION EMISSION DATA

| Pollutant/source | No. of data points | Data ratings | Emission factor range, g/kg steam | Average emission factor, g/kg steam | Emission factor rating | Reference Number |
|---|---|---|---|---|---|---|
| Particulate matter | | | | | | |
| Uncontrolled | 5 | b | 1.5-7.7 | 3.9 | C | 12 |
| Controlled | | | | | | |
| Mechanical collector | 3 | a | 0.50-4.09 | 2.1 | D | 7,8 |
| Wet Scrubber | 7 | a | 0.15-0.49 | 0.4 | B | 1,2,3,4, 5,6,9 |
| PM-10 | | | | | | |
| Controlled | | | | | | |
| Wet Scrubber | 1 | a | NA | 0.34 | D | 9 |
| Carbon dioxide | | | | | | |
| Uncontrolled[a] | 10 | a | 303-476 | 390 | A | 1,2,3,4, 5,6,7,8,9 |
| Nitrogen oxides | | | | | | |
| Uncontrolled[a] | 3 | a | 0.12-0.43 | 0.3 | C | 8,9 |
| Polycyclic organic matter | | | | | | |
| Uncontrolled[a] | 2 | a | 1.9E-4-3.1E-4 | 2.5E-4 | D | 8 |

[a] Measurements taken downstream of PM control systems.

## TABLE 4-4. LIST OF CONVERSION FACTORS

| Multiply | By | To obtain |
|---|---|---|
| mg/dscm | 4.37E-4 | gr/dscf |
| $m^2$ | 10.764 | $ft^2$ |
| acm/min | 35.31 | acfm |
| m/s | 3.281 | ft/s |
| kg/h | 2.205 | lb/h |
| kPa | 4.0 | in. of $H_2O$ |
| lpm | 0.264 | gal/min |
| kg/Mg | 2.0 | lb/ton |

Temperature conversion equations

F= (9/5)*C+32

C= (5/9)*(F-32)

# REPORT ON REVISIONS TO
# 5TH EDITION AP-42
# Section 1.8
# Bagasse Combustion In Sugar Mills

Prepared for:

Contract No. 68-D2-0160, Work Assignment 50
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Table of Contents

# 1.0 INTRODUCTION

This report supplements the Emission Factor (EMF) Documentation for AP-42 Section 1.8, Bagasse Combustion In Sugar Mills, dated April 1993. The EMF describes the source and rationale for the material in the most recent updates to the 4th Edition, while this report provides documentation for the updates written in both Supplements A and B to the 5th Edition.

Section 1.8 of AP-42 was reviewed by internal peer reviewers to identify technical inadequacies and areas where state-of-the-art technological advances need to be incorporated. Based on this review, text has been updated or modified to address any technical inadequacies or provide clarification. Additionally, emission factors were checked for accuracy with information in the EMF Document and new emission factors generated if recent test data were available.

If discrepancies were found when checking the factors with the information in the EMF Document, the appropriate reference materials were then checked. In some cases, the factors could not be verified with the information in the EMF Document or from the reference materials, in which case the factors were not changed.

Four sections follow this introduction. Section 2 of this report documents the revisions and the basis for the changes. Section 3 presents the references for the changes documented in this report. Section 4 presents the revised AP-42 Section 1.8, and Section 5 contains the EMF documentation dated April 1993.

## 2.0 REVISIONS

This section documents the revisions made to Section 1.8 of the 5th Edition of AP-42. At the request of EPA, the metric units were removed.

### 2.1 Particulate Matter, PM

The uncontrolled and controlled (with mechanical collector) PM emission factors were checked against Table 4-1 of the EMF Document and no mathematical errors were detected. Therefore, no changes were made to these emission factors.

Approximately 75 particulate test reports from various sugar mills (each dated early 1990's) were reviewed and 53 contained data for bagasse boilers controlled with wet scrubbers. The remaining test reports did not specify a control device; however, the PM emissions were low, indicating some type of control. For this reason, data was not used from any reports not specifying a control device. There were typically 3 test runs conducted by EPA Method 5, making a total of 165 data points. These were combined with the 7 data points from the existing AP-42 Document, making a total of 172 data points.

The existing emission factor was 1.6 lb/ton bagasse with an overall rating or "B". By combining the new data, the emission factor is 1.4 lb/ton bagasse with an overall rating of "A". Table 1 presents the average PM emission factor for each location. Operating parameters and detailed test data for each test site are given in Appendix A.

Table 1. Summary of PM Emission Factors for Bagasse Boilers

| 08/12/96 Entry No. | Electronic Filename | No. of Boilers | Fuel Type | SCC | Control Device 1 | No. of Test Runs | Average PM (lb/1000lb Steam) | (lb/ton Bagasse) |
|---|---|---|---|---|---|---|---|---|
| 1 | ref18_4 | 1 | bagasse | 10201101 | Wet Scrubber | 3 | 0.36 | 1.45 |
| 2 | ref18_5 | 1 | bagasse | 10201101 | Wet Scrubber | 3 | 0.39 | 1.55 |
| 3 | ref18_6 | 1 | bagasse | 10201101 | Wet Scrubber | 3 | 0.37 | 1.48 |
| 4 | ref18_7 | 1 | bagasse | 10201101 | Wet Scrubber | 3 | 0.27 | 1.08 |
| 5 | ref18_8 | 1 | bagasse | 10201101 | Wet Scrubber | 3 | 0.28 | 1.10 |
| 6 | ref18_9 | 1 | bagasse | 10201101 | Wet Scrubber | 3 | 0.31 | 1.24 |
| 7 | ref18_10 | 1 | bagasse | 10201101 | Wet Scrubber | 3 | 0.25 | 0.99 |
| 8 | ref18_12 | 1 | bagasse | 10201101 | Wet Scrubber | 3 | 0.25 | 0.75 |
| 9 | ref18_15 | 1 | bagasse | 10201101 | Wet Scrubber | 3 | 0.13 | 0.52 |
| 10 | ref18_17 | 1 | bagasse | 10201101 | Wet Scrubber | 3 | 0.22 | 0.87 |
| 11 | ref 18_21 | 1 | bagasse | 10201101 | Wet Scrubber | 3 | 0.42 | 1.68 |
| 12 | ref 18_22 | 1 | bagasse | 10201101 | Wet Scrubber | 3 | 0.28 | 1.11 |
| 13 | ref 18_23 | 1 | bagasse | 10201101 | Wet Scrubber | 3 | 0.24 | 0.98 |
| 14 | ref 18_24 | 1 | bagasse | 10201101 | Wet Scrubber | 3 | 0.32 | 1.27 |
| 15 | ref 18_24 | 1 | bagasse | 10201101 | Wet Scrubber | 3 | 0.23 | 0.91 |
| 16 | ref18_29 | 1 | bagasse | 10201101 | Wet Scrubber | 3 | 0.50 | 2.00 |
| 17 | ref18_30 | 1 | bagasse | 10201101 | Wet Scrubber | 3 | 0.39 | 1.55 |
| 18 | ref18_31 | 1 | bagasse | 10201101 | Wet Scrubber | 3 | 0.41 | 1.64 |
| 19 | ref18_33 | 1 | bagasse | 10201101 | Wet Scrubber | 3 | 0.34 | 1.37 |
| 20 | ref18_34 | 1 | bagasse | 10201101 | Wet Scrubber | 3 | 0.24 | 0.95 |
| 21 | ref18_35 | 1 | bagasse | 10201101 | Wet Scrubber | 3 | 0.26 | 1.06 |
| 22 | ref 18_36 | 1 | bagasse | 10201101 | Wet Scrubber | 3 | 0.33 | 1.32 |
| 23 | ref 18_37 | 1 | bagasse | 10201101 | Wet Scrubber | 3 | 0.52 | 2.09 |
| 24 | ref 18_38 | 1 | bagasse | 10201101 | Wet Scrubber | 3 | 0.40 | 1.61 |
| 25 | ref 18_39 | 1 | bagasse | 10201101 | Wet Scrubber | 3 | 0.42 | 1.69 |
| 26 | ref 18_40 | 1 | bagasse | 10201101 | Wet Scrubber | 3 | 0.39 | 1.56 |
| 27 | ref 18_41 | 1 | bagasse | 10201101 | Wet Scrubber | 3 | 0.34 | 1.36 |
| 28 | ref 18_42 | 1 | bagasse | 10201101 | Wet Scrubber | 3 | 0.37 | 1.47 |
| 29 | ref 18_43 | 1 | bagasse | 10201101 | Wet Scrubber | 3 | 0.35 | 1.39 |

