NATIONAL COUNCIL FOR AIR AND STREAM IMPROVEMENT

A COMPREHENSIVE COMPILATION AND REVIEW OF WOOD-FIRED BOILER EMISSIONS

TECHNICAL BULLETIN NO. 1013
MARCH 2013

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PRESIDENT'S NOTE

The forest products industry continues to be the major industrial user of wood fuels, which are burned at its manufacturing facilities to generate steam, electric power, and process heat. Because wood is a carbon-neutral renewable resource, interest in replacing fossil fuels with wood fuels has grown dramatically in recent years. In addition to forest product companies, electric utilities and independent power producers are increasing their use of wood fuels. Despite the benefits of using wood fuels, some environmental advocacy groups cite emissions from wood-fired boilers as the basis for their opposition to the installation of new biomass boilers.

Over the last 40 years, NCASI has addressed questions about emissions from wood-fired boilers given their importance to the forest products industry. NCASI has conducted investigations of particulate matter, SO_2, NO_x, CO, volatile organic compounds, sulfuric acid mist, HCl, mercury, and dioxin emissions. These investigations have entailed evaluation of various stack sampling methods and continuous emissions monitors, sampling and analysis of wood fuels, and extensive stack testing on wood-fired boilers. The data generated in these studies have allowed NCASI to identify the key factors influencing the emissions of these substances and evaluate emissions reductions that might be achieved by the application of various control measures.

In addition to the targeted investigations conducted by NCASI, many individual companies have carried out emission tests on numerous wood-fired boilers during the last four years. EPA required comprehensive stack tests on about 50 wood-fired boilers in 2009-2010 to obtain data for its Boiler MACT rulemaking. Additional testing was performed by some companies on other boilers in anticipation of new EPA emission limits. NCASI obtained the stack sampling and associated laboratory reports for most of these tests, which allowed for a detailed quality assurance review of each report.

The large body of additional data from these recent comprehensive tests was incorporated into NCASI's emissions database for wood-fired boilers. These data were grouped according to factors having a major impact on emissions of a particular substance (e.g., control device, boiler design, or fuel properties), and advanced statistical techniques were applied to calculate means, medians, standard deviations, and upper prediction limits for each data set. The resulting collection of emission factors is now the most complete, up-to-date set of factors representative of current wood-fired boiler operations in North America. They supersede previous factors published by NCASI in 2004 for criteria pollutants and in 2010 for non-criteria pollutants ("air toxics").

NCASI stakeholders will find the information in this report helpful as they engage in permitting activities related to wood-fired boilers, prepare emission inventory reports for state and provincial agencies, and respond to annual air release reporting obligations.

NCASI is preparing a companion report that will summarize emission test data for combination boilers—i.e., those boilers co-firing wood fuels with significant amounts of other fuels such as coal, oil, natural gas, petroleum coke, wastewater treatment plant residuals, and paper recycling residuals. That report will be completed later this year.

Ronald A. Yeske

March 2013

NOTE DU PRÉSIDENT

L'industrie des produits forestiers continue d'être un important utilisateur de combustibles ligneux, lesquels sont brûlés par ses installations de fabrication pour générer de la vapeur, de l'électricité et de la chaleur destinée au procédé. L'intérêt pour les combustibles ligneux comme solution de remplacement aux combustibles fossiles a considérablement augmenté au cours des dernières années en raison de la renouvelabilité et de la carboneutralité du bois. Non seulement les sociétés forestières ont augmenté leur consommation de combustibles ligneux mais aussi les producteurs indépendants d'électricité et les services publics d'électricité. En dépit des avantages que procurent les combustibles ligneux, certains groupes environnementaux s'opposent à l'installation de nouvelles chaudières à biomasse en invoquant comme argument les émissions de ces chaudières.

Au cours des 40 dernières années, NCASI a examiné la question des émissions des chaudières brûlant des résidus de bois en raison de l'importance de ces chaudières pour l'industrie des produits forestiers. NCASI a réalisé des études sur les émissions de particules, de SO_2, de NO_x, de CO, de composés organiques volatils, de brouillard d'acide sulfurique, d'acide chlorhydrique (HCl), de mercure et de dioxines. Ces études ont donné lieu à l'évaluation de diverses méthodes d'échantillonnage à la cheminée et de systèmes de surveillance continue des émissions, à l'échantillonnage et à l'analyse de combustibles ligneux, ainsi qu'à l'échantillonnage à grande échelle de chaudières brûlant des résidus de bois. Les données obtenues dans le cadre de ces études ont permis à NCASI de mettre en lumière les facteurs clés influençant les émissions de ces substances et d'évaluer les réductions d'émissions qui pourraient être réalisées en appliquant un certain nombre de mesures de contrôle.

En plus, un grand nombre de sociétés forestières ont procédé, au cours des quatre dernières années, à des essais de caractérisation sur de nombreuses chaudières brûlant des résidus de bois. L'Agence de protection de l'environnement (EPA) avait exigé que des essais complets à la cheminée soient effectués sur environ 50 chaudières de ce type en 2009-2010 afin d'obtenir des données en vue du règlement Boiler MACT. Certaines sociétés ont effectué des essais additionnels sur d'autres types de chaudières en prévision de nouvelles limites d'émissions que pourraient fixer l'EPA. NCASI a obtenu les données de ces essais et les rapports de laboratoire associés à la plupart de ces essais, ce qui a permis à NCASI d'effectuer un examen complet d'assurance-qualité de chaque rapport.

NCASI a incorporé ce grand nombre de données additionnelles dans sa base de données sur les émissions des chaudières brûlant des résidus de bois et les a regroupées selon des facteurs qui ont un impact majeur sur les émissions d'une substance particulière (p. ex. le dispositif de contrôle de la pollution, la conception de la chaudière ou les propriétés du combustible). NCASI a ensuite utilisé des méthodes statistiques de pointe pour calculer des moyennes, des médianes, des écarts-types et des limites de prédiction supérieures pour chaque ensemble de données. Les facteurs d'émission issus de ce travail représentent maintenant l'ensemble de facteurs le plus complet et le plus récent sur le fonctionnement actuel des chaudières brûlant des résidus de bois en Amérique du Nord. Ces facteurs remplacent les facteurs précédents publiés par NCASI en 2004 pour les principaux polluants atmosphériques et en 2010 pour les autres polluants atmosphériques (« substances toxiques atmosphériques »).

Les parties prenantes de NCASI trouveront utiles les renseignements dans le présent rapport au moment d'entreprendre leurs activités reliées à la délivrance de permis sur les chaudières brûlant des résidus de bois, de préparer des inventaires d'émissions à déclarer aux agences gouvernementales des États et des provinces et de répondre aux exigences de déclarations annuelles sur les rejets atmosphériques.

NCASI prépare actuellement un rapport complémentaire qui contiendra un résumé des données de caractérisation des émissions provenant de chaudières mixtes, c.-à-d. des chaudières qui brûlent des résidus de bois avec une importante quantité d'autres combustibles tels que le charbon, le mazout, le gaz naturel, le coke de pétrole, les biosolides ou les résidus de papier. Ce rapport sera terminé au cours de l'année 2013.

Ronald A. Yeske

Mars 2013

A COMPREHENSIVE COMPILATION AND REVIEW OF WOOD-FIRED BOILER EMISSIONS

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ABSTRACT

A significant amount of emissions data for boilers exclusively burning wood residues are summarized in this report. Data for a few boilers burning less than 10% gas or less than 5% wastewater treatment plant residuals (sludge), with the remainder being wood residues, are also included. The bulk of the new data was generated during the last four years as a result of mandatory and voluntary sampling efforts related to EPA's post-2007 Boiler MACT rulemaking activity. The testing conducted since July 2009 had focused on a few key compounds: formaldehyde, HCl, HF, the 11 trace metals listed as hazardous air pollutants (including mercury), PCDD/Fs, total filterable particulate matter and carbon monoxide. In several instances, measurements for methane, other trace metals, condensible PM, filterable $PM_{2.5}$, SO_2, NO_x and VOC as C (Method 25A) were also made.

NCASI obtained stack test and associated laboratory reports for almost all of these tests, and then carried out a detailed QA/QC review to identify any errors and correct, if necessary, the reported results. For formaldehyde, HCl, HF, methane and N_2O (GHGs), the 11 trace metal HAPs, PCDD/Fs, filterable $PM_{2.5}$, condensible PM (CPM), CO, SO_2, NO_x and THC/VOCs, new emission factors from recently generated data are developed in this report. For the rest of the air emissions, including organics other than HCHO, and non-HAP trace metals, the new data from these Boiler MACT-related tests were combined with (1) quality assured data available in NCASI files pertaining to a few boilers operating in the wood products sector and (2) a significant amount of data retained from the previous NCASI compilation for wood-fired boilers (NCASI Technical Bulletin No. 973). This earlier NCASI report included a compilation of all the test data contained in the background document for Section 1.6 of EPA's AP-42 publication (Wood Residue Combustion in Boilers), in addition to some data available in NCASI files.

An elaborate statistical data treatment procedure was applied to the combined set of emissions data to obtain representative means, medians, standard deviations and upper prediction limits for the various air toxics, trace metals, criteria pollutants, PAHs and PCDD/Fs associated with wood residue combustion in industrial boilers. This procedure used the Kaplan Meier and SDln algorithms to handle moderately censored (up to 80% non-detects) and heavily censored (over 80% non-detects) data sets, respectively. It also involved the identification of statistical outliers which were then rejected when confirmed by graphical observation.

The statistical parameters for the emissions presented in this report are based on the best available test data for all the pollutants considered. The emission factors thus developed are believed to best characterize pollutant emissions from currently operating industrial wood-fired boilers and represent an improvement over those in NCASI Technical Bulletin Nos. 973 and 884. Furthermore, compared to Section 1.6 of EPA's AP-42 publication, the factors are more statistically sound, besides being based on much more recent and comprehensive emission tests.

KEYWORDS

air toxics, CO, condensible PM, criteria pollutants, dioxins, Dutch oven, emission factors, filterable PM, fluidized bed, formaldehyde, fuel cell, GHG, HCl, methane, mercury, N_2O, NO_x, PAHs, $PM_{2.5}$, resin wood, SO_2, stoker, suspension burner, THC, TNMHC, trace metals, wood residue combustion

RELATED NCASI PUBLICATIONS

Technical Bulletin No. 973 (February 2010). *Compilation of 'air toxic' and total hydrocarbon emissions data for pulp and paper mill sources – a second update.*

Special Report No. 09-02 (March 2009). *Sulfur capture in combination bark boilers - an update.*

Technical Bulletin No. 914 (February 2006). *An analysis of factors affecting long-duration NO_x emissions from wood-fired boilers.*

Technical Bulletin No. 884 (August 2004). *Compilation of criteria air pollutant emissions data for sources at pulp and paper mills including boilers.*

Technical Bulletin No. 858 (February 2003). *Compilation of 'air toxic' and total hydrocarbon emissions data for sources at kraft, sulfite and non-chemical pulp mills - an update.*

Technical Bulletin No. 646 (February 1993). *Emission factors for NO_x, SO_2, and volatile organic compounds for boilers, kraft pulp mills, and bleach plants.*

Technical Bulletin No. 640 (September 1992). *Sulfur capture in combination bark boilers.*

UNE COMPILATION ET UN EXAMEN DÉTAILLÉS DES ÉMISSIONS DE CHAUDIÈRES BRÛLANT DES RÉSIDUS DE BOIS

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RÉSUMÉ

Le présent rapport est le résumé d'une importante quantité de données sur les émissions de chaudières brûlant exclusivement des résidus de bois. Il inclut également des données sur quelques chaudières brûlant moins de 10% de gaz naturel ou moins de 5% de biosolides (boues). La majorité des nouvelles données proviennent de campagnes d'échantillonnage volontaires et obligatoires réalisées au cours des quatre dernières années suite aux activités de l'EPA sur le règlement Boiler MACT après 2007. Ces campagnes, réalisées depuis juillet 2009, se sont concentrées sur quelques composés importants seulement : formaldéhyde, HCl, HF, les 11 métaux traces figurant sur la liste des polluants atmosphériques dangereux (y compris le mercure), les PCDD/F, les particules totales filtrables et le monoxyde de carbone. Dans plusieurs cas, les campagnes ont aussi inclus des mesures sur le méthane, d'autres métaux traces, les particules condensables, les $PM_{2.5}$ filtrables, le SO_2, les NO_x et les COV exprimés sous forme de C (méthode 25A).

NCASI a obtenu les données des essais à la cheminée et les rapports de laboratoire associés à la plupart de ces essais, puis a effectué un examen complet d'AQ/CQ afin de repérer les erreurs et de corriger, s'il y avait lieu, les résultats dans les rapports. Dans ce rapport, NCASI présente de nouveaux facteurs d'émission calculés à partir de données obtenues récemment pour le formaldéhyde, l'acide chlorhydrique (HCl), le fluorure d'hydrogène (HF), le méthane et l'oxyde nitreux (N_2O) (GES), les 11 métaux traces sur la liste des polluants atmosphériques dangereux, les PCDD/F, les $PM_{2.5}$, filtrables, les particules condensables, le CO, le SO_2, les NO_x et les HT/COV. Dans le cas des autres substances, dont les matières organiques autres que le HCHO et les métaux traces qui ne sont pas sur la liste des polluants atmosphériques dangereux, NCASI a combiné les nouvelles données obtenues grâce aux essais réalisés dans le cadre de Boiler MACT avec (1) des données sur quelques chaudières de l'industrie des produits du bois dans les dossiers de NCASI qui avaient fait l'objet d'un examen d'assurance-qualité et (2) une quantité considérable de données provenant de la compilation précédente de données sur les chaudières à résidus de bois (Bulletin technique de NCASI n° 973). Ce précédent rapport de NCASI présentait une compilation de toutes les données d'essais contenues dans le document de référence du chapitre 1.6 du guide AP-42 de l'EPA (*Wood Residue Combustion in Boilers*) en plus des certaines données dont disposait NCASI dans ses dossiers.

NCASI a appliqué une procédure de traitement statistique élaboré aux données combinées pour calculer des valeurs représentatives de moyennes, de médianes, d'écarts-types et de limites de prédiction supérieures pour les diverses substances toxiques atmosphériques, les métaux traces, les principaux polluants atmosphériques, les HAP et les PCDD/F associés à la combustion des résidus de bois dans les chaudières industrielles. Cette procédure a fait appel aux algorithmes de Kaplan Meier et SDln pour traiter les ensembles de données modérément censurés (jusqu'à 80% de valeurs non détectées) et les ensembles de données très censurés (plus de 80% de valeurs non détectées), respectivement. NCASI a aussi identifié les valeurs aberrantes et rejeté celles dont l'aberration statistique était confirmée par observation graphique.

Les paramètres statistiques présentés dans ce rapport reposent sur les meilleures données d'essais pour tous les polluants étudiés. On estime donc que les facteurs d'émission calculés à partir de ces données sont ceux qui caractérisent le mieux les émissions provenant des chaudières industrielles à résidus de bois présentement en exploitation, et ils représentent également une amélioration par rapport à ceux présentés dans les Bulletins techniques n^{os} 973 et 884. De plus, comparativement aux facteurs dans le chapitre 1.6 du guide AP-42 de l'EPA, les facteurs sont statistiquement plus solides en plus de reposer sur des essais à la cheminée plus récents et plus complets.

MOTS-CLÉS

bois de résine, chargeur, chaudière à lit en suspension, chaudière hollandaise, CO, combustion aux résidus de bois, dioxines, facteurs d'émission, formaldéhyde, GES, HAP, HCl, HT, HTNM, lit fluidisé, mercure, métaux traces, méthane, N_2O, NO_x, particules condensables, particules filtrables, pile à combustible, $PM_{2.5}$, principaux polluants atmosphériques, SO_2, substances toxiques atmosphériques

AUTRES PUBLICATIONS DE NCASI

Bulletin technique n° 973 (février 2010). *Compilation des données d'émissions de substances toxiques atmosphériques et d'hydrocarbures totaux des sources des fabriques de pâtes et papiers – seconde mise à jour* (seul le résumé est en français)

Rapport spécial n° 09-02 (mars 2009). *Capture du soufre dans les chaudières à écorces à combustibles multiples – mise à jour* (seul le résumé est en français)

Bulletin technique n° 914 (février 2006). *Une analyse des facteurs affectant les émissions de NOx des chaudières à biomasse, à long terme* (seul le résumé est en français)

Bulletin technique n° 884 (août 2004). *Compilation des données sur les émissions des principaux polluants atmosphériques reliés aux sources des fabriques de pâtes et papiers, incluant les chaudières* (seul le résumé est en français)

Bulletin technique n° 858 (février 2003). *Mise à jour de la compilation des données sur les substances toxiques atmosphériques et les émissions d'hydrocarbures totaux pour les sources des fabriques de pâte Kraft, de pâte au bisulfite et de pâte mécanique* (seul le résumé est en français)

Bulletin technique n° 646 (février 1993). *Emission factors for NO_x, SO_2, and volatile organic compounds for boilers, kraft pulp mills, and bleach plants.*

Bulletin technique n° 640 (septembre 1992). *Sulfur capture in combination bark boilers.*

CONTENTS

Tables AA-1, AA-2, AA-3, AA-4, and AA-5 are available for download as Microsoft Excel files on the NCASI members only website at http://www.ncasi.org/publications/Detail.aspx?id=3633

TABLES

FIGURES

A COMPREHENSIVE COMPILATION AND REVIEW OF WOOD-FIRED BOILER EMISSIONS

1.0 INTRODUCTION

The forest products industry (FPI) relies extensively on wood fuels to generate steam, electric power, and process heat at its manufacturing facilities. Bark, hog fuel, wood chips, sawdust, sanderdust, and planer shavings provide a significant source of energy for the operation of boilers, thermal oil heaters, and wood dryers. The current emphasis on replacing fossil fuels with renewable energy sources has resulted in the growing use of wood fuels by electric power producers, other industries, and public institutions. This has resulted in increased scrutiny of emissions from wood combustion, particularly from boilers. Consequently, there is a pressing need for reliable up-to-date information on these emissions.

Many view the Environmental Protection Agency's AP-42 emission factor document as the best available source of information on emissions from combustion sources, including wood-fired boilers. Section 1.6 in AP-42, "Wood Waste Combustion in Boilers," describes the various types of wood-fired boilers and applicable control technologies, and contains emission factors for most pollutants emitted from these boilers. However, the most recent emission test data included in this section were from 2001, with the vast majority generated between 1975 and 1995 (USEPA 2003). As of the end of 2012, EPA had no specific plans to revise the outdated emission factors provided in the AP-42 compilation.

In NCASI Technical Bulletin No. 973 (NCASI 2010), and earlier in Technical Bulletin No. 858 (NCASI 2003), the detailed emission test data provided in the background document to Section 1.6 of AP-42 (ERG 2001) were combined with additional test data available in NCASI files, and an elaborate set of statistical data treatment procedures was applied to these combined data. Subsequently, revised emission factors were calculated for most organic and inorganic air toxics, including trace metals. Also included in these reports were (1) available data, pertaining to wood combustion in industrial boilers, on polycyclic organic matter (POM) emissions and (2) data on emissions of polychlorinated dibenzo-dioxins and furans (PCDD/Fs). Criteria pollutants (CPs) including CO, SO_2, NO_x, filterable particulate matter (FPM, PM_{10}, $PM_{2.5}$), condensible PM (CPM), and volatile organic compounds (VOCs) were last summarized in Technical Bulletin No. 884 (NCASI 2004). Beginning in December 2009, NCASI updated many of these criteria pollutant emission factors in the Criteria Pollutant Air Emissions Electronic Database, which it makes available in January of each year to its members. NCASI plans to issue an update to Technical Bulletin 884, which addressed CPs for all FPI activities, in the coming months. Finally, NCASI provided a full characterization of air emissions from wood combustion in a recent *TAPPI Journal* article "Environmental Aspects of Wood Residue Combustion in Forest Products Industry Boilers" (Someshwar et al. 2011).

A significant number of FPI facilities, and a few other facilities burning mainly wood residues in industrial boilers or electric generating units (EGUs), have been tested for several key air toxics and CPs since about July 2009. Most of the sampling was mandated by EPA to obtain data it believed necessary to set emission limits for hazardous air pollutants (HAPs) emitted by boilers. EPA focused on hydrogen chloride (HCl), mercury (Hg), PCDD/Fs, CO and PM (total FPM). For many boilers, EPA also required tests for hydrogen fluoride, formaldehyde (HCHO), the remaining 10 trace metals listed as HAPs besides Hg, SO_2, NO_x, total hydrocarbons (THCs), $PM_{2.5}$ and CPM. Thus, a significant amount of new data has become available.

These new data, contained in test reports that had to be submitted to EPA for their rulemaking activity (and therefore in public domain), and other similar data contained in test reports generated mainly since July 2009 by mills and companies and made available to NCASI but not necessarily submitted to EPA, have been used to update the emission factors in earlier NCASI publications. These test reports were subject to a thorough QA/QC review and appropriate corrections were made before the results were incorporated into an updated emissions database. The updated database was used to generate new emission factors using advanced statistical data treatment procedures. It should be noted there were some air toxics, primarily organic compounds, for which no new data were available. For these substances, the emission factors have remained unchanged in this latest compilation.

NCASI believes this most recent compilation of wood combustion emissions data, and the resulting summary statistics (means, medians, standard deviations, upper prediction limits, etc.), represent the most complete and up-to-date set of emission factors applicable to wood-fired industrial boilers. It therefore should supersede all older emission factor compilations including those presented in Section 1.6, "Wood Residue Combustion in Boilers," of EPA's AP-42 Emission Factor document and those presented in the earlier NCASI reports Technical Bulletin 973 (NCASI 2010) and Technical Bulletin 884 (NCASI 2004).

2.0 DATA SOURCES

In NCASI Technical Bulletin No. 973, the emission test data compiled in the background document for Section 1.6 of AP-42 were taken in their entirety and added to a limited amount of additional test data for wood-fired boilers available in NCASI files. A robust set of statistical data treatment procedures was applied to the combined "air toxics" data to calculate average statistics for wood-fired boiler emissions. In the opinion of NCASI, these comprehensive statistical parameters were more meaningful than the average values presented in AP-42 because of the more sophisticated statistical protocols for handling non-detect and outlier values and because of the additional data not included in EPA's compilation. Nevertheless, as mentioned earlier, the AP-42 data were mainly from the 1975 to 1995 time frame. More importantly, since full reports for most of the AP-42 data were difficult or impossible to obtain, NCASI could not subject these data to a detailed QA/QC review to ensure the data were of acceptable quality.

As part of its information-gathering activities in support of developing new MACT standards for boilers and incinerators to replace those vacated in 2007 by the courts, EPA obtained a large number of reports for boiler stack tests conducted by companies. The majority of the tests were mandated by EPA to address perceived information gaps on emissions of hazardous air pollutants and related criteria air pollutants from boilers burning fossil and non-fossil fuels. Emission tests were required in 2009 and 2010 on over 50 boilers burning biomass fuels, and most of these were located at forest products industry sites and used wood fuels, either alone or in combination with other biomass and fossil fuels. Besides the EPA-mandated testing, some pulp mills and wood products plants subsequently carried out their own tests for selected compounds that were anticipated to be subject to numerical emission limits in the rules being developed by EPA. All these stack sampling efforts generated a large new body of emissions data. NCASI was able to obtain the complete stack test and associated laboratory reports for almost all of these "new" tests.

The tests obviously concentrated on air toxics likely to be regulated by EPA, namely the 11 trace metal HAPs including mercury, acid gases HCl and HF (both for boilers with wet and dry particulate control devices), formaldehyde (HCHO), dioxins and furans (PCDD/Fs), CO, and total FPM. In some of the testing, SO_2, NO_x, THCs, CPM and filterable $PM_{2.5}$ were measured. Some THC tests were accompanied by tests for CH_4 so that total non-methane hydrocarbons (TNMHCs) or VOCs could be determined. Beyond the testing related to EPA's rulemaking, NCASI obtained sampling reports for two wood-fired boilers where several organics, trace metals, certain criteria pollutants, and polycyclic aromatic hydrocarbon (PAH) emissions were measured.

Given the existence of a significant amount of recent data for formaldehyde, HCl, HF, PCDD/Fs, 11 trace metal hazardous air pollutants (HAPs), filterable $PM_{2.5}$ (for boilers with electrostatic precipitators), condensible PM (CPM), CO, SO_2, NO_x and THCs/VOCs, new emission factors were developed for these pollutants. For other air toxics, mostly organics (acetaldehyde, benzene, methanol, etc.), trace metals other than the 11 HAPs, PAHs, methane and nitrous oxide (N_2O), either the new data were combined with older data from Technical Bulletin 973 and AP-42 Section 1.6 or with new data that became available to NCASI from testing unrelated to EPA's boiler rulemakings, and were used to generate new or revised emission factors in this report. Emission factors for filterable PM, filterable $PM_{2.5}$ for boilers not equipped with ESPs, and filterable PM_{10} that were previously taken from AP-42 Section 1.6 are retained in this report.

Table 2.1 summarizes the sources of new data for a few key pollutants for which new emission factors were developed in this report. New data sources were (1) EPA-mandated Boiler MACT and CISWI testing conducted in 2009 and 2010; (2) company-conducted testing carried out in 2009 and later years; (3) pre-2009 company testing not previously available to NCASI; and (4) data previously only in the wood products boiler database.

Table 2.1 Number of Units with New Data Included in this Report for Certain Key Pollutants

Pollutant	EPA-Required Boiler MACT/ CISWI Tests	Company-Conducted Tests, 2009-2012	NCASI, Pre-2009, Pulp and Paper Units	NCASI, Pre-2009, Wood Products Units
Hg	26	15	4	6
HCl	24	10	1	9
HF	20	1	0	1
HCHO	18	0	0	16
NO_x	19	5	2	10
SO_2	19	6	2	4
THC	18	1	1	2
CH_4	13	0	0	0
$FPM_{2.5}$	16	0	0	1
FPM_{10}	2	0	0	1
CPM	22	1	0	0
PCDD/Fs	21	10	0	0

The test data used for this report were limited to boilers and thermal oil heaters that burned only wood residues during the testing period, or wood residues in combination with natural gas where the gas provided less than 10% of the total heat input, or wood residues in combination with wastewater treatment plant residuals where the residuals provided less than 5% of the total heat input. It is reasoned that a small amount of gas (typically under 5%), along with the main wood residue fuel, would not have a measurable impact on the air emissions compared to when only wood residues are burned. Similarly, emissions data when burning a small amount (typically under 5%) of virgin pulp and papermaking wastewater treatment plant (WWTP) residuals (sludges) along with the predominant wood residue fuel are also included, since such sludges are esssentially comprised of wood fiber (unlike sludges from deinking mill operations which can have significant inert material). The burning of small amounts of such dewatered sludges in essentially wood residue-fired boilers has been shown elsewhere to have no discernible impact on air toxic emissions (NCASI 2010). However, test data obtained when sludges contribute a larger heat input fraction will be summarized in a forthcoming report dealing with combination boiler emissions.

3.0 DATA QA/QC AND STATISTICAL DATA TREATMENT PROCEDURES

Stack testing and associated laboratory reports obtained by NCASI were subjected to a detailed review to ensure proper sampling and analytical procedures had been employed and that the reported emission rates had been calculated correctly. A brief summary of the QA/QC procedures applied is given below.

NCASI recalculated emission rates from the test report data using an Excel spreadsheet template designed specifically for making these computations in the most standardized way possible. A separate file was prepared for each test report, with template data entry performed by NCASI staff trained in its use.

Emissions rates were recalculated from the most basic data in the test report. In the case of metals, PM, PCDD/F, HCl, and HF, the lab results were used to calculate emissions. In the case of CO, NO_x, SO_2, THC, CH_4, and formaldehyde, the analyzer readings were used for calculations after any necessary corrections performed by the stack sampling company. The stack flow rates and volume of gas sampled were used to calculate the concentration of each pollutant in the stack gas.

For each test run, the heat input was calculated using the F_d factor for the fuel mix burned during the test. The heat input was also calculated according to the heat value of the fuels and/or the steam generation rate where available, but only for the sake of comparison. All emissions rates were calculated using the F_d factor-based heat input.

All non-detect test runs were calculated at the detection limit. Any results that were above the detection limit were treated as detects, regardless of whether or not they were below the reporting limit (or practical quantition limit). All emission concentrations were calculated both at the oxygen level present in the stack and in lb/MMBtu. When at least one sampling run was above the detection limit, the test average was computed using half the detection limit for the non-detect runs.

In keeping with EPA's Boiler MACT protocol for reporting of Hg emissions, all non-detect (ND) sampling train fractions using either EPA Method 29 or the Ontario Hydro method were replaced by the respective detection limits before the fractions were summed to yield a total emision estimate for a unit (total is reported as ND if all fractions were ND). Similarly, the EPA Boiler MACT protocol of replacing NDs for any of the 17 PCDD/F congeners with zeros before summing and estimating the total toxic equivalent PCDD/F emission rate was adopted.

In tabulating the results for $PM_{2.5}$ test runs performed concurrently with filterable PM and/or condensable PM (see Table B1 in Appendix B), ADL designated lab results above the detection limit of the stack test method (1.35 mg for $PM_{2.5}$ by Method 201A, 2 mg for FPM by Method 5, and 4 mg for CPM by Method 202) and ND designated lab results below those detection limits. Each run also included a designation of whether or not that value met the Practical Limit of Quantitation (PLQ), which is three times the detection limit for each method. The actual mass measured by the lab (lab catch) for each fraction is also included.

For determining pollutant averages across several boilers, ND values representing the test average (when all runs were ND) for a given boiler were treated using the Kaplan-Meier method for handling censored data sets or data sets with non-detects. The SDln method was used for handling data with severe censoring. Details of both procedures used are given in NCASI Technical Bulletin No. 973 (NCASI 2010).

For certain air toxics for which significant new, quality assured data were available, the older test data used to compute averages in Technical Bulletin 973 and in Section 1.6 of AP-42 were no longer used and new averages were computed with only the new data. For air emissions of various other organics and non-HAP metals, for which only a limited amount of new data were generated beyond what was already available, the additional data were combined with the existing Technical Bulletin 973 data, and the statistical averages recomputed.

The emission factors provided in this report are believed to represent the most robust set of emission factors relevant to current wood-fired boiler operations. Of course, there will be a huge number of stack tests conducted over the next three to four years as a result of EPA's new final Boiler MACT Rule, and much additional data for mercury, HCl, CO, filterable particulate matter, and trace metals can be expected. NCASI will revisit the need to update the emission factors for these substances once those tests are completed and results provided to EPA.

