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Wood Residue-Fired Steam Generator Particulate Matter Control Technology Assessment

Emission Standards and Engineering Division

U.S. ENVIRONMENTAL PROTECTION AGENCY
Office of Air, Noise, and Radiation
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I. INTRODUCTION

In the United States the paper and pulp industry produces approximately 80 million tons of wood waste each year,[1] which in heating value corresponds to 110 million barrels of oil or 32 million tons of anthracite coal. This is approximately 75 percent of our annual consumption of residual fuel oil and 5 percent of our annual consumption of coal.

Prior to the 1960's the method of disposal for wood waste consisted mostly of incineration in Dutch ovens or open air tepees. Since then the advent of the spreader stroker boiler and the increasing costs of fossil-fuels has made wood residue an economical fuel to burn in large boilers for the generation of process steam.

There are several hundred steam generating boilers in the pulp and paper and allied forest product industry that use fuel which is partly or totally derived from wood residue. These boilers range in size from 6 megawatts (20 million Btu per hour) heat input to 146 megawatts (500 million Btu per hour) heat input and are estimated to be emitting 225 tons of particulate matter per day after application of existing air pollution control devices.[2]

On November 22, 1976, EPA amended the standards of performance for new fossil-fuel-fired steam generators to allow the heat content of wood residue to be used for determining compliance with the standard. Prior to this amendment, performance tests on such boilers had to be conducted with the boiler consuming 100 percent fossil fuel. After the wood residue amendment, a combination boiler was required to burn its normal fuel mix to determine compliance with the Federal particulate matter standard of 43 nanograms per joule. In most cases the use of mechanical collectors has provided State compliance for wood residue boilers, but in those States where a stringent regulation exists 108 to 215 nanograms per joule more efficient control systems are used.

The control system that has the widest application is a mechanical collector in series with a wet-impingement scrubber. This system has demonstrated the ability to provide compliance with the Federal particulate matter standard for boilers firing nonsalt-laden wood residue.

For boilers burning salt laden wood residue, the high temperature baghouse has been proved to provide compliance with the Federal particulate matter standard. Also the baghouse provides compliance on boiler burning nonsalt-laden wood residue, but concern over fire hazards from burning cinders has inhibited the use of this system.

II. DESCRIPTION OF INDUSTRY

There are several hundred steam generating boilers in use in the pulp and paper and allied forest product industry which burn wood residue waste, both to alleviate a potential solid waste disposal problem and to provide an economical fuel substitute for fossil fuels. The number of bark boilers is growing at the rate of 15 percent each year. The trend is toward fewer but larger sized boilers.[3]

The major breakthrough came in the mid-40's with the development of the spreader stoker, which offered a much more efficient method of burning than the earlier "Dutch oven" type furnaces. A modern bark boiler, in conjunction with other heat and chemical recovery units, can supply all the steam requirements of most mills by utilizing wood residue as the dominant fuel.[4]

The first processing step to provide this fuel involves debarking of the logs to be used by the Kraft process or for lumber. The debarking is accomplished in a variety of methods which utilize natural or mechanical friction. Succeeding this, the various sizes of bark are fed through a disintegrator or "hog" to produce a uniform size bark chip. After hogging, the bark is conveyed to a surge bin or storage facility, sized to allow for one to two hours of boiler firing at maximum capacity.

Final distribution of the bark is accomplished from the individual boiler chutes with either a pneumatic or mechanical distributor.

III. CHARACTERISTICS OF WOOD RESIDUE

In wood processing approximately 50 percent of the weight of the raw wood (logs) is removed to produce sound lumber. Though the total waste usually averages approximately 50 percent, distribution of the different types of waste such as slab edgings, trimmings, bark, sawdust, and shavings may vary depending on mill conditions and product desired. Usually, this residue is divided into 18 percent slab edgings and trimmings, 10 percent bark, and 20 percent sawdust and shavings.[5]

The mills frequently use sawdust or shavings and sawdust mixtures for steam production, because they can be burned without further processing. The remainder of the waste products requires further size reduction in a "hog" machine to facilitate storage, feeding, and combustion. These newly sized products, in addition to a varying percentage of sawdust and shavings, present constitute "hog fuel."