Table 1. (Continued)

| 08/12/96 Entry No. | Electronic Filename | No. of Boilers | Fuel Type | SCC | Control Device 1 | No. of Test Runs | Average PM (lb/1000lb Steam) | (lb/ton Bagasse) |
|---|---|---|---|---|---|---|---|---|
| 30 | ref 18_44 | 1 | bagasse | 10201101 | Wet Scrubber | 3 | 0.47 | 1.88 |
| 31 | ref 18_45 | 1 | bagasse | 10201101 | Wet Scrubber | 3 | 0.38 | 1.53 |
| 32 | ref 18_46 | 1 | bagasse | 10201101 | Wet Scrubber | 3 | 0.25 | 1.01 |
| 33 | ref 18_47 | 1 | bagasse | 10201101 | Wet Scrubber | 3 | 0.39 | 1.55 |
| 34 | ref 18_48 | 1 | bagasse | 10201101 | Wet Scrubber | 3 | 0.32 | 1.29 |
| 35 | ref 18_49 | 1 | bagasse | 10201101 | Wet Scrubber | 3 | 0.38 | 1.50 |
| 36 | ref 18_50 | 1 | bagasse | 10201101 | Wet Scrubber | 3 | 0.31 | 1.24 |
| 37 | ref 18_51 | 1 | bagasse | 10201101 | Wet Scrubber | 3 | 0.24 | 0.94 |
| 38 | ref 18_52 | 1 | bagasse | 10201101 | Wet Scrubber | 3 | 0.30 | 1.19 |
| 39 | ref 18_56 | 1 | bagasse | 10201101 | Wet Scrubber | 3 | 0.23 | 0.94 |
| 40 | ref 18_32 | 1 | bagasse | 10201101 | Wet Scrubber | 3 | 0.26 | 1.02 |
| 41 | ref18_1 | 1 | bagasse | 10201101 | Twin Wet Scrubbers | 6 | 0.39 | 1.55 |
| 42 | ref18_2 | 1 | bagasse | 10201101 | Twin Wet Scrubbers | 3 | 0.53 | 2.13 |
| 43 | ref18_3 | 1 | bagasse | 10201101 | Twin Wet Scrubbers | 3 | 0.52 | 2.08 |
| 44 | ref18_11 | 1 | bagasse | 10201101 | Twin Wet Scrubbers | 3 | 0.32 | 1.29 |
| 45 | ref18_13 | 1 | bagasse | 10201101 | Twin Wet Scrubbers | 3 | 0.35 | 1.41 |
| 46 | ref18_14 | 1 | bagasse | 10201101 | Twin Wet Scrubbers | 3 | 0.38 | 1.53 |
| 47 | ref18_16 | 1 | bagasse | 10201101 | Twin Wet Scrubbers | 3 | 0.52 | 2.07 |
| 48 | ref18_18 | 1 | bagasse | 10201101 | Twin Wet Scrubbers | 3 | 0.27 | 1.07 |
| 49 | ref18_19 | 1 | bagasse | 10201101 | Twin Wet Scrubbers | 3 | 0.3 | 1.21 |
| 50 | ref18_20 | 1 | bagasse | 10201101 | Twin Wet Scrubbers | 3 | 0.37 | 1.48 |
| 51 | ref 18_21 | 1 | bagasse | 10201101 | Twin Wet Scrubbers | 3 | 0.43 | 1.7 |

Table 1. (Continued)

| 08/12/96 Entry No. | Electronic Filename | No. of Boilers | Fuel Type | SCC | Control Device 1 | No. of Test Runs | Average PM (lb/1000lb Steam) | Average PM (lb/ton Bagasse) |
|---|---|---|---|---|---|---|---|---|
| 52 | ref 18_26 | 1 | bagasse | 10201101 | Twin Wet Scrubbers | 3 | 0.29 | 1.15 |
| 53 | ref 18_27 | 1 | bagasse | 10201101 | Twin Wet Scrubbers | 3 | 0.51 | 2.05 |
| 54 | ref 18_28 | 1 | bagasse | 10201101 | Twin Wet Scrubbers | 3 | 0.35 | 1.39 |
| 55 | Table 4-1 | 1 | bagasse | 10201101 | Wet Scrubbers | 1 | 0.46 | 1.84 |
| 56 | Table 4-1 | 1 | bagasse | 10201101 | Wet Scrubbers | 1 | 0.47 | 1.88 |
| 57 | Table 4-1 | 1 | bagasse | 10201101 | Wet Scrubbers | 1 | 0.41 | 1.64 |
| 58 | Table 4-1 | 1 | bagasse | 10201101 | Wet Scrubbers | 1 | 0.25 | 1 |
| 59 | Table 4-1 | 1 | bagasse | 10201101 | Wet Scrubbers | 1 | 0.49 | 1.96 |
| 60 | Table 4-1 | 1 | bagasse | 10201101 | Wet Scrubbers | 1 | 0.15 | 0.6 |
| 61 | Table 4-1 | 1 | bagasse | 10201101 | Wet Scrubbers | 1 | 0.36 | 1.44 |
| | | | | | | Average: | 0.35 | 1.39 |
| | | | | | | High: | 0.53 | 2.13 |
| | | | | | | Low: | 0.13 | 0.52 |
| | | | | | | Std. Dev.: | 0.09 | 0.38 |
| | | | | | | No. of Points: | 172 | |

## 2.2 Particulate Matter Less Than 10 MICROS, PM-10

The PM-10 emission factors were checked against Table 4-1 of the EMF Document and remain the same as in the 7/93 version of AP-42.

## 2.3 Nitrogen Oxides, $NO_x$

The $NO_x$ emission factor was checked against Table 4-2 of the EMF Document and remains the same as in the 7/93 version of AP-42.

## 2.4 Carbon Dioxide, $CO_2$

The $CO_2$ emission factor was checked against Table 4-2 of the EMF Document and remains the same as version 7/93 AP-42.

## 2.5 Polycyclic Organic Matter, POM

The POM emission factors were checked against Table 4-2 of the EMF Document and remain the same as in the 7/93 version of AP-42.

## 3.0 REFERENCES


1. *Source Test Report For Particulate Emissions Twin Impingement Wet Scrubber Number 6 Boiler*, Talisman Sugar Corporation South Bay, Florida, February 1 and 4, 1991.