Detailed data corresponding to each boiler tested are presented in Appendix A. Brief comments are provided where the test results for one or more pollutants appear to be unusual, especially for HCl, Hg, CO, and FPM. The presentation of the detailed boiler-specific data in this fashion should help users appreciate the range and type of data generated across many types of boilers, and also perhaps identify more closely with one or two boilers that might match one's own situation with respect to the kind of boiler, fuels fired, PM control device, etc.

Summary emission factors for organic and inorganic air toxics, trace metals, PAHs, and PCDD/Fs are presented in Section 4.0. Section 5.0 presents summary emission factors for criteria pollutants including VOCs as C, CO, SO_2, NO_x, CPM, and the ratio of filterable $PM_{2.5}$ to total FPM. Finally, in Section 6.0, the summary emissions data for wood-fired boilers are examined for potential relationships between the emissions of Hg and total FPM, between emissions of HCHO and CO, between THCs and CO, between CPM and CO, between NO_x emissions and the firing of high N-containing resin woods, and between the ratio of filterable $PM_{2.5}$ to total FPM ($PM_{2.5}$/FPM) and the magnitude of total FPM.

4.0 EMISSION FACTORS

The extensive data presented for each boiler in Appendix A have been used to develop emission factors for organic and inorganic air toxics, trace metals, PAHs, PCDD/Fs, and several criteria pollutants. Trace metal, $PM_{2.5}$ and CPM emission factors are separated into categories based on the final PM control device (ESP/FFs, wet scrubbers or multiclones). Due to their high solubility in water, HCl and HF emissions are separated by wet versus dry PM controls. CO is separated by boiler type (stokers, fuel cells/Dutch ovens, suspension burners, fluidized bed combustors). NO_x emission factors are separated based on whether wood residues with normal N content or with elevated N content (due to the presence of urea-formaldehyde (UF) resins) are burned. This section presents the summary statistics for the emission factors (mean, median, standard deviation, upper prediction limit, etc.) for boilers burning mainly wood residues (with perhaps small amounts of gas and/or WWTP residuals). As previously mentioned, these summary tables should serve as replacements to the emission factors provided in Section 1.6 of EPA's AP-42 document, and also those factors provided in prior NCASI wood-fired boiler emission factor compilations in Technical Bulletins No. 973 (NCASI 2010) and 884 (NCASI 2004).

4.1 Organic Air Toxic Emissions from Wood-Fired Boilers

Table 4.1 provides a summary of gaseous organic and inorganic air toxic emissions from wood-fired boilers. Information concerning the specifics of each boiler, such as the fuel description, boiler type, boiler heat input, and the PM control device, as well as average emissions for each air toxic corresponding to each boiler, is provided in electronic format (Excel) in Table AA-1 (downloadable from the NCASI members only website).

As mentioned in Technical Bulletin 973 (NCASI 2010), even in cases where the majority of data originated from the AP-42 background document for Section 1.6, the mean emission rates for wood-fired boilers as estimated by NCASI were not always in agreement with the means presented in AP-42. This is the result of rigorous statistical data treatment procedures applied by NCASI to these data sets that are often "censored" (comprising of non-detects). Two key procedures that were applied to these data even before the Kaplan-Meier subroutine to handle censored data sets was applied included (1) the rejection of all non-detect data where the detection limits exceeded the highest detected observation in a data set, and (2) the determination of statistical outliers that, once identified, were rejected only after graphical confirmation. Thus, the mean for some compounds including acetaldehyde, acrolein, benzene, hydrogen chloride, and phenol were different (mostly lower) than the averages presented in EPA's AP-42 document. EPA's procedures used in the AP-42 document called for assigning one-half the method detection limit to all non-detect values, and performing only a qualitative evaluation of potential outliers.

Relative to the new air toxic emission data obtained from recent Boiler MACT and related company test reports, these tests were conducted on two electrical generating units (EGUs), 28 pulp mill bark/wood residue boilers, and 38 wood products mill wood-fired units. Of the 68 wood-fired units, 44 were stokers, seven suspension burners, nine fuel cells, two Dutch ovens, five fluidized beds and one unspecified type.

Relative to the old AP-42 gaseous organic and inorganic air toxic emission test data retained in Table 4.1, those data corresponded to a total of 64 wood-fired boilers, all of which reported burning "inland" wood residues during the emission testing period. Fifty-seven of the 64 boilers in the AP-42 data set corresponded to wood-fired boilers burning "inland" wood residues for which data were summarized in electronic spreadsheet files supporting the background document to EPA's AP-42 chapter on wood residue combustion (ERG 2001). The data for the remaining seven boilers were available in NCASI files (much of the data on pulp mill wood-fired boilers in EPA's AP-42 background document were also available in NCASI files). Of the 57 boilers in the AP-42 data set, 12 were located at furniture plants, 11 were electric generating units (EGU), five were located at pulp mills, and 29 were located at wood products mills. The data for non-FPI mills were included in this summary since the wood fuels and operating practices for these boilers were thought to be similar to those of boilers burning wood residues at pulp and paper mills and wood products plants, with one exception. The boiler located at the American Ref-Fuel Company, Niagara Falls, New York (B08) was reportedly burning "wood wastes," but further investigation indicated that treated wood was part of the wood fuel mix fired in this boiler during the tests. Thus, data for this boiler were excluded from the analysis.

Prominent VOCs emitted as a result of wood combustion include acetaldehyde, acrolein, benzene, formaldehyde, methanol and naphthalene.

Table 4.1 Summary of Air Toxic Emissions from Wood-Fired Boilers (lb/10^6 Btu)

Compound	Sources*	Detects	Min	Max	Median	Mean	Std. Dev.	UPL**
Acetaldehyde[a]	28	23	1.56E-05	1.96E-03	1.57E-04	2.83E-04	4.11E-04	1.28E-03
Acetone	10	7	7.84E-05	7.14E-03	2.14E-04	1.19E-03	2.10E-03	6.43E-03
Acetophenone	4,2	2	3.23E-09	3.68E-06	1.84E-06	1.84E-06	--	--
Acrolein[a]	12,10	6	3.15E-05	1.10E-03	1.27E-04	2.60E-04	3.78E-04	8.84E-04
Benzaldehyde	7,5	2	<9.60E-07	4.22E-04	5.40E-05	1.89E-04	1.90E-04	6.84E-04
Benzene[b]	31,30	26	2.41E-07	1.02E-02	2.35E-04	9.80E-04	2.02E-03	5.87E-03
Bis(2-Chloroisopropyl) ether	1	1	--	--	6.15E-07	6.15E-07	--	--
Bis(2-ethylhexyl)phthalate	1	1	--	--	4.65E-08	4.65E-08	--	--
Bromobenzene	1	0	<7.67E-06	<7.67E-06	--	--	--	--
Bromodichloromethane	3	0	ND	<5.90E-03	--	--	--	--
Bromomethane	3	3	2.38E-06	2.80E-05	3.67E-06	1.14E-05	1.44E-05	3.52E-05
Butylbenzylphthalate	2	1	ND	2.70E-05	1.34E-05	1.34E-05	--	--
n-Butyraldehyde	2	2	6.05E-05	7.70E-05	6.88E-05	6.88E-05	--	--
Carbon Tetrachloride	7,5	3	<2.65E-06	4.70E-05	2.55E-06	2.01E-05	2.55E-05	6.22E-05
Carbon-Disulfide	1	1	--	--	1.25E-04	1.25E-04	--	--
3-Carene	2	0	<2.30E-03	<2.6E-03	--	--	--	--
Chlorobenzene	3,2	2	5.54E-10	3.30E-05	1.66E-05	1.66E-05	--	--
Chloroform	7,5	3	2.55E-06	4.70E-05	2.55E-06	2.01E-05	2.55E-05	6.22E-05
Chloromethane	4	3	<1.6E-08	9.80E-05	2.66E-05	3.78E-05	4.21E-05	1.07E-04
2-Chloronaphthalene	1	1	--	--	2.41E-09	2.41E-09	--	--
2-Chlorophenol	5,4	1	<2.09E-08	5.70E-08	1.85E-08	1.85E-08	--	5.70E-08
4-Chlorotoluene	1	0	<1.83E-06	<1.83E-06	--	--	--	--
cis-1,3-Dichloropropene	1	0	<5.48E-06	<5.48E-06	--	--	--	--
m,p-Cresol	1	0	<1.00E-05	<1.00E-05	--	--	--	--
o-Cresol	1	0	<1.00E-05	<1.00E-05	--	--	--	--
Crotonaldehyde	3,2	2	1.08E-05	7.89E-05	4.49E-05	4.49E-05	--	--
Cumene	2,1	1	--	--	1.77E-05	1.77E-05	--	--
p-Cymene	2,1	1	--	--	2.61E-06	2.61E-06	--	--
Decachlorobiphenyl	1	1	--	--	2.65E-10	2.65E-10	--	--
Dibromochloromethane	1	0	<7.48E-07	<7.48E-07	--	--	--	--
1,2-Dibromoethane	1	0	<1.83E-06	<1.83E-06	--	--	--	--
1,2-Dibromo-3-chloropropane	1	0	<1.10E-06	<1.10E-06	--	--	--	--
1,2-Dibromoethene	1	1	--	--	5.48E-05	5.48E-05	--	--
1,1-Dichlorobenzene	1	0	<1.79E-05	<1.79E-05	--	--	--	--

(Continued on next page. See note at end of table.)

Table 4.1 Continued

Compound	Sources*	Detects	Min	Max	Median	Mean	Std. Dev.	UPL**
1,3-Dichlorobenzene	1	0	<1.64E-05	<1.64E-05	--	--	--	--
1,4-Dichlorobenzene	1	1	2.79E-04	2.79E-04	--	--	--	--
Dichlorobiphenyl	3	3	3.79E-10	9.26E-10	9.00E-10	7.35E-10	5.91E-05	9.75E-05
1,1-Dichloroethane	1	0	<2.99E-05	<2.99E-05	--	--	--	--
1,2-Dichloroethane	1	1	--	--	2.92E-05	2.92E-05	--	--
1,2-Dichloroethene	1	1	1.37E-03	1.37E-03	--	--	--	--
1,2-Dichloropropane	2	1	<7.30E-07	3.33E-05	1.68E-05	1.68E-05	--	--
Diethylphthalate	2	1	ND	2.70E-05	2.18E-05	2.18E-05	--	--
2,5-Dimethyl benzaldehyde	2	2	4.45E-05	1.09E-04	7.68E-05	7.68E-05	--	--
Dimethyl Sulfide	1	1	--	--	0 ppb	0 ppb	--	--
Di-n-Butyl Phthalate	2	2	8.53E-06	5.81E-05	3.33E-05	3.33E-05	--	--
4,6-Dinitro-2-methylphenol	1	1	--	--	2.10E-06	2.10E-06	--	--
2,4-Dinitrophenol	5,4	1	<1.64E-07	4.03E-07	1.31E-07	1.31E-07	--	4.03E-07
2,4-Dinitrotoluene	1	1	--	--	9.42E-07	9.42E-07	--	--
Di-n-octyl phthalate	1	1	--	--	1.10E-07	1.10E-07	--	--
Ethanol	5	1	<7.40E-04	1.69E-03	4.77E-04	4.77E-04		1.69E-03
Ethyl Benzene	6,3	3	1.33E-06	3.13E-05	3.13E-05	3.95E-04	6.54E-04	1.47E-03
Formaldehyde	34,33	30	<6.04E-06	5.10E-03	3.77E-04	1.02E-03	1.50E-03	4.64E-03
Hexachlorobenzene	1	1	--	--	1.03E-06	1.03E-06	--	--
Hexachlorobiphenyl	2	2	2.89E-10	8.01E-10	5.45E-10	5.45E-10	--	--
Hexaldehyde	4	3	9.82E-06	2.82E-04	4.16E-05	9.37E-05	1.27E-04	3.03E-04
n-Hexane	2	1	<5.20E-05	5.50E-04	2.88E-04	2.88E-04	--	--
Hexachlorobutadiene	1	0	<3.65E-07	<3.65E-07	--	--	--	--
Hydrogen Chloride[b]	31	27	3.83E-06	3.91E-02	3.46E-04	4.36E-03	9.31E-03	2.69E-02
Hydrogen Chloride[c]	13	11	1.72E-05	1.39E-03	1.11E-04	2.66E-04	3.87E-04	1.22E-03
Hydrogen Fluoride[b]	17	11	<3.83E-06	2.54E-03	7.47E-05	2.35E-04	6.08E-04	1.72E-03
Hydrogen Fluoride[c]	5,3	2	ND	4.23E-05	8.50E-06	1.69E-05	2.24E-05	5.38E-05
Isobutanol	1	0	<3.00E-05	<3.00E-05	--	--	--	--
Isobutyraldehyde	1	1	--	--	1.47E-04	1.47E-04		
Isopropanol	4	2	<1.00E-03	9.20E-03	1.10E-03	3.64E-03	5.48E-03	1.27E-02
Isovaleraldehyde	1	1	--	--	6.32E-05	6.32E-05	--	--
Methanol	10,9	5	<1.30E-04	1.48E-03	4.82E-04	7.32E-04	4.15E-04	1.42E-03

(Continued on next page. See note at end of table.)

Table 4.1 Continued

Compound	Sources*	Detects	Min	Max	Median	Mean	Std. Dev.	UPL**
Methyl Ethyl Ketone	10,7	6	4.85E-08	6.73E-05	5.39E-06	1.56E-05	2.43E-05	5.57E-05
Methyl Isobutyl Ketone	5,2	1	<6.10E-05	8.60E-04	4.45E-04	4.45E-04	--	--
2-Methylnaphthalene	2	2	4.05E-08	2.75E-07	1.58E-07	1.58E-07	--	--
Methylene Chloride	7	3	<1.00E-05	1.52E-03	2.82E-05	5.47E-04	4.93E-04	1.36E-03
Monochlorobiphenyl	1	1	--	--	2.18E-10	2.18E-10	--	--
Naphthalene	20,18	16	<1.13E-08	4.87E-04	8.13E-06	9.96E-05	1.38E-04	4.37E-04
2-Nitrophenol	5	1	<2.09E-08	9.71E-07	2.74E-07	2.74E-07	--	9.71E-07
4-Nitrophenol	5,4	1	<1.05E-07	2.90E-07	9.41E-08	9.41E-08	--	2.90E-07
Pentachlorobiphenyl	2	2	6.49E-10	1.76E-09	1.20E-09	1.20E-09	--	--
Pentachlorophenol	7	2	<4.19E-08	1.10E-06	4.48E-08	2.29E-07	3.43E-07	1.10E-06
Pentanal	1	1	--	--	1.53E-04	1.53E-04	--	--
2-Pentanone	1	0	<3.03E-05	<3.03E-05	--	--	--	--
Phenol	15,14	10	3.12E-09	1.51E-03	1.53E-05	1.60E-04	1.13E-04	4.38E-04
Propanol	1	0	<2.00E-05	<2.00E-05	--	--	--	--
Propionaldehyde	4	3	<7.7E-05	1.12E-03	2.14E-05	2.52E-04	5.32E-04	1.13E-03
Styrene[a]	4	2	<2.00E-06	1.86E-03	1.54E-05	4.77E-04	1.13E-03	2.34E-03
alpha-Pinene	4,1	1	--	--	8.36E-06	8.36E-06	--	--
beta-Pinene	4	2	1.67E-06	6.50E-03	1.10E-03	1.64E-03	4.01E-03	8.25E-03
alpha-Terpineol	3,1	1	--	--	4.73E-06	4.73E-06	--	--
Tetrachlorobiphenyl	2	2	1.60E-09	3.39E-09	2.50E-09	2.50E-09	--	--
Tetrachloroethene	2	1	<7.30E-07	4.89E-05	2.46E-05	2.46E-05	--	--
Tolualdehydes (m,p,o)	2	2	1.38E-04	1.82E-04	1.60E-04	1.60E-04	--	--
Toluene[a]	12,8	6	3.40E-08	9.00E-05	3.67E-06	2.11E-05	2.84E-05	9.29E-05
Tribromomethane	1	0	<3.65E-07	<3.65E-07	--	--	--	--
Trichlorobiphenyl	3	3	5.45E-10	5.51E-09	1.78E-09	2.61E-09	5.91E-05	9.75E-05
1,2,3-Trichlorobenzene	1	0	<2.19E-06	<2.19E-06	--	--	--	--
1,2,4-Trichlorobenzene	2	0	<3.65E-05	<1.10E-04	--	--	--	--
1,1,1-Trichloroethane	4	3	3.28E-06	1.70E-04	3.93E-05	5.78E-05	8.10E-05	1.91E-04
1,1,2-Trichloroethane	2	0	<1.02E-05	<2.4E-04	--	--	--	--
Trichloroethylene	4,2	1	<1.83E-06	3.88E-05	1.99E-05	1.99E-05	--	--
Trichlorofluoromethane	3	1	<3.65E-07	4.05E-05	1.59E-05	1.59E-05	--	4.05E-05
2,4,6-Trichlorophenol	6	1	<2.09E-08	1.09E-06	2.76E-07	2.76E-07	--	1.09E-06
1,2,3-Trichloropropane	1	0	<2.19E-06	<2.19E-06	--	--	--	--
Valeraldehyde	2	2	9.27E-05	1.53E-04	1.23E-04	1.23E-04	--	--
Vinyl Chloride	1	1	--	--	1.84E-05	1.84E-05	--	--

(Continued on next page. See note at end of table.)

Table 4.1 Continued

Compound	Sources*	Detects	Min	Max	Median	Mean	Std. Dev.	UPL**
m,p-Xylene	7,3	3	6.90E-10	7.82E-06	2.79E-06	3.54E-06	3.96E-06	1.01E-05
o-Xylene	5,3	3	2.83E-10	3.13E-05	2.61E-06	1.13E-05	1.74E-05	4.00E-05
Xylenes (mixed isomers)	5,2	2	9.73E-10	1.04E-05	5.22E-06	5.22E-06	--	--

NOTES: Shaded rows show statistics derived exclusively from new data obtained from recent Boiler MACT and related company test reports. Averages are not estimated when data set has all non-detects (NDs); only min and max DLs are provided in those cases.

*"Sources" If two number entries are shown, the first number represents the total number of sources that were tested, and the second number represents the number of sources that were included in the analysis for estimating averages; the difference represents sources where data were rejected mainly because they yielded non-detects with detection limits exceeding the highest detected observation. Occasionally, an observation confirmed to be a statistical outlier was also rejected.

**UPL Upper prediction limit estimated using mean + 1.65 x std. dev. for normally distributed data and the Chebyshev Inequality with 85% confidence coefficient for non-normally distributed or skewed data.

[a] See Section 4.5 for further discussion. [b] Boilers with dry PM controls. [c] Boilers with wet PM control (wet scrubbers or wet ESP).

ND = non-detect; detection limit unknown.

4.2 Comparison with Average Gaseous Emissions Summarized in NCASI Technical Bulletin 973

Table 4.2 compares the mean wood-fired boiler emission rates for certain key gaseous air toxics in this report with mean emission rates for the same air toxics as summarized in NCASI Technical Bulletin 973. It should be noted that the majority of the data summarized in Technical Bulletin 973 originated from the background document for Section 1.6 of AP-42 (Wood Waste Combustion). It should also be noted that, as previously mentioned, the data in Technical Bulletin 973 for formaldehyde and hydrochloric acid emissions were completely replaced by the new Boiler MACT-related data in this report. Mean HCHO emissions are seen to be reduced by about 300%. For HCl, the new data are divided into boilers with dry PM controls (e.g., ESPs) and boilers with wet PM controls (e.g., wet scrubbers). The new data clearly show that the mean HCl emissions for boilers with wet PM controls are over an order of magnitude lower than the mean for boilers with dry PM controls, as would be expected.

Table 4.2 Mean Gaseous Air Toxics – Comparison with Technical Bulletin 973 Means

Compound	TB 973, Table 21A			Current Report			% Increase over TB 973 Mean
	Sources	Detects	Mean, lb/10^6Btu	Sources	Detects	Mean, lb/10^6Btu	
Acetaldehyde	26	20	2.73E-04	28	23	2.83E-04	4
Benzaldehyde	3	1	4.37E-05	7,5	2	1.89E-04	332
Benzene	26	22	1.10E-03	30	26	9.80E-04	-11
Carbon Tetrachloride	5	1	1.26E-05	5	3	2.01E-05	60
Chloroform	4	3	2.59E-05	5	3	2.01E-05	-22
Chloromethane	3	2	4.03E-05	4	3	3.78E-05	-6
Ethyl Benzene	2	2	1.76E-05	3	3	3.95E-04	2144
Formaldehyde	54	50	4.04E-03	33	30	1.02E-03	-75
Hydrogen Chloride[a]	7	6	1.61E-03	31	27	4.36E-03	171
Hydrogen Chloride[b]			1.61E-03	13	11	2.66E-04	-83
Methanol	4	3	7.99E-04	9	5	7.32E-04	-8
Methylene Chloride	5	3	6.22E-04	7	3	5.47E-04	-12
Phenol	10	10	9.46E-05	14	10	1.60E-04	69
Propionaldehyde	2	2	3.21E-05	4	3	2.52E-04	685
Toluene	7	5	2.43E-05	8	6	2.11E-05	-13

[a] Boilers with dry PM controls. [b] Boilers with wet PM controls.

4.3 Trace Metal Air Toxic Emissions from Wood Residue-Fired Boilers

Table 4.3 summarizes trace metal emission data for wood residue-fired boilers. As previously mentioned, since a large amount of new data became available for the 11 metals listed as hazardous air pollutants (HAP metals: Sb, As, Be, Cd. Cr, Co, Pb, Mn, Hg, Ni and Se), the old data for these HAP metals were discarded and the data used for deriving the values in Table 4.3 came primarily from the Boiler MACT and other related company test reports. The decision to discard the old data was based on the fact that the newer data for HAP metal emissions represent the performance of current PM control devices operating on wood-fired boilers, and PM control is known to have improved appreciably over the years across most boiler types. As before, data for boilers equipped with ESPs/fabric filters, wet scrubbers, or multiclones are grouped separately (NCASI 2010). Information concerning the specifics of each boiler, such as the fuel description, boiler type, boiler heat input, and the PM control device, as well as average emissions for each trace metal corresponding to each boiler, is provided in electronic format in Table AA-2 (downloadable from the NCASI members only website).

Data used to develop Table 4.3 came from tests conducted on two wood-fired electrical generating units (EGUs), 28 pulp mill bark/wood residue boilers, and 38 wood products mill wood-fired units. Of the 68 wood-fired boilers, there were 44 stokers, seven suspension burners, nine fuel cells, two Dutch ovens, five fluidized beds and one unspecified type.

Relative to the non-HAP metal emissions data extracted from AP-42 files and retained in Table 4.3, data from 38 boilers in the AP-42 background document were considered even though several were not located at FPI facilities. Thirty-five of the 38 boilers corresponded to wood-fired boilers burning "inland" wood residues for which data were summarized in electronic spreadsheet files supporting the background document to EPA's AP-42 chapter on wood residue combustion (ERG 2001). The data for the remaining three boilers were available in NCASI files (much of the data on pulp mill wood-fired boilers in EPA's AP-42 background document were also available in NCASI files). Of the 38 boilers, three were located at furniture plants, eight were electric generating units (EGU), 11 were located at pulp mills, and 16 were located at wood products mills. Once again, the fuels and combustion conditions in the non-FPI boilers were thought to be representative of FPI boilers burning wood residues. Just as for the organic air toxic data, in spite of the majority data originating from the AP-42 background document, the mean emissions for wood-fired boilers presented in Table 4.3 may not necessarily agree with the means presented in EPA's AP-42 chapter on wood residue combustion (EPA 2003) for reasons similar to those outlined above for the organic air toxic emissions data. The averages presented in Table 4.3 should best represent current FPI boiler metal emission rates.

Table 4.3 Summary of Trace Metal Emissions from Wood-Fired Boilers (lb/10^6 Btu)

Trace Metal	PM Control Device	Sources*	Detects	Min.	Max.	Median	Mean	Std. Dev.	UPL**
Antimony	ESP/Fabric Filter	16	14	6.64E-08	1.15E-06	1.55E-07	3.02E-07	3.20E-07	1.09E-06
Antimony	Mechanical Collector	4	4	1.75E-06	3.76E-06	3.46E-06	3.11E-06	9.26E-07	4.64E-06
Antimony	Wet Scrubber	3	3	9.43E-07	3.59E-06	1.47E-06	2.00E-06	1.40E-06	4.32E-06
Arsenic	ESP/Fabric Filter	22	19	1.29E-07	9.35E-06	3.69E-07	1.88E-06	2.74E-06	8.55E-06
Arsenic	Mechanical Collector	7,6	5	1.24E-06	2.79E-05	3.22E-06	7.20E-06	9.88E-06	2.35E-05
Arsenic	Wet Scrubber	10	10	1.89E-06	2.67E-05	1.01E-05	1.11E-05	8.96E-06	2.59E-05
Barium	Fabric Filter	2	2	1.59E-04	2.60E-04	2.10E-04	2.10E-04	--	--
Barium	Wet Scrubber	4,3	3	6.69E-06	8.15E-05	2.02E-05	3.61E-05	3.99E-05	1.02E-04
Barium	Mechanical Collector	1	1	--	--	4.83E-03	4.83E-03	--	--
Beryllium	ESP/Fabric Filter	21,17	7	6.28E-09	1.71E-07	7.11E-09	3.01E-08	4.90E-08	1.11E-07
Beryllium	Mechanical Collector	7	3	2.14E-08	7.54E-07	4.00E-08	1.34E-07	2.53E-07	5.52E-07
Beryllium	Wet Scrubber	9,8	6	2.90E-08	9.91E-08	4.23E-08	5.52E-08	3.10E-08	1.06E-07
Cadmium	ESP/Fabric Filter	23	22	7.45E-08	1.35E-06	3.90E-07	3.66E-07	2.76E-07	1.04E-06
Cadmium	Mechanical Collector	7	7	1.44E-06	1.16E-05	4.76E-06	4.99E-06	3.60E-06	1.09E-05
Cadmium	Wet Scrubber	11	11	1.53E-06	6.07E-06	3.09E-06	3.20E-06	1.36E-06	5.44E-06
Chromium	ESP/Fabric Filter	22	22	1.01E-07	9.40E-06	1.34E-06	2.44E-06	2.58E-06	8.71E-06
Chromium	Mechanical Collector	7	7	4.75E-06	3.98E-05	2.40E-05	2.45E-05	1.36E-05	4.70E-05
Chromium	Wet Scrubber	8	8	2.63E-06	1.50E-05	1.00E-05	9.75E-06	4.35E-06	1.69E-05
Chromium^{+6} [a]	ESP/Fabric Filter	5,2	2	5.90E-08	4.86E-07	2.72E-07	2.72E-07	--	--
Chromium^{+6}	Mechanical Collector	3,2	2	6.61E-06	7.33E-06	6.97E-06	6.97E-06	--	--
Chromium^{+6}	Wet Scrubber	2,1	1	--	--	2.35E-07	2.35E-07	--	--
Cobalt	ESP/Fabric Filter	16	16	2.46E-08	3.02E-05	1.03E-07	2.35E-06	7.46E-06	2.07E-05
Cobalt	Mechanical Collector	3	3	6.85E-07	2.21E-06	2.12E-06	1.67E-06	8.56E-07	3.08E-06
Cobalt	Wet Scrubber	3	3	5.60E-07	4.69E-06	6.11E-07	1.95E-06	2.37E-06	5.86E-06
Copper	ESP/Fabric Filter	6	6	2.54E-06	1.10E-05	4.14E-06	4.99E-06	3.15E-06	1.02E-05
Copper	Mechanical Collector	12	12	1.00E-07	4.25E-04	1.01E-04	1.11E-04	1.13E-04	3.91E-04
Copper	Wet Scrubber	8	8	2.78E-11	4.89E-05	1.34E-05	1.82E-05	1.69E-05	4.61E-05
Lead	ESP/Fabric Filter	24	24	3.59E-08	2.89E-05	1.97E-06	5.21E-06	6.96E-06	2.21E-05
Lead	Mechanical Collector	7	6	8.87E-06	1.01E-04	1.54E-05	3.11E-05	3.00E-05	1.07E-04
Lead	Wet Scrubber	11	11	1.33E-05	9.78E-05	3.49E-05	3.62E-05	2.22E-05	9.13E-05
Manganese	ESP/Fabric Filter	22	22	0.00E+00	5.52E-04	2.27E-05	9.13E-05	1.54E-04	4.67E-04
Manganese	Mechanical Collector	7	6	4.48E-04	8.25E-03	2.49E-03	2.76E-03	2.63E-03	9.45E-03
Manganese	Wet Scrubber	9	9	6.86E-05	6.93E-04	1.27E-04	2.50E-04	2.29E-04	8.24E-04

(Continued on next page. See notes at end of table.)

Table 4.3 Continued

Trace Metal	PM Control Device	Sources*	Detects	Min.	Max.	Median	Mean	Std. Dev.	UPL**
Mercury	ESP/Fabric Filter	29	29	7.33E-08	6.62E-06	6.26E-07	1.06E-06	1.36E-06	4.35E-06
Mercury	Mechanical Collector	7	7	3.74E-07	5.04E-06	1.15E-06	1.77E-06	1.67E-06	4.52E-06
Mercury	Wet Scrubber	15	15	1.83E-07	2.23E-06	8.26E-07	9.61E-07	5.26E-07	2.25E-06
Molybdenum	Fabric Filter	2	2	1.13E-06	3.01E-06	2.07E-06	2.07E-06	--	--
Nickel	ESP/Fabric Filter	22	22	1.93E-07	1.48E-05	1.58E-06	2.80E-06	3.28E-06	1.08E-05
Nickel	Mechanical Collector	7	7	2.80E-06	2.79E-05	1.17E-05	1.32E-05	1.03E-05	3.03E-05
Nickel	Wet Scrubber	9	9	2.33E-06	1.16E-05	8.84E-06	7.34E-06	3.79E-06	1.36E-05
Phosphorus	ESP/Fabric Filter	2	2	1.93E-05	6.01E-04	3.10E-04	3.10E-04	--	--
Phosphorus	Wet Scrubber	2	2	3.54E-05	1.6E-04	9.85E-05	9.85E-05	--	--
Phosphorus	Mechanical Collector	1	1	--	--	5.45E-03	5.45E-03	--	--
Potassium	Fabric Filter	1	1	--	--	3.88E-02	3.88E-02	--	--
Selenium	ESP/Fabric Filter	22	16	2.51E-08	7.12E-06	9.22E-07	1.62E-06	2.03E-06	6.56E-06
Selenium	Mechanical Collector	7	5	4.00E-07	1.84E-05	5.39E-07	3.25E-06	6.19E-06	1.90E-05
Selenium	Wet Scrubber	9	9	2.49E-07	4.11E-06	1.03E-06	1.71E-06	1.52E-06	4.21E-06
Silver	Mechanical Collector	2	2	1.39E-04	1.7E-03	9.37E-04	9.37E-04	--	--
Silver	Wet Scrubber	2	2	1.20E-07	1.9E-06	9.85E-07	9.85E-07	--	--
Sodium	Fabric Filter	1	1	--	--	3.63E-04	3.63E-04	--	--
Strontium	Fabric Filter	1	1	--	--	1.01E-05	1.01E-05	--	--
Thallium	Wet Scrubber	1	1	--	--	1.85E-06	1.85E-06	--	--
Tin	Fabric Filter	1	1	--	--	3.91E-05	3.91E-05	--	--
Titanium	Fabric Filter	1	1	--	--	2.01E-05	2.01E-05	--	--
Vanadium	Fabric Filter	1	1	--	--	5.94E-07	5.94E-07	--	--
Yttrium	Fabric Filter	1	1	--	--	3.01E-07	3.01E-07	--	--
Zinc	ESP/Fabric Filter	9	9	1.67E-05	7.09E-04	4.38E-05	1.30E-04	2.22E-04	6.87E-04
Zinc	Mechanical Collector	10	10	2.11E-06	7.83E-03	5.08E-04	1.29E-03	2.35E-03	7.16E-03
Zinc	Wet Scrubber	6	6	3.11E-10	2.78E-03	2.50E-04	6.58E-04	1.07E-03	3.40E-03

NOTE: Shaded rows show statistics derived exclusively from new data obtained from recent Boiler MACT and related company test report.