This so-called hog fuel may contain on the average, 50 percent moisture, but the moisture content may vary considerably, depending on the particular type of wood processing involved. Other than the moisture content, wood shows a remarkably uniform composition. It usually contains less than 1 percent ash and little or no sulfur. Table 2 shows a comparative chemical analysis of wood and bark, coal, and oil. Table 3 analyzes hogged fuel, while covering moisture content on an "as received" as well as an "air dried" basis.

IV. BOILER DESIGN AND OPERATION

In general, bark boilers can be divided into two ranges of sizes, less than 1133.7 kilograms steam per minute (200 million Btu per hour) and 113.7 kilograms steam per minute to 6048.0 kilograms steam per minute (1066 million Btu per hour).[6] Three basic classes of furnace design are commonly used for wood firing: Dutch ovens, spreader stokers, and suspension burners.

In a Dutch oven the burning is done in two stages: (1) drying and gasification, and (2) combustion of gaseous products. The first stage is accomplished in a cell separated from the boiler section by a bridge wall; the combustion stage takes place in the main boiler section. This type of unit is not responsive to steam load changes and has poor temperature stability. It has poor combustion control and is not commonly used to fire multiple fuels.[7]

The spreader stoker type boilers operate with three stage burning in a single chamber: (1) drying (in suspension), (2) distillation and burning of volatile matter, and (3) burning of fixed carbon. This type of operation has a fast response to load changes, has improved combustion control, and can be operated with multiple fuels.[8]

In order to increase steam production in a spreader stoker boiler or to keep the boiler temperature up while burning wood fuel of poor or variable quality, gas or oil is often burned as an auxiliary fuel. Gas or oil is the auxiliary fuel normally used, but coal can also be used when provided for in design.[9]

Another type of boiler that, as yet, has had limited application, is the suspension-fired boiler which is similar to a pulverized coal-fired boiler. This type of boiler requires finely hogged bark to guarantee that the bark will burn in suspension.

Most bark boilers have spreader stoker firing equipment and burn the bark on the grate in a thin layer. The most popular type of stoker is the traveling grate stoker. It is ideally suited for areas with high ash content bark, since it provides for continuous ash discharge. It also can better compensate for bad bark distribution than can a dump grate stoker. Because of this, the traveling grate stoker requires less grate area and results in a physically smaller sized boiler.

At present, bark boiler emissions are more affected by the various process operations than they are by the application of air pollution control equipment. Boiler design, auxiliary equipment design, bark handling techniques, excess air used, wood moisture content, and equipment operation all have a significant effect. The most predominant effect by far, however, is the type and amount of fly ash reinjection.[10]

Fly ash reinjection systems, which return collected particles to the combustion zone to achieve more complete combustion of the carbon, represent a compromise between two conflicting objectives. While reinjection increases boiler efficiency from 1 to 4 percent and minimizes the emissions of uncombusted carbon, it also increases boiler maintenance requirements, decreases the average fly ash particle size, increases the dust load to the collector, and makes collection more difficult. Properly designed reinjection systems should separate the sand and the char from the exhaust gases, reinject the larger carbon fraction to the boiler, and reinject the fine sand particles to the ash disposal system.

V. CHARACTERISTICS OF PARTICULATE EMISSIONS

The particulate carried in the wood-fired boiler exhaust gas consists of two separate and distinguishable materials - sand and bark char or fly ash. The sand is usually entrained with the char, the quantity depending on the method by which the original wood was logged and delivered. The fly ash particulates have a low specific gravity, 0.15 to 0.5, and a large surface area to particle mass ratio.[11] A typical size distribution curve is given in Table 4.

The bark fly ash, unlike most fly ash, is primarily unburned carbon. With collection and reinjection to the boiler, greater carbon burnout can increase boiler efficiency from one to four percent. The reinjection of collected ash also significantly increases the dust loading since the sand is also recirculated with the fly ash.