2. *Source Test Report For Particulate Emissions Twin Impingement Wet Scrubber Number 5 Boiler*, Talisman Sugar Corporation South Bay, Florida, February 5, 1991.

3. *Source Test Report For Particulate Emissions Twin Impingement Wet Scrubber Number 4 Boiler*, Talisman Sugar Corporation South Bay, Florida, February 11, 1991.

4. *Source Test Report For Particulate Emissions Impingement Wet Scrubber Number 3 Boiler,* Atlantic Sugar Association, Belle Glade, Florida, November 27, 1990.

5. *Source Test Report For Particulate Emissions Impingement Wet Scrubber Number 4 Boiler,* Atlantic Sugar Association, Belle Glade, Florida, November 29, 1990.

6. *Source Test Report Number 3 Boiler Impingement Wet Scrubber Particulate Emissions*, Sugar Cane Growers Cooperative of Florida, Belle Glade, Florida, December 6, 1990.

7. *Source Test Report Number 4 Boiler Impingement Wet Scrubber Particulate Emissions*, Sugar Cane Growers Cooperative of Florida, Belle Glade, Florida, December 11, 1990.

8. *Source Test Report For Particulate Emissions Impingement Wet Scrubber Number 5 Boiler*, United States Sugar Cane Corporation, Bryant, Florida, January 13, 1991.

9. *Source Test Report For Particulate Emissions Impingement Wet Scrubber Number 1 Boiler,* United States Sugar Corporation, Bryant, Florida, January 8, 1991.

10. *Source Test Report For Particulate Emissions Impingement Wet Scrubber Number 3 Boiler*, United States sugar Corporation, Bryant, Florida, January 24, 1991.

11. *Source Test Report Number 5 Boiler Impingement Wet Scrubbers Particulate Emissions*, Sugar Cane Growers Cooperative of Florida, Belle Glade, Florida, December 5, 1990.

12. *Source Test Report Number 8 Boiler Impingement Wet Scrubber Particulate Emissions*, Sugar Cane Growers Cooperative of Florida, Belle Glade, Florida, December 12, 1990.

13. *Source Test Report For Particulate Emissions Twin Impingement Wet Scrubbers Number 1 Boiler*, Sugar Cane Growers Cooperative of Florida, Belle Glade, Florida, November 19, 1990.

14. *Source Test Report For Particulate Emissions Twin Impingement Wet Scrubbers Number 2 Boiler*, Sugar Cane Growers Cooperative of Florida, Belle Glade, Florida, November 28, 1990.

15. *Source Test Report For Particulate Emissions Impingement Wet Scrubber Number 2 Boiler*, U. S. Sugar Corporation, Bryant, Florida, January 23, 1991.

16. *Source Test Report For Particulate Emissions Twin Impingement Wet Scrubber Boiler Number 4*, Talisman Sugar Corporation, South Bay, Florida, December 9, 1991.

17. *Source Test Report For Particulate Emissions Impingement Wet Scrubber Boiler Number 8*, Sugar Cane Growers Cooperative of Florida Airport Road, Belle Glade, Florida, November 27, 1991.

18. *Source Test Report For Particulate Emissions Twin Impingement Wet Scrubbers Boiler Number 1*, Sugar Cane Growers Cooperative of Florida, Belle Glade, Florida, November 14, 1991.

19. *Source Test Report For Particulate Emissions Twin Impingement Wet Scrubbers Boiler Number 2*, Sugar Cane Growers Cooperative of Florida, Belle Glade, Florida, November 15, 1991.

20. *Source Test Report For Particulate Emissions Twin Impingement Wet Scrubbers Boiler Number 6*, Talisman Sugar Corporation, South Bay, Florida, December 11, 1991.

21. *Source Test Report For Particulate Emissions Boilers 3 and 4*, Atlantic Sugar Association, Belle Glade, Florida, November 20 and 21, 1991.

22. *Source Test Report For Particulate And Volatile Organic Compound Emissions, Nominal 10% Soil Feed Impingement Wet Scrubber Boiler Number 1*, Bryant, Florida, December 19, 1991.

23. *Source Test Report For Particulate Emissions Impingement Wet Scrubber Boiler Number 5*, Bryant, Florida, March 5, 1992.

24. *Source Test Report For Particulate And Volatile Organic Compound Emissions, Nominal 10% Soil Feed Impingement Wet Scrubber Boiler Number 3*, Bryant, Florida, December 17, 1991.

25. *Source Test Report For Particulate Emissions Impingement Wet Scrubber Boiler Number 4*, November 26, 1991.

26. *Source Test Report For Particulate Emissions Twin Impingement Wet Scrubbers Boiler Number 5*, November 20, 1991.

27. *Source Test Report For Particulate Emissions Twin Impingement Wet Scrubber Boiler Number 5*, Talisman Sugar Corporation, South Bay, Florida, December 10, 1991.

28. *Source Test Report For Particulate Emissions Twin Impingement Wet Scrubbers Boiler Number 3*, November 21, 1991.

29. *Atlantic Sugar Association Compliance Particulate Emissions Test Report Boiler #2*, Belle Glade, Florida Facility, February 1, 1991.

30. *Osceola Farms Company Compliance Particulate Emissions Test Report Boiler #2*, Pahokee, Florida Facility, February 7, 1991.

31. *Particulate Emissions Compliance Test Report Boiler #1*, Atlantic Sugar Association, Belle Glade, Florida Facility, December 11, 1990.

32. *Particulate Emissions Testing Atlantic Sugar Association Boiler #1*, Belle Glade, Florida Facility, December 16, 1991.

33. *Particulate Emissions Compliance Test Report Boiler #5, Atlantic Sugar Association*, Belle Glade, Florida Facility, January 8, 1992.

34. *Atlantic Sugar Association Particulate Emissions Test Report Boiler #5*, January 10, 1991.

35. *Okeelanta Corporation Compliance Particulate Emissions Test Report Boiler #12*, South Bay Florida Facility, December 17, 1991.

36. *Particulate Emissions Testing Atlantic Sugar Association Boiler #2*, Belle Glade, Florida Facility, December 12, 1991.

37. *Okeelanta Corporation Compliance Particulate Emissions Test Report Boiler #11*, South Bay Florida Facility, January 21 & 22, 1992.

38. *Okeelanta Corporation Compliance Particulate Emissions Test Report Boiler #10*, South Bay Florida Facility, January 29, 30 & 31, 1992.

39. *Okeelanta Corporation Compliance Particulate Emissions Test Report Boiler #6*, South Bay Florida Facility, January 24, 1992.

40. *Okeelanta Corporation Compliance Particulate Emissions Test Report Boiler #14*, South Bay Florida Facility, January 10 & 13, 1992.

41. *Okeelanta Corporation Compliance Particulate Emissions Test Report Boiler #15*, South Bay Florida Facility, January 8, 1992.

42. *Okeelanta Corporation Compliance Particulate Emissions Test Report Boiler #4*, South Bay Florida Facility, December 11 & 12, 1991.

43. *Okeelanta Corporation Compliance Particulate Emissions Test Report Boiler #5*, South Bay Florida Facility, December 12 & 13, 1991.

44. *Okeelanta Corporation Particulate Emissions Test Report Boiler #5*, December 12, 1990.

45. *Okeelanta Corporation Particulate Emissions Test Report Boiler #6*, December 13 and 14, 1990.

46. *Okeelanta Corporation Particulate Emissions Test Report Boiler #10*, January 29 and 30, 1991.