*If this column has two entries, the 1st entry represents the total number of sources that were tested and the 2nd entry represents the sources for which data were included in the analysis for estimating averages; the difference represents sources where data were rejected mainly because they yielded non-detects with detection limits exceeding the highest detected observation. Occasionally, an observation confirmed to be a statistical outlier was also rejected.

**UPL Upper prediction limit estimated using mean + 1.65 x std. dev. for normally distributed data and the Chebyshev Inequality with 85% confidence coefficient for non-normally distributed data.

[a] See Section 4.5 for further discussion.

4.4 Comparison with Average Trace Metal Emissions Summarized in NCASI Technical Bulletin 973

Table 4.4 compares the mean wood-fired boiler emissions for the 11 trace metal HAP emissions in this report with mean emissions for the same trace metal HAPs as summarized in NCASI Technical Bulletin No. 973. As previously mentioned, data for the 11 trace metal HAPs used for Technical Bulletin No. 973 were completely replaced by the new Boiler MACT-related trace metal HAP emissions data in this report. The data are separated by PM control device type. Only the data for boilers with either ESPs/Fabric filters or wet scrubbers are shown.

For boilers with ESPs/FFs, mean emissions for As, Co, Hg and Ni increased while the mean emissions for the rest decreased. For boilers with wet scrubbers, mean emissions of Sb, As, Co, Mn, Hg and Se increased while mean emissions for the remainder decreased.

Table 4.4 Mean Trace Metal HAPs – Comparison with Technical Bulletin 973 Means

		TB 973, Table 21A			Current Report			% Increase over TB 973 Mean
Trace Metal	PM Control Device	Sources	Detects	Mean, $lb/10^6Btu$	Sources	Detects	Mean, $lb/10^6Btu$	
Antimony	ESP/Fabric Filter	1	1	4.23E-07	16	14	3.02E-07	-29
Antimony	Wet Scrubber	1	1	4.98E-07	3	3	2.00E-06	302
Arsenic	ESP/Fabric Filter	9	7	8.11E-07	22	19	1.88E-06	132
Arsenic	Wet Scrubber	6	5	2.86E-06	10	10	1.11E-05	288
Beryllium	ESP/Fabric Filter	5	2	3.27E-06	17	7	3.01E-08	-99
Beryllium	Wet Scrubber	5	2	1.23E-06	8	6	5.52E-08	-96
Cadmium	ESP/Fabric Filter	9	8	1.68E-06	23	22	3.66E-07	-78
Cadmium	Wet Scrubber	9	8	4.06E-06	11	11	3.20E-06	-21
Chromium	ESP/Fabric Filter	10	10	4.34E-06	22	22	2.44E-06	-44
Chromium	Wet Scrubber	9	9	1.21E-05	8	8	9.75E-06	-19
Cobalt	ESP/Fabric Filter	2	2	4.68E-07	16	16	2.35E-06	402
Cobalt	Wet Scrubber	1	1	1.97E-07	3	3	1.95E-06	890
Lead	ESP/Fabric Filter	10	10	9.91E-06	24	24	5.21E-06	-47
Lead	Wet Scrubber	11	11	4.72E-05	11	11	3.62E-05	-23
Manganese	ESP/Fabric Filter	7	7	9.55E-05	22	22	9.13E-05	-4
Manganese	Wet Scrubber	6	6	3.77E-05	9	9	2.50E-04	563
Mercury	ESP/Fabric Filter	8	7	8.63E-07	29	29	1.06E-06	23
Mercury	Wet Scrubber	7	7	6.68E-07	15	15	9.61E-07	44
Nickel	ESP/Fabric Filter	5	4	2.66E-06	22	22	2.80E-06	5
Nickel	Wet Scrubber	8	8	1.38E-05	9	9	7.34E-06	-47
Selenium	ESP/Fabric Filter	5	3	1.69E-06	22	16	1.62E-06	-4
Selenium	Wet Scrubber	3	2	1.40E-06	9	9	1.71E-06	22

4.5 Critical Review of Air Toxic Emission Data for Wood-Fired Boilers

Some of the unexpected or suspicious average emissions in Tables 4.1 and 4.3 were scrutinized, as were individual mill test results statistically identified as outliers by either the Dixon's ($n \leq 25$) or Rosner's ($n > 25$) method. The following sections discuss the findings of these investigations and provide further information on which outliers were rejected and which were not based upon subsequent graphical analysis and confirmation.

Acrolein was detected in six of 12 wood-fired boiler stacks that were tested for this compound, the detects ranging from 3.15E-05 lb/10^6 Btu to 0.023 lb/10^6 Btu. The high measurement of 0.023 lb/10^6 Btu in one boiler stack (wood products mill - Boiler Code B50) was determined to be a clear statistical outlier (Dixon's method), being almost 21 times higher than the next highest detect value of 0.0011 lb/10^6 Btu. This data point was rejected for determination of population averages after graphical confirmation. Also, on further inquiry it was learned that this measurement was non-representative of wood combustion in the FPI since the testing was carried out on a "dump stack." According to a company representative, "the combustion unit is integrated for dryer and boiler firing. The 'dump stack' is used when dryer loads don't allow all of the fluidized bed unit's exhaust to be handled by the dryer. Like most fluidized bed units, turn-down is limited by the fluidization volume" (NCASI file information). Excluding this data point, the statistically derived mean for this data set is estimated at 2.60E-04 lb/10^6 Btu, which is significantly lower than the AP-42 mean for wood combustion of 4.04E-03 lb/10^6 Btu which includes the discarded data point.

One boiler (B78) burning wood residues at a paper mill and equipped with a wet ESP and a venturi scrubber had the highest emissions for all organics that were measured in this boiler's stack including **acetaldehyde** (0.002 lb/10^6 Btu), **acrolein** (0.0011 lb/10^6 Btu – after rejecting acrolein data for Boiler B50), **benzene** (0.065 lb/10^6 Btu), **styrene** (0.0019 lb/10^6 Btu), and **toluene** (0.0036 lb/10^6 Btu). Formaldehyde, the other major air toxic emission from wood-fired boilers, was not reported as being measured from this boiler. These emissions were generally determined to be statistical outliers in their respective data sets. The outlier emissions for benzene and toluene were rejected after graphical confirmation. However, the emissions for acetaldehyde, acrolein, and styrene were not rejected as they were not determined to be outliers. It is not clear whether they resulted from wood combustion or from the possible use of pulp mill condensates in the venturi scrubber used on this boiler.

Hexavalent chromium was measured at 1.39E-06 lb/10^6 Btu in the B134 boiler equipped with an ESP. However, these emissions for Cr^{+6} were significantly greater than corresponding emissions for total Cr in the same boiler stack (5.03E-07 lb/10^6 Btu). Thus, they were rejected for purposes of determining averages.

4.5.1 *Results of Outlier Tests*

The following **maximum** wood-fired boiler emissions were determined to be outliers (Dixon's test). However, after further graphical observation and analysis, they were not rejected for purposes of determining averages.

- 0.00196 lb/10^6 Btu **acetaldehyde** for boiler PM – B78
- 0.0126, 0.0216, 0.0311 and 0.0391 lb/10^6 Btu **hydrogen chloride (boilers with dry PM control devices)** for boilers PM – BB8, PM – BB2, PM – BB6 and PM – BB25, respectively
- 9.35E-06 lb/10^6 Btu **arsenic** for boiler EGU – BB2 with ESP
- 7.09E-04 lb/10^6 Btu **zinc** for boiler B49 with ESP
- 2.78E-03 lb/10^6 Btu **zinc** for boiler B25 with wet scrubber

The following **maximum** wood-fired boiler emissions were determined to be outliers (Dixon's or Rosner's test). After further graphical observation and analysis, they were rejected for purposes of determining averages.

- 0.023 lb/10^6 Btu **acrolein** for boiler WPM - B50 (next highest = 0.0011)
- 0.0648 lb/10^6 Btu **benzene** for boiler PM - B78 (next highest = 0.0102)
- 0.0536 lb/10^6Btu **formaldehyde** for WPM – BB7 (next highest = 0.0051)
- 0.0276 lb/10^6 Btu **methanol** for boiler WPM - BB7 (next highest = 0.00148)
- 0.00363 lb/10^6 Btu **toluene** for boiler B78 (next highest = 9.0E-05)
- 1.48E-03 lb/10^6 Btu **barium** for boiler PM - WN1 w/wet scrubber (next highest = 8.15E-05)

4.6 PAH/PAC Emissions from Wood Residue-Fired Boilers

Trace quantities of polycyclic aromatic compounds (PACs) or polycyclic aromatic hydrocarbons (PAHs) are inadvertently manufactured during combustion of wood or fossil fuels. The formation of PACs/PAHs, which are a subset of a larger group of compounds known as polycyclic organic matter or POM, occurs as a result of combustion of carbonaceous material under reducing conditions. Since wood combustion involves the burning of carbonaceous matter under partly reducing conditions (unlike gas, oil, and coal), its combustion has a greater potential to form trace quantities of PACs/PAHs.

Table 4.5 presents a summary of the PAC or PAH emissions data for wood-fired boilers. PAC/PAH emissions data available for three wood-fired boilers, a suspension burner, a fuel cell and a fluidized bed, were combined with the PAC/PAH data available for several wood-fired boilers in the background document for Section 1.6 of AP-42 (ERG 2001) and new averages calculated. Table AA-3, downloadable from the NCASI members only website, provides details of fuel description, boiler type, boiler heat input, and the PM control device, as well as average emissions of various PACs/PAHs for all the wood-fired boilers included in this summary. These data could be useful for the purpose of annual reporting of the category of PACs in the US under the SARA Section 313 program or of PAHs as alternate threshold compounds in Canada under the NPRI program.

Table 4.5 Summary of Polycyclic Organic Matter Emissions (PACs) from Wood-Fired Boilers

CAS No.	PAH/PAC Congener	C[6]	U[6]	n	lb/10^6 Btu min	max	median	mean	stdev	UPL[7]
00208-96-8	Acenaphthene	C		15	2.49E-09	8.30E-06	1.03E-07	8.53E-07	2.12E-06	4.36E-06
00083-32-9	Acenaphthylene	C		17	8.58E-09	3.13E-05	5.81E-07	4.69E-06	8.95E-06	1.94E-05
00056-55-3	Benzo(a)anthracene	C	U	13	1.03E-09	3.62E-07	1.26E-08	8.13E-08	1.25E-07	2.88E-07
00218-01-9	Benzo(a)phenanthrene[1]	C	U	14	2.16E-09	5.03E-07	9.13E-09	7.90E-08	1.34E-07	3.01E-07
00050-32-8	Benzo(a)pyrene	C	U	18	5.90E-10	2.67E-05	1.52E-08	2.73E-06	6.76E-06	1.39E-05
00205-99-2	Benzo(b)fluoranthene	C	U	16	3.78E-10	7.08E-07	1.26E-08	1.42E-07	2.46E-07	5.48E-07
00192-97-2	Benzo(e)pyrene	C		4	2.25E-09	6.84E-07	7.95E-08	2.11E-07	3.23E-07	7.45E-07
00191-24-2	Benzo(g,h,i)perylene[2]	C		14	1.30E-09	9.18E-07	9.91E-09	1.51E-07	3.26E-07	6.88E-07
00205-82-3	Benzo(j,k)fluoranthene	C	U	1	--	--	1.56E-07	1.56E-07	--	--
00207-08-9	Benzo(k)fluoranthene	C	U	12	6.42E-10	1.49E-07	1.83E-08	5.18E-08	6.01E-08	1.51E-07
00189-55-9	Benzo(r,s,t)pentaphene[3]	C	U	--	--	--	--	--	--	--
00226-36-8	Dibenz(a,h)acridine	C	U	--	--	--	--	--	--	--
00224-42-0	Dibenz(a,j)acridine	C	U	--	--	--	--	--	--	--
05385-75-1	Dibenzo(a,e)fluoranthene	C	U	--	--	--	--	--	--	--
00192-65-4	Dibenzo(a,e)pyrene	C	U	--	--	--	--	--	--	--
00053-70-3	Dibenzo(a,h)anthracene	C	U	12	5.12E-10	2.69E-08	8.88E-09	9.56E-09	8.24E-09	2.32E-08
00189-64-0	Dibenzo(a,h)pyrene	C	U	--	--	--	--	--	--	--
00191-30-0	Dibenzo(a,l)pyrene	C	U	--	--	--	--	--	--	--
00194-59-2	Dibenzo(c,g)carbozole-7H	C	U	--	--	--	--	--	--	--
00057-97-6	Dimethylbenz(a)anthracene-7,12	C	U	--	--	--	--	--	--	--
00206-44-0	Fluoranthene[4]	C	U	16	5.93E-09	1.06E-05	4.57E-07	1.67E-06	2.82E-06	6.32E-06
00086-73-7	Fluorene	C		17	3.06E-09	2.67E-05	1.89E-07	3.01E-06	6.67E-06	1.40E-05
00193-39-5	Indeno(1,2,3-c,d)pyrene	C	U	14	1.26E-09	7.45E-07	9.13E-09	1.02E-07	2.11E-07	4.50E-07
00056-49-5	Methylcholanthrene-3	C	U		--	--	--	--	--	--
03697-24-3	Methylchrysene-5	C	U		--	--	--	--	--	--
05522-43-0	Nitropyrene-1	C	U		--	--	--	--	--	--
00198-55-0	Perylene	C		3	5.18E-10	8.90E-08	6.58E-09	3.20E-08	4.94E-08	1.14E-07
00085-01-8	Phenanthrene	C		15	8.79E-09	3.50E-05	2.64E-06	6.46E-06	1.09E-05	2.45E-05
00129-00-0	Pyrene	C		17	5.63E-09	2.67E-05	9.88E-07	3.54E-06	6.62E-06	1.45E-05
	Total for NPRI Reporting							**2.40E-05**		
	Total for SARA 313 Reporting							**5.03E-06**		
	Other Non-Reportable PAHs									

Table 4.5 Continued

CAS No.	PAH/PAC Congener	C[6]	U[6]	n	min	max	median	mean	stdev	UPL[7]
					lb/10[6] Btu					
	Anthracene	5		17	3.06E-09	2.67E-05	1.76E-07	2.68E-06	6.67E-06	1.37E-05
	1-Methylnaphthalene	5		1	--	--	2.54E-06	2.54E-06	--	--
	2-Methylnaphthalene	5		4	4.05E-08	2.99E-06	1.29E-06	1.40E-06	1.47E-06	3.82E-06
	7,12-Dimethylbenzo(a)anthracene	5		1			4.57E-09	4.57E-09	--	--
	2-Chloronaphthalene	5		3	2.41E-09	4.58E-08	1.20E-08	2.01E-08	2.28E-08	5.77E-08
	9,10-Dimethylanthracene	5		1	--	--	2.14E-09	2.14E-09	--	--
	2-Methylanthracene	5		1	--	--	1.60E-08	1.60E-08	--	--
	3-Methylchloanthrene	5		1	--	--	8.68E-09	8.68E-09	--	--
	1-Methylnaphthalene	5		1	--	--	2.54E-06	2.54E-06	--	--
	1-Methylphenanthrene	5		1	--	--	2.59E-07	2.59E-07	--	--
	9-Methylphenanthrene	5		1	--	--	8.73E-08	8.73E-08	--	--
	Benzo(a)fluorene	5		1	--	--	3.10E-08	3.10E-08	--	--
	Benzo(b)fluorene	5		1	--	--	4.35E-09	4.35E-09	--	--
	Coronene	5		1	--	--	3.03E-08	3.03E-08	--	--
	Dibenzo(a,c)anthracene	5		1	--	--	3.88E-09	3.88E-09	--	--
	Picene	5		1	--	--	2.46E-09	2.46E-09	--	--
	Pyridine	5		1	--	--	<1.0E-05	<1.0E-05	--	--

n = number of sources tested. [1]Or chrysene. [2]Reported separately under SARA 313. [3]Same CAS No. as for Dibenzo(a,i)pyrene in NPRI. [4]Or benzo(j,k)fluorine. [5]Non-reportable under SARA 313 or NPRI. [6]C, U – PAH compound reportable under Canada's NPRI or the US's SARA 313 (TRI) program; PAH – polycyclic aromatic hydrocarbons. [7]UPL Upper prediction limit estimated using mean + 1.65 x std. dev. for normally distributed data.

4.7 PCDD/F Emissions from Wood Residue-Fired Boilers

Polychlorinated dibenzo-*p*-dioxins (PCDDs) and polychlorinated dibenzofurans (PCDFs), collectively known as dioxins, are formed and emitted from most thermal processes, including the combustion of fuels. NCASI maintains a database of PCDD/F emissions for combustion processes of relevance to the forest products industry. The summary emission factors are published every year in the *NCASI Handbook of Chemical-Specific Information for SARA 313 Form R Reporting*. As previously mentioned, a large amount of data for wood-fired boilers became available as a result of EPA's Boiler MACT data collection activities, and these data included typically a test comprised of three four-hour runs for PCDD/Fs using EPA Method 23.

Congener-specific PCDD/F emissions data from recent tests were available for 31 wood-fired boilers that principally burned wood residues during the tests. Three of the boilers burned a small amount of kraft pulp mill wastewater treatment plant (WWTP) residuals (sludge), one boiler burned a small amount of knotter rejects (biomass), and four boilers burned a small amount of gas (under 5% of total heat input). Based upon limited test data in boilers burning wood residues with and without bleached pulp mill WWTP residuals, NCASI showed how such burning had no discernible impact on the air emissions of PCDD/Fs from such boilers (NCASI 1995). EPA made this same observation in its locating and estimating document for PCDD/F emissions (USEPA 1997). Other tests conducted on Canadian boilers have confirmed this observation (Paprican 2002). It was concluded that

> the impact of sludges in general on boiler dioxin and furan emissions is likely to depend on the chloride, sulfur and moisture contents of the sludge relative to that of the wood waste. If the sludge chloride content is significantly higher than that in the wood waste, and the sludge sulfur content is not correspondingly high, it is likely to increase dioxin formation. Similarly, if the sludge is quite wet, it is likely to reduce the boiler combustion efficiency and increase the dioxin and furan formation potential (Paprican 2002, p. 9).

Of the 31 wood-fired boilers, 19 were located at pulp mills, 10 at wood products mills, one at an electric generating plant, and one at a non-FPI industrial location. For PM control, 19 had ESPs, eight had wet scrubbers, one had an ESP followed by a wet scrubber, and three had only multiclones. Eighteen of the 31 wood-fired boilers were of the stoker design, seven were fuel cells, two were Dutch ovens, and four were bubbling or circulating fluidized bed combustors. Table 4.6 provides mean, median and range emissions for the 17 dioxin isomers corresponding to the 31 wood-fired boilers firing mainly wood residues. (Note that the protocol for estimation of PCDD/F emissions using EPA Method 23 requires all non-detect measurements for congeners to be set = 0). Table AA-4 (downloadable from the NCASI members only website) provides detailed data on the 17 PCDD/F congeners emitted from all 31 wood-fired boilers. It also provides the calculation procedure to estimate WHO-TEF/2005 toxic equivalents (TEQs) from the congener data.

Figure 4.1 shows the profile of PCDD/F emissions for the 31 wood-fired boilers in units of ng WHO-TEF/2005 TEQ/dscm @ 7% O_2. Also identified are the type of boiler and the PM control device on each boiler. This graph suggests there is no clear relationship between boiler or PM control type and the PCDD/F emissions for these 31 boilers.

Figure 4.2 plots the PCDD/F emissions (in WHO-TEF/2005 TEQ units) for 18 of these 31 wood-fired boilers against the wood fuel chloride content. The Cl contents for these wood fuels were measured around the same period as the air emission tests. It is seen that the correlation between wood fuel Cl content and PCDD/F emissions is weak ($r^2 = 0.09$), as would be expected for the case of inland wood residues which typically have Cl contents under 300 ppm (as opposed to salt-laden wood residues which have Cl contents well in excess of 3000 ppm).

Table 4.6 PCDD/F Emissions for 31 Industrial Wood-Fired Boilers

	µg/OD ton Wood[1]					µg/OD ton Wood[1]			
CDD Isomer	mean	median	min	max	CDF Isomer	mean	median	min	max
2,3,7,8-TCDD	0.005	0.000	0.000	0.044	2,3,7,8-TCDF	0.063	0.029	0.000	0.396
1,2,3,7,8-PeCDD	0.011	0.001	0.000	0.066	1,2,3,7,8-PeCDF	0.031	0.007	0.000	0.152
1,2,3,4,7,8-HxCDD	0.007	0.000	0.000	0.037	2,3,4,7,8-PeCDF	0.043	0.017	0.000	0.250
1,2,3,6,7,8-HxCDD	0.017	0.008	0.000	0.103	1,2,3,4,7,8-HxCDF	0.028	0.012	0.000	0.163
1,2,3,7,8,9-HxCDD	0.017	0.004	0.000	0.212	1,2,3,6,7,8-HxCDF	0.024	0.011	0.000	0.129
1,2,3,4,6,7,8-HpCDD	0.075	0.048	0.000	0.449	1,2,3,7,8,9-HxCDF	0.005	0.000	0.000	0.032
1,2,3,4,6,7,8,9-OCDD	0.190	0.093	0.000	1.047	2,3,4,6,7,8-HxCDF	0.020	0.009	0.000	0.118
					1,2,3,4,6,7,8-HpCDF	0.044	0.022	0.000	0.274
					1,2,3,4,7,8,9-HpCDF	0.007	0.000	0.000	0.039
					1,2,3,4,6,7,8,9-OCDF	0.039	0.019	0.000	0.235
Total CDDs	0.322	0.215[2]	0.000	1.222	**Total CDFs**	0.306	0.149[2]	0.011	1.639
	Total CDD/Fs, µg/ton wood[1]					0.628	0.501[2]	0.011	2.536

[1]Oven dry (OD) ton of bark or wood residue; converted from ng/dscm @ 7% O_2 assuming 9,460 dscf/10^6 Btu and 8,400 Btu//lb (OD) of wood residue fired. [2]Note that unlike for means, the sum of the medians for each isomer across a given population will not equal the median of the sums of all isomers for each source. The total shown here represents the median of the sums.

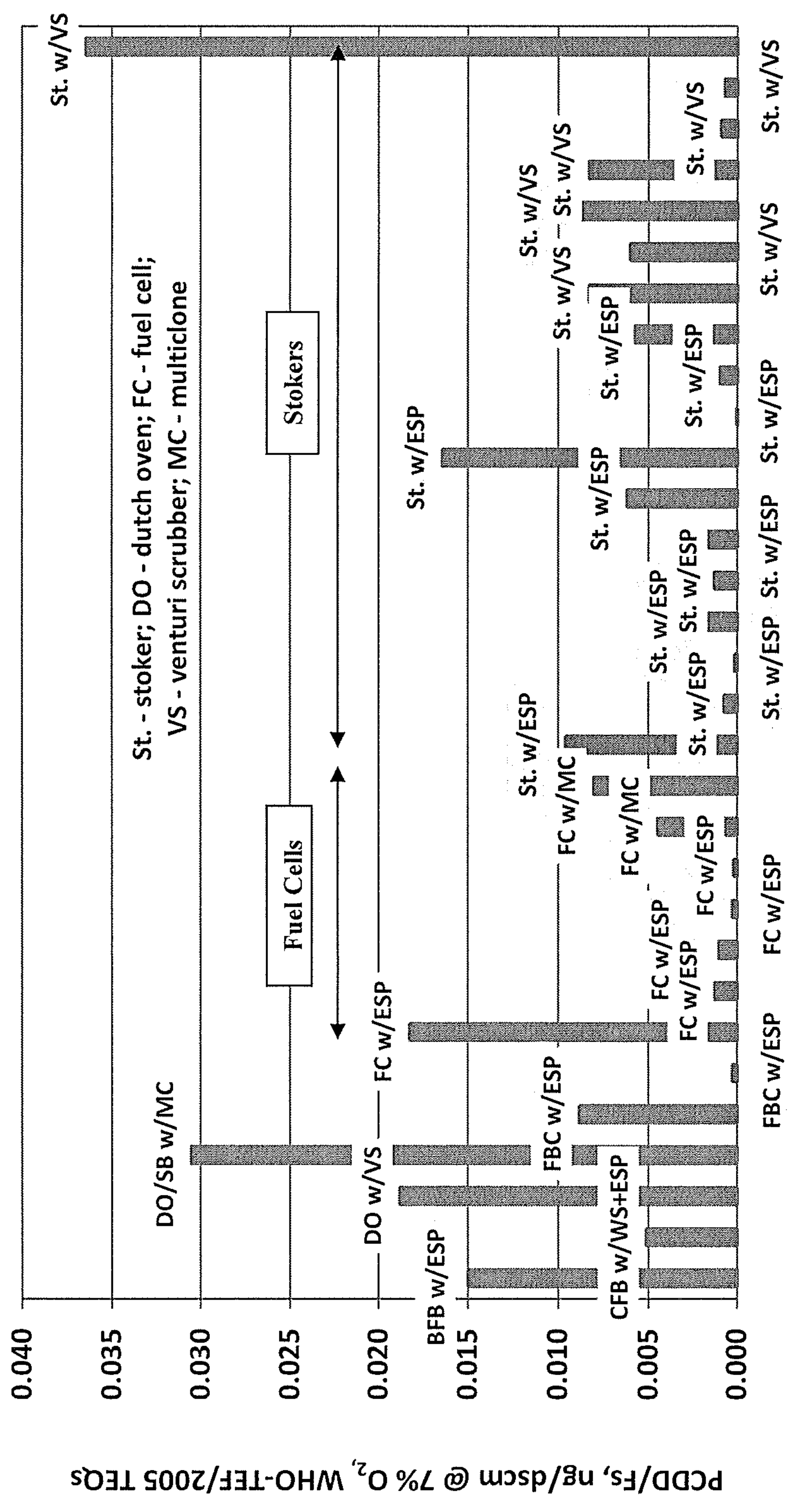

Figure 4.1 PCDD/F Emissions (WHO-TEF/2005 TEQs) for 31 Industrial Wood-Fired Boilers

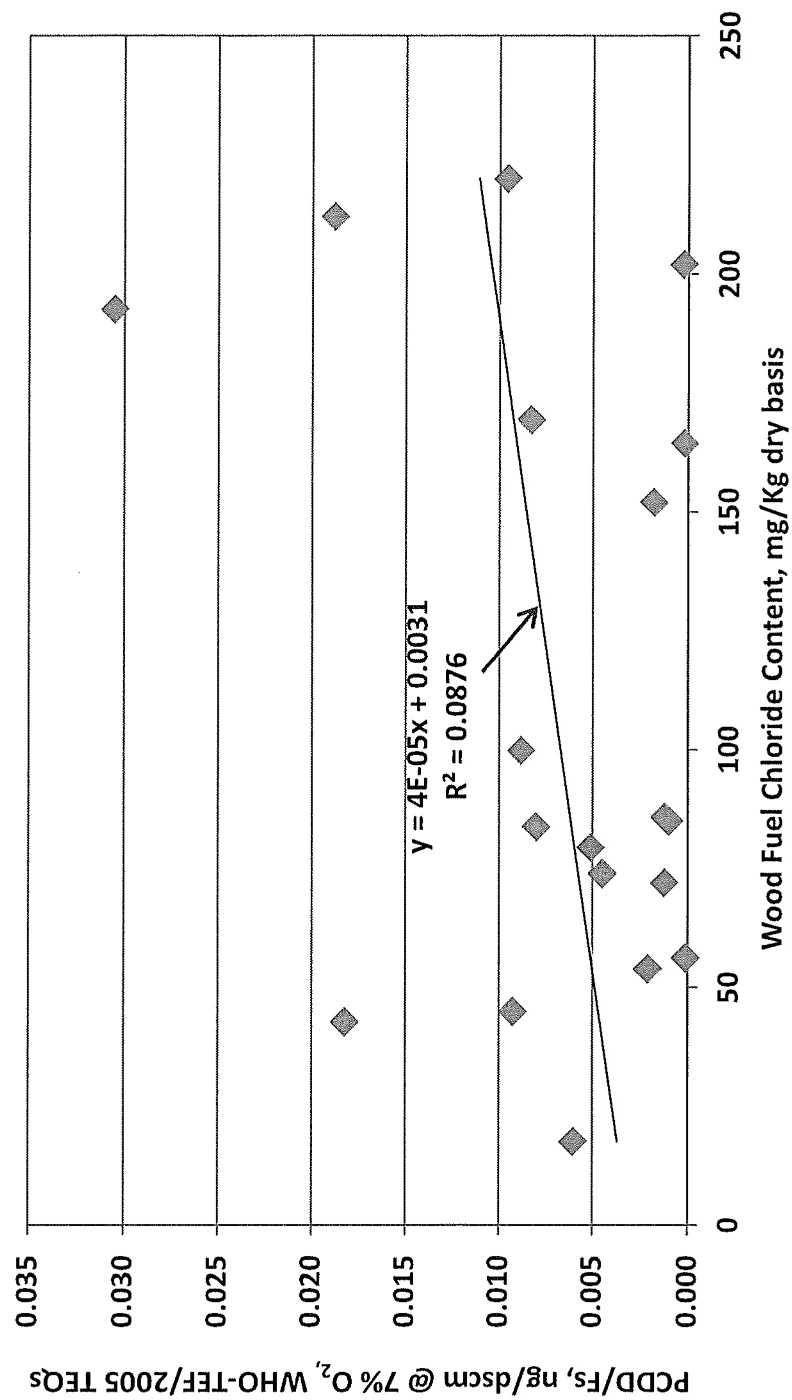

Figure 4.2 WHO-TEF/2005 TEQ Emissions vs Fuel Chloride Content - 18 Wood-Fired Boilers

5.0 CRITERIA POLLUTANT AND GHG EMISSIONS FROM WOOD-FIRED BOILERS

The principal criteria pollutant emissions of concern from wood combustion are particulates, CO, and NO_x. The ash content of stem wood fuel (wood chips, sanderdust, sawdust, planer shavings, etc.) ranges from 0.3 to about 3.0% (dry basis), while the ash content of bark fuel ranges from 3 to 10% (dry basis, median 5.2%, mean 8.0%) (NCASI 1999). Thus, the ash content of bark and wood fuels is generally lower than the ash content of most coals. However, uncontrolled particulate emissions from bark and wood combustion result from both the inorganic content of the bark/wood fuel and from the unburned carbon in the fly ashes (from incomplete combustion). Also, like coal combustion, uncontrolled particulate emissions will be greater where fly ash reinjection is practiced.