Bark boiler emissions are more affected by the various process operations than they are by the application of air pollution control equipment. Boiler design, auxiliary equipment design, bark handling techniques, and equipment operation all have a significant effect. The process operation which has the greatest adverse effect is the type and amount of fly ash reinjection. A tenfold dust loading increase has been reported with 100 percent reinjection.[12]

VI. EMISSION CONTROL TECHNOLOGY

A survey of currently operated facilities which fire wood residue alone or in combination with fossil fuel shows that most operate with mechanical collectors; some operate with low energy wet scrubbers, and a few facilities currently use higher energy venturi scrubbers (HEVS) or electrostatic precipitators (ESP). One facility reviewed is using a high temperature baghouse control system.

Practically all of the facilities currently meeting the new source particulate matter standard (43 nanograms per joule) are using wet scrubbers of the venturi or wet impinger type. Table I presents a summary of the best systems in operation today.

Currently, the use of multitube cyclone mechanical collectors on hogged fuel boilers provides the sole source of particulate removal for a majority of existing plants. The most commonly used system employs two multicyclones in series, allowing for the first collector to remove the bulk of the dust and a second collector with special high efficiency vanes for the removal of the finer particles. Collection efficiency for this arrangement ranges from 65 to 95 percent. This efficiency range is not sufficient to provide compliance with the Federal particulate matter standard, but does provide a widely used first stage collection to which other control systems are added.

Of special note is one facility using a Swedish designed mechanical collector in series with conventional multiclone collectors. The Swedish collector is a small diameter multitube cyclone with a movable vane ring that imparts a spinning motion to the gases while at the same time maintaining a low pressure differential. This system is reducing emissions from the largest boiler found in the review to 107 nanograms per joule.[13]

Electrostatic precipitators have been demonstrated to allow compliance with the particulate matter standard when coal is used as an auxiliary fuel. Available information indicates that this type of control provides high collection efficiencies on combination wood residue coal-fired boilers. One ESP collects particulate matter from a 50 percent bark, 50 percent coal combination-fired boiler. An emission level of 13 nanograms per joule (.03 pounds per million Btu) was obtained using test procedures recommended by the American Society of Mechanical Engineers.

The fabric filter (baghouse) particulate control system provides the highest collection efficiency available, 99.9 percent. On one facility currently using a baghouse on a wood residue-fired boiler, the sodium chloride content of the ash being filtered is high enough (70 percent) that the possibility of fire is practically eliminated. Source test data collected with EPA Method 5 showed this system reduces the particulate emissions to 5 nanograms per joule (.01 pounds per million Btu) while this boiler is firing 100 percent bark.[15]

The application of fabric filters to control emissions from hogged fuel boilers has recently gained acceptance from several facilities of the paper and pulp industry, mainly due to the development of improved designs and operation procedures that reduce fire hazards. Several large sized boilers, firing salt and non-salt laden wood residue, are being equipped with fabric filter control systems this year and the performance of these installations will verify the effectiveness of fabric filtration.

Practically all of the facilities currently meeting the new source particulate matter standard are using wet scrubbers of the venturi or wet-impinger type. These units are usually connected in series with a mechanical collector. Three facilities reviewed which are using the wet-impingement type wet scrubber on large boilers burning 100 percent bark are producing particulate emissions well below the 43 nanograms per joule standard at operating pressure drops of 1.5 to 2 kPa (6 to 8 inches, H_2O). Five facilities using venturi type wet scrubbers on large boilers, two burning half oil and half bark, and the other three burning 100 percent bark, are producing particulate emissions consistently below the standard at pressure drops of 2.5 to 5 kPa (10 to 20 inches, H_2O).

One facility has a large boiler burning 100 percent bark emitting a maximum of 5023 nanograms per joule of particulate matter into a multicyclone dust collector rated at an efficiency of 87 percent. The outlet loading from this mechanical collector is directed through two wet-impingement type scrubbers in parallel. With this arrangement of scrubbers, a collection efficiency of 97.7 percent is obtained at pressure drops of 2 kPa (8 inches, H_2O). Source test data collected with EPA Method 5 showed particulate matter emissions to be 15 nanograms per joule, well below the 43 nanograms per joule standard.[16]

Another facility with a boiler of similar size and fuel was emitting a maximum of 4650 nanograms per joule into a multicyclone dust collector operating at a collection efficiency of 66 percent. The outlet loading from this collector is drawn into two wet-impingement scrubbers arranged in parallel. The operating pressure drop on these scrubbers was varied within the range of 1.6 to 2.0 kPa (6 to 8 inches, H_2O), resulting in a proportional decrease in discharged loadings of 25.8 to 18.5 nanograms per joule.[17] Source test data collected on this source was done with the Montana Sampling Train.