47. *Okeelanta Corporation Particulate Emissions Test Report Boiler #4*, December 10 and 11, 1990.

48. *Okeelanta Corporation Particulate Emissions Test Report Boiler #11*, December 6 and 7, 1990.

49. *Particulate Emissions Testing Okeelanta Corporation Boiler #12*, January 31 & February 1, 1991.

50. *Okeelanta Corporation Particulate Emissions Test Report Boiler #14*, February 4 and 5, 1991.

51. *Okeelanta Corporation Particulate Emissions Test Report Boiler #15*, February 8, 1991.

52. *Stack Test For Total Gaseous Non-Methane Organic Compounds Report 1371-S Boiler No. 5 - Bryant*, United States Sugar Corporation, February 15, 1990.

52. *Atlantic Sugar Association Compliance Emission Test Program, Unit No. 5, Belle Glade, FL*, Eastmount Engineering, January 1992.

## 4.0 REVISED SECTION 1.8

This section contains the revised section 1.8 of AP-42, 5th Edition. The electronic version can be located on the EPA TTN at http://134.67.104.12/html/chief/fsnpub.htm.

# 5.0 EMISSION FACTOR DOCUMENTATION, APRIL 1993

This section contains the complete Emission Factor Documentation for AP-42 Section 1.8, Bagasse Combustion in Sugar Mills, dated April 1993. The electronic version can be located on the EPA TTN at http://134.67.104.12/html/chief/fbgdocs.htm

# Appendix A:  Supporting Information

| | | | |
|---|---|---|---|
| AP-42 Emission Factor Updates | QC by: | | Test Fuel Data[e] | |
| Chapter 1.8: Bagasse Fired Boilers | | Data Rating: Control Devices: Twin Wet Scrubbers | | |
| Research by: Edward Skompski July 19, 1995 | Revised by: | | Bagasse Fuel Data | |
| | | [a]Data from Table 1 on page 3. | | |
| | | [b]Calculation: (Concentration (lb/hr)/Stm(lb/hr))*1000 = (lb/1000 lb steam) | | |
| Report: Source Test Report for Particulate Emissions of Twin Impingement | | [c]Calculation: (Conc. (lb/hr)/Stm(lb/hr))*2(lbstm/lbbag)*2000lb/ton bag | | |
| Wet Scrubbers on the number 6 Boiler Talisman Sugar Corporation | | [d]Steam data from Appendix E. | Conversion (lbsteam/lb bag) | 2 |
| Air Consulting and Engineering, February 1991 | | [e]Fuel data from AP-42, chapter 1.8 documentation. | | |

ref18_1.wk4

| Test Run Number | 1 | 2 | 3 | 4 | 5 | 6 | |
|---|---|---|---|---|---|---|---|
| Particulate Emissions | | | | | | | |
| Test Data[a] | February 1 | | | February 4 | | | Average |
| | | | | | | | |
| Emission Rate (lb/hr) | 108.36 | 96.66 | 98.32 | 88.138 | 91.236 | 86.942 | 94.943 |
| " (lb/MMbtu) | 0.234 | 0.206 | 0.208 | 0.174 | 0.183 | 0.18 | 0.198 |
| Steam Production (lb/hr)[d] | 235625 | 236875 | 241250 | 258750 | 255625 | 247753 | 245980 |
| | | | | | | | |
| Conc. (lb/1000lb steam)[b] | 0.46 | 0.41 | 0.41 | 0.34 | 0.36 | 0.35 | 0.39 |
| Conc. (lb/ton bagasse)[c] | 1.84 | 1.63 | 1.63 | 1.36 | 1.43 | 1.40 | 1.55 |

| | | | | | |
|---|---|---|---|---|---|
| AP-42 Emission Factor Updates | QC by: | | | Test Fuel Data[e] | |
| Chapter 1.8: Bagasse Fired Boilers | | Data Rating: | Control Devices: Twin Wet Scrubbers | | |
| Research by: Edward Skompski July 19, 1995 | Revised by: | | | Bagasse Fuel Data | |
| | | | | | |
| | | | | Conversion (lbsteam/lb bag) | 2 |

Report: Source Test Report for Particulate Emissions of Twin Impingement Wet Scrubbers on the number 6 Boiler Talisman Sugar Corporation Air Consulting and Engineering, February 1991

ref18 2.wk4

[a]Data from Table 1 on page 3.

[b]Calculation: (Concentration (lb/hr)/Stm(lb/hr))*1000 = (lb/1000 lb steam)

[c]Calculation: (Conc. (lb/hr)/Stm(lb/hr))*2(lbstm/lbbag)*2000lb/ton bag

[d]Steam data from Appendix E.

[e]Fuel data from AP-42, chapter 1.8 documentation.

| Test Run Number | 1 | 2 | 3 | |
|---|---|---|---|---|
| Particulate Emissions | | | | |
| Test Data[a] | February 5 | | | Average |
| | | | | |
| Emission Rate (lb/hr) | 60.335 | 78.835 | 72.433 | 70.534 |
| " (lb/MMbtu) | 0.233 | 0.305 | 0.289 | 0.276 |
| Steam Production (lb/hr)[d] | 133810 | 133700 | 130600 | 132703 |
| | | | | |
| Conc. (lb/1000lb steam)[b] | 0.45 | 0.59 | 0.55 | 0.53 |
| Conc. (lb/ton bagasse)[c] | 1.80 | 2.36 | 2.22 | 2.13 |

| | | |
|---|---|---|
| AP-42 Emission Factor Updates | QC by: | |
| Chapter 1.8: Bagasse Fired Boilers | | Data Rating: Control Devices: Twin Wet Scrubbers |
| Research by: Edward Skompski July 19, 1995 | Revised by: | |

| | |
|---|---|
| Test Fuel Data[e] | |
| | |
| Bagasse Fuel Data | |
| | |
| | |
| | |
| Conversion (lbsteam/lb bag) | 2 |
| | |

Report: Source Test Report for Particulate Emissions of Twin Impingement Wet Scrubbers on the number 6 Boiler Talisman Sugar Corporation Air Consulting and Engineering, February 1991

ref18 3.wk4

[a]Data from Table 1 on page 3.

[b]Calculation: (Concentration (lb/hr)/Stm(lb/hr))*1000 = (lb/1000 lb steam)

[c]Calculation: (Conc. (lb/hr)/Stm(lb/hr))*2(lbstm/lbbag)*2000lb/ton bag

[d]Steam data from Appendix E.

[e]Fuel data from AP-42, chapter 1.8 documentation.