NO_x emissions are mainly the result of fuel NO_x, with most inland bark nitrogen contents being in the 0.1 to 0.3% range (dry basis). Average NO_x emissions from wood combustion in typical pulp mill boilers are lower than those from coal or residual oil combustion, but slightly higher than average NO_x emissions from natural gas and distillate oil burning. However, combustion of wood fuels containing nitrogen from other sources (e.g., urea formaldehyde resin) will result in additional NO_x emissions (fuel NO_x).

SO_2 emissions from wood combustion are very low, since bark and other wood residues contain very little sulfur (NCASI 1978). CO emissions and other products of incomplete combustion are highly variable and are a function of boiler design, operating conditions, combustion efficiency, and fuel quality.

A significant amount of criteria pollutant emissions data were also generated during the recent Boiler MACT-related testing effort on wood-, combination wood- and fossil fuel-fired industrial boilers. Just as for the data on air toxics, NCASI conducted a detailed review of test reports from the Boiler MACT and related testing programs for the data on criteria pollutants. For the criteria pollutants, more emphasis was placed on checking PM, $PM_{2.5}$, CPM, and THC results. Since CO, SO_2, and NO_x measurements were obtained via continuous analyzers, which were found to be generally reliable, less detailed examination of these pollutants was carried out.

Table 5.1 shows the minimum, maximum, median, mean, standard deviation and upper prediction limit derived from the test results in these reports for THCs (total hydrocarbons) as C, TNMHCs (total non-methane hydrocarbons, also called VOCs) as C, SO_2, CO, NO_x[1] and condensible particulate matter (CPM). Note THC values were obtained from EPA Method 25A measurements. Where methane (using EPA M18) was also measured, it was subtracted from the Method 25A THC value to obtain the TNMHC value. Table AA-5, downloadable from the NCASI members only website, provides details of fuel description, boiler type, boiler heat input, and the PM control device, as well as average emissions of various criteria pollutants, for all the wood-fired boilers where data are summarized in Table 5.1. The factors in Table 5.1 apply to the burning of predominantly bark and/or wood residues in industrial boilers. Considering the vast majority of these tests were conducted after 2008, these emission factors are considered to be more representative of current boiler operations compared with those in Section 1.6 of EPA's AP-42 document, the latter being based mainly on stack tests conducted 10 to 30 years ago.

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[1]As indicated in footnote f of Table 5.1, NO, NO_2, and NOx were measured simultaneously during 6 runs in one 100% wood-fired stoker unit, yielding an average NO_2/NO_x ratio of 6.9%.

Table 5.1 Uncontrolled VOC, CO, SO_2, NO_x and CPM Emissions from Wood Combustion Units[a]

	Sources	Min	Max	Median	Mean	StdDev	UPL[j]
Volatile Organic Compounds - all sizes & types							
THCs as C[b]	19[d]	5.69E-04	3.26E-02	4.40E-03	7.62E-03	8.40E-03	2.81E-02
TNMHCs as C[c]	11[c]	3.32E-04	1.90E-02	2.57E-03	4.44E-03	4.90E-03	1.64E-02
Carbon Monoxide							
Stokers	26	1.82E-02	2.23E+00	5.02E-01	7.24E-01	6.69E-01	1.95E+00
Fuel Cells/Dutch Ovens	8	1.16E-01	9.04E-01	3.60E-01	4.44E-01	3.02E-01	9.97E-01
Suspension Burners	5	5.42E-02	2.28E+00	2.26E-01	5.98E-01	9.48E-01	2.34E+00
Fluid Bed Combustors	2	6.51E-02	8.05E-02	7.28E-02	7.28E-02	--	--
Sulfur Dioxide – all sizes & types	30	ND	6.62E-02	3.18E-03	1.06E-02	1.77E-02	4.31E-02
Oxides of Nitrogen[e,f] – all sizes & types							
Wood w/o Significant UF Resin Content[g]	27	1.19E-01	4.21E-01	2.03E-01	2.12E-01	6.74E-02	3.27E-01
Wood w/ Significant UF Resin Content[h]	8	3.90E-01	1.26E+00	7.82E-01	7.91E-01	3.18E-01	1.39E+00
Condensible Particulate Matter (CPM)							
Boilers with ESPs/FFs	13	1.91E-03	3.57E-02	5.86E-03	8.90E-03	9.19E-03	2.58E-02
Boilers with Multiclones	4	4.83E-03	1.94E-02	6.62E-03	9.37E-03	6.78E-03	2.18E-02
Boilers with Wet Scrubbers[i]	3	3.03E-03	3.65E-02	3.93E-03	1.45E-02	1.90E-02	4.94E-02

[a] Source – Boiler MACT testing in boilers firing essentially 100% wood residues and/or bark. [b]Total hydrocarbons expressed as C, using EPA Method 25A. [c] Total non-methane hydrocarbons (VOCs) obtained by applying the mean non-methane hydrocarbon to THC fraction of 58.3% estimated from simultaneous or near simultaneous measurements for methane and THCs on 11 wood-fired boilers (3 stokers, 5 fuel cells, 1 Dutch oven, 2 FBCs) to the average statistics on THCs for the 19 boilers. [d] Although THCs were measured on 19 boilers, only 11 of these were also measured for methane. [e] Value is for both wet and dry wood-fired boilers. [f] NO, NO_2 and NO_x were measured simultaneously during 6 runs in one 100% wood-fired stoker unit yielding an average NO_2/NO_x ratio of 6.9%. [g] For firing of wood without significant resin content (< 20% UF resin wood content) and all moisture contents. [h] Wood residues with >20% UF resin wood content. [i] Note that CPM emissions for wood-fired boilers with wet scrubbers could be influenced by the wet scrubber itself. [j] Upper Prediction Limit with 95% confidence interval; all data sets assumed to be normally distributed.
ND = non-detect; detection limit unknown.

THCs were measured on 19 wood-fired boilers (two Dutch ovens, five fuel cells, nine stokers, two FBCs, and one suspension burner). However, methane was simultaneously measured only in 11 of these 19 boilers. A mean fraction of CH_4 (EPA M18) to THC as C (M25A) of 41.7% was computed for these 11 wood-fired boilers (three stokers, five fuel cells, one Dutch oven, and two FBCs). A mean fraction of 58.3% (100 – 41.7) was then applied to the estimates of THC for all 19 wood-fired boilers to yield corresponding estimates for TNMHCs (or VOCs) from wood combustion. Emission factors for THCs and TNMHCs are presented collectively for the entire group of wood combustion boiler types since insufficient data exist to warrant separating them into separate boiler type categories.

Emission factors for carbon monoxide, on the other hand, are separated by boiler type (stokers, fuel cells/Dutch ovens, suspension burners, fluid bed combustors) since sufficient data were available and the differing combustion dynamics in these boiler types would merit such categorization.

Emission factors for sulfur dioxide are lumped in one group, since the minimal amount of sulfur in the wood fuel, and subsequent capture of over 95% of this sulfur in the wood ashes (NCASI 1978), are the prime factors for these emissions.

Emission factors for the oxides of nitrogen or NO_x are categorized by boilers that burn wood without significant resin content (<20% UF resinated wood) and all levels of moisture content, and wood mixtures that have significant fractions of UF resinated wood (>20% resinated wood). Urea-formaldehyde-based resins contain significant amounts of nitrogen which result in elevated fuel NO_x contributions.

Relative to condensible particulate matter or CPM, only tests where the latest version of EPA Method 202 (promulgated in December 2010) was utilized were considered. For Boiler MACT-related testing, this corresponded to any testing carried out after July of 2009, since the facilities that conducted these tests were instructed by EPA to use OTM 28, which became the December 2010 version of EPA Method 202. It should be noted that the CPM emission factor in Section 1.6 of AP-42 is based on measurements made with the earlier version of Method 202 and could thus be considered invalid since they were not generated using the latest version of M202. In general, CPM emissions using the older M202 versions could be biased high for sources with SO_2 emissions or biased low for sources with ammonia emissions. However, boilers burning predominantly wood or wood-bark are expected to emit minimal amounts of SO_2 and NH_3.

Table 5.2 reproduces the estimates for filterable $PM_{2.5}$ emissions from Section 1.6 of AP-42 (USEPA 2003), where $PM_{2.5}$ is given as a fraction of total filterable PM (FPM). The fraction is provided for wood-fired boilers with several types of PM control devices. The 2009 and later stack test reports related to Boiler MACT data collection had FPM emissions data and corresponding filterable $PM_{2.5}$ emissions data for 13 wood-fired boilers equipped with ESPs, two boilers equipped with mechanical collectors, and one with no PM control device. The ratio of filterable $PM_{2.5}$ to total FPM was calculated for each of these PM control types and these data are summarized in Table 5.3.

One boiler equipped with an ESP and one with a fabric filter had questionable $FPM_{2.5}$/FPM ratios; both of these were discarded. For the remaining 11 wood-fired boilers equipped with ESPs, the average fraction of FPM that was filterable $PM_{2.5}$ is estimated at ~41%, lower than the 65% in AP-42. The average fraction of $FPM_{2.5}$/FPM for the two boilers equipped with multiclones is estimated at 54%, identical to the fraction presented in AP-42 for units with multiclones and fly ash reinjection. Finally, the $FPM_{2.5}$/FPM fraction for a single boiler with no control is estimated at ~28% in Table 5.3 as opposed to 76% in AP-42.

Table 5.2 Total Filterable PM (FPM), PM_{10} and $PM_{2.5}$ Emissions from Wood Combustion Units (USEPA 2003)

	PM_{10}, $PM_{2.5}$ as % of FPM Cumulative Mass			FPM Emission Factor	
PM Control Device	PM_{10}	$PM_{2.5}$	Wood Fuel Fired	lb/10^6 Btu[a]	kg/10^9J
			Bark		
			Bark and Wet Wood	0.56	0.24
			Dry Wood	0.40	0.17
None	90[c]	76[c]	Wet Wood	0.33	0.14
			Bark	0.54	0.23
			Bark and Wet Wood	0.35	0.15
			Dry Wood	0.30	0.13
Mechanical Collector[b]	91[c] / 32[d]	54[c] / 16[d]	Wet Wood	0.22	0.095
			Bark		
			Bark and Wet Wood		
			Dry Wood		
Electrolyzed Gravel Bed	74	65	Wet Wood	0.1	0.04
			Bark		
			Bark and Wet Wood		
			Dry Wood		
Wet Scrubber	98	98	Wet Wood	0.066	0.028
			Bark		
			Bark and Wet Wood		
			Dry Wood		
Fabric Filter	74	65	Wet Wood	0.1	0.04
			Bark		
			Bark and Wet Wood		
			Dry Wood		
Electrostatic Precipitator	74	65[e]	Wet Wood	0.054	0.023

[a] Based on an average higher heating value of 9000 Btu/lb of dry wood. [b] Mechanical collectors include cyclones and multiclones. [c] With flyash reinjection. [d] Without flyash reinjection. [e] See Table 5.3 for an estimate based on more recent Boiler MACT data.

Greenhouse gas (GHG) emissions from wood residue combustion include those of carbon dioxide, methane (CH_4), and nitrous oxide (N_2O). As previously noted, a signficant number of boilers were tested both for THCs and CH_4, so that estimates for TNMHCs (THC – CH_4) or VOCs could be derived. A recent NCASI study dealt with the measurement of methane and N_2O from biomass-fired boilers and recovery furnaces (NCASI 2012). Table 5.4 summarizes the data for methane and N_2O emissions from wood combustion. Also included is the CO_2 emission factor for wood residue combustion from AP-42 Section 1.6.

Table 5.3 Boiler MACT Data on Filterable PM and $PM_{2.5}$ Emissions for Wood- and Bark-Fired Boilers with ESPs/FFs, Multiclones and No Control

Boiler Code	Boiler Type	Avg FPM, $lb/10^6Btu$	Avg $FPM_{2.5}$, $lb/10^6Btu$	$FPM_{2.5}$/ FPM	Control Device
PM – BB1	Stoker	0.00248	0.00113	45.6%	ESP
PM – BB4	FBC	0.00131	0.00103	78.7%	ESP
PM – BB16	BFB	0.05270	0.00970	18.4%	ESP
PM – BB17	Stoker	0.00307	0.00046	14.8%	ESP
PM – BB18	FBC	0.0986	0.00628	6.4%	ESP
PM – BB24	Stoker	0.00607	0.00055	9.1%	ESP
PM - BB25	Stoker	0.00094	0.00099	106.4%[a]	FF
WPM – BB20	Fuel Cell	0.00376	0.00159	42.2%	ESP
WPM - BB21	Fuel Cell	0.00122	0.00061	50.1%	ESP
WPM - BB23	Fuel Cell	0.00240	0.00123	51.2%	ESP
WPM - BB25	Wellons	0.01320	0.00904	68.7%	ESP
WPM – BB30	Stoker	0.00117	0.00121	103.0%[a]	ESP
WPM – BB38	Fuel Cell	0.00683	0.00448	65.6%	ESP
	Average for 11 Boilers w/ESPs/FFs			**41.0%**	
WPM – BB24	Fuel Cell	0.13200	0.06570	49.8%	Multiclone
WPM – BB26	Fuel Cell	0.02180	0.01270	58.1%	Multiclone
	Average for 2 Boilers w/multiclones only			**54.0%**	
WPM – BB44	Fuel Cell	0.25300	0.07000	**27.7%**	None

[a]Invalid data, since $FPM_{2.5}$ cannot be > FPM; not used in estimating average fraction.

Table 5.4 Greenhouse Gas Emissions from Wood Combustion (in $lb/10^6$ Btu)

	Sources	Min	Max	Median	Mean	StdDev	UPL[e]
Nitrous Oxide[a,d]	4	3.31E-04	1.54E-03	8.62E-04	8.99E-04	5.78E-04	1.85E-03
Methane (CH_4)[b,d]	13	<1.96E-04	1.14E-02	2.17E-03	4.00E-03	4.12E-03	1.42E-02
CO_2[c]					195		

[a] From NCASI Technical Bulletin No. 998 (NCASI 2012). [b] From data generated during Boiler MACT and related testing efforts covered in this report. [c] From Table 1.6-3 of AP-42, Section 1.6. [d] Applicable to boilers of all sizes & types. [e] Upper Prediction Limit with 95% confidence interval – normally distributed.

6.0 POTENTIAL RELATIONSHIPS BETWEEN WOOD-FIRED BOILER POLLUTANTS

This section explores potential relationships, mostly expected, between various test average and hourly average wood combustion boiler emissions summarized in this report. Although extensive and concurrent data generated on individual boilers would be needed to properly explore most such relationships, the relationship between average and/or hourly average emissions more or less simultaneously measured for many of these boilers is investigated in an attempt to further understand how wood combustion emissions of Hg, HCHO, THCs, CPM, NO_x, and $PM_{2.5}$ behave.

6.1 Relationship between Hg and FPM Emissions

Higher filterable particulate matter emissions from a boiler are often thought to imply higher total Hg emissions. This would of course be true if particulate Hg (Hg^P) comprised the major form of Hg emitted from a boiler. Figure 6.1 explores the relationship between average total Hg emissions and average FPM emissions (typicaly averages of three runs) corresponding to 27 wood-fired boilers most of which were equipped with ESPs (one of the 27 had a fabric filter). It is interesting to note that the two highest values for average Hg emissions occurred at western mills that are known to purchase urban hog fuel (also known as construction and demolition debris). The 3rd highest value is at a western sawmill, although it is not known whether this mill purchased any urban hog fuel. Figure 6.2 explores the same relationship for 11 wood-fired boilers equipped with wet scrubbers. No relationship between total Hg and total FPM emissions is apparent in either case, suggesting that at least for these boilers, a reduction in FPM emissions need not result in a corresponding reduction of Hg emissions. For these wood-fired boilers, particulate Hg (Hg^P) may not comprise a significant fraction of total Hg emissions compared with elemental (Hg^0) and gaseous, oxidized Hg (Hg^{+X}).

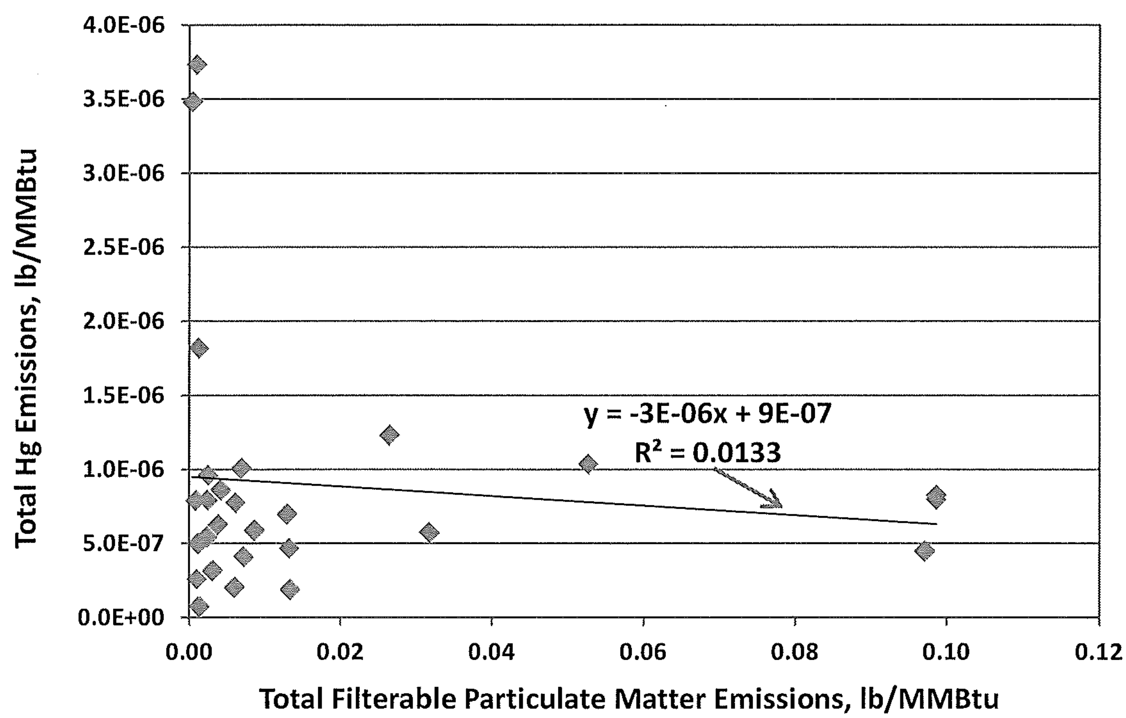

Figure 6.1 Total Hg Emissions and Emissions of Total FPM for WFBs with ESPs

Alternately, the Hg^p emitted is present in such fine PM that most of it is not captured in the ESP. However, it should be noted that the interpretation of these Method 29 results is complicated by the fact there are five analytical fractions that must be summed to obtain the total mercury emissions, with the non-detect fractions included at their respective detection limits, and the detection limits are different for each fraction. Review of sampling reports has shown that non-detects obtained for one or more of the 3 middle fractions of the Method 29 Hg sampling train where oxidized Hg (Hg^x) is expected to be captured often unduly influence the estimate for total Hg emissions.

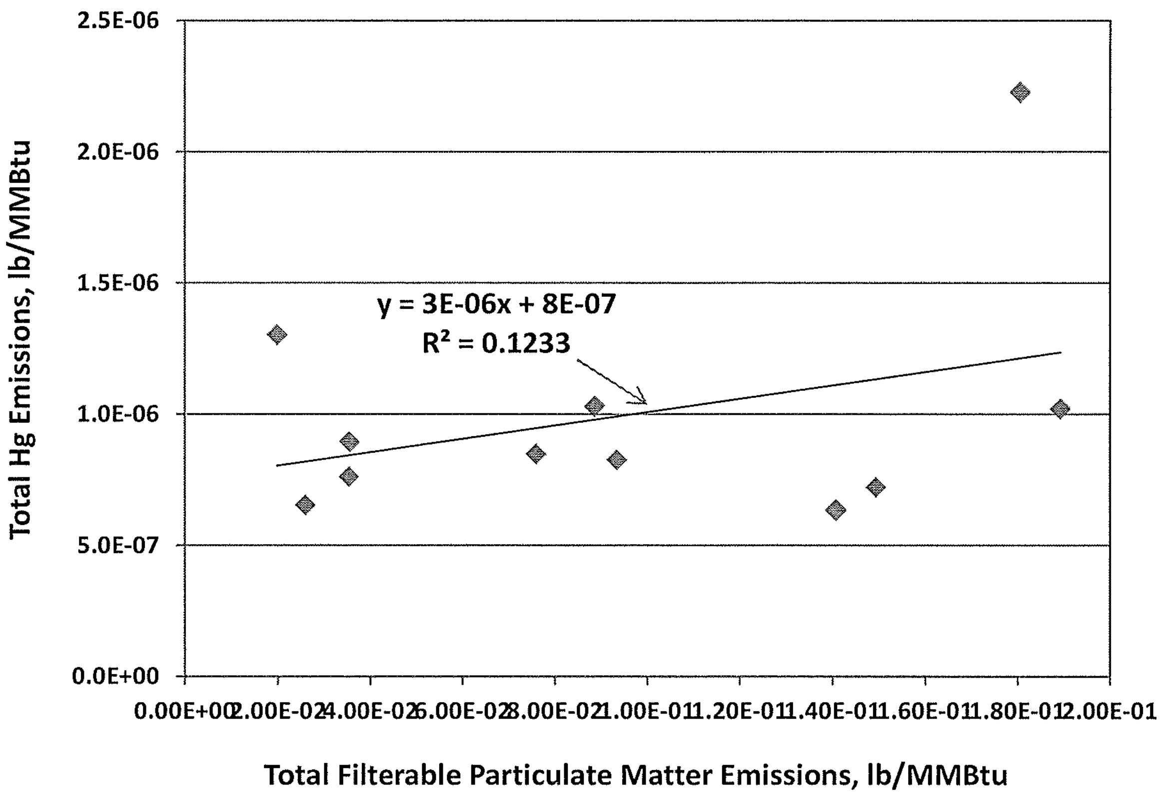

Figure 6.2 Total Hg Emissions and Emissions of Total FPM for 11 WFBs with Wet Scrubbers

6.2 Relationship Between HCHO and CO Emissions

For biomass boilers, CO, a product of incomplete combustion (PIC), is often considered to be a good surrogate for other organic PICs, and thus a positive relationship between the levels of CO in wood-fired boiler stack emissions and organic PICs is generally suspected. Formaldehyde is clearly a wood combustion PIC, and Figure 6.3 explores the relationship between average emissions of HCHO and CO (typically average of three one-hour runs for each) for 19 wood-fired boilers. It should be noted that the tests for HCHO and CO were conducted simultaneously only in the case of 15 of these 19 boilers. A mild to moderate linear relationship is observed from these data ($r^2 = 0.49$), although the scatter in the data is quite evident.

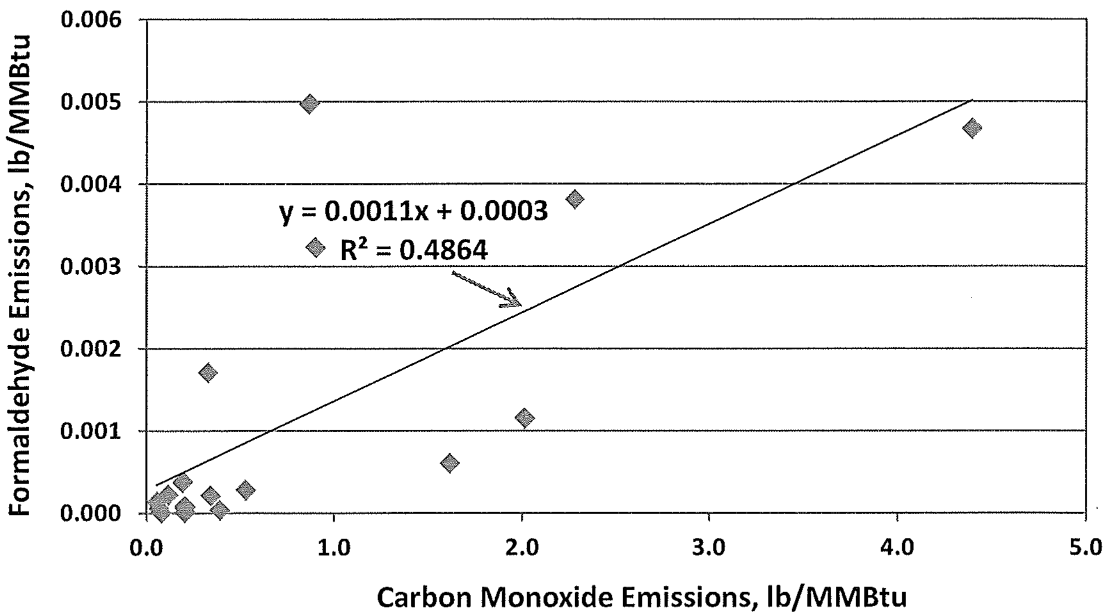

Figure 6.3 Formaldehyde vs CO (Average Emissions) for 19 WFBs

The individual one-hour run data corresponding to 15 of the 19 boilers with simultaneous CO and HCHO measurements are shown plotted in Figure 6.4 (as opposed to the three-hour averages shown in Figure 6.3 with some measurements not obtained simultaneously). Once again, only a mild to moderate relationship is observed ($r^2 = 0.29$).

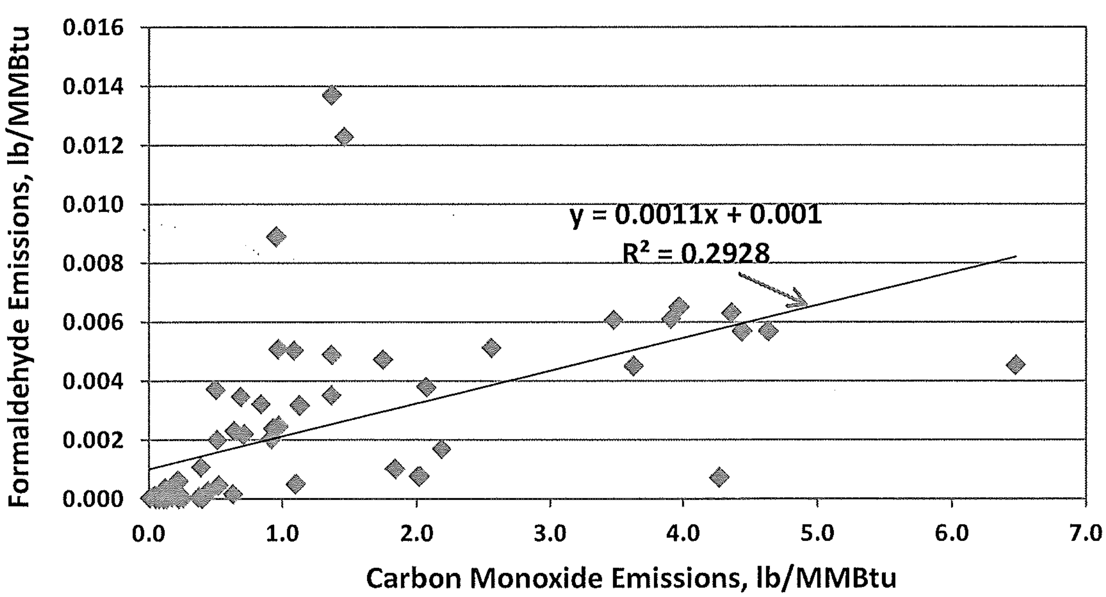

Figure 6.4 HCHO vs CO (Simultaneous Hourly Average Emissions) for 15 WFBs

6.3 Relationship Between THC and CO Emissions

Total hydrocarbons may also be considered to be wood combustion PICs. Figure 6.5 examines the relationship between average emissions of THCs as C (using EPA Method 25A) and CO (typically average of three one-hour runs) for 26 wood-fired boilers (simultaneous tests conducted for THCs and CO in 23 of the boilers). A moderate linear relationship is observed ($r^2 = 0.62$), although this relationship is generally only evident at elevated levels of CO.

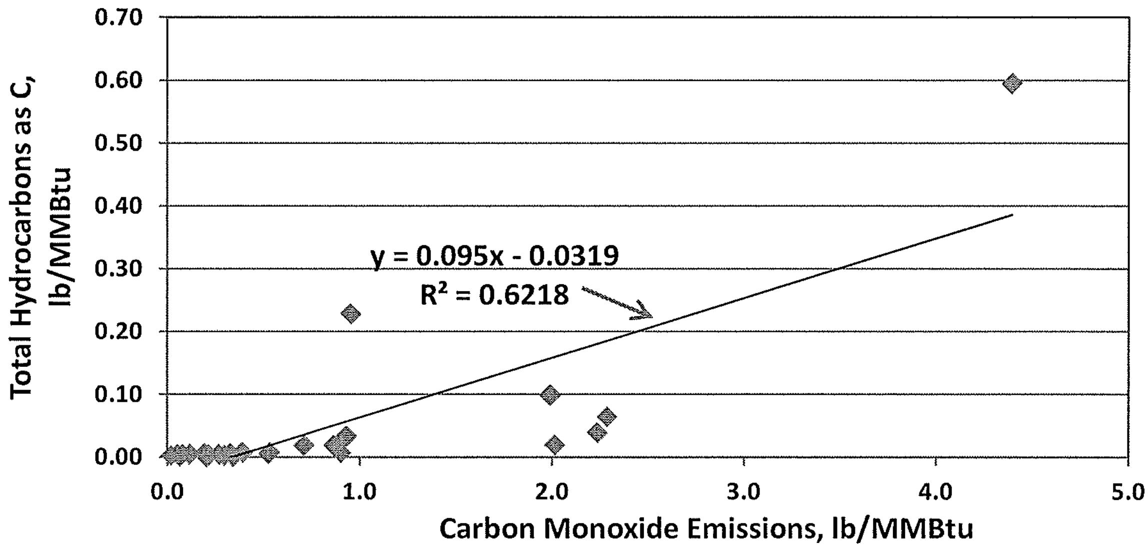

Figure 6.5 THC (as C) vs CO (Average Emissions) for 26 WFBs

Figure 6.6 plots simultaneously measured hourly averages of THC and CO for 23 of the 26 boilers. Once again, only a mild to moderate relationship is observed ($r^2 = 0.45$).