Facilities using a venturi type wet scrubber were found to be able to meet the 43 nanograms per joule standard at higher pressure drops than the impingement type scrubber. One facility with a large boiler burning 100 percent bark had a multi-cyclone dust collector in series with a venturi wet scrubber operating at a pressure drop of 5 kPa (20 inches, H_2O). Source test data using EPA Method 5 showed this system reduced emissions to an average outlet loading of 17.2 nanograms per joule of particulate matter.[17] Another facility with a boiler burning 40 percent bark and 60 percent oil has a multicyclone and venturi scrubber system obtaining 25.8 nanograms per joule at a pressure drop of 2.5 kPa (10 inches, H_2O).[19] The Florida Wet Train was used to obtain emission data at this source. A facility of similar design but burning 100 percent bark is obtaining the same emission control, 25.8 nanograms per joule, at a pressure drop of 3 kPa (12 inches, H_2O).[20] Source test data collected on this source was obtained with EPA Method 5.

VII. REFERENCES

1. "Economics of Environmentally Acceptable Wood Waste Burning" by Jorgen G. Nedenhaz. February 1978.

2. "Air Pollution Control Technology and Costs in Nine Selected Areas." Industrial Gas Cleaning Institute, Inc. September 1972.

3. "Handling Ash from Bark-Fired Boilers." Robert L. Bump. Power, p. 94, February 1977.

4. Ibid.

5. "Comparison of Fossil and Wood Fuels," E. H. Hall, EPA Report Number EPA-600/2-76-056, March 1976.

6. "Kraft Mill Bark Boilers," L. C. Hardison, EPA Contract Number 68-02-0301. September 1972.

7. "An Investigation of Source Particulate Measurement Procedures, Particle Sizes, and Practical Control Technology for Wood Fuel-Fired Boilers," National Council of the Paper Industry for Air and Stream Improvement. Technical Bulletin No. 72. June 1974.

8. Ibid.

9. "Boilers Fired With Wood and Bark Residues," David C. Junge, Oregon State University. Research Bulletin 17. November 1975.

10. Reference 2.

11. "Studies on the Collection of Bark Char Throughout the Industry," Alvah Barron, Jr. Tappi, August 1970. Volume 53, Number 8.

12. Ibid

13. "Combination Fuel Boiler Particulate Emission Control Pilot Studies," National Council of the Paper Industry for Air and Stream Improvement. Technical Bulletin Number 73, June 1974.

14. Source Test Data on Westvaco Co., Covington, Virginia, from Westvaco Co. (September 1977)

15. Source Test Data on Simpson Timber Co., Shelton, Washington, from Olympic Air Pollution Control Authority. (September 1977)

16. "Wet Scrubber Application to Hogged Fuel Boiler." John W. Robinson. Kirby Timber Corp. A paper for presentation at the 68th Annual Meeting of the Air Pollution Control Association, June 1975.

17. "Hogged Fuel Boiler Emissions Control - A Case History." Herman K. Effenberger. A paper for presentation at Environmental Division Conference of Tappi, May 1972.

18. "An Examination of the Performance of Wet Scrubbers on Combination Fuel-Fired Boilers." Andrew G. Kutyna. November 1976.