Note: Run three invalid and not used in calculations

| Test Run Number | 1 | 2 | 4 | |
|---|---|---|---|---|
| Particulate Emissions | | | | |
| Test Data[a] | February 11 | | | Average |
| | | | | |
| Emission Rate (lb/hr) | 62.79 | 63.84 | 67.01 | 64.55 |
| " (lb/MMbtu) | 0.265 | 0.259 | 0.289 | 0.271 |
| Steam Production (lb/hr)[d] | 122060 | 126440 | 123440 | 123980 |
| | | | | |
| Conc. (lb/1000lb steam)[b] | 0.51 | 0.50 | 0.54 | 0.52 |
| Conc. (lb/ton bagasse)[c] | 2.06 | 2.02 | 2.17 | 2.08 |

| | | | | |
|---|---|---|---|---|
| AP-42 Emission Factor Updates | QC by: | | Test Fuel Data[e] | |
| Chapter 1.8: Bagasse Fired Boilers | | Data Rating: Control Devices: Twin Wet Scrubbers | | |
| Research by: Edward Skompski July 19, 1995 | Revised by: | | Bagasse Fuel Data | |
| Report: Source Test Report for Particulate Emissions of Twin Impingement Wet Scrubbers on the number 6 Boiler Talisman Sugar Corporation Air Consulting and Engineering, February 1991 | | [a]Data from Table 1 on page 3. | | |
| | | [b]Calculation: (Concentration (lb/hr)/Stm(lb/hr))*1000 = (lb/1000 lb steam) | | |
| | | [c]Calculation: (Conc. (lb/hr)/Stm(lb/hr))*2(lbstm/lbbag)*2000lb/ton bag | | |
| | | [d]Steam data from Appendix E. | Conversion (lbsteam/lb bag) | 2 |
| | | [e]Fuel data from AP-42, chapter 1.8 documentation. | | |
| ref18 4.wk4 | | | | |

| Test Run Number | 1 | 2 | 3 | |
|---|---|---|---|---|
| Particulate Emissions | | | | |
| Test Data[a] | November 27, 1990 | | | Average |
| | | | | |
| Emission Rate (lb/hr) | 47.46 | 41.72 | 42.39 | 43.86 |
| " (lb/MMbtu) | 0.198 | 0.176 | 0.176 | 0.183 |
| Steam Production (lb/hr)[d] | 121200 | 119700 | 122000 | 120967 |
| | | | | |
| Conc. (lb/1000lb steam)[b] | 0.39 | 0.35 | 0.35 | 0.36 |
| Conc. (lb/ton bagasse)[c] | 1.57 | 1.39 | 1.39 | 1.45 |

| | | | |
|---|---|---|---|
| AP-42 Emission Factor Updates | QC by: | | Test Fuel Data[e] | |
| Chapter 1.8: Bagasse Fired Boilers | | Data Rating: Control Devices: Twin Wet Scrubbers | | |
| Research by: Edward Skompski July 19, 1995 | Revised by: | | Bagasse Fuel Data | |
| Report: Source Test Report for Particulate Emissions of Twin Impingement Wet Scrubbers on the number 6 Boiler Talisman Sugar Corporation Air Consulting and Engineering, February 1991 | | [a]Data from Table 1 on page 3. | | |
| | | [b]Calculation: (Concentration (lb/hr)/Stm(lb/hr))*1000 = (lb/1000 lb steam) | | |
| | | [c]Calculation: (Conc. (lb/hr)/Stm(lb/hr))*2(lbstm/lbbag)*2000lb/ton bag | | |
| | | [d]Steam data from Appendix E. | Conversion (lbsteam/lb bag) | 2 |
| ref18 5.wk4 | | [e]Fuel data from AP-42, chapter 1.8 documentation. | | |

| | | | | |
|---|---|---|---|---|
| Test Run Number | 1 | 2 | 3 | |
| Particulate Emissions | | | | |
| Test Data[a] | November 29, 1990 | | | Average |
| | | | | |
| Emission Rate (lb/hr) | 42.21 | 44.18 | 45.67 | 44.02 |
| " (lb/MMbtu) | 0.199 | 0.196 | 0.2 | 0.198 |
| Steam Production (lb/hr)[d] | 109100 | 115600 | 117100 | 113933 |
| | | | | |
| Conc. (lb/1000lb steam)[b] | 0.39 | 0.38 | 0.39 | 0.39 |
| Conc. (lb/ton bagasse)[c] | 1.55 | 1.53 | 1.56 | 1.55 |

| | | | |
|---|---|---|---|
| AP-42 Emission Factor Updates | QC by: | | Test Fuel Data[e] |
| Chapter 1.8: Bagasse Fired Boilers | | Data Rating: Control Devices: Twin Wet Scrubbers | |
| Research by: Edward Skompski July 19, 1995 | Revised by: | | Bagasse Fuel Data |
| Report: Source Test Report for Particulate Emissions of Twin Impingement Wet Scrubbers on the number 6 Boiler Talisman Sugar Corporation Air Consulting and Engineering, February 1991 | | | |
| | | | Conversion (lbsteam/lb bag) 2 |
| ref18 6.wk4 | | | |

[a]Data from Table 1 on page 3.

[b]Calculation: (Concentration (lb/hr)/Stm(lb/hr))*1000 = (lb/1000 lb steam)

[c]Calculation: (Conc. (lb/hr)/Stm(lb/hr))*2(lbstm/lbbag)*2000lb/ton bag

[d]Steam data from Appendix E.

[e]Fuel data from AP-42, chapter 1.8 documentation.

| Test Run Number | 1 | 2 | 3 | |
|---|---|---|---|---|
| Particulate Emissions | | | | |
| Test Data[a] | December 6, 1990 | | | Average |
| | | | | |
| Emission Rate (lb/hr) | 41.09 | 36 | 38.02 | 38.37 |
| " (lb/MMbtu) | 0.203 | 0.183 | 0.194 | 0.193 |
| Steam Production (lb/hr)[d] | 103853 | 103853 | 103853 | 103853 |
| | | | | |
| Conc. (lb/1000lb steam)[b] | 0.40 | 0.35 | 0.37 | 0.37 |
| Conc. (lb/ton bagasse)[c] | 1.58 | 1.39 | 1.46 | 1.48 |

| | | | |
|---|---|---|---|
| AP-42 Emission Factor Updates | QC by: | | Test Fuel Data[e] | |
| Chapter 1.8: Bagasse Fired Boilers | | Data Rating: Control Devices: Twin Wet Scrubbers | | |
| Research by: Edward Skompski July 19, 1995 | Revised by: | | Bagasse Fuel Data | |
| | | [a]Data from Table 1 on page 3. | | |
| | | [b]Calculation: (Concentration (lb/hr)/Stm(lb/hr))*1000 = (lb/1000 lb steam) | | |
| Report: Source Test Report for Particulate Emissions of Twin Impingement Wet Scrubbers on the number 6 Boiler Talisman Sugar Corporation Air Consulting and Engineering, February 1991 | | [c]Calculation: (Conc. (lb/hr)/Stm(lb/hr))*2(lbstm/lbbag)*2000lb/ton bag | | |
| | | [d]Steam data from Appendix E. | Conversion (lbsteam/lb bag) | 2 |
| | | [e]Fuel data from AP-42, chapter 1.8 documentation. | | |
| ref18 7.wk4 | | | | |

| Test Run Number | 1 | 2 | 3 | |
|---|---|---|---|---|
| Particulate Emissions | | | | |
| Test Data[a] | December 11, 1990 | | | Average |
| | | | | |
| Emission Rate (lb/hr) | 61.02 | 64.03 | 65.27 | 63.44 |
| " (lb/MMbtu) | 0.152 | 0.159 | 0.164 | 0.158 |
| Steam Production (lb/hr)[d] | 235511 | 235511 | 235511 | 235511 |
| | | | | |
| Conc. (lb/1000lb steam)[b] | 0.26 | 0.27 | 0.28 | 0.27 |
| Conc. (lb/ton bagasse)[c] | 1.04 | 1.09 | 1.11 | 1.08 |

| | | | | |
|---|---|---|---|---|
| AP-42 Emission Factor Updates | QC by: | | Test Fuel Data[e] | |
| Chapter 1.8: Bagasse Fired Boilers | | Data Rating: Control Devices: Twin Wet Scrubbers | | |
| Research by: Edward Skompski July 19, 1995 | Revised by: | | Bagasse Fuel Data | |
| | | | | |
| | | | | |
| | | | | |
| | | | Conversion (lbsteam/lb bag) | 2 |
| | | | | |

Report: Source Test Report for Particulate Emissions of Twin Impingement Wet Scrubbers on the number 6 Boiler Talisman Sugar Corporation Air Consulting and Engineering, February 1991

ref18 8.wk4

[a]Data from Table 1 on page 3.