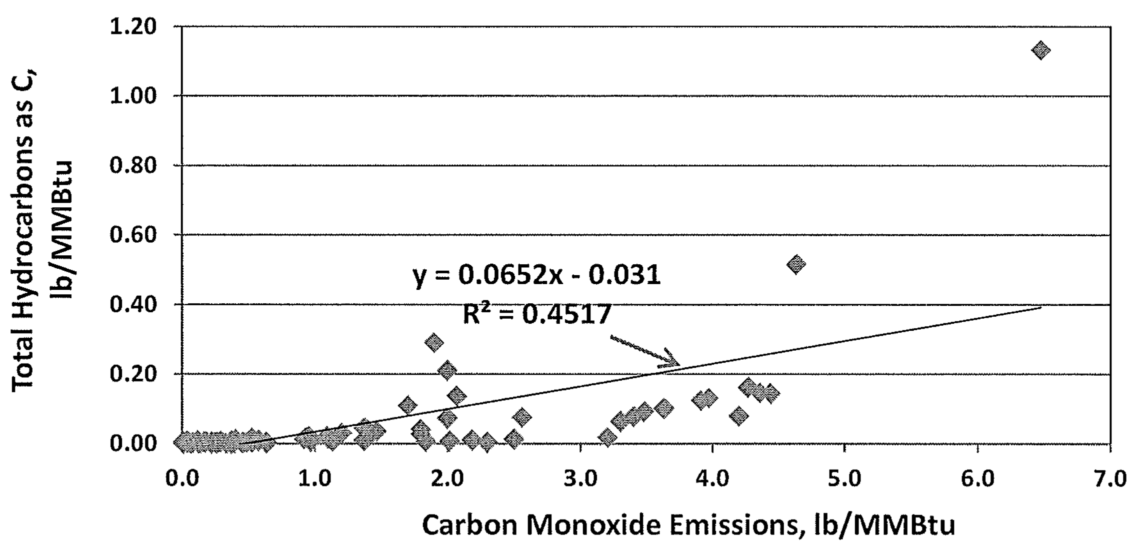

Figure 6.6 THC vs CO (Simultaneous Hourly Average Emissions) for 23 WFBs

6.4 Relationship Between CPM and CO Emissions

For wood combustion, condensible PM would be expected to consist of mainly heavier hydrocarbons, since sulfuric acid mist (SAM) and ammonia-based CPM are generally not expected from wood burning. Thus, in a sense, CPM may also be considered to be wood combustion PICs. Figure 6.7 explores this relationship between average emissions (test average) of CPM and CO for 21 wood-fired boilers (simultaneous tests conducted for CPM and CO in only four of these 21 boilers). A mild to moderate relationship is observed from these data ($r^2 = 0.41$), although the scatter in the data is quite evident.

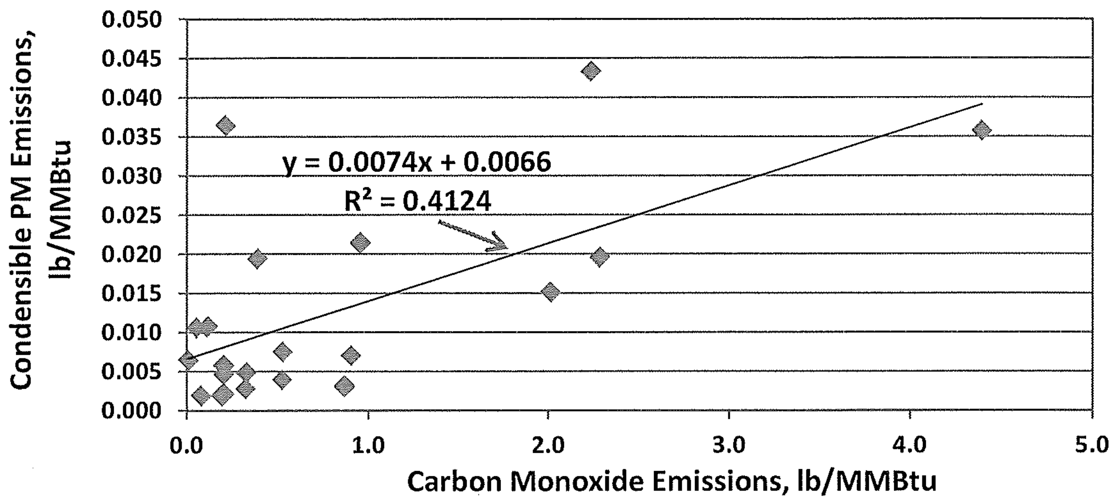

Figure 6.7 CPM vs CO (Average Emissions) for 21 WFBs

Figure 6.8 plots simultaneously measured hourly averages of CPM and CO for four of the 21 boilers. This figure shows that CPM and CO are totally uncorrelated for wood-fired boilers ($r^2 = 0.005$).

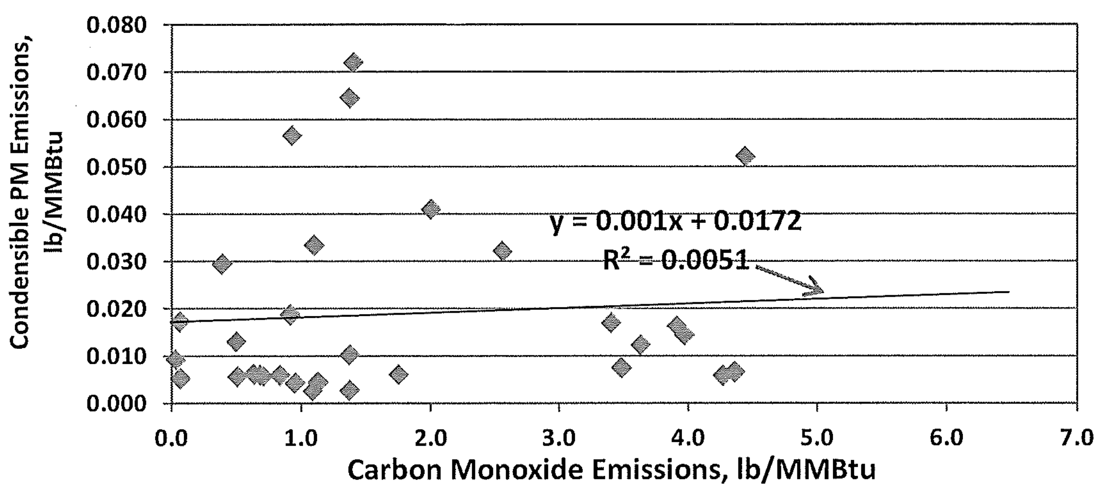

Figure 6.8 CPM vs CO (Simultaneous Hourly Average Emissions) for Four WFBs

6.5 NO_x Emissions and the Burning of High N-Containing Resin Woods

In the wood products sector of the forest products industry, resinated wood residuals from panel manufacturing are generally used as fuel in direct-fired dryers, boilers, and wood energy systems. The residuals may be in the form of sanderdust, sawdust, or chipped board trim. Urea-formaldehyde (UF) resin, the type of adhesive generally used for particleboard, medium density fiberboard, and hardwood plywood, contains significantly higher levels of nitrogen compared to other resin types. Consequently, wood fuels containing UF resins have high levels of nitrogen, which contribute to formation of additional fuel NO_x during combustion. Figure 6.9 demonstrates NO_x emissions from wood-fired boilers burning UF resin-containing wood in significant amounts, say more than 20% of the total heat input, are higher, sometimes much higher, than those from boilers burning wood residues not containing UF resins. As shown in Table 5.1, the average NO_x emissions from 27 boilers not burning wood fuels with UF resins is 0.21 lb/10^6 Btu as opposed to an average of 0.79 lb/10^6 Btu for eight boilers burning wood residues with significant (over 20% of the total heat input) fractions of UF-resinated materials.

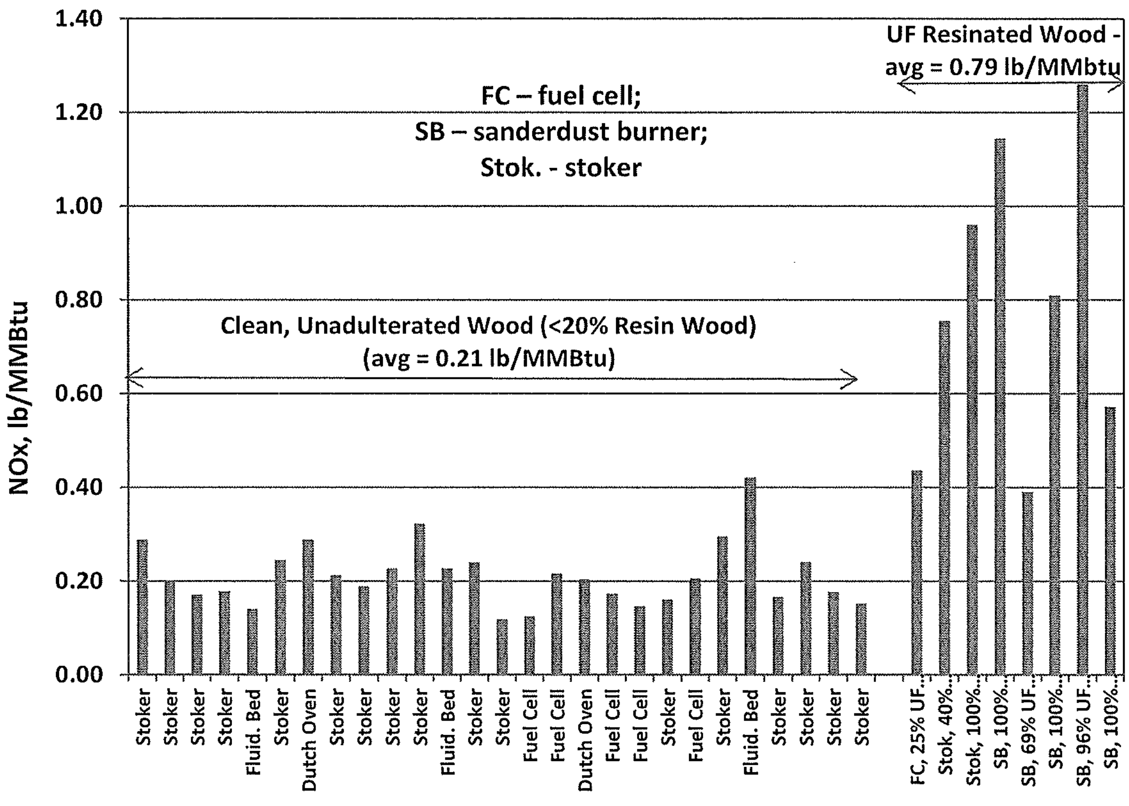

Figure 6.9 NO_x from Burning Clean, Unadulterated Wood and N-Containing Resin Wood

6.6 Relationship between Ratio of $PM_{2.5}$ to FPM and FPM Emissions for WFBs with ESPs

As the emission rate of total FPM from a wood-fired boiler equipped with an ESP goes down due to more efficient capture in the ESP, it would be expected that the fraction of total FPM emissions that exists as filterable $PM_{2.5}$ would go up. Most PM control devices, including ESPs, are less efficient in capturing fine and ultrafine PM. Thus, rather than prescribe a single ratio for $PM_{2.5}$ to FPM for wood-fired boilers with ESPs, as has been done in Section 5.0 (see Tables 5.2 and 5.3), a more nuanced relationship that takes into account such a potential relationship may be more appropriate. Figure 6.10 explores such a relationship between the ratio of $PM_{2.5}$ to FPM and total FPM from data corresponding to 13 wood-fired boilers equipped with ESPs, data that were presented and summarized earlier in Table 5.3. Although additional data would be needed to define a more precise relationship (r^2 for this power relationship was only 0.47), the data do depict a sort of asymptotic behavior between the $PM_{2.5}$/FPM ratio and FPM, suggesting that arriving at this fraction from such a plot for a given measured value of total FPM rather than depending on a single fraction assumed applicable to all FPM levels may be more appropriate. For example, the average $PM_{2.5}$/FPM ratio for 11 Boilers with ESPs and/or FFs is shown in Table 5.3 to be ~41%, whereas the asymptotic value of this ratio from Figure 6.10 for boilers with FPM emissions exceeding ~0.02 lb/10^6 Btu can be less than 20%.

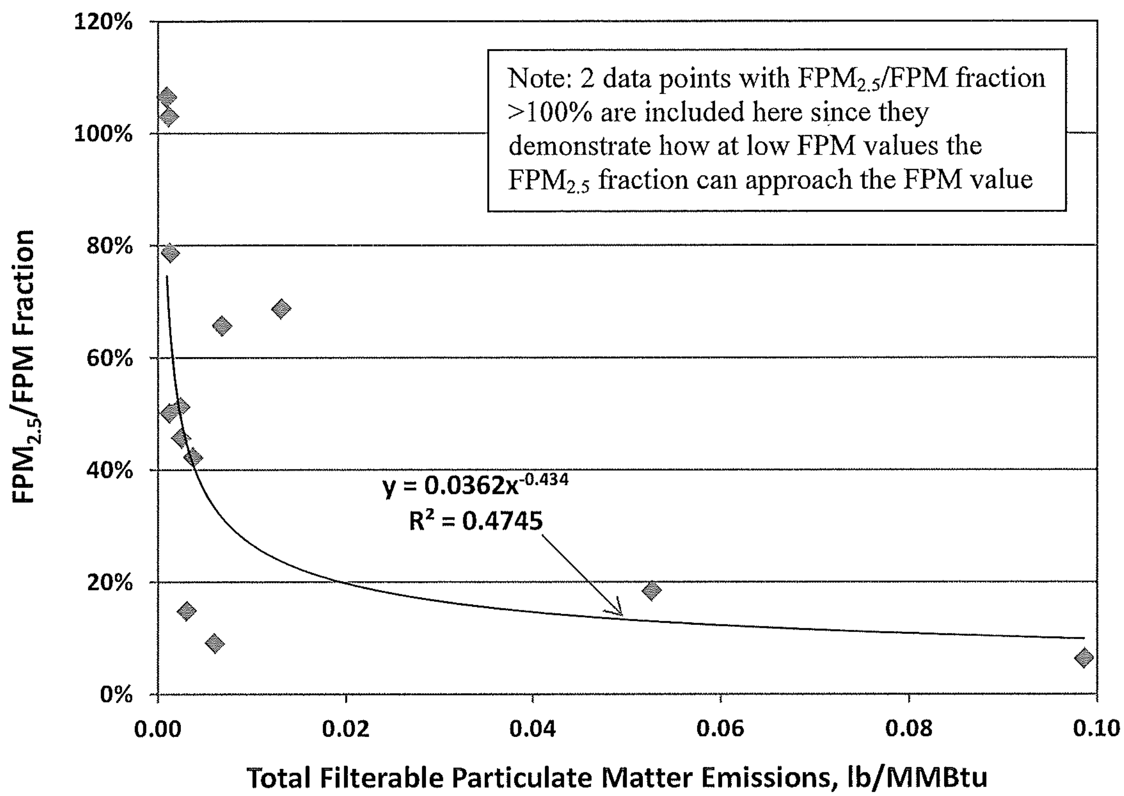

Figure 6.10 $PM_{2.5}$/FPM Fraction versus FPM for 13 Wood-Fired Boilers with ESPs

7.0 SUMMARY

A significant amount of emissions data for boilers burning mainly wood residues has been generated in the last four years as a result of mandatory and voluntary sampling efforts related to EPA's post-2007 Boiler MACT rulemaking activity. The testing conducted since July 2009 has focused on a few key compounds: formaldehyde, HCl, HF, 11 trace metals listed as hazardous air pollutants (including mercury), PCDD/Fs, total filterable particulate matter, and carbon monoxide. In several instances, measurements for methane, other trace metals, condensible PM, filterable $PM_{2.5}$, SO_2, NO_x, and

VOCs as C (Method 25A) were also made. NCASI obtained stack test and associated laboratory reports for almost all these tests, and then carried out a detailed QA/QC review to identify any errors and correct, if necessary, the reported results. The data from these tests were then combined, except for formaldehyde, HCl, HF, the 11 trace metals, PCDD/F, filterable $PM_{2.5}$, condensible PM (CPM), CO, SO_2, NO_x, and THCs/VOCs, with (1) quality assured data available in NCASI files pertaining to a few boilers operating in the wood products sector and (2) a significant amount of data retained from the previous NCASI compilation for wood-fired boilers [NCASI Technical Bulletin No. 973; NCASI (2010)]. This earlier NCASI report included a compilation of all test data contained in the background document for Section 1.6, Wood Residue Combustion in Boilers, in EPA's AP-42 publication in addition to some data available in NCASI files. The data retained from Technical Bulletin 973 mainly included those for organics and trace metals that were not routinely tested for during the recent Boiler MACT-related tests. Older data for formaldehyde, HCl, HF, the 11 trace metals, and PCDD/F were not used since much more, and likely better quality, data were available from the post-2008 testing efforts.

Most of the tests in this combined data set were conducted when wood fuels represented 100% of the heat input to the combustion unit. A few of the tests were conducted where natural gas was co-fired with the wood, but represented less than 10% of the total heat input, and where wastewater treatment plant residuals (from non-deinking mills) were co-fired with the wood, but represented less than 5% of the total heat input. Emissions from boilers co-firing these small amounts of natural gas or treatment plant residuals with wood residuals are expected to be essentially the same as those from units firing 100% wood residuals.

An elaborate statistical data treatment procedure was applied to the combined set of emissions data to obtain representative means, medians, standard deviations and upper prediction limits for the various air toxics, trace metals, criteria pollutants, PAHs, and PCDD/Fs for wood residue combustion in industrial boilers. As described in Technical Bulletin 973, this procedure used the Kaplan Meier and SDln subroutines to handle moderately censored (up to 80% non-detects) and heavily censored (over 80% non-detects) data sets, and also involved identifying statistical outliers and determining whether to accept or reject them based on graphical confirmation.

The emission statistics presented in this report are based on the best available test data for all the pollutants considered. The emission factors herein are believed to best characterize pollutant emissions from currently operating industrial wood-fired boilers and represent an improvement over those in Technical Bulletin 973. Furthermore, compared to Section 1.6 of EPA's AP-42 publication, the factors are more statistically sound and based on much more recent and comprehensive emission tests.

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APPENDIX A

DETAILED DATA FOR EACH BOILER TESTED

In this section, the average air toxic and criteria pollutant emissions for each boiler whose data are considered in this report are tabulated individually. First the recent emission test averages (typically three runs) for each boiler tested as a result of the impending Boiler MACT regulations are presented. These generally comprise testing conducted fairly recently, since about July of 2009, and include at least the four pollutants of current regulatory concern for biomass boilers, namely, HCl, Hg, CO, and FPM. Tests for PCDD/Fs and 10 trace metals listed as hazardous air pollutants were also conducted as part of the sampling effort at most locations. HCHO, other trace metals, and other criteria pollutants were also sampled at many sites.

Second, data generated for various wood products industry wood-fired boilers that were in NCASI files but were not included in the previous compilation presented in NCASI Technical Bulletin 973 (NCASI 2010) are included. Third, emission averages for air toxics and criteria pollutants are presented for each boiler where these data were retained from the previous two data compilations in NCASI Technical Bulletins 973 (NCASI 2010) and 884 (2004). These averages mainly included those for organics and trace metals that were generally not tested for during the recent Boiler MACT-related testing efforts.

When the data originated from test reports that have been submitted to EPA as part of the Boiler MACT rulemaking exercise (and therefore available in the public domain), the facility names are identified. Otherwise, boilers are identified only by Boiler Codes.

The detailed data for each boiler are provided separately so that if necessary one could locate a boiler/control device/fuel mix combination identical to the one operating at one's facility and then proceed to use that boiler's emissions instead of the averages across all boilers. Further, it is hoped that the detailed data presented in this manner would provide the reader a better picture of how certain emissions behave in conjunction with other emissions simultaneously tested for in a given wood-fired boiler.

Each detailed emissions table below also includes information on the description of the boiler (stoker, fluidized bed, Dutch oven, suspension burner, etc.), the average total heat input to the boiler during the tests in 10^6 Btu/hr, the PM control device (wet scrubber, ESP, fabric filter, just multiclone, etc.), the date of testing, and the relative amounts of the fuel mix (wood residues, wood residuals containing urea-formaldehyde resins, natural gas, wastewater treatment plant residuals).

1.0 ORGANIC/INORGANIC AIR TOXIC, TRACE METAL, CRITERIA POLLUTANT AND PCDD/F EMISSIONS FOR WOOD-FIRED BOILERS – NEW BOILER MACT AND B-M-RELATED DATA

Boralex Stratton Energy LP, Stratton, ME

Table A1 Boiler Code – EGU - BB1; Bark Boiler Burning 100% Wood-Bark

Description of Boiler, Heat Input, Control Device & Fuel Mix	Air Toxics				Criteria Pollutants	
	Non-metals	lb/MMBtu	Metals	lb/MMBtu	Pollutant	lb/MMBtu
Boiler #1, Stoker (431 MMBtu/hr); ESP; 10/09; Wood - 95%, Bark - 5%;	HCHO	2.10E-04	Antimony	3.69E-07	CO	3.42E-01
	HCl	4.04E-04	Arsenic	3.69E-07	NO_x	6.38E-02[2]
	HF	1.35E-04	Beryllium	9.22E-08	$PM_{2.5}$[1]	4.95E-03
			Cadmium	1.46E-07	SO_2	2.33E-04
			Chromium	3.04E-07	THC	3.51E-04
			Cobalt	9.70E-08		
	PCDD/F TEQs*	1.25E-03	Lead	3.91E-06		
	*WHO-TEF/2005		Manganese	0.00E+00		
			Mercury	5.07E-07		
			Nickel	4.72E-07		
			Selenium	9.22E-07		

[1]Total FPM (filterable particulate matter) was not measured for this boiler; thus a $PM_{2.5}$ to FPM ratio could not be estimated.
[2]This unit has a renerative SCR (RSCR) system for NO_x control, but is not required to operate it. The low NO_x emissions (0.0638 lb/MMBtu) are likely a result of the RSCR system in operation. The Title V NO_x limit for this boiler is 0.24 lb/10^6Btu (24 hr block average). The unit is permitted to burn up to 65% by weight C&D (24 hr limit) and up to 138,000 tpy of off-spec fiber from a nearby deinking mill. *Italicized entries denote NDs shown at detection levels.*

District Energy Cogeneration Facility, St. Paul, MN

Table A2 Boiler Code – EGU - BB2; Bark Boiler Burning Bark & 8% Gas

Description of Boiler, Heat Input, Control Device & Fuel Mix	Air Toxics				Criteria Pollutants	
	Non-metals	lb/MMBtu	Metals	lb/MMBtu	Pollutant	lb/MMBtu
#7 Boiler (EU007), Stoker (511 MMBtu/hr); ESP; 3/07; 92% bark, 8% gas	HCl	2.02E-04	Arsenic	9.35E-06		
			Beryllium	*3.20E-07*		
			Cadmium	4.73E-07		
			Chromium	5.82E-06		
			Lead	1.76E-05		
			Manganese	9.86E-05		
			Mercury	5.72E-07		
			Nickel	2.92E-06		
			Selenium	4.91E-06		

Italicized entries denote NDs shown at detection levels.

Domtar Paper, Bennettsville, SC

Table A3 Boiler Code – PM - BB1; Bark Boiler Burning Bark/Resin Wood & 2% Gas

Description of Boiler, Heat Input, Control Device & Fuel Mix	Air Toxics				Criteria Pollutants	
	Non-metals	lb/MMBtu	Metals	lb/MMBtu	Pollutant	lb/MMBtu
#7 Boiler (EU007), Stoker (299 MMBtu/hr); ESP; 7/09; 90% bark, 8% resin wood, 2% gas	HCHO	6.95E-05	Antimony	9.03E-08	CO	2.05E-01
	HCl	*6.49E-05*	Arsenic	1.67E-07	CPM[1,2]	4.65E-03
	HF	*6.65E-05*	Beryllium	*1.35E-08*	NO_x	2.88E-01
			Cadmium	1.01E-07	FPM	2.48E-03
			Chromium	1.13E-06	$PM_{2.5}$	1.13E-03
			Cobalt	7.99E-08	$PM_{2.5}$/FPM[2]	45.6%
			Lead	1.24E-06	Methane	*1.96E-04*
			Manganese	2.76E-06		
	PCDD/F TEQs*	1.13E-04	Mercury	9.60E-07		
	*WHO-TEF/2005		Nickel	1.67E-06		
			Selenium	1.38E-06		

FPM = filterable particulate matter. [1] CPM obtained using latest version of M202. [2]All 3 runs for $PM_{2.5}$ and CPM were <PQL and one of the 3 runs for $PM_{2.5}$ was also <DL; the $PM_{2.5}$/FPM ratio appears to be valid but conservative. *Italicized entries denote NDs shown at detection levels.*

Grays Harbor Paper, Hoquiam, WA

Table A4 Boiler Code – PM - BB2; Bark Boiler Burning 100% Wood/Bark

Description of Boiler, Heat Input, Control Device & Fuel Mix	Air Toxics				Criteria Pollutants	
	Non-metals	lb/MMBtu	Metals	lb/MMBtu	Pollutant	lb/MMBtu
#6 Boiler, Dutch Oven (123 MMBtu/hr); MC only[2]; 8/09; 100% wood/bark mix	HCHO	1.11E-05	Mercury	5.04E-06	CO	2.05E-01
	HCl	2.16E-02			CPM[1]	5.75E-03
	HF	*8.90E-04*			NO_x	2.88E-01
					FPM	1.83E-01
	PCDD/F TEQs*	1.88E-02			SO_2	4.42E-02
	*WHO-TEF/2005				THC	5.69E-04

FPM = filterable particulate matter. [1] CPM obtained using latest version of M202. [2] After the multiclones, about 20% of flue gas from this boiler goes through a high efficiency wet scrubber; however, the results shown here are for the gases that were only treated by the MC. Significant reductions in FPM, Hg and PCDD/F emissions were achieved past the high efficiency wet scrubber, indicating that high fraction of Hg and PCDD/Fs exiting the MC existed in the PM phase. *Italicized entries denote NDs shown at detection levels.*

Green Bay Packaging, Morrilton, AR

Table A5 Boiler Code – PM - BB3; Bark Boiler Burning 100% Bark

Description of Boiler, Heat Input, Control Device & Fuel Mix	Air Toxics				Criteria Pollutants	
	Non-metals	lb/MMBtu	Metals	lb/MMBtu	Pollutant	lb/MMBtu
#3 Wood Waste Boiler (SN-04) (Stoker) (372 MMBtu/hr); Wet Scrubber; 10/09; 100% bark	HCHO	2.79E-04	Antimony	9.43E-07	CO	5.27E-01
	HCl	1.39E-03	Arsenic	1.40E-05	CPM[1]	3.93E-03
	HF	4.23E-05	Beryllium	5.89E-08	NO_x	3.22E-01
			Cadmium	3.09E-06	FPM	1.98E-02
			Chromium	1.09E-05	SO_2	1.19E-03
			Cobalt	5.60E-07	THC	1.89E-03
			Lead	2.48E-05		
			Manganese	7.90E-05		
	PCDD/F TEQs*	8.28E-03	Mercury	1.30E-06		
	*WHO-TEF/2005		Nickel	3.67E-06		
			Selenium	6.31E-07		

FPM = filterable particulate matter. [1] CPM obtained using latest version of M202. *Italicized entries denote NDs shown at detection levels.*

Temple-Inland, Rome, GA

Table A6 Boiler Code – PM - BB4; Bark Boiler Burning 100% Bark

Description of Boiler, Heat Input, Control Device & Fuel Mix	Air Toxics				Criteria Pollutants	
	Non-metals	lb/MMBtu	Metals	lb/MMBtu	Pollutant	lb/MMBtu
#Wood Fired Boiler (WF) (FBC) (672 MMBtu/hr); ESP; 7/09; 100% bark	HCHO	*6.04E-06*	Antimony	2.91E-07	CO	8.05E-02
	HCl	1.85E-03	Arsenic	1.79E-06	CPM[1,2]	1.91E-03
	HF	6.13E-05	Beryllium	*4.73E-08*	NO_x	2.27E-01
			Cadmium	1.07E-07	FPM	1.31E-03
			Chromium	1.54E-06	$FPM_{2.5}$	1.03E-03
			Cobalt	1.40E-06	$PM_{2.5}$/FPM[2]	78.7%
			Lead	2.60E-06	SO_2	2.01E-02
	PCDD/F TEQs*	8.80E-03	Manganese	7.29E-05	THC	4.40E-03
	*WHO-TEF/2005		Mercury	7.33E-08	Methane	1.13E-03
			Nickel	1.13E-06		
			Selenium	*4.73E-07*		

FPM = filterable particulate matter. [1] CPM obtained using latest version of M202. [2]All 3 runs for $PM_{2.5}$, FPM and CPM were ADL. *Italicized entries denote NDs shown at detection levels.*

Table A7 Boiler Code – PM - BB5; Bark Boiler Burning 100% Bark

Description of Boiler, Heat Input, Control Device & Fuel Mix	Air Toxics				Criteria Pollutants	
	Non-metals	lb/MMBtu	Metals	lb/MMBtu	Pollutant	lb/MMBtu
No. 3 Power Boiler (Stoker) (498 MMBtu/hr); ESP; 6/10; 100% bark	HCl	2.33E-04	Mercury	7.99E-07	CO	1.91E+00
	PCDD/F TEQs*	6.18E-03			FPM	8.43E-04
	*WHO-TEF/2005					

FPM = filterable particulate matter. *Italicized entries denote NDs shown at detection levels.*

Table A8 Boiler Code – PM - BB6; Bark Boiler Burning Bark & 6% Gas

Description of Boiler, Heat Input, Control Device & Fuel Mix	Air Toxics				Criteria Pollutants	
	Non-metals	lb/MMBtu	Metals	lb/MMBtu	Pollutant	lb/MMBtu
No. 3 Power Boiler (Stoker) (154 MMBtu/hr); ESP; 8/10; 94% bark, 6% gas	HCl	3.11E-02	Antimony	7.54E-08	CO	2.46E-02
			Arsenic	2.25E-07	FPM	4.04E-04
			Beryllium	*6.84E-09*	SO_2	6.62E-02
			Cadmium	2.98E-07		
			Chromium	6.35E-07		
	PCDD/F TEQs*	1.64E-02	Cobalt	2.46E-08		
	*WHO-TEF/2005		Lead	3.37E-07		
			Manganese	4.92E-06		
			Mercury	3.48E-06		
			Nickel	1.09E-06		
			Selenium	3.80E-07		

FPM = filterable particulate matter. *Italicized entries denote NDs shown at detection levels.*

Comments

This boiler also burns purchased C&D wood. It is not clear whether C&D wood was burned during the 8/10 testing, but the higher than normal HCl and Hg emissions measured may be indicative of higher Cl and Hg in the wood fired.