19. Ibid.

20. Ibid.

TABLE 1

SUMMARY OF TESTS ON BARK BOILERS

	Oregon	Montana	Texas	Montana	Oregon	Virginia	Georgia	Georgia	Washington
Type of Fuel	Bark	Bark	Bark	Bark	Bark	Bark/Coal	Bark/Oil	Bark/Oil	Bark
(% bark/auxiliary)	(100/0)	(100/0)	(100/0)	(100/0)	(100/0)	(50/50)	(98/2)	(70/30)	(100/0)
Control System	cyclone wet scrubber	cyclone wet scrubber	cyclone wet scrubber	cyclone wet scrubber	cyclone wet scrubber	cyclone ESP	cyclone wet scrubber	cyclone	baghouse
Pressure Drop (inches, W.G.)	7.5	8.10	8.0	7.0					5.0
10^6 Btu/hr fired	240	200	200	270	240	260	175	500	266
Emissions, nanogram per joule	37	19	15	42	38	13	28	107	5
($lb/10^6$ Btu)	(.087)	(.043)	(.035)	(.098)	(.088)	(.03)	(.065)	(.25)	(.01)

TABLE 2

COMPARATIVE CHEMICAL ANALYSIS OF WOOD AND BARK, COAL, AND OIL

Analyses (dry basis), % by wt	Wood and Bark						Coal			Residual Fuel Oil
	Pine(a) Bark	Oak(a) Bark	Spruce(a) Bark	Redwood(a) Bark	Redwood(b)	Pine(b)	Washed Penn. Coal	Western(d) Coal	Penn.(c) Coal	Range of (e) No. 6 Oil
Proximate										
Volatile matter	72.9	76.0	69.6	72.6	82.5	79.4	35.8	43.4	37.7	
Fixed carbon	24.2	18.7	26.6	27.0	17.3	20.1	57.3	51.7	52.2	
Ash	2.9	5.3	3.8	0.4	0.2	0.5	6.9	4.9	10.1	
Ultimate										
Hydrogen	5.6	5.4	5.7	5.1	5.9	6.3	5.1	6.4	5.0	9.5 - 12.0
Carbon	53.4	49.7	51.8	51.9	53.5	51.8	78.1	54.6	74.2	86.5 - 90.2
Sulfur	0.1	0.1	0.1	0.1	0	0	1.2	0.4	2.1	0.7 - 3.5
Nitrogen	0.1	0.2	0.2	0.1	0.1	0.1	1.6	1.0	1.5	--
Oxygen	37.9	39.3	38.4	42.4	40.3	41.3	7.1	33.8	7.1	--
Ash	2.9	5.3	3.8	0.4	0.2	0.5	6.9	3.3	10.1	0.1 - 0.5
Heating value, Btu/lb	9030	8370	8740	8350	9220	9130	13,970	9,420	13,310	17,410 - 18,990
Ash Analyses, % by wt										
SiO_2	39.0	11.1	32.0	14.3				30.7(d)	49.7(d)	
Fe_2O_3	3.0	3.3	6.4	3.5				18.9	11.4	
TiO_2	0.2	0.1	0.8	0.3				1.1	1.2	
Al_2O_3	14.0	0.1	11.0	4.0				19.6	26.8	
Mn_3O_4	Trace	Trace	1.5	0.1				--		
CaO	25.5	64.5	25.3	6.0				11.3	4.2	
MgO	6.5	1.2	4.1	6.6				3.7	0.8	
Na_2O	1.3	8.0	8.0	18.0				2.4	2.9	
K_2O	6.0	0.2	2.4	10.6						
SO_3	0.3	2.0	2.1	7.4				12.2	2.5	
Cl	Trace	Trace	Trace	18.4						

(a) Reference (22). (b) Reference (11). (c) Reference (23). (d) Reference (24). (e) Reference (22).

TABLE 3

CHEMICAL ANALYSES OF HOGGED FUELS

(%, except as noted)

Item	Type of Fuel		
	Western Hemlock	Douglas Fir	Pine Sawdust
Moisture, as received	57.9	35.9	--
Moisture, air-dried	7.3	6.5	6.3
Proximate analysis, dry:			
Fuel			
Volatile matter	74.2	82.0	79.4
Fixed carbon	23.6	17.2	20.1
Ash	2.2	0.8	0.5
Ultimate analysis, dry:			
Fuel			
Hydrogen	5.8	6.3	6.3
Carbon	50.4	52.3	51.8
Nitrogen	0.1	0.1	0.1
Oxygen	41.4	40.5	41.3
Sulfur	0.1	0	0
Ash	2.2	0.8	0.5
Heating value, dry: (joule/kg)	20.05×10^6	21.05×10^6	21.25×10^6