[b]Calculation: (Concentration (lb/hr)/Stm(lb/hr))*1000 = (lb/1000 lb steam)

[c]Calculation: (Conc. (lb/hr)/Stm(lb/hr))*2(lbstm/lbbag)*2000lb/ton bag

[d]Steam data from Appendix E.

[e]Fuel data from AP-42, chapter 1.8 documentation.

| Test Run Number | 1 | 2 | 3 | |
|---|---|---|---|---|
| Particulate Emissions | | | | |
| Test Data[a] | January 13, 1991 | | | Average |
| | 59.666 | 72.445 | 68.833 | 66.981 |
| Emission Rate (lb/hr) | 0.114 | 0.137 | 0.129 | 0.127 |
| " (lb/MMbtu) | 241343 | 243971 | 243971 | 243095 |
| Steam Production (lb/hr)[d] | | | | |
| | | | | |
| Conc. (lb/1000lb steam)[b] | 0.25 | 0.30 | 0.28 | 0.28 |
| Conc. (lb/ton bagasse)[c] | 0.99 | 1.19 | 1.13 | 1.10 |

| | | | | |
|---|---|---|---|---|
| AP-42 Emission Factor Updates | QC by: | | Test Fuel Data[e] | |
| Chapter 1.8: Bagasse Fired Boilers | | Data Rating: Control Devices: Twin Wet Scrubbers | | |
| Research by: Edward Skompski July 19, 1995 | Revised by: | | Bagasse Fuel Data | |
| | | | | |
| | | | | |
| | | | | |
| | | | Conversion (lbsteam/lb bag) | 2 |
| | | | | |

Report: Source Test Report for Particulate Emissions of Twin Impingement Wet Scrubbers on the number 6 Boiler Talisman Sugar Corporation Air Consulting and Engineering, February 1991

ref18 9.wk4

[a]Data from Table 1 on page 3.

[b]Calculation: (Concentration (lb/hr)/Stm(lb/hr))*1000 = (lb/1000 lb steam)

[c]Calculation: (Conc. (lb/hr)/Stm(lb/hr))*2(lbstm/lbbag)*2000lb/ton bag

[d]Steam data from Appendix E.

[e]Fuel data from AP-42, chapter 1.8 documentation.

| | | | | |
|---|---|---|---|---|
| Test Run Number | 1 | 2 | 3 | |
| Particulate Emissions | | | | |
| Test Data[a] | January 8, 1991 | | | Average |
| | | | | |
| Emission Rate (lb/hr) | 47.92 | 42.99 | 50.1 | 47.003 |
| " (lb/MMbtu) | 0.16 | 0.145 | 0.174 | 0.160 |
| Steam Production (lb/hr)[d] | 154194 | 152927 | 148889 | 152003 |
| | | | | |
| Conc. (lb/1000lb steam)[b] | 0.31 | 0.28 | 0.34 | 0.31 |
| Conc. (lb/ton bagasse)[c] | 1.24 | 1.12 | 1.35 | 1.24 |

| | | | | |
|---|---|---|---|---|
| AP-42 Emission Factor Updates | QC by: | | Test Fuel Data[e] | |
| Chapter 1.8: Bagasse Fired Boilers | | Data Rating: Control Devices: Twin Wet Scrubbers | | |
| Research by: Edward Skompski July 19, 1995 | Revised by: | | Bagasse Fuel Data | |
| | | [a]Data from Table 1 on page 3. | | |
| | | [b]Calculation: (Concentration (lb/hr)/Stm(lb/hr))*1000 = (lb/1000 lb steam) | | |
| Report: | Source Test Report for Particulate Emissions of Twin Impingement Wet Scrubbers on the number 6 Boiler Talisman Sugar Corporation Air Consulting and Engineering, February 1991 | [c]Calculation: (Conc. (lb/hr)/Stm(lb/hr))*2(lbstm/lbbag)*2000lb/ton bag | | |
| | | [d]Steam data from Appendix E. | Conversion (lbsteam/lb bag) | 2 |
| | | [e]Fuel data from AP-42, chapter 1.8 documentation. | | |

ref18 10.wk4

| Test Run Number | 1 | 2 | 3 | |
|---|---|---|---|---|
| Particulate Emissions | | | | |
| Test Data[a] | January 24, 1991 | | | Average |
| | | | | |
| Emission Rate (lb/hr) | 45.43 | 43.54 | 23.33 | 37.433 |
| " (lb/MMbtu) | 0.156 | 0.151 | 0.079 | 0.129 |
| Steam Production (lb/hr)[d] | 151667 | 149189 | 153243 | 151366 |
| | | | | |
| Conc. (lb/1000lb steam)[b] | 0.30 | 0.29 | 0.15 | 0.25 |
| Conc. (lb/ton bagasse)[c] | 1.20 | 1.17 | 0.61 | 0.99 |

| | | | | |
|---|---|---|---|---|
| AP-42 Emission Factor Updates | QC by: | | Test Fuel Data[d] | |
| Chapter 1.8: Bagasse Fired Boilers | | Data Rating: Control Devices: Twin Wet Scrubber | | |
| Research by: John Wescott July 24, 1995 | Revised by: | | Bagasse Fuel Data | |
| | | | | |
| | | | | |
| | | | | |
| | | | Conversion (lbsteam/lb bag) | 2 |

Report: Source Test Report, Number 5 Boiler, Impingement Wet Scrubbers, Particulate Emissions, Sugar Cane Growers Cooperative of Florida

ref18_11.wk4

[a]Data from section 1.0 on page 3 and Appendix A.

[b]Calculation: (Concentration (lb/hr)/Stm(lb/hr))*1000 = (lb/1000 lb steam)

[c]Calculation: (Conc. (lb/hr)/Stm(lb/hr))*2(lbstm/lbbag)*2000lb/ton bag

[d]Fuel data from AP-42, chapter 1.8 documentation.

| | | | | |
|---|---|---|---|---|
| Test Run Number | 1 | 2 | 3 | |
| Particulate Emissions | | | | |
| Test Data[a] | | December 5, 1990 | | Average |
| | | | | |
| Emission Rate (lb/hr) | 55.62 | 59.69 | 49.53 | 54.95 |
| " (lb/MMbtu) | 0.188 | 0.204 | 0.176 | 0.189 |
| Steam Production (lb/hr) | 173,611 | 172,222 | 165,000 | 170,278 |
| | | | | |
| Conc. (lb/1000lb steam)[b] | 0.32 | 0.35 | 0.30 | 0.32 |
| Conc. (lb/ton bagasse)[c] | 1.28 | 1.39 | 1.20 | 1.29 |