Table A9 Boiler Code – PM - BB7a; Bark Boiler Burning 100% Bark

Description of Boiler, Heat Input, Control Device & Fuel Mix	Air Toxics				Criteria Pollutants	
	Non-metals	lb/MMBtu	Metals	lb/MMBtu	Pollutant	lb/MMBtu
SN-WB1 Wood Boiler (Stoker) (191.5 MMBtu/hr); Wet Scrubber; 7/03; 100% bark	HCl	8.66E-05	Arsenic	1.89E-06	FPM	1.49E-01
			Beryllium	*5.20E-08*		
			Cadmium	2.67E-06		
			Chromium	9.14E-06		
			Lead	2.69E-05		
			Manganese	2.78E-04		
			Mercury	7.21E-07		
			Nickel	2.66E-06		
			Selenium	2.49E-07		

FPM = filterable particulate matter. *Italicized entries denote NDs shown at detection levels.*

Table A10 Boiler Code – PM - BB7b; Bark Boiler Burning Bark & 3% Gas

Description of Boiler, Heat Input, Control Device & Fuel Mix	Air Toxics				Criteria Pollutants	
	Non-metals	lb/MMBtu	Metals	lb/MMBtu	Pollutant	lb/MMBtu
9A Boiler (Stoker) (414 MMBtu/hr); Wet Scrubber; 10/10; 97% Wood/bark, 3% Gas	HCl	1.11E-04	Mercury	5.52E-07	CO	2.88E-01
	PCDD/F TEQs*	8.74E-04				
	*WHO-TEF/2005					

Comments

Tests conducted in December 2010 on this boiler with significant amounts of TDF (tire-derived fuel) and gas yielded FPM emissions of around 0.081 lb/MMBtu.

Table A11 Boiler Code – PM - BB7c; Bark Boiler Burning Wood/Bark & <1% Gas

Description of Boiler, Heat Input, Control Device & Fuel Mix	Air Toxics				Criteria Pollutants	
	Non-metals	lb/MMBtu	Metals	lb/MMBtu	Pollutant	lb/MMBtu
10A Boiler (Stoker) (611 MMBtu/hr); Wet Scrubber; 8/10; 99.5% wood/bark, 0.5% Gas	HCl	2.11E-04	Mercury	1.83E-07		
	PCDD/F TEQs*	8.27E-03				
	*WHO-TEF/2005					

Comments

Tests conducted in May 2010 on this boiler with significant amounts of TDF and gas yielded CO and FPM emissions of around 0.1 and 0.08 lb/MMBtu.

Rayonier, Fernandina Beach, FL

Table A12 Boiler Code – PM - BB8; Bark Boiler Burning Bark & Some Sludge

Description of Boiler, Heat Input, Control Device & Fuel Mix	Air Toxics				Criteria Pollutants	
	Non-metals	lb/MMBtu	Metals	lb/MMBtu	Pollutant	lb/MMBtu
BFB (PB06) (454 MMBtu /hr); ESP; 10/08; Bark & Sludge (% unknown)	HCl	1.26E-02	Arsenic	1.37E-06	FPM	9.71E-02
			Beryllium	*2.61E-07*		
			Cadmium	6.22E-07		
			Chromium	3.58E-06		
			Lead	2.89E-05		
	PCDD/F TEQs*	5.11E-03	Manganese	5.69E-05		
	*WHO-TEF/2005		Mercury	4.48E-07		
			Nickel	3.57E-06		
			Selenium	*2.61E-06*		

FPM = filterable particulate matter. *Italicized entries denote NDs shown at detection levels.*

Comments

The high FPM emissions from this ESP-equipped BFB unit are unexpected. The amount of sludge co-fired with the bark during the 10/08 tests was unknown. High levels of sludge firing could result in higher PM emissions.

Bowater Newsprint, Grenada, MS

Table A13 Boiler Code – PM - BB9; Bark Boiler Burning 97% Wood Bark, 3% Sludge

Description of Boiler, Heat Input, Control Device & Fuel Mix	Air Toxics				Criteria Pollutants	
	Non-metals	lb/MMBtu	Metals	lb/MMBtu	Pollutant	lb/MMBtu
Bark Boiler (Stoker) (239 MMBtu/hr); Wet Scrubber; 2/97; 97% Wood/Bark, 3% Sludge	HCl	3.27E-04	Arsenic	3.66E-06	CO	2.96E-01
	HF	8.50E-06	Beryllium	*9.48E-08*	NO_x	2.40E-01
			Cadmium	3.21E-06	FPM	2.59E-02
			Chromium	2.63E-06	SO_2	9.96E-04
			Lead	2.17E-05	THC	2.60E-03
			Manganese	6.86E-05		
			Mercury	6.53E-07		
			Nickel	5.55E-06		
			Selenium	3.94E-06		

FPM = filterable particulate matter. *Italicized entries denote NDs shown at detection levels.*

Boise White Paper, Jackson, AL

Table A14 Boiler Code – PM - BB10; Bark Boiler Burning 100% Wood Bark

Description of Boiler, Heat Input, Control Device & Fuel Mix	Air Toxics				Criteria Pollutants	
	Non-metals	lb/MMBtu	Metals	lb/MMBtu	Pollutant	lb/MMBtu
Combination Boiler, 102-0001-Z013 (Stoker) (319 MMBtu/hr); Wet Scrubber; 8/09; 100% Wood/Bark	HCl	*3.35E-04*	Antimony	1.47E-06	CO	2.15E-01
	HF	*0.00E+00*	Arsenic	1.97E-06	CPM[1]	3.65E-02
			Beryllium	3.40E-08	NO_x	2.01E-01
			Cadmium	6.07E-06	FPM	1.41E-01
			Chromium	1.50E-05	SO_2	4.87E-03
			Cobalt	4.69E-06	THC	2.72E-03
			Lead	3.49E-05	Methane	2.17E-03
	PCDD/F TEQs*	6.02E-03	Manganese	2.42E-04		
	*WHO-TEF/2005		Mercury	6.34E-07		
			Nickel	9.45E-06		
			Selenium	1.03E-06		

FPM = filterable particulate matter. [1] CPM obtained using latest version of M202. *Italicized entries denote NDs shown at detection levels.*

Rayonier, Jesup, GA

Table A15 Boiler Code – PM - BB11; Bark Boiler Burning 100% Wood Bark

Description of Boiler, Heat Input, Control Device & Fuel Mix	Air Toxics				Criteria Pollutants	
	Non-metals	lb/MMBtu	Metals	lb/MMBtu	Pollutant	lb/MMBtu
Power Boiler #1, PB01 (Stoker) (158 MMBtu/hr); Wet Scrubber; 5/07; 100% Wood/Bark	HCl	7.13E-04	Mercury	1.97E-06		

FPM = filterable particulate matter.

Comments

One set of tests conducted on this boiler for FPM in May of 2004 with 9 to13% oil (rest bark) yielded FPM emissions of about 0.15 lb/MMBtu.

Table A16 Boiler Code – PM - BB12; Bark Boiler Burning Wood/Bark & < 7% Gas

Description of Boiler, Heat Input, Control Device & Fuel Mix	Air Toxics				Criteria Pollutants	
	Non-metals	lb/MMBtu	Metals	lb/MMBtu	Pollutant	lb/MMBtu
Combination Boiler (UT-3) (Stoker) (690 MMBtu /hr); ESP; 8/10; 93.6% Wood/Bark,	HCl	1.07E-04	Mercury	8.62E-07	CO	9.30E-01
	PCDD/F TEQs*	1.65E-05			FPM	4.17E-03
	*WHO-TEF/2005				THC	3.26E-02

FPM = filterable particulate matter.

Table A17 Boiler Code – PM - BB13; Bark Boiler Burning Wood/Bark & <1% Gas

Description of Boiler, Heat Input, Control Device & Fuel Mix	Air Toxics				Criteria Pollutants	
	Non-metals	lb/MMBtu	Metals	lb/MMBtu	Pollutant	lb/MMBtu
Power Boiler (AA-015) (Stoker) (614 MMBtu/hr); ESP; 9/10; 99.3% Wood/Bark, 0.7% gas	HCl	8.89E-04	Mercury	5.43E-07	CO	3.17E-01
	HF	*8.11E-05*			FPM	2.32E-03
	PCDD/F TEQs*	9.56E-04			NO_x	1.71E-01
	*WHO-TEF/2005				SO_2	*4.76E-03*

FPM = filterable particulate matter. *Italicized entries denote NDs shown at detection levels.*

Table A18 Boiler Code – PM - BB14a; Bark Boiler Burning Wood/Bark

Description of Boiler, Heat Input, Control Device & Fuel Mix	Air Toxics				Criteria Pollutants	
	Non-metals	lb/MMBtu	Metals	lb/MMBtu	Pollutant	lb/MMBtu
No. 1 Power Boiler (Stoker) (532 MMBtu/hr); Scrubber (Venturi); 9/10; 100% Bark	HCl	1.72E-05	Mercury	8.26E-07	CO	7.53E-01
	PCDD/F TEQs*	3.84E-02			FPM	9.34E-02
	*WHO-TEF/2005					

FPM = filterable particulate matter. *Italicized entries denote NDs shown at detection levels.*

Table A19 Boiler Code – PM - BB14b; Bark Boiler Burning 100% Wood/Bark

Description of Boiler, Heat Input, Control Device & Fuel Mix	Air Toxics				Criteria Pollutants	
	Non-metals	lb/MMBtu	Metals	lb/MMBtu	Pollutant	lb/MMBtu
No. 2 Power Boiler (Stoker) (212 MMBtu/hr); ESP; 9/10; 100% Bark	HCl	4.00E-05	Mercury	2.03E-07	CO	7.44E-02
	PCDD/F TEQs*	8.99E-03			FPM	5.93E-03
	*WHO-TEF/2005					

FPM = filterable particulate matter.

Temple-Inland, Waverly (New Johnsonville), TN

Table A20 Boiler Code – PM - BB15; Bark Boiler Burning 100% Wood/Bark

Description of Boiler, Heat Input, Control Device & Fuel Mix	Air Toxics				Criteria Pollutants	
	Non-metals	lb/MMBtu	Metals	lb/MMBtu	Pollutant	lb/MMBtu
Wood Refuse Boiler (Stoker) (397 MMBtu/hr); Venturi Scrubber; 7/09; 100% Wood/Bark	HCl	1.63E-04	Antimony	3.59E-06	CPM[1]	3.03E-03
	HF	*1.55E-04*	Arsenic	2.67E-05	FPM	7.60E-02
			Beryllium	*1.08E-07*		
			Cadmium	3.86E-06		
			Chromium	1.44E-05		
			Cobalt	6.11E-07		
	PCDD/F TEQs*	9.23E-03	Lead	9.78E-05		
	*WHO-TEF/2005		Manganese	7.08E-05		
			Mercury	8.48E-07		
			Nickel	1.10E-05		
			Selenium	1.32E-06		

FPM = filterable particulate matter. [1] CPM obtained using latest version of M202. *Italicized entries denote NDs shown at detection levels.*

Resolute Forest Products, Calhoun, TN

Table A21 Boiler Code – PM - BB16; Bark Boiler Burning 100% Wood/Bark

Description of Boiler, Heat Input, Control Device & Fuel Mix	Air Toxics				Criteria Pollutants	
	Non-metals	lb/MMBtu	Metals	lb/MMBtu	Pollutant	lb/MMBtu
Bubbling Fluidized Bed Boiler (659 MMBtu/hr); ESP; 8/09; 100% Wood/Bark	HCl	1.83E-04	Antimony	9.20E-07	CPM[1,2]	9.42E-03
	HF	7.47E-05	Arsenic	3.34E-06	FPM	5.27E-02
			Beryllium	*2.20E-07*	$PM_{2.5}$	9.70E-03
			Cadmium	5.44E-07	$PM_{2.5}$/FPM[2]	18.4%
			Chromium	4.93E-06		
			Cobalt	2.63E-06		
			Lead	8.51E-06		
			Manganese	5.52E-04		
			Mercury	1.03E-06		
			Nickel	6.66E-06		
			Selenium	2.41E-06		

FPM = filterable particulate matter. [1] CPM obtained using latest version of M202. [2]FPM, $PM_{2.5}$, CPM were all ADL; thus, both CPM and the $PM_{2.5}$/FPM fraction are valid. *Italicized entries denote NDs shown at detection levels.*

Clearwater Paper Corporation, Lewiston, ID

Table A22 Boiler Code – PM - BB17; Bark Boiler Burning Wood/Bark & 3% Gas

Description of Boiler, Heat Input, Control Device & Fuel Mix	Air Toxics				Criteria Pollutants	
	Non-metals	lb/MMBtu	Metals	lb/MMBtu	Pollutant	lb/MMBtu
Power Boiler #4 (Emission Point 781) (Stoker) (711MMBtu/hr); ESP; 11/09; 97% Wood/Bark; 3% Gas; additional metals testing 8/06 - 93% bark, 7% gas;	HCHO	4.67E-03	Antimony	9.79E-08	CO	4.39E+00
	HCl	3.79E-05	Arsenic	7.06E-07	CPM[1,2]	3.57E-02
	HF	3.83E-05	Beryllium	6.28E-09	NO_x	1.78E-01
			Cadmium	4.29E-07	FPM	3.07E-03
			Chromium	2.54E-06	$PM_{2.5}$	4.56E-04
			Cobalt	1.01E-07	$PM_{2.5}$/FPM[2]	14.8%
			Lead	2.96E-06	SO_2	3.68E-02
			Manganese	1.24E-05	THC	5.95E-01
			Mercury	3.15E-07		
			Nickel	2.13E-06		
			Selenium	1.57E-06		

FPM = filterable particulate matter. [1] CPM obtained using latest version of M202. [2]All 3 runs for $PM_{2.5}$ were <PQL and 2 of 3 runs were <DL. FPM and CPM were ADL.

Domtar, Kingsport, TN

Table A23 Boiler Code – PM - BB18; Bark Boiler Burning Wood/Bark & <1% Sludge

Description of Boiler, Heat Input, Control Device & Fuel Mix	Air Toxics				Criteria Pollutants	
	Non-metals	lb/MMBtu	Metals	lb/MMBtu	Pollutant	lb/MMBtu
Hog Fuel Boiler (HFB1-1) (FBC) (487 MMBtu /hr); ESP; 11/09; 99.3% Wood/Bark; 0.7% Sludge	HCHO	5.66E-05	Antimony	1.15E-06	CO	6.51E-02
	HCl	3.11E-03	Arsenic	6.90E-06	CPM[1,2]	1.17E-02
	HF	1.80E-04	Beryllium	1.71E-07	NO_x	1.40E-01
			Cadmium	5.27E-07	FPM	9.86E-02
			Chromium	9.40E-06	PM_{10}[3]	1.87E-02
			Cobalt	2.07E-06	$FPM_{2.5}$	6.28E-03
			Lead	1.52E-05	$PM_{2.5}$/FPM[2]	6.4%
			Manganese	5.24E-04	PM_{10}/FPM[2]	19.0%
			Mercury	8.24E-07	SO_2	1.53E-02
			Nickel	6.38E-06	THC	1.53E-03
			Phosphorus	6.01E-04	Methane	1.03E-03
			Selenium	*1.11E-06*		

FPM = filterable particulate matter. [1] CPM obtained using latest version of M202. [2]FPM, $PM_{2.5}$, PM_{10}, CPM were all ADL; however, 2 of 3 runs for CPM were <PQL. [3]PM_{10} was not co-sampled with FPM on this unit. *Italicized entries denote NDs shown at detection levels.*

Comments

The FPM emissions measured were erratic, with Runs 1, 2 and 3 registering 0.226, 0.056, and 0.014 lb/MMBtu. All three runs had comments in the lab reports about "loose particulate material in filter container." However, no reason could be found to explain the high emissions during Run 1.

Table A24 Boiler Code – PM - BB19; Bark Boiler Burning 100% Wood/Bark

Description of Boiler, Heat Input, Control Device & Fuel Mix	Air Toxics				Criteria Pollutants	
	Non-metals	lb/MMBtu	Metals	lb/MMBtu	Pollutant	lb/MMBtu
Power Boiler 5 (Stoker) (282 MMBtu/hr); ESP; Metals except Hg - 5/07; Rest - 7/10; 100% Wood/Bark;			Arsenic	3.59E-06	CO	4.41E-01
			Beryllium	6.01E-08	FPM	1.29E-02
			Cadmium	3.78E-07	NO_x	2.45E-01
			Chromium	7.12E-06	SO_2	9.59E-04
			Lead	6.94E-06		
	PCDD/F TEQs*	1.82E-03	Manganese	1.14E-04		
	*WHO-TEF/2005		Mercury	6.97E-07		
			Nickel	3.47E-06		
			Selenium	7.12E-06		

FPM = filterable particulate matter.

International Paper, Augusta, GA

Table A25 Boiler Code – PM - BB20; Bark Boiler Burning Wood/Bark & 4% Gas

Description of Boiler, Heat Input, Control Device & Fuel Mix	Air Toxics				Criteria Pollutants	
	Non-metals	lb/MMBtu	Metals	lb/MMBtu	Pollutant	lb/MMBtu
#3 Power Boiler (Stoker) (466 MMBtu/hr); ESP; 8/07; 96.1% Wood/Bark; 3.9% Gas			Arsenic	3.12E-06	FPM	2.64E-02
			Beryllium	*3.78E-07*		
			Cadmium	4.17E-07		
			Chromium	3.37E-06		
			Lead	8.69E-06		
			Manganese	1.42E-04		
			Mercury	1.23E-06		
			Nickel	1.41E-06		
			Selenium	3.29E-06		

FPM = filterable particulate matter. *Italicized entries denote NDs shown at detection levels.*

International Paper, Cantonment, FL

Table A26 Boiler Code – PM - BB21; Bark Boiler Burning 100% Wood/Bark

Description of Boiler, Heat Input, Control Device & Fuel Mix	Air Toxics				Criteria Pollutants	
	Non-metals	lb/MMBtu	Metals	lb/MMBtu	Pollutant	lb/MMBtu
Power Boiler 4, EU ID 37 (Stoker) (475 MMBtu/hr); Wet Scrubber; 3/05; 100% Wood/Bark			Arsenic	2.07E-05	FPM	1.33E-01
			Beryllium	2.90E-08		
			Cadmium	1.53E-06		
			Chromium	5.44E-06		
			Lead	3.57E-05		
			Manganese	1.27E-04		
			Nickel	2.33E-06		
			Selenium	2.85E-06		

FPM = filterable particulate matter.

NewPage, Wickliffe, KY

Table A27 Boiler Code – PM - BB22; Bark Boiler Burning 100% Wood/Bark

Description of Boiler, Heat Input, Control Device & Fuel Mix	Air Toxics				Criteria Pollutants	
	Non-metals	lb/MMBtu	Metals	lb/MMBtu	Pollutant	lb/MMBtu
Bark Boiler (B09) (Stoker) (343 MMBtu/hr); ESP; 9/05; 100% Wood/Bark			Arsenic	*8.02E-07*	CO	2.69E-01
			Beryllium	*2.01E-07*	FPM	8.55E-03
			Cadmium	4.95E-07	NO_x	2.13E-01
			Chromium	6.34E-07	SO_2	1.29E-03
			Lead	1.99E-06	THC	4.03E-03
	PCDD/F TEQs*	2.13E-03	Manganese	3.17E-05		
	*WHO-TEF/2005		Mercury	5.89E-07		
			Nickel	2.79E-06		
			Selenium	*2.01E-06*		

FPM = filterable particulate matter. *Italicized entries denote NDs shown at detection levels.*

Table A28 Boiler Code – PM - BB23a; Bark Boiler Burning 100% Wood/Bark

Description of Boiler, Heat Input, Control Device & Fuel Mix	Air Toxics				Criteria Pollutants	
	Non-metals	lb/MMBtu	Metals	lb/MMBtu	Pollutant	lb/MMBtu
10C Hogged Fuel Boiler (Stoker) (542 MMBtu/hr); Wet Scrubber; 4/11; 100% Wood/Bark			Cadmium	3.47E-06	CO	7.22E-01
			Lead	1.33E-05	FPM	3.54E-02
			Mercury	8.94E-07	NO_x	1.89E-01
					SO_2	7.90E-04

FPM = filterable particulate matter.

Table A29 Boiler Code – PM - BB23b; Bark Boiler Burning 100% Wood/Bark

Description of Boiler, Heat Input, Control Device & Fuel Mix	Air Toxics				Criteria Pollutants	
	Non-metals	lb/MMBtu	Metals	lb/MMBtu	Pollutant	lb/MMBtu
No. 12 Hogged Fuel Boiler (Stoker) (916 MMBtu/hr); Wet Scrubber; 4/11; 100% Wood/Bark			Cadmium	1.55E-06	CO	4.76E-01
			Lead	2.50E-05	FPM	3.53E-02
			Mercury	7.62E-07	NO_x	2.27E-01
					SO_2	1.10E-03

FPM = filterable particulate matter.

Georgia Pacific, Brunswick, GA

Table A30 Boiler Code – PM - BB24; Bark Boiler Burning Bark & < 4% Gas/Oil

Description of Boiler, Heat Input, Control Device & Fuel Mix	Air Toxics				Criteria Pollutants	
	Non-metals	lb/MMBtu	Metals	lb/MMBtu	Pollutant	lb/MMBtu
No. 4 Power Boiler (U700) (Stoker) (473 MMBtu/hr); ESP; 8/09; 96.3% Wood/Bark; 2.7% gas; 1.0% oil			Antimony	*3.14E-07*	CPM[1,2]	1.02E-02
			Arsenic	*3.14E-07*	FPM	6.07E-03
			Beryllium	*1.30E-07*	$PM_{2.5}$	5.51E-04
			Cadmium	1.76E-07	$PM_{2.5}$/FPM	9.1%
			Chromium	9.03E-07		
			Cobalt	8.70E-08		
			Lead	1.03E-06		
			Manganese	7.13E-06		
			Mercury	7.73E-07		
			Nickel	1.75E-06		
			Selenium	2.43E-06		

FPM = filterable particulate matter. [1] CPM obtained using latest version of M202. [2]All 3 runs for $PM_{2.5}$ were <PQL and 2 of 3 runs were <DL; thus the $PM_{2.5}$/FPM fraction is valid but conservative. *Italicized entries denote NDs shown at detection levels.*

Kimberly-Clark Corporation, Everett, WA

Table A31 Boiler Code – PM - BB25; Bark Boiler Burning Bark & 5% Gas

Description of Boiler, Heat Input, Control Device & Fuel Mix	Air Toxics				Criteria Pollutants	
	Non-metals	lb/MMBtu	Metals	lb/MMBtu	Pollutant	lb/MMBtu
No. 14 Cogeneration Boiler (Stoker) (601 MMBtu/hr); FF; 8/09; 95.2% hog fuel; 4.8% gas	HCl	3.91E-02	Antimony	3.75E-07	CPM[1]	2.89E-03
	HF	2.19E-04	Arsenic	7.63E-06	FPM	9.38E-04
			Beryllium	4.77E-09	$FPM_{2.5}$	9.99E-04
			Cadmium	1.37E-07	$PM_{2.5}$/FPM[2]	106.4%
			Chromium	1.11E-06		
			Cobalt	4.77E-08		
			Lead	7.54E-06		
			Manganese	4.07E-06		
			Mercury	3.73E-06		
			Nickel	1.50E-06		
			Selenium	9.75E-07		

FPM = filterable particulate matter. [1] CPM obtained using latest version of M202. [2] 2 of 3 runs for $PM_{2.5}$ and all 3 runs for FPM and CPM were ADL. All 3 runs for $PM_{2.5}$ and CPM were <PQLs and 2 of 3 runs for FPM were < PQL. The $PM_{2.5}$/FPM fraction is invalid as $PM_{2.5}$ exceeds FPM. CO, HCHO, NO_x, SO_2 and THC emissions were only measured with significant gas firing (>10%) with bark in this boiler.

Comments

The results shown here represent one of three runs conducted on this boiler when <5% gas was fired along with the hog fuel. The other two runs had natural gas burn rates of 12% and 41%.

HCl emissions for this boiler that is equipped with a fabric filter exceed the current 12/11 proposed BM limit of 0.022 lb/MMBtu. This is a coastal mill and could have some of the hog fuel derived from salt-laden logs, although this could not be confirmed from the test reports. Polishing with trona or sodium carbonate injection could be used to bring the HCl emissions below the 12/11 limit.

Three tests for CO with about 20% gas, rest bark, in this boiler during the same time as the other tests (August 2009) yielded an average of only 0.031 lb/MMBtu, suggesting that CO can be easily controlled with gas in this boiler.

The measured emissions for Hg were higher than would be expected with most inland wood residues. All five fractions of the M29 train were above the detection limit for this run, so the high emissions could not be ascribed to method detection limit issues.

Plum Creek, Columbia Falls, WA

Table A32 Boiler Code – WPM - BB18; Bark Boiler Burning 100% Bark[1]

Description of Boiler, Heat Input, Control Device & Fuel Mix	Air Toxics				Criteria Pollutants	
	Non-metals	lb/MMBtu	Metals	lb/MMBtu	Pollutant	lb/MMBtu
Hog fuel boiler (Stoker) (14.0 MMBtu/hr); Wet Scrubber in 6/89 for FPM, PM10, CPM tests; WESP for 10/09 tests for other pollutants; 100% Bark	HCHO	7.03E-02	Antimony	3.17E-07	CO	9.55E-01
	HCl	*1.52E-04*	Arsenic	2.11E-07	NO_x	1.19E-01
	HF	*2.00E-04*	Beryllium	*7.58E-08*	SO_2	6.08E-02
			Cadmium	1.35E-06	FPM	2.20E-01
			Chromium	1.96E-06	PM_{10}	1.76E-01
			Cobalt	3.02E-05	PM_{10}/FPM	80.0%
			Lead	9.35E-06	PM+CPM	2.41E-01
			Manganese	1.38E-05	PM_{10}+CPM	1.97E-01
	PCDD/F TEQs*	9.96E-04	Mercury	6.62E-06	THC	2.28E-01
	*WHO-TEF/2005		Nickel	5.67E-06	Methane	1.07E-02
			Selenium	*3.03E-07*		

FPM = filterable particulate matter. [1]This unit sends its flue gas to a veneer dryer, and the emissions during the 10/09 tests were measured after the veneer dryer. NCASI suggested to the mill that they ask EPA to delete the data from the Boiler MACT database since the emissions included veneer dryer exhaust. The data are therefore not included in the preparation of the summary tables for 100% wood-fired boilers. *Italicized entries denote NDs shown at detection levels.* FPM, PM_{10}, CPM tested for separately in 1989. PM_{10} tests for this wet scrubber equipped unit may be invalid since no test method has yet been developed for measuing PM_{10} or $PM_{2.5}$ in wet sources.

Comments

The current proposed (12/11) Boiler MACT limits may not apply to this boiler as the flue gas from this boiler passes through a veneer dryer.

The average mercury emissions measured (6.62E-06 lb/MMBtu) far exceed the proposed 12/11 BM limit for solid fuel boilers (3.1E-06 lb/MMBtu). It is not clear how the veneer dryer could have influenced these emissions. The three test runs for Hg yielded results of 1.36E-05, 3.53E-06 and 2.71E-06 lb/MMBtu, respectively, suggesting the emissions for Run 1 were unusually high and perhaps suspect. CO emissions for this wet scrubber equipped stoker unit were well above the proposed BM limits, suggesting boiler optimization enhancement may be in order. FPM measurements with the WESP PM control unit were unavailable.