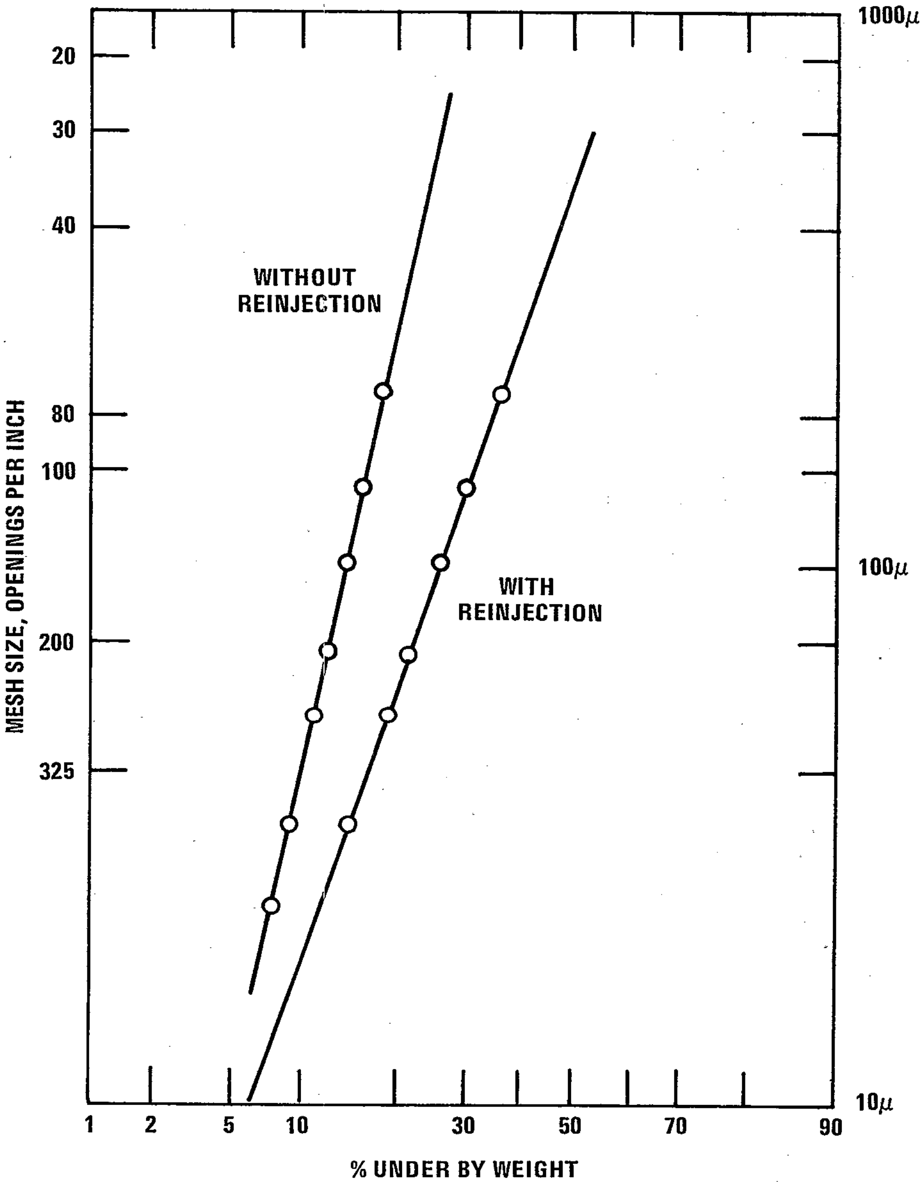

Figure 1. Particle size distribution of bark boiler flyash.

TECHNICAL REPORT DATA

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16. ABSTRACT

This document presents the results of a performance review of particulate matter control systems on wood-fired steam generators. This review describes the industry, presents the characteristics of wood residue and particulate emissions, and discusses the control equipment and emission limits which represent Best Available Control Technology (BACT).

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
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