| AP-42 Emission Factor Updates | QC by: | | Test Fuel Data[d] | |
|---|---|---|---|---|
| Chapter 1.8: Bagasse Fired Boilers | | Data Rating: Control Devices: Wet Scrubber | | |
| Research by: John Wescott July 24, 1995 | Revised by: | | Bagasse Fuel Data | |
| | | [a]Data from section 1.0 on page 3 and Appendix A. | | |
| | | [b]Calculation: (Concentration (lb/hr)/Stm(lb/hr))*1000 = (lb/1000 lb steam) | | |
| Report: Source Test Report, Number 8 Boiler, Impingement Wet Scrubber, Particulate Emissions, Sugar Cane Growers Cooperative of Florida | | [c]Calculation: (Conc. (lb/hr)/Stm(lb/hr)) * 2(lbstm/lbbag) * 2000lb/ton bag | | |
| ref18_12.wk4 | | [d]Fuel data from AP-42, chapter 1.8 documentation. | Conversion (lbsteam/lb bag) | 2 |

| | | | | | |
|---|---|---|---|---|---|
| Test Run Number | 1 | 2 | 3 | 4 | |
| Particulate Emissions | | | | | |
| Test Data[a] | December 12, 1990 | | | | Average |
| | | | | | |
| Emission Rate (lb/hr) | 61.34 | 60.88 | 59.08 | 57.63 | 59.73 |
| " (lb/MMbtu) | 0.147 | 0.149 | 0.144 | 0.139 | 0.145 |
| Steam Production (lb/hr) | 245,000 | 240,947 | 240,800 | 243,478 | 242,556 |
| | | | | | |
| Conc. (lb/1000lb steam)[b] | 0.25 | 0.25 | 0.25 | 0.24 | 0.25 |
| Conc. (lb/ton bagasse)[c] | 1.00 | 1.01 | 0.98 | 0.00 | 0.75 |

| | | |
|---|---|---|
| AP-42 Emission Factor Updates | QC by: | |
| Chapter 1.8: Bagasse Fired Boilers | | Data Rating: Control Devices: Twin Wet Scrubbers |
| Research by: John Wescott July 24, 1995 | Revised by: | |

Report: Source Test Report for Particulate Emissions

Twin Impingement Wet Scrubbers, Number 1 Boiler

Sugar Cane Growers Cooperative of Florida

ref18_13.wk4

[a]Data from section 1.0 on page 3 and Appendix A.

[b]Calculation: (Concentration (lb/hr)/Stm(lb/hr))*1000 = (lb/1000 lb steam)

[c]Calculation: (Conc. (lb/hr)/Stm(lb/hr))*2(lbstm/lbbag)*2000lb/ton bag

[d]Fuel data from AP-42, chapter 1.8 documentation.

| Test Fuel Data[d] | |
|---|---|
| | |
| Bagasse Fuel Data | |
| | |
| | |
| | |
| Conversion (lbsteam/lb bag) | 2 |

| | | | | |
|---|---|---|---|---|
| Test Run Number | 1 | 2 | 3 | |
| Particulate Emissions | | | | |
| Test Data[a] | | November 19, 1990 | | Average |
| | | | | |
| Emission Rate (lb/hr) | 41.67 | 44.07 | 44.95 | 43.56 |
| " (lb/MMbtu) | 0.196 | 0.212 | 0.224 | 0.211 |
| Steam Production (lb/hr) | 125,064 | 122,336 | 124,075 | 123,825 |
| | | | | |
| Conc. (lb/1000lb steam)[b] | 0.33 | 0.36 | 0.36 | 0.35 |
| Conc. (lb/ton bagasse)[c] | 1.33 | 1.44 | 1.45 | 1.41 |

AP-42 Emission Factor Updates

Chapter 1.8: Bagasse Fired Boilers

Research by: John Wescott July 24, 1995

QC by:

Revised by:

Data Rating: Control Devices: Twin Wet Scrubbers

| Test Fuel Data[d] | |
|---|---|
| | |
| Bagasse Fuel Data | |
| | |
| | |
| | |
| Conversion (lbsteam/lb bag) | 2 |

[a]Data from section 1.0 on page 3 and Appendix A.

[b]Calculation: (Concentration (lb/hr)/Stm(lb/hr))*1000 = (lb/1000 lb steam)

[c]Calculation: (Conc. (lb/hr)/Stm(lb/hr)) * 2(lbstm/lbbag) * 2000lb/ton bag

[d]Fuel data from AP-42, chapter 1.8 documentation.

Report: Source Test Report for Particulate Emissions

Twin Impingement Wet Scrubbers, Number 2 Boiler

Sugar Cane Growers Cooperative of Florida

ref18_14.wk4

| | | | | |
|---|---|---|---|---|
| Test Run Number | 1 | 2 | 3 | |
| Particulate Emissions | | | | |
| Test Data[a] | | November 28, 1990 | | Average |
| | | | | |
| Emission Rate (lb/hr) | 41.89 | 53.73 | 44.01 | 46.54 |
| " (lb/MMbtu) | 0.206 | 0.258 | 0.212 | 0.225 |
| Steam Production (lb/hr) | 119,351 | 122,514 | 122,182 | 121,349 |
| | | | | |
| Conc. (lb/1000lb steam)[b] | 0.35 | 0.44 | 0.36 | 0.38 |
| Conc. (lb/ton bagasse)[c] | 1.40 | 1.75 | 1.44 | 1.53 |

| | | |
|---|---|---|
| AP-42 Emission Factor Updates | QC by: | |
| Chapter 1.8: Bagasse Fired Boilers | | Data Rating: Control Devices: Wet Scrubber |
| Research by: John Wescott July 24, 1995 | Revised by: | |

Report: Source Test Report for Particulate Emissions

Impingement Wet Scrubber, Number 2 Boiler

Sugar Cane Growers Cooperative of Florida

ref18_15.wk4

| | |
|---|---|
| Test Fuel Data[d] | |
| | |
| Bagasse Fuel Data | |
| | |
| | |
| | |
| Conversion (lbsteam/lb bag) | 2 |

[a]Data from section 1.0 on page 3 and Appendix A.

[b]Calculation: (Concentration (lb/hr)/Stm(lb/hr))*1000 = (lb/1000 lb steam)

[c]Calculation: (Conc. (lb/hr)/Stm(lb/hr))*2(lbstm/lbbag)*2000lb/ton bag

[d]Fuel data from AP-42, chapter 1.8 documentation.

| | | | | |
|---|---|---|---|---|
| Test Run Number | 1 | 2 | 3 | |
| Particulate Emissions | | | | |
| Test Data[a] | | January 23, 1991 | | Average |
| | | | | |
| Emission Rate (lb/hr) | 17.029 | 14.067 | 27.315 | 19.47 |
| " (lb/MMbtu) | 0.058 | 0.048 | 0.093 | 0.066 |
| Steam Production (lb/hr) | 150,380 | 148,831 | 149,189 | 149,467 |
| | | | | |
| Conc. (lb/1000lb steam)[b] | 0.11 | 0.09 | 0.18 | 0.13 |
| Conc. (lb/ton bagasse)[c] | 0.45 | 0.38 | 0.73 | 0.52 |

| | | | |
|---|---|---|---|
| AP-42 Emission Factor Updates | QC by: | | Test Fuel Data[e] |
| Chapter 1.8: Bagasse Fired Boilers | | Data Rating: Control Devices: Twin Wet Scrubbers | |
| Research by: Edward Skompski July 19, 1995 | Revised by: | | Bagasse Fuel Data |

Report: Source Test Report for Particulate Emissions of Twin Impingement Wet Scrubbers on the number 4 Boiler Talisman Sugar Corporation Air Consulting and Engineering, December 1991

ref18_16.wk4

[a]Data from Table 1 on page 3.