Temple-Inland, Diboll, TX

Table A33 Boiler Code – WPM - BB19; Bark Boiler Burning 100% Resin Wood

Description of Boiler, Heat Input, Control Device & Fuel Mix	Air Toxics				Criteria Pollutants	
	Non-metals	lb/MMBtu	Metals	lb/MMBtu	Pollutant	lb/MMBtu
EPN PB-44 (Suspension Burner) (25.7 MMBtu/hr); ESP, 10/09 tests for HCHO; 6/09 & 6/11 tests for Cd, Pb, Hg, NO_x, SO_2, and FPM; rest - 6/07; 100% Resin Wood	HCHO	*1.34E-04*	Arsenic	7.85E-07	CO	5.42E-02
	HCl	*2.61E-05*	Beryllium	3.93E-08	CPM[3]	1.06E-02
			Cadmium	4.35E-07	NO_x[1]	9.71E-02
			Chromium	7.85E-07	NO_x[2]	1.14E+00
			Lead	8.61E-07	FPM	7.19E-03
			Manganese	1.99E-04	SO_2	1.23E-03
			Mercury	4.11E-07	THC	3.54E-03
			Nickel	1.40E-06		
			Selenium	1.57E-07		

FPM = filterable particulate matter. [1]Two sets of NO_x emissions are reported; the low NO_x emissions of 0.097 lb/MMBtu are most likely from 100% gas firing (baseline), although this could not be confirmed. [2]The higher NO_x emissions from the second set are consistent with the firing of high N content UF resin wood residuals in this boiler. [3] CPM obtained using older version of M202. *Italicized entries denote NDs shown at detection levels.*

Weyerhaueser, Dierks, AR

Table A34 Boiler Code – WPM - BB20; Bark Boiler Burning Wood

Description of Boiler, Heat Input, Control Device & Fuel Mix	Air Toxics				Criteria Pollutants	
	Non-metals	lb/MMBtu	Metals	lb/MMBtu	Pollutant	lb/MMBtu
Boiler #7 , SN-45 (Fuel Cell) (210 MMBtu /hr); ESP, 7/09; 100% Wood	HCHO	2.21E-04	Antimony	1.29E-07	CO	1.16E-01
	HCl	9.96E-04	Arsenic	1.29E-07	CPM[1,2]	1.07E-02
	HF	1.79E-04	Beryllium	*8.44E-09*	FPM	3.76E-03
			Cadmium	7.45E-08	$PM_{2.5}$	1.59E-03
			Chromium	1.01E-07	$PM_{2.5}$/FPM[2]	42.3%
			Cobalt	1.99E-07	NO_x	1.23E-01
			Lead	3.59E-08	SO_2	6.05E-03
			Manganese	4.57E-07	THC	4.25E-03
	PCDD/F TEQs*	1.82E-02	Mercury	6.26E-07	Methane	3.37E-03
	*WHO-TEF/2005		Nickel	1.93E-07		
			Selenium	1.43E-07		

FPM = filterable particulate matter. [1] CPM obtained using latest version of M202. [2]2 of the 3 runs for $PM_{2.5}$ were <PQL. *Italicized entries denote NDs shown at detection levels.*

Weyerhaeuser, Raymond, WA

Table A35 Boiler Code – WPM - BB21; Bark Boiler Burning 100% Wood-Bark

Description of Boiler, Heat Input, Control Device & Fuel Mix	Air Toxics				Criteria Pollutants	
	Non-metals	lb/MMBtu	Metals	lb/MMBtu	Pollutant	lb/MMBtu
Hog Fuel Boiler EU1 (Fuel Cell) (69.1 MMBtu /hr); ESP, 8/09; 100% Wood-Bark	HCHO	7.87E-05	Antimony	*1.79E-07*	CO	2.05E-01
	HCl	*2.43E-04*	Arsenic	*1.79E-07*	CPM[1,2]	2.11E-03
	HF	*2.53E-04*	Beryllium	*8.89E-08*	FPM	1.22E-03
			Cadmium	9.29E-08	$PM_{2.5}$	6.11E-04
			Chromium	6.81E-07	$PM_{2.5}$/FPM[2]	50.1%
			Cobalt	1.05E-07	NO_x	2.16E-01
			Lead	2.06E-07	SO_2	1.03E-03
	PCDD/F TEQs*	2.43E-04	Manganese	1.34E-05	THC	2.43E-03
	*WHO-TEF/2005		Mercury	1.82E-06	Methane	1.58E-03
			Nickel	7.17E-07		
			Selenium	3.74E-07		

FPM = filterable particulate matter. [1] CPM obtained using latest version of M202. [2] All 3 runs for $PM_{2.5}$ and CPM and 2 of 3 runs for FPM were <PQL. Also, 2 of 3 runs for $PM_{2.5}$ and CPM were below DLs. *Italicized entries denote NDs shown at detection levels.*

Rosboro Lumber, Springfield, OR

Table A36 Boiler Code – WPM - BB22; Bark Boiler Burning 100% Wood-Bark

Description of Boiler, Heat Input, Control Device & Fuel Mix	Air Toxics				Criteria Pollutants	
	Non-metals	lb/MMBtu	Metals	lb/MMBtu	Pollutant	lb/MMBtu
DV 01.1 (Dutch Oven) (27.8 MMBtu/hr); MC, 7/09; 90% Bark; 10% Wood[2]	HCHO	1.71E-03	Antimony	3.76E-06	CO	3.29E-01
	HCl	5.48E-03	Arsenic	2.79E-05	CPM[1]	4.83E-03
	HF	9.07E-05	Beryllium	2.14E-08	NO_x	2.03E-01
			Cadmium	4.76E-06	FPM	1.21E-01
			Chromium	1.28E-05	SO_2	2.31E-03
			Cobalt	6.85E-07	THC	4.94E-03
			Lead	3.63E-05	Methane	1.55E-03
	PCDD/F TEQs*	3.05E-02	Manganese	4.48E-04		
	*WHO-TEF/2005		Mercury	1.64E-06		
			Nickel	3.01E-06		
			Selenium	1.84E-05		

FPM = filterable particulate matter. [1] CPM obtained using latest version of M202. [2] Part of the combustion air fed to this unit comes from a veneer dryer exhaust.

Potlatch Corporation, St. Maries, ID

Table A37 Boiler Code – WPM - BB23; Bark Boiler Burning 100% Wood-Bark

Description of Boiler, Heat Input, Control Device & Fuel Mix	Air Toxics				Criteria Pollutants	
	Non-metals	lb/MMBtu	Metals	lb/MMBtu	Pollutant	lb/MMBtu
Boiler No. 2, PB-1 CE (Fuel Cell) (30.3 MMBtu/hr); ESP; 7/09; 100% Wood-Bark	HCHO	4.97E-03	Antimony	8.72E-08	CO	8.69E-01
	HCl	2.90E-05	Arsenic	3.00E-07	CPM[1,2]	3.09E-03
	HF	3.86E-05	Beryllium	*7.66E-09*	FPM	2.40E-03
			Cadmium	1.27E-07	$PM_{2.5}$	1.23E-03
			Chromium	6.90E-07	$PM_{2.5}$/FPM[2]	51.3%
			Cobalt	5.30E-08	NO_x	1.73E-01
			Lead	8.46E-07	SO_2	ND
	PCDD/F TEQs*	1.75E-04	Manganese	6.30E-06	THC	1.84E-02
	*WHO-TEF/2005		Mercury	7.92E-07	Methane	1.06E-02
			Nickel	4.17E-07		
			Selenium	5.80E-06		

FPM = filterable particulate matter. [1] CPM obtained using latest version of M202. [2]All 3 runs for $PM_{2.5}$ and CPM and one run for FPM were <PQL. Also, 1 run each for $PM_{2.5}$ and CPM was <DL. *Italicized entries denote NDs shown at detection levels.*

Anthony Forest Products, Urbana, AR

Table A38 Boiler Code – WPM - BB24; Bark Boiler Burning 100% Bark

Description of Boiler, Heat Input, Control Device & Fuel Mix	Air Toxics				Criteria Pollutants	
	Non-metals	lb/MMBtu	Metals	lb/MMBtu	Pollutant	lb/MMBtu
Boiler #1, SN-12 (Fuel Cell) (29.1 MMBtu/ hr); MC; 9/09; 100% Bark	HCHO	2.77E-04	Antimony	3.64E-06	CO	5.32E-01
	HCl	2.01E-04	Arsenic	1.24E-06	CPM[1,2]	7.49E-03
			Beryllium	*1.26E-07*	FPM	1.32E-01
			Cadmium	7.53E-06	$PM_{2.5}$	6.57E-02
			Chromium	4.75E-06	$PM_{2.5}$/FPM[2]	49.8%
			Cobalt	2.21E-06	NO_x	1.46E-01
			Lead	8.87E-06	SO_2	3.74E-03
	PCDD/F TEQs*	1.03E-02	Manganese	2.91E-03	THC	6.86E-03
	*WHO-TEF/2005		Mercury	8.50E-07	Methane	3.46E-03
			Nickel	7.12E-06		
			Selenium	9.73E-07		

FPM = filterable particulate matter. [1] CPM obtained using latest version of M202. [2]All 3 runs for $PM_{2.5}$, FPM and CPM were ADL. *Italicized entries denote NDs shown at detection levels.*

Potlatch Corporation, Warren, AR

Table A39 Boiler Code – WPM - BB25; Bark Boiler Burning 100% Wood-Bark

Description of Boiler, Heat Input, Control Device & Fuel Mix	Air Toxics				Criteria Pollutants	
	Non-metals	lb/MMBtu	Metals	lb/MMBtu	Pollutant	lb/MMBtu
Wellons Boiler,SN-02 (Stoker) (320 MMBtu/hr); ESP; 9/09; 100% Wood-Bark	HCHO	3.77E-04	Antimony	1.55E-07	CO	1.94E-01
	HCl	*3.83E-06*	Arsenic	3.50E-07	CPM[1,2]	1.91E-03
	HF	*3.83E-06*	Beryllium	7.11E-09	FPM	1.32E-02
			Cadmium	4.31E-07	$PM_{2.5}$	9.04E-03
			Chromium	8.76E-07	$PM_{2.5}$/FPM[2]	68.5%
			Cobalt	2.09E-07	NO_x	1.61E-01
			Lead	1.92E-06	SO_2	1.49E-02
	PCDD/F TEQs*	9.56E-03	Manganese	9.95E-05	THC	4.91E-03
	*WHO-TEF/2005		Mercury	4.68E-07	Methane	4.32E-03
			Nickel	5.85E-07		
			Selenium	*2.51E-08*		

FPM = filterable particulate matter. [1] CPM obtained using latest version of M202. [2]All 3 runs for CPM were <PQL and 1 run for CPM was <DL. *Italicized entries denote NDs shown at detection levels.*

Weyerhaeuser, Warrenton, OR (now owned by Hampton Affiliates)

Table A40 Boiler Code – WPM - BB26; Bark Boiler Burning 100% Wood-Bark

Description of Boiler, Heat Input, Control Device & Fuel Mix	Air Toxics				Criteria Pollutants	
	Non-metals	lb/MMBtu	Metals	lb/MMBtu	Pollutant	lb/MMBtu
Hog Fuel Boiler No.3 (Fuel Cell) (47.6 MMBtu/ hr); MC; 8/09; 100% Wood-Bark	HCHO	3.32E-05	Antimony	1.75E-06	CO	3.91E-01
	HCl	*2.04E-04*	Arsenic	3.22E-06	CPM[1,2]	1.94E-02
	HF	*2.04E-04*	Beryllium	*8.01E-08*	FPM	2.18E-01
			Cadmium	1.80E-06	$PM_{2.5}$	1.27E-01
			Chromium	1.69E-05	$PM_{2.5}$/FPM[1]	58.3%
			Cobalt	2.12E-06	NO_x	2.06E-01
			Lead	2.40E-05	SO_2	1.76E-03
			Manganese	1.95E-03	THC	7.18E-03
			Mercury	2.85E-06	Methane	5.20E-04
			Nickel	2.80E-06		
			Selenium	1.25E-06		

FPM = filterable particulate matter. [1] CPM obtained using latest version of M202. [2]All 3 runs for $PM_{2.5}$, FPM and CPM were ADL. *Italicized entries denote NDs shown at detection levels.*

Temple-Inland, Diboll, TX

Table A41 Boiler Code – WPM - BB27; Bark Boiler Burning 100% Bark

Description of Boiler, Heat Input, Control Device & Fuel Mix	Air Toxics				Criteria Pollutants	
	Non-metals	lb/MMBtu	Metals	lb/MMBtu	Pollutant	lb/MMBtu
Fiberboard Boiler (EPN-FB-25) (Stoker) (177 MMBtu/ hr); Wet Scrubber; 5/07; 100% Bark	HCl	9.01E-05	Arsenic	1.69E-05	CO	7.11E-01
			Beryllium	4.23E-08	FPM	9.86E-02
			Cadmium	2.29E-06	THC	1.86E-02
			Chromium	7.80E-06		
			Lead	4.24E-05		
			Manganese	1.26E-04		
			Mercury	7.97E-07		
	PCDD/F TEQs*	4.49E-03	Nickel	1.16E-05		
	*WHO-TEF/2005		Selenium	3.92E-07		

FPM = filterable particulate matter. *Italicized entries denote NDs shown at detection levels.*

Masonite Corporation, Laurel, MS

Table A42 Boiler Code – WPM - BB28a; Bark Boiler Burning 100% Wood-Bark

Description of Boiler, Heat Input, Control Device & Fuel Mix	Air Toxics				Criteria Pollutants	
	Non-metals	lb/MMBtu	Metals	lb/MMBtu	Pollutant	lb/MMBtu
Boiler#14 (BB003) (Stoker) (223 MMBtu/hr); Wet Scrubber; 6/05; 100% Wood-Bark	HCl	4.69E-05	Arsenic	2.70E-06	CO	6.74E-01
			Beryllium	9.43E-08	FPM	1.89E-01
			Cadmium	4.83E-06	NO_x	2.96E-01
			Chromium	1.27E-05		
			Lead	3.79E-05		
			Manganese	6.93E-04		
			Mercury	1.02E-06		
			Nickel	1.09E-05		
			Selenium	4.11E-06		

FPM = filterable particulate matter.

Masonite Corporation, Laurel, MS

Table A43 Boiler Code – WPM - BB28b; Bark Boiler Burning 100% Wood-Bark

Description of Boiler, Heat Input, Control Device & Fuel Mix	Air Toxics				Criteria Pollutants	
	Non-metals	lb/MMBtu	Metals	lb/MMBtu	Pollutant	lb/MMBtu
Boiler #15 (BB004) (Stoker) (229 MMBtu/hr); Wet Scrubber; 3/05; 100% Wood-Bark	HCl	1.02E-04	Arsenic	1.62E-05	FPM	1.81E-01
			Beryllium	9.91E-08		
			Cadmium	2.56E-06		
			Lead	3.79E-05		
			Manganese	5.63E-04		
			Mercury	2.23E-06		
			Nickel	8.84E-06		
			Selenium	8.72E-07		

FPM = filterable particulate matter.

Table A45 Boiler Code – WPM - BB30; Bark Boiler Burning 100% Bark

Description of Boiler, Heat Input, Control Device & Fuel Mix	Air Toxics				Criteria Pollutants	
	Non-metals	lb/MMBtu	Metals	lb/MMBtu	Pollutant	lb/MMBtu
800 Wood Waste Boiler (Stoker) (178 MMBtu/hr); ESP; 8/09; 100.0% Bark	HCHO	1.15E-03	Antimony	8.98E-08	CO	2.01E+00
	HCl	7.88E-05	Arsenic	3.24E-07	CPM[1,2]	1.51E-02
	HF	4.00E-05	Beryllium	1.04E-08	NO_x	1.67E-01
			Cadmium	4.84E-07	FPM	1.17E-03
			Chromium	8.45E-06	$PM_{2.5}$	1.21E-03
			Cobalt	2.59E-07	$PM_{2.5}$/FPM[2]	103.4%
			Lead	8.05E-07	SO_2	4.80E-03
	PCDD/F TEQs*	7.15E-04	Manganese	5.86E-06	THC	1.90E-02
	*WHO-TEF/2005		Mercury	4.98E-07	Methane	1.14E-02
			Nickel	1.48E-05		
			Selenium	1.31E-06		

FPM = filterable particulate matter. [1] CPM obtained using latest version of M202. [2] 2 of 3 runs for FPM/PM2.5 and 1 of 3 runs for CPM were <PLQ. 2 of 3 runs for PM2.5 and 1 of 3 runs for FPM were also <DL. Fraction $PM_{2.5}$/FPM ratio is invalid since $PM_{2.5}$ is > FPM.

Roseburg Forest Products, Missoula, MT

Table A46 Boiler Code – WPM - BB31; Bark Boiler Burning 100% Bark

Description of Boiler, Heat Input, Control Device & Fuel Mix	Air Toxics				Criteria Pollutants	
	Non-metals	lb/MMBtu	Metals	lb/MMBtu	Pollutant	lb/MMBtu
Boiler #1 (Suspension Burner) (35 MMBtu/hr); MC; 9/04; 97% sanderdust, 3% gas;	HCl	3.75E-03	Arsenic	*8.26E-05*		
			Beryllium	*9.07E-08*		
			Cadmium	1.16E-05		
			Chromium	3.50E-05		
			Lead	1.24E-05		
			Manganese	2.80E-03		
			Mercury	3.74E-07		
			Nickel	2.79E-05		
			Selenium	*4.53E-06*		

Italicized entries denote NDs shown at detection levels.

Table A47 Boiler Code – WPM - BB32; Bark Boiler Burning 100% Resin Wood

Description of Boiler, Heat Input, Control Device & Fuel Mix	Air Toxics				Criteria Pollutants	
	Non-metals	lb/MMBtu	Metals	lb/MMBtu	Pollutant	lb/MMBtu
FB-1 (Suspension Burner) (17.6 MMBtu/hr); ESP; 3/11; 100.0% Resin Wood	HCl	4.70E-04	Cadmium	*1.09E-07*	CO	2.26E-01
			Lead	6.20E-07	NO_x	8.09E-01
			Mercury	2.59E-07	FPM	9.77E-04
					SO_2	2.77E-03

FPM = filterable particulate matter. *Italicized entries denote NDs shown at detection levels.*

Comments

NO_x emissions are fairly high, suggesting high N content in the resin wood fired in this unit.

Table A48 Boiler Code – WPM - BB33; Bark Boiler Burning 100% Wood

Description of Boiler, Heat Input, Control Device & Fuel Mix	Air Toxics				Criteria Pollutants	
	Non-metals	lb/MMBtu	Metals	lb/MMBtu	Pollutant	lb/MMBtu
ES1- Wood Fired Boiler (Stoker) (46.5 MMBtu/hr); MC; 7/04; 100.0% Wood	HCl	1.57E-04	Arsenic	*7.53E-06*	FPM	2.84E-01
			Beryllium	*4.21E-07*		
			Cadmium	1.44E-06		
			Chromium	3.80E-05		
			Lead	*8.21E-05*		
			Manganese	4.87E-04		
			Nickel	1.17E-05		
			Selenium	*9.47E-07*		

FPM = filterable particulate matter. *Italicized entries denote NDs shown at detection levels.*

Table A49 Boiler Code – WPM - BB34; Bark Boiler Burning 100% Resin Wood

Description of Boiler, Heat Input, Control Device & Fuel Mix	Air Toxics				Criteria Pollutants	
	Non-metals	lb/MMBtu	Metals	lb/MMBtu	Pollutant	lb/MMBtu
Wood-fired Boiler (Suspension Burner) (26 MMBtu/hr); MC; 6/03; 100.0% Resin Wood	HCl	2.89E-04	Arsenic	9.27E-06	FPM	2.80E-01
			Beryllium	4.00E-08		
			Cadmium	2.73E-06		
			Chromium	3.98E-05		
			Lead	1.54E-05		
			Manganese	2.49E-03		
			Mercury	1.15E-06		
			Nickel	1.39E-05		
			Selenium	4.00E-07		

FPM = filterable particulate matter.

Table A50 Boiler Code – WPM - BB35; Bark Boiler Burning 100% Bark

Description of Boiler, Heat Input, Control Device & Fuel Mix	Air Toxics				Criteria Pollutants	
	Non-metals	lb/MMBtu	Metals	lb/MMBtu	Pollutant	lb/MMBtu
LU-09 (Stoker) (142 MMBtu/hr); Wet Scrubber; 5/11; 100.0% Bark			Mercury	1.03E-06	CO	1.02E+00
					FPM	8.86E-02

FPM = filterable particulate matter.

Table A51 Boiler Code – WPM - BB36; Bark Boiler Burning Resin Wood <2% Gas

Description of Boiler, Heat Input, Control Device & Fuel Mix	Air Toxics				Criteria Pollutants	
	Non-metals	lb/MMBtu	Metals	lb/MMBtu	Pollutant	lb/MMBtu
BW-B001 (Coen Suspension Burner) (27.9 MMBtu/hr); ESP; 1/03, 3/08 & 12/10; 95.0% Resin Wood, 5.0% Gas			Cadmium	3.90E-07	CO	1.00E-01
			Lead	9.80E-07	CPM	6.44E-03
			Mercury	1.87E-07	NO_x	1.26E+00
					FPM	2.04E-02
					SO_2	3.03E-03

FPM = filterable particulate matter. [1] CPM obtained using older version of M202.

Weyerhaeuser, Bruce, MS

Table A53 Boiler Code – WPM - BB38; Bark Boiler Burning 100% Bark

Description of Boiler, Heat Input, Control Device & Fuel Mix	Air Toxics				Criteria Pollutants	
	Non-metals	lb/MMBtu	Metals	lb/MMBtu	Pollutant	lb/MMBtu
AA-002 No. 2 Boiler (Fuel Cell) (99 MMBtu/hr); ESP; 8/09; 100% Bark			Antimony	4.97E-07	CPM[1,2]	5.86E-03
			Arsenic	1.55E-07	FPM	6.83E-03
			Beryllium	*1.92E-08*	$PM_{2.5}$	4.48E-03
			Cadmium	2.12E-07	$PM_{2.5}$/FPM[2]	65.6%
			Chromium	1.81E-06		
			Cobalt	9.85E-08		
			Lead	1.96E-06		
	PCDD/F TEQs*	1.23E-03	Manganese	4.69E-05		
	*WHO-TEF/2005		Mercury	1.01E-06		
			Nickel	9.89E-07		
			Selenium	1.88E-07		

FPM = filterable particulate matter. [1] CPM obtained using latest version of M202. [2]All 3 runs for $PM_{2.5}$, FPM and CPM were ADL. Also, all 3 runs for CPM were <PQL. *Italicized entries denote NDs shown at detection levels.*

Table A54 Boiler Code – WPM - BB39; Bark Boiler Burning Bark & Sawdust

Description of Boiler, Heat Input, Control Device & Fuel Mix	Air Toxics				Criteria Pollutants	
	Non-metals	lb/MMBtu	Metals	lb/MMBtu	Pollutant	lb/MMBtu
EPN22 (Stoker) (170.4 MMBtu /hr); ESP; 2/11; 50% Bark; 50% Sawdust			Mercury	5.72E-07	CO	5.50E-01
					FPM	3.16E-02

FPM = filterable particulate matter.

2.0 ORGANIC/INORGANIC AIR TOXIC, TRACE METAL, AND CRITERIA POLLUTANT EMISSIONS FOR WOOD-FIRED BOILERS – SELECTIVE WOOD PRODUCTS MILL DATA NOT PREVIOUSLY INCLUDED IN TECHNICAL BULLETIN 973

Table A55 Boiler Code – WPM – BB40; Bark Boiler Burning 100% Bark

Description of Boiler, Heat Input, Control Device & Fuel Mix	Air Toxics				Criteria Pollutants	
	Non-metals	lb/MMBtu	Metals	lb/MMBtu	Pollutant	lb/MMBtu
001-01 (Stoker) (98 MMBtu /hr); ESP; 8/05; 100% Bark					CO	1.82E-02
					NO_x	2.41E-01
					FPM	3.93E-03
					THC[1]	1.64E-03

FPM = filterable particulate matter; may or may not exclude methane.

Table A56 Boiler Code – WPM - BB41; Bark Boiler Burning Green & Resin Wood

Description of Boiler, Heat Input, Control Device & Fuel Mix	Air Toxics				Criteria Pollutants	
	Non-metals	lb/MMBtu	Metals	lb/MMBtu	Pollutant	lb/MMBtu
Boiler No. 1 (Stoker) (56.2 MMBtu/hr); MC; 7/92; Green & Resin Wood					CO	1.99E+00
					NO_x	1.76E-01
					SO_2	4.04E-03
					FPM	1.65E-01
					VOC as C	9.83E-02

FPM = filterable particulate matter.

Table A57 Boiler Code – WPM - BB42; Bark Boiler Burning Green & Resin Wood

Description of Boiler, Heat Input, Control Device & Fuel Mix	Air Toxics				Criteria Pollutants	
	Non-metals	lb/MMBtu	Metals	lb/MMBtu	Pollutant	lb/MMBtu
Boiler No. 1 (Stoker) (107 MMBtu/hr); MC; 7/92; Green & Resin Wood					CO	2.23E+00
					CPM[1]	4.33E-02
					NO_x	1.52E-01
					FPM	7.57E-01
					PM+CPM	8.00E-01
					VOC as C	3.87E-02

FPM = filterable particulate matter. [1] CPM obtained using latest version of M202.

Table A58 Boiler Code – WPM - BB43; Bark Boiler Burning 100% Resin Wood

Description of Boiler, Heat Input, Control Device & Fuel Mix	Air Toxics				Criteria Pollutants	
	Non-metals	lb/MMBtu	Metals	lb/MMBtu	Pollutant	lb/MMBtu
Suspension Burner (75.7 MMBtu/hr); ESP; 4/08; 100% Resin Wood					CO	3.26E-01
					CPM[1]	2.78E-03
					NO_x	5.72E-01
					FPM	1.78E-02

FPM = filterable particulate matter. [1] CPM obtained using latest version of M202.

Table A59 Boiler Code – WPM - BB1a; Bark Boiler Burning Hog Fuel, Resin Wood & 1% Oil

Description of Boiler, Heat Input, Control Device & Fuel Mix	Air Toxics				Criteria Pollutants	
	Non-metals	lb/MMBtu	Metals	lb/MMBtu	Pollutant	lb/MMBtu
Suspension Burner (96 MMBtu/hr); Wet Scrubber; 7/95; 69% hog fuel; 30% resin wood; 1% oil	1,1,2-Trichloroethane	*1.02E-05*	**After Multiclone**		**After Multiclone**	
	1,1-Dichloroethane	*2.99E-05*	Antimony	3.29E-06	CO	2.28E+00
	1,2,3-Trichlorobenzene	*2.19E-06*	Arsenic	7.21E-06	CPM[1]	2.57E-02
	1,2,3-Trichloropropane	*2.19E-06*	Beryllium	7.54E-07	NO_x	3.90E-01
	1,2,4-Trichlorobenzene	*3.65E-06*	Cadmium	5.07E-06	FPM	1.40E+00
	1,2-Dibromo-3-chloropropane	*1.10E-06*	chromium	2.40E-05	PM+CPM	1.30E+00
	1,2-Dibromoethane	*1.83E-06*	Copper	1.00E-04	SO_2	9.05E-03
	1,2-Dichlorobenzene	*1.79E-05*	Lead	1.01E-04	VOC as C	6.38E-02
	1,2-Dichloroethene	1.37E-03	Manganese	8.25E-03		
	1,2-Dichloropropane	*7.30E-07*	Mercury	5.08E-07	**After Wet Scrubber**	
	1,3-Dichlorobenzene	*1.64E-05*	Nickel	2.64E-05	CPM[1]	7.44E-03
	1,4-Dichlorobenzene	2.79E-04	Phosphorus	5.45E-03	FPM	2.99E-01
	2,5-Dimethylbenzaldehyde	1.09E-04	Selenium	5.39E-07	PM+CPM	3.06E-01
	2-Chloronaphthalene	4.58E-08	Silicon	1.21E-01		
	2-Methylnaphthalene	2.99E-06	Zinc	7.58E-04	**Uncontrolled (bef. MC)**	
	4-Chlorotoluene	*1.83E-06*			CPM[1]	3.31E-02
	Acenaphthene	4.23E-07	**After Wet Scrubber**		FPM	2.63E+00
	Acenaphthylene	5.80E-07	Arsenic	6.14E-06	PM+CPM	1.94E+00
	Acetaldehyde	5.10E-04				
	Acetone	2.45E-03				
	Acrolein	2.01E-04				
	Anthracene	1.01E-06				
	Benz(a)anthracene	2.63E-07				
	Benzaldehyde	4.22E-04				
	Benzo(a)pyrene	3.84E-07				
	Benzo(b)fluoranthene	7.08E-07				
	Benzo(e)pyrene	6.84E-07				
	Benzo(g,h,i)perylene	9.17E-07				
	Benzo(k)fluoranthene	1.42E-07				
	Bromobenzene	*7.67E-05*				
	Bromodichloromethane	*7.30E-07*				
	Butanal	7.70E-05				

(Continued on next page. See notes at end of table.)

Table A59 Continued

Description of Boiler, Heat Input, Control Device & Fuel Mix	Air Toxics				Criteria Pollutants	
	Non-metals	lb/MMBtu	Metals	lb/MMBtu	Pollutant	lb/MMBtu
Suspension Burner (96.3 MMBtu/hr); Wet Scrubber; 7/95; 69% hog fuel; 30% resin wood; 1% oil	Carbon Tetrachloride	*3.65E-07*				
	Chloroethane	*1.10E-06*				
	Chloroform	*2.56E-06*				
	Chrysene	5.03E-07				
	cis-1,3-Dichloropropene	*5.48E-06*				
	Crotonaldehyde	7.89E-05				
	Dibenzo(a,h)anthracene	1.21E-08				
	Dibromochloromethane	*7.84E-07*				
	Fluoranthene	3.00E-06				
	Fluorene	4.88E-07				
	HCHO	3.81E-03				
	Hexachlorobutadiene	*3.65E-07*				
	Hexanal	9.82E-06				
	Indeno(1,2,3-cd)pyrene	3.49E-07				
	Isobutyraldehyde	1.47E-04				
	Isovaleraldehyde	1.58E-06				
	Methyl ethyl ketone (MEK)	6.73E-05				
	Methylene chloride	*1.31E-04*				
	Naphthalene	5.86E-05				
	o-Tolualdehyde	7.30E-05				
	Pentanal	1.53E-04				
	Perylene	8.90E-08				
	Phenanthrene	6.01E-06				
	Propionaldehyde	2.14E-05				
	Pyrene	3.27E-06				
	Tetrachloroethylene	*7.30E-07*				
	Tolualdehydes	1.82E-04				
	Trans-1,3-Dichloropropene	*6.94E-06*				
	Tribromomethane	*3.65E-07*				
	Trichloroethylene	*1.83E-06*				
	Trichlorofluoromethane	*3.65E-07*				

FPM = filterable particulate matter. [1] CPM obtained using older version of M202. *Italicized entries denote NDs shown at detection levels.*

Table A60 Boiler Code – WPM - BB1b; Bark Boiler Burning Wood/Bark & Resin Wood

Description of Boiler, Heat Input, Control Device & Fuel Mix	Air Toxics				Criteria Pollutants	
	Non-metals	lb/MMBtu	Metals	lb/MMBtu	Pollutant	lb/MMBtu
Stoker (70 MMBtu/hr); ESP; 5/03; 60% Wood/ Bark; 40% resin wood	HCHO	5.10E-03			NO	4.54E-01
	HCl	2.15E-03			NO_2	5.83E-02
	Methanol	9.74E-04			NO_x	7.55E-01
					NO_2/NO_x	7.7%

FPM = filterable particulate matter. Note: The NO_2 to NO_x ratio was determined to be 7.7% in this wood-fired boiler.

Table A61 Boiler Code – WPM - BB2; Bark Boiler Burning Dry Wood & Resin Wood

Description of Boiler, Heat Input, Control Device & Fuel Mix	Air Toxics				Criteria Pollutants	
	Non-metals	lb/MMBtu	Metals	lb/MMBtu	Pollutant	lb/MMBtu
Fuel Cell (161 MMBtu/hr); ESP; 5/03; 75% Dry Wood; 25% Resin wood	1-Methylphenanthrene	1.40E-06			CO	9.04E-01
	2-Chloronaphthalene	1.20E-08			CPM[1]	7.01E-03
	2-Methylanthracene	1.60E-08			NO_x	4.36E-01
	2-Methylnaphthalene	2.30E-06			FPM	7.10E-03
	3-Methylcholanthrene	8.68E-09			SO_2	3.33E-03
	7,12-Dimethylbenzo(a)anthracene	4.57E-09			VOC as C	6.38E-03
	9,10-Dimethylanthracene	2.14E-09				
	9-Methylphenanthrene	8.73E-08				
	Acenaphthene	4.92E-07				
	Acenaphthylene	3.61E-06				
	Acetaldehyde	8.30E-04				
	Acetone	7.14E-03				
	Acrolein	*6.46E-04*				
	Anthracene	1.76E-07				
	Benz(a)anthracene	7.93E-08				
	Benzaldehyde	*5.40E-05*				
	Benzo(a)fluorene	3.10E-08				
	Benzo(a)pyrene	4.38E-08				
	Benzo(b)fluoranthene	1.36E-07				
	Benzo(b)fluorene	4.35E-09				
	Benzo(e)pyrene	1.56E-07				
	Benzo(g,h,i)perylene	7.52E-08				
	Benzo(k)fluoranthene	1.23E-07				
	Chrysene	1.51E-07				
	Coronene	3.03E-08				
	Crotonaldehyde	*5.98E-05*				
	Dibenzo(a,c)anthracene	3.88E-09				
	Fluoranthene	1.01E-06				
	Fluorene	1.36E-07				
	HCHO	3.23E-03				
	Hexanal	2.02E-04				
	Indeno(1,2,3-cd)pyrene	2.79E-08				
	Methanol	4.82E-04				
	Naphthalene	1.84E-05				

(Continued on next page. See notes at end of table.)

Table A61 Continued

Description of Boiler, Heat Input, Control Device & Fuel Mix	Air Toxics				Criteria Pollutants	
	Non-metals	lb/MMBtu	Metals	lb/MMBtu	Pollutant	lb/MMBtu
Fuel Cell (161.1 MMBtu/hr); ESP; 5/03; 75% Dry Wood; 25% Resin wood	Perylene	6.58E-09				
	Phenanthrene	3.06E-06				
	Phenol	1.51E-03				
	Picene	2.46E-09				
	Propionaldehyde	1.12E-03				
	Pyrene	9.88E-07				
	Tetralin	9.58E-08				

FPM = filterable particulate matter. [1] CPM obtained using older version of M202. *Italicized entries denote NDs shown at detection levels.*

Table A62 Boiler Code – WPM - BB3; Bark Boiler Burning 100% Wood

Description of Boiler, Heat Input, Control Device & Fuel Mix	Air Toxics				Criteria Pollutants	
	Non-metals	lb/MMBtu	Metals	lb/MMBtu	Pollutant	lb/MMBtu
B10 (Fluidized Bed) (32.5 MMBtu/hr); MC; 1/95; 100% Wood	2-pentanone	*3.00E-05*			NO_x	4.21E-01
	Acetaldehyde	1.57E-04				
	Acetone	8.77E-04				
	Acrolein	6.60E-04				
	Benzene	5.33E-05				
	Benzo(a)pyrene	*1.00E-05*				
	Bromomethane	3.67E-06				
	Chloromethane	3.00E-05				
	Ethanol	*2.00E-05*				
	Ethylbenzene	1.33E-06				
	HCHO	1.02E-03				
	Hexanal	*1.00E-04*				
	Isobutanol	*3.00E-05*				
	m,p-Cresol	*1.00E-05*				
	Methyl ethyl ketone (MEK)	7.50E-07				
	Methylene chloride	*1.00E-05*				
	Naphthalene	*1.00E-05*				
	o-Cresol	*1.00E-05*				
B10 (Fluidized Bed) (32.5 MMBtu/hr); MC; 1/95; 100% Wood	Phenol	*1.00E-05*				
	Propanol	*2.00E-05*				
	Propionaldehyde	7.67E-05				
	Pyridine	*1.00E-05*				
	Styrene	*2.00E-06*				
	Toluene	3.67E-06				
	Trichlorofluoromethane	*2.00E-06*				

Italicized entries denote NDs shown at detection levels.

Table A63 Boiler Code – WPM - BB4; Bark Boiler Burning 100% Resin Wood

Description of Boiler, Heat Input, Control Device & Fuel Mix	Air Toxics				Criteria Pollutants	
	Non-metals	lb/MMBtu	Metals	lb/MMBtu	Pollutant	lb/MMBtu
Stoker (94 MM Btu/hr); EFB; 5/92; 100% Resin Wood	acetaldehyde	3.96E-05			CO	1.62E+00
	HCHO	6.05E-04			NO_x	9.60E-01
					FPM	1.43E-01
					PM+CPM	3.03E-02
					SO_2	7.67E-04

FPM = filterable particulate matter.

Table A64 Boiler Code – WPM - BB5; Bark Boiler Burning 100% Wood

Description of Boiler, Heat Input, Control Device & Fuel Mix	Air Toxics			
	Non-metals	lb/MMBtu	Metals	lb/MMBtu
Stoker (109 MMBtu/hr); EFB; 10/02; 100% Wood	Acetaldehyde	6.25E-05		
	Benzene	1.30E-05		
	HCHO	1.08E-04		
	HCN	2.05E-05		

Table A65 Boiler Code – WPM - BB6a; Bark Boiler Burning 100% Wood

Description of Boiler, Heat Input, Control Device & Fuel Mix	Air Toxics			
	Non-metals	lb/MMBtu	Metals	lb/MMBtu
Line 1 Konus (26.2 MMBtu/hr); EFB; 10/02; 100% Bark	Benzene	6.75E-05		
	HCHO	4.44E-04		
	phenol	*1.20E-03*		

Italicized entries denote NDs shown at detection levels.

Table A66 Boiler Code – WPM - BB6b; Bark Boiler Burning 100% Wood

Description of Boiler, Heat Input, Control Device & Fuel Mix	Air Toxics			
	Non-metals	lb/MMBtu	Metals	lb/MMBtu
Line 2 Konus (32.1 MMBtu /hr); EFB; 6/97; 100% Bark	Benzene	1.63E-03		

Table A67 Boiler Code – WPM - BB7; Bark Boiler Burning 100% Resin Wood

Description of Boiler, Heat Input, Control Device & Fuel Mix	Air Toxics			
	Non-metals	lb/MMBtu	Metals	lb/MMBtu
SPADBL01 (Suspension Burner) (3.3 MMBtu/hr); None; 5/03; 100% Resin Wood	HCl	1.02E-02		
	HCHO	5.36E-02		
	Methanol	2.76E-02		
SPADBL01 (Suspension Burner) (3.3 MMBtu/hr); None; 5/03; 100% Resin Wood				

Table A68 Boiler Code – WPM - BB8; Bark Boiler Burning 100% Wood

Description of Boiler, Heat Input, Control Device & Fuel Mix	Air Toxics			
	Non-metals	lb/MMBtu	Metals	lb/MMBtu
Stoker (15.9 MMBtu/hr); None; 12/92; 100% Wood	HCHO	5.00E-04		

Table A69 Boiler Code – WPM - BB9a; Bark Boiler Burning 100% Bark

Description of Boiler, Heat Input, Control Device & Fuel Mix	Air Toxics			
	Non-metals	lb/MMBtu	Metals	lb/MMBtu
Boiler No. 1 (Stoker) (65 MMBtu/hr); Multiclone; 9/02; 100% Bark	HCHO	7.08E-04		
	Methanol	*1.30E-04*		
	Phenol	*1.30E-04*		

Italicized entries denote NDs shown at detection levels.

Table A70 Boiler Code – WPM - BB9b; Bark Boiler Burning 100% Bark

Description of Boiler, Heat Input, Control Device & Fuel Mix	Air Toxics			
	Non-metals	lb/MMBtu	Metals	lb/MMBtu
Boiler No. 2 (Stoker) (59.3 MMBtu/hr); Multiclone; 9/02; 100% Bark	HCHO	6.90E-04		
	Methanol	*1.50E-04*		
	Phenol	*1.50E-04*		

Italicized entries denote NDs shown at detection levels.

Table A71 Boiler Code – WPM - BB10; Bark Boiler Burning 100% Resin Wood

Description of Boiler, Heat Input, Control Device & Fuel Mix	Air Toxics			
	Non-metals	lb/MMBtu	Metals	lb/MMBtu
B2 (Suspension Burner) (30 MMBtu/hr); ESP; 11/02; 100% Resin Wood	HCHO	*8.26E-04*		
	HCl	1.39E-03		
	Methanol	*8.26E-04*		

Italicized entries denote NDs shown at detection levels.

Table A72 Boiler Code – WPM - BB11; Bark Boiler Burning 100% Green Wood

Description of Boiler, Heat Input, Control Device & Fuel Mix	Air Toxics			
	Non-metals	lb/MMBtu	Metals	lb/MMBtu
Stoker (6.1 MMBtu/hr); FF; 6/90; 100% Green Wood	HCHO	6.57E-04		

Table A73 Boiler Code – WPM - BB12; Bark Boiler Burning 100% Wood

Description of Boiler, Heat Input, Control Device & Fuel Mix	Air Toxics			
	Non-metals	lb/MMBtu	Metals	lb/MMBtu
5600-Wellons Energy System (Fuel Cell) (187.0 MMBtu/hr); ESP 8/96; 100% Wood	HCHO	6.77E-04		

Table A74 Boiler Code – WPM - BB13; Bark Boiler Burning 100% Bark

Description of Boiler, Heat Input, Control Device & Fuel Mix	Air Toxics			
	Non-metals	lb/MMBtu	Metals	lb/MMBtu
Fuel Cell (12.9 MMBtu/hr); MC 8/02; 100% Bark	HCHO	3.63E-04		

Table A75 Boiler Code – WPM - BB14; Bark Boiler Burning 100% Bark

Description of Boiler, Heat Input, Control Device & Fuel Mix	Air Toxics			
	Non-metals	lb/MMBtu	Metals	lb/MMBtu
Stoker (21.4 MMBtu/hr); FF, 3/03; 100% Bark	HCHO	1.60E-04		
	HCl	2.50E-03		
	HF	2.54E-03		

Table A76 Boiler Code – WPM - BB15; Bark Boiler Burning 100% Wood

Description of Boiler, Heat Input, Control Device & Fuel Mix	Air Toxics				Criteria Pollutants	
	Non-metals	lb/MMBtu	Metals	lb/MMBtu	Pollutant	lb/MMBtu
Type (NS) (114 MMBtu/hr); MC, 5/04; 100% Wood	HCHO	1.14E-03			PM+CPM	5.63E-03

Table A77 Boiler Code – WPM - BB17; Bark Boiler Burning 100% Wood

Description of Boiler, Heat Input, Control Device & Fuel Mix	Air Toxics			
	Non-metals	lb/MMBtu	Metals	lb/MMBtu
Fixed Grate (18.8 MMBtu/hr); FF, 2/92; 100% Wood	HCHO	2.26E-04		

Table A78 Boiler Code – WPM – BB44; Bark Boiler Burning 100% Green Wood

Description of Boiler, Heat Input, Control Device & Fuel Mix	Air Toxics			
	Non-metals	lb/MMBtu	Metals	lb/MMBtu
Fuel Cell (17.5 MMBtu/hr); No PM Control; 7/02; 100% Green Wood			FPM	2.53E-01
			PM_{10}	8.50E-02
			$PM_{2.5}$	7.00E-02
			$PM_{2.5}$/FPM	27.7%
			PM_{10}/FPM	33.6%

3.0 ORGANIC/INORGANIC AIR TOXIC, TRACE METAL, AND CRITERIA POLLUTANT EMISSIONS FOR WOOD-FIRED BOILERS – DATA RETAINED FROM NCASI TECHNICAL BULLETINS 973 AND 884

Viking Energy of McBain, McBain, MI

Table A79 Boiler Code – EGU - B125; Bark Boiler Burning 100% Wood-Bark

Fuel & Source Description	Pollutant	lb/MMBtu
Virgin wood waste, PW/PB waste, CD&D - Spreader Stoker, 234-255 MMBtu/hr, ESP	2-Chloronaphthalene	2.41E-09
	2-Methylnaphthalene	2.75E-07
	Copper	5.33E-06
	Naphthalene	4.64E-07
	Zinc	1.66E-04

Reference: EPA AP-42, Section 1.6, Wood Waste Combustion, Background Data

Washington Water Power Co., Kettle Falls, WA

Table A80 Boiler Code – EGU - B127; Bark Boiler Burning 100% Wood-Bark

Fuel & Source Description	Pollutant	lb/MMBtu
Hog fuel - Wood waste fired boiler, Stoker, 415 KPPH, ESP	Benzene	1.90E-03

Reference: EPA AP-42, Section 1.6, Wood Waste Combustion, Background Data

Wheelabrator Ridge Energy Inc., Auburndale, FL

Table A81 Boiler Code – EGU - B133; Bark Boiler Burning 100% Wood-Bark

Fuel & Source Description	Pollutant	lb/MMBtu
100% wood - Conventional WFB w/waterwall construction, Stoker, 630 MMBtu/hr, FF	Benzene	1.15E-03
	Chromium^{+6}	4.86E-07
	Dichlorobiphenyl	9.00E-10
	Zinc	1.82E-05

Reference: EPA AP-42, Section 1.6, Wood Waste Combustion, Background Data

Wheelabrator Shasta Energy Company, Anderson, CA

Table A82 Boiler Code – EGU - B134; Bark Boiler Burning 100% Wood-Bark

Fuel & Source Description	Pollutant	lb/MMBtu
Pine & fir - Wood-fired boiler, Stoker, 20 MW, ESP	1,1,1-Trichloroethane	*4.43E-05*
	2,4,6-Trichlorophenol	*2.09E-08*
	2,4-Dinitrophenol	*2.09E-07*
	2-Chlorophenol	*2.09E-08*
	2-Nitrophenol	*2.09E-08*
	4-Nitrophenol	*1.05E-07*
	Acetaldehyde	6.90E-05
	Benzene	2.35E-04
	Benzene	2.35E-04
	Chloroform	*3.97E-05*
	Chromium^{+6}	1.39E-06
	Copper	3.26E-06
	Decachlorobiphenyl	2.65E-10
	Hexachlorobiphenyl	8.01E-10
	m,p-Xylene	*3.53E-05*
	Methylene Chloride	*2.82E-05*
	Naphthalene	7.44E-05
	o-Xylene	*3.53E-05*
	Pentachlorobiphenyl	1.76E-09
	Pentachlorophenol	*4.19E-08*
	Phenol	7.80E-07
	Tetrachlorobiphenyl	3.39E-09
	Tetrachloroethene	*5.51E-05*
	Toluene	*3.06E-05*
	Trichlorobiphenyl	5.51E-09
	Trichloroethylene	*4.37E-05*
	Xylenes (mixed isomers)	*1.82E-05*
	Zinc	1.67E-05

Reference: EPA AP-42, Section 1.6, Wood Waste Combustion, Background Data.
Italicized entries denote NDs shown at detection levels.

Wheelabrator Shasta Energy Company, Anderson, CA

Table A83 Boiler Code – EGU - B135; Bark Boiler Burning 100% Wood-Bark

Fuel & Source Description	Pollutant	lb/MMBtu
Hog Wood - Wood-fired boiler, Stoker, 170 KPPH, ESP	1,1,1-Trichloroethane	3.93E-05
	1,2-Dibromoethene	5.48E-05
	1,2-Dichloroethane	2.92E-05
	1,2-Dichloropropane	3.33E-05
	Benzene	1.90E-04
	Bromomethane	2.80E-05
	Carbon Tetrachloride	4.54E-05
	Chlorobenzene	3.32E-05
	Chloroform	3.52E-05
	Ethylbenzene	3.13E-05
	Methylene Chloride	5.60E-04
	o-Xylene	3.13E-05
	Tetrachloroethene	4.89E-05
	Toluene	2.72E-05
	Trichloroethylene	3.88E-05
	Trichlorofluoromethane	4.05E-05
	Vinyl Chloride	1.84E-05

Reference: EPA AP-42, Section 1.6, Wood Waste Combustion, Background Data

BVTBC Genesee Power Station, Flint, MI

Table A84 Boiler Code – EGU - B23; Bark Boiler Burning 100% Wood-Bark

Fuel & Source Description	Pollutant	lb/MMBtu
Wood waste (lumbering, tree triming, CD&D), Stoker, 331 KPPH, ESP	Acrolein	3.15E-05

Reference: EPA AP-42, Section 1.6, Wood Waste Combustion, Background Data

Craven County Wood Energy Plant, New Bern, NC

Table A85 Boiler Code – EGU - B29; Bark Boiler Burning 100% Wood-Bark

Fuel & Source Description	Pollutant	lb/MMBtu
100% clean wood - conventional Zurn traveling grate spreader stoker, 45 MW, ESP	2,4,6-Trichlorophenol	1.09E-06
	2,4-Dinitrotoluene	9.42E-07
	2,5-Dimethyl benzaldehyde	4.45E-05
	4,6-Dinitro-2-methylphenol	2.10E-06
	Acetaldehyde	3.49E-04
	Acrolein	1.27E-04
	Benzaldehyde	1.12E-04
	Benzene	2.41E-07
	Benzoic Acid	8.63E-06
	bis(2-Chloroisopropyl) ether	6.15E-07
	Chlorobenzene	5.54E-10
	Crotonaldehyde	1.08E-05
	Di-n-octyl phthalate	1.10E-07
	Hexachlorobenzene	1.03E-06
	Hexaldehyde	3.31E-05
	m,p-Xylene	6.90E-10
	Methyl Ethyl Ketone	1.97E-05
	Naphthalene	4.75E-06
	n-Butyraldehyde	6.05E-05
	o-Xylene	2.83E-10
	Pentachlorophenol	1.07E-06
	Phenol	1.53E-05
	Tolualdehydes	1.38E-04
	Toluene	3.43E-08
	Valeraldehyde	9.27E-05
	Xylenes (mixed isomers)	1.85E-05

Reference: EPA AP-42, Section 1.6, Wood Waste Combustion, Background Data

Delano Energy Company, Inc., Delano, CA

Table A86 Boiler Code – EGU - B30; Bark Boiler Burning 100% Wood-Bark

Fuel & Source Description	Pollutant	lb/MMBtu
Urban WW (orchard prunings, peach and olive pits,etc.), FBC, 31 MW, FF	2-Methylnaphthalene	4.05E-08
	Acetaldehyde	1.66E-05
	Barium	2.60E-04
	Chromium^{+6}	5.90E-08
	Copper	2.54E-06
	Dichlorobiphenyl	9.26E-10
	Molybdenum	3.01E-06
	Naphthalene	1.82E-07
	Phosphorus	1.93E-05
	Trichlorobiphenyl	5.45E-10
	Zinc	2.37E-05

Reference: EPA AP-42, Section 1.6, Wood Waste Combustion, Background Data

Dinuba Energy Company, Inc., Dinuba, CA

Table A87 Boiler Code – EGU - B31; Bark Boiler Burning 100% Wood-Bark

Fuel & Source Description	Pollutant	lb/MMBtu
Chips/SD (40%); urban WW (30%); for. res. (10%) - Travelling Grate, 125 KPPH, ESP	Dichlorobiphenyl	3.79E-10
	Hexachlorobiphenyl	2.89E-10
	Monochlorobiphenyl	2.18E-10
	Naphthalene	1.25E-06
	Pentachlorobiphenyl	6.49E-10
	Tetrachlorobiphenyl	1.60E-09
	Trichlorobiphenyl	1.78E-09

Reference: EPA AP-42, Section 1.6, Wood Waste Combustion, Background Data

LFC Power Systems Corporation, Hillman, MI

Table A88 Boiler Code – EGU - B72; Bark Boiler Burning 100% Wood-Bark

Fuel & Source Description	Pollutant	lb/MMBtu
Wood Residues - Stoker, ESP	Zinc	6.97E-05

Reference: EPA AP-42, Section 1.6, Wood Waste Combustion, Background Data

North Fork Energy Incorporated, North Fork, CA

Table A89 Boiler Code – EGU - B86; Bark Boiler Burning 100% Wood-Bark

Fuel & Source Description	Pollutant	lb/MMBtu
Hog-wood and bark (pine, fir) - FBC, 100 KPPH, APCD - NA	Acetaldehyde	2.50E-05
	Benzene	2.55E-05

Reference: EPA AP-42, Section 1.6, Wood Waste Combustion, Background Data

Thilmany Pulp & Paper Company, Kaukauna, WI

Table A90 Boiler Code – PM - B110; Bark Boiler Burning 100% Wood-Bark

Fuel & Source Description	Pollutant	lb/MMBtu
Wood bark.- Vibrating hydrograte, 90 KPPH, Wet Scrubber	Barium	8.15E-05
	Copper	4.89E-05

Reference: EPA AP-42, Section 1.6, Wood Waste Combustion, Background Data

Resolute Forest Products, Calhoun, TN

Table A91 Boiler Code – PM - B20; Bark Boiler Burning 100% Wood-Bark

Fuel & Source Description	Pollutant	lb/MMBtu
Bark Boiler, 176 KPPH, Wet Scrubber	Zinc	4.23E-04

Reference: EPA AP-42, Section 1.6, Wood Waste Combustion, Background Data

Georgia Pacific Corporation, Monticello, MS

Table A92 Boiler Code – PM - B49; Bark Boiler Burning 100% Wood-Bark

Fuel & Source Description	Pollutant	lb/MMBtu
Wood Residues, Stoker, ESP	Zinc	7.09E-04

Reference: EPA AP-42, Section 1.6, Wood Waste Combustion, Background Data

Kimberly-Clark Corporation, Everett, WA

Table A93 Boiler Code – PM - B62; Bark Boiler Burning 100% Wood-Bark

Fuel & Source Description	Pollutant	lb/MMBtu
Hog Fuel - Stoker, 435 KPPH, FF	Barium	1.59E-04
	Copper	1.10E-05
	Molybdenum	1.13E-06
	Potassium	3.88E-02
	Sodium	3.63E-04
	Strontium	1.01E-05
	Tin	3.91E-05
	Titanium	2.01E-05
	Vanadium	5.94E-07
	Yttrium	3.01E-07
	Zinc	8.48E-05

Reference: EPA AP-42, Section 1.6, Wood Waste Combustion, Background Data

Mead Corporation, Chillicothe, OH

Table A94 Boiler Code – PM - B78; Bark Boiler Burning 100% Wood-Bark

Fuel & Source Description	Pollutant	lb/MMBtu
Wood waste boiler, Stoker, 416 MMBtu/hr, ESP/VS	Acetaldehyde	1.96E-03
	Acetone	1.62E-04
	Acrolein	1.10E-03
	Barium	2.02E-05
	Benzene	6.48E-02
	Copper	7.81E-06
	Phosphorus	3.54E-05
	Styrene	1.86E-03
	Toluene	3.63E-03
	Zinc	6.19E-05

Reference: EPA AP-42, Section 1.6, Wood Waste Combustion, Background Data

Mead Paper Company, Escanaba, MI

Table A95 Boiler Code – PM - B79; Bark Boiler Burning 100% Wood-Bark

Fuel & Source Description	Pollutant	lb/MMBtu
Bark boiler, Stoker, Scrubber	Benzene	3.80E-04

Reference: EPA AP-42, Section 1.6, Wood Waste Combustion, Background Data

Mead Paper Company, Escanaba, MI

Table A96 Boiler Code – PM - WFB12; Bark Boiler Burning 100% Wood-Bark

Fuel & Source Description	Pollutant	lb/MMBtu
Bark boiler, Stoker, Scrubber	Carbon Tetrachloride	*9.20E-06*

Reference: EPA AP-42, Section 1.6, Wood Waste Combustion, Background Data

Mead Paper Company, Escanaba, MI

Table A97 Boiler Code – PM - WFB13; Bark Boiler Burning 100% Wood-Bark

Fuel & Source Description	Pollutant	lb/MMBtu
Bark boiler, Stoker, Scrubber	Carbon Tetrachloride	*6.00E-06*

Reference: EPA AP-42, Section 1.6, Wood Waste Combustion, Background Data

Mead Paper Company, Escanaba, MI

Table A98 Boiler Code – PM - WFB14; Bark Boiler Burning 100% Wood-Bark

Fuel & Source Description	Pollutant	lb/MMBtu
Bark boiler, Stoker, Scrubber	Carbon Tetrachloride	*5.90E-06*

Reference: EPA AP-42, Section 1.6, Wood Waste Combustion, Background Data

Mead Paper Company, Escanaba, MI

Table A99 Boiler Code – PM - WFB15; Bark Boiler Burning 100% Wood-Bark

Fuel & Source Description	Pollutant	lb/MMBtu
Bark boiler, Stoker, Scrubber	Carbon Tetrachloride	*6.20E-06*

Reference: EPA AP-42, Section 1.6, Wood Waste Combustion, Background Data.
Italicized entries denote NDs shown at detection levels.

Champion International, Sheldon, TX

Table A100 Boiler Code – PM - WFB16a; Bark Boiler Burning 100% Wood-Bark

Fuel & Source Description	Pollutant	lb/MMBtu
Spreader Stoker, 272 MMBtu/hr, Wet Scrubber	3-Carene	*2.60E-03*
	Acetaldehyde	*7.40E-04*
	Acetone	*3.70E-04*
	Acetophenone	3.68E-06
	Acrolein	*1.50E-03*
	alpha-Pinene	*1.50E-03*
	alpha-Terpineol	4.73E-06
	Benzaldehyde	*7.40E-04*
	Benzene	*1.50E-03*
	Benzoic Acid	3.74E-05
	beta-Pinene	*2.60E-03*
	Bromodichloromethane	*5.90E-03*
	Butylbenzylphthalate	ND
	Chloroform	*1.50E-03*
	Cumene	*2.20E-03*
	Diethylphthalate	*0.00E+00*
	Di-n-Butyl Phthalate	8.53E-06
	Ethanol	*7.40E-04*
	Ethyl Benzene	*1.80E-03*
	Isopropanol	*1.10E-03*
	m,p-Xylene	*1.80E-03*
	Methanol	1.48E-03
	Methyl Ethyl Ketone	*1.50E-03*
	Methyl Isobutyl Ketone	*1.10E-03*
	Naphthalene	7.85E-06
	o-Xylene	*1.80E-03*
	p-Cymene	*2.60E-03*
	Phenol	2.88E-06
	Toluene	*1.80E-03*
	Xylenes (mixed isomers)	*7.44E-04*

Reference: EPA AP-42, Section 1.6, Wood Waste Combustion, Background Data.
Italicized entries denote NDs shown at detection levels.

International Paper, Orange, TX

Table A101 Boiler Code – PM - WFB17; Bark Boiler Burning 100% Wood-Bark

Fuel & Source Description	Pollutant	lb/MMBtu
Spreader Stoker, 485 MMBtu/hr, Wet Scrubber	1,1,1-Trichloroethane	3.28E-06
	3-Carene	*2.30E-03*
	Acetaldehyde	7.80E-04
	Acetone	7.84E-05
	Acrolein	6.52E-05
	alpha-Pinene	8.36E-06
	Benzaldehyde	*9.60E-07*
	Benzene	2.11E-04
	Benzoic Acid	1.15E-04
	beta-Pinene	1.67E-06
	Bromodichloromethane	*ND*
	Butylbenzylphthalate	2.68E-05
	Carbon-Disulfide	1.25E-04
	Chloroform	4.70E-05
	Chloromethane	9.80E-05
	Cumene	1.77E-05
	Diethylphthalate	4.36E-05
	Dimethyl Sulfide	*0 ppb*
	Di-n-Butyl Phthalate	5.81E-05
	Ethanol	*9.00E-04*
	Ethyl Benzene	3.91E-06
	Isopropanol	*1.00E-03*
	m,p-Xylene	7.82E-06
	Methanol	1.23E-03
	Methyl Ethyl Ketone	1.15E-05
	Methylene Chloride	3.50E-04
	Naphthalene	2.25E-04
	n-Hexane	5.50E-04
	o-Xylene	2.61E-06
	p-Cymene	2.61E-06
	Styrene	1.54E-05
	Toluene	9.01E-05
	Xylenes (mixed isomers)	1.23E-05

Reference: EPA AP-42, Section 1.6, Wood Waste Combustion, Background Data.
Italicized entries denote NDs shown at detection levels.

International Paper, Bastrop, LA

Table A102 Boiler Code – PM - WFB18a; Bark Boiler Burning 100% Wood-Bark

Fuel & Source Description	Pollutant	lb/MMBtu
Spreader Stoker, 267 MMBtu/hr, Multiclone	Acetaldehyde	*7.40E-04*
	Acetone	*7.50E-04*
	Acetophenone	*1.50E-03*
	Acrolein	*7.50E-04*
	alpha-Pinene	*7.50E-04*
	alpha-Terpineol	*1.50E-03*
	Benzaldehyde	*1.10E-03*
	Benzene	1.02E-02
	beta-Pinene	*1.10E-03*
	Ethanol	*7.40E-04*
	Ethyl Benzene	*1.10E-03*
	Isopropanol	5.36E-03
	m,p-Xylene	*1.10E-03*
	Methyl Ethyl Ketone	*7.50E-04*
	Methyl Isobutyl Ketone	*1.10E-03*
	Toluene	*7.50E-04*

Reference: EPA AP-42, Section 1.6, Wood Waste Combustion, Background Data

International Paper, Bastrop, LA

Table A103 Boiler Code – PM - WFB19a; Bark Boiler Burning 100% Wood-Bark

Fuel & Source Description	Pollutant	lb/MMBtu
Spreader Stoker, 550 MMBtu/hr, ESP	Acetaldehyde	*5.40E-04*
	Acetone	*5.50E-04*
	Acetophenone	*1.30E-03*
	Acrolein	*5.50E-04*
	alpha-Pinene	*5.50E-04*
	alpha-Terpineol	*1.30E-03*
	Benzaldehyde	*1.10E-03*
	Benzene	*5.50E-04*
	beta-Pinene	6.55E-03
	Ethanol	1.69E-03
	Ethyl Benzene	*9.10E-04*
	Isopropanol	9.18E-03
	m,p-Xylene	*9.10E-04*
	Methyl Ethyl Ketone	*7.30E-04*
	Methyl Isobutyl Ketone	8.60E-04
	Toluene	*7.30E-04*

Reference: EPA AP-42, Section 1.6, Wood Waste Combustion, Background Data.
Italicized entries denote NDs shown at detection levels.

Weyerhaeuser Company, Longview, WA

Table A104 Boiler Code – PM - WFB20a; Bark Boiler Burning 100% Wood-Bark

Fuel & Source Description	Pollutant	lb/MMBtu
Spreader Stoker, 824 MMBtu/hr, Electroscrubber	1,1,1-Trichloroethane	1.67E-04
	Acetone	3.83E-04
	Benzene	9.85E-05
	Chloroform	2.55E-06
	Chloromethane	*1.60E-08*
	m,p-Xylene	2.79E-06
	Methyl Ethyl Ketone	4.85E-08
	Methylene Chloride	1.52E-03
	Naphthalene	*9.00E-04*
	Toluene	2.34E-05

Reference: EPA AP-42, Section 1.6, Wood Waste Combustion, Background Data.
Italicized entries denote NDs shown at detection levels.

Verso Paper Corporation, Quinnesec, MI