[b]Calculation: (Concentration (lb/hr)/Stm(lb/hr))*1000 = (lb/1000 lb steam)

[c]Calculation: (Conc. (lb/hr)/Stm(lb/hr))*2(lbstm/lbbag)*2000lb/ton bag

[d]Steam data from Appendix D.

[e]Fuel data from AP-42, chapter 1.8 documentation.

| | |
|---|---|
| Conversion (lbsteam/lb bag) | 2 |

| Test Run Number | 1 | 2 | 3 | |
|---|---|---|---|---|
| Particulate Emissions | | | | |
| Test Data[a] | December 9, 1991 | | | Average |
| | | | | |
| Emission Rate (lb/hr) | 60.88 | 57.38 | 60.33 | 59.530 |
| " (lb/MMbtu) | 0.265 | 0.253 | 0.267 | 0.262 |
| Steam Production (lb/hr)[d] | 116688 | 113533 | 114629 | 114950 |
| | | | | |
| Conc. (lb/1000lb steam)[b] | 0.52 | 0.51 | 0.53 | 0.52 |
| Conc. (lb/ton bagasse)[c] | 2.09 | 2.02 | 2.11 | 2.07 |

| | | | | |
|---|---|---|---|---|
| AP-42 Emission Factor Updates | QC by: | | Test Fuel Data[e] | |
| Chapter 1.8: Bagasse Fired Boilers | | Data Rating: Control Devices: Wet Scrubber | | |
| Research by: Edward Skompski July 20, 1995 | Revised by: | | Bagasse Fuel Data | |
| Report: Source Test Report for Particulate Emissions of Impingement Wet Scrubber on the number 8 Boiler Sugar Cane Growers Coop of Florida Air Consulting and Engineering, November 1991 | | [a]Data from Table 1 on page 3. | | |
| | | [b]Calculation: (Concentration (lb/hr)/Stm(lb/hr))*1000 = (lb/1000 lb steam) | | |
| | | [c]Calculation: (Conc. (lb/hr)/Stm(lb/hr))*2(lbstm/lbbag)*2000lb/ton bag | | |
| | | [d]Steam data from Appendix D. | Conversion (lbsteam/lb bag) | 2 |
| ref18_17.wk4 | | [e]Fuel data from AP-42, chapter 1.8 documentation. | | |

| Test Run Number | 1 | 2 | 3 | |
|---|---|---|---|---|
| Particulate Emissions | | | | |
| Test Data[a] | November 27, 1991 | | | Average |
| | | | | |
| Emission Rate (lb/hr) | 62.98 | 44.5 | 48.53 | 52.003 |
| " (lb/MMbtu) | 0.138 | 0.093 | 0.102 | 0.111 |
| Steam Production (lb/hr)[d] | 234545 | 243704 | 243600 | 240616 |
| | | | | |
| Conc. (lb/1000lb steam)[b] | 0.27 | 0.18 | 0.20 | 0.22 |
| Conc. (lb/ton bagasse)[c] | 1.07 | 0.73 | 0.80 | 0.87 |

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| | | | | |
|---|---|---|---|---|
| AP-42 Emission Factor Updates | QC by: | | Test Fuel Data[e] | |
| Chapter 1.8: Bagasse Fired Boilers | | Data Rating: Control Devices: Twin Wet Scrubbers | | |
| Research by: Edward Skompski July 20, 1995 | Revised by: | | Bagasse Fuel Data | |
| Report: Source Test Report for Particulate Emissions of Twin Impingement Wet Scrubbers on the number 1 Boiler Sugar Cane Growers Coop of Florida Air Consulting and Engineering, December 1991 | | [a]Data from Table 1 on page 3. | | |
| | | [b]Calculation: (Concentration (lb/hr)/Stm(lb/hr))*1000 = (lb/1000 lb steam) | | |
| | | [c]Calculation: (Conc. (lb/hr)/Stm(lb/hr))*2(lbstm/lbbag)*2000lb/ton bag | | |
| | | [d]Steam data from Appendix D. | Conversion (lbsteam/lb bag) | 2 |
| ref18_18.wk4 | | [e]Fuel data from AP-42, chapter 1.8 documentation. | | |

| Test Run Number | 1 | 2 | 3 | |
|---|---|---|---|---|
| Particulate Emissions | | | | |
| Test Data[a] | November 14, 1991 | | | Average |
| | | | | |
| Emission Rate (lb/hr) | 30.67 | 32.25 | 32.64 | 31.853 |
| " (lb/MMbtu) | 0.153 | 0.158 | 0.16 | 0.157 |
| Steam Production (lb/hr)[d] | 117818 | 120000 | 120000 | 119273 |
| | | | | |
| Conc. (lb/1000lb steam)[b] | 0.26 | 0.27 | 0.27 | 0.27 |
| Conc. (lb/ton bagasse)[c] | 1.04 | 1.08 | 1.09 | 1.07 |

| | | |
|---|---|---|
| AP-42 Emission Factor Updates | QC by: | |
| Chapter 1.8: Bagasse Fired Boilers | | Data Rating: Control Devices: Twin Wet Scrubbers |
| Research by: Edward Skompski July 20, 1995 | Revised by: | |

Report: Source Test Report for Particulate Emissions of Twin Impingeme nt Wet Scrubbers on the number 2 Boiler Sugar Cane Growers Coop of Florida Air Consulting and Engineering, November 1991

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| | |
|---|---|
| Test Fuel Data[e] | |
| | |
| Bagasse Fuel Data | |
| | |
| | |
| | |
| Conversion (lbsteam/lb bag) | 2 |
| | |

[a]Data from Table 1 on page 3.

[b]Calculation: (Concentration (lb/hr)/Stm(lb/hr))*1000 = (lb/1000 lb steam)

[c]Calculation: (Conc. (lb/hr)/Stm(lb/hr))*2(lbstm/lbbag)*2000lb/ton bag

[d]Steam data from Appendix D.

[e]Fuel data from AP-42, chapter 1.8 documentation.

| Test Run Number | 1 | 2 | 3 | |
|---|---|---|---|---|
| Particulate Emissions | | | | |
| Test Data[a] | November 15, 1991 | | | Average |
| | | | | |
| Emission Rate (lb/hr) | 41.32 | 34.28 | 33.12 | 36.240 |
| " (lb/MMbtu) | 0.206 | 0.17 | 0.164 | 0.180 |
| Steam Production (lb/hr)[d] | 119172 | 119564 | 119564 | 119433 |
| | | | | |
| Conc. (lb/1000lb steam)[b] | 0.35 | 0.29 | 0.28 | 0.30 |
| Conc. (lb/ton bagasse)[c] | 1.39 | 1.15 | 1.11 | 1.21 |

| | | | |
|---|---|---|---|
| AP-42 Emission Factor Updates | QC by: | | Test Fuel Data[e] |
| Chapter 1.8: Bagasse Fired Boilers | | Data Rating: Control Devices: Twin Wet Scrubbers | |
| Research by: Edward Skompski July 20, 1995 | Revised by: | | Bagasse Fuel Data |
| Report: Source Test Report for Particulate Emissions of Twin Impingement Wet Scrubbers on the number 6 Boiler Talisman Sugar Corporation Air Consulting and Engineering, December 1991 | | [a]Data from Table 1 on page 3.<br>[b]Calculation: (Concentration (lb/hr)/Stm(lb/hr))*1000 = (lb/1000 lb steam)<br>[c]Calculation: (Conc. (lb/hr)/Stm(lb/hr))*2(lbstm/lbbag)*2000lb/ton bag<br>[d]Steam data from Appendix D. | |

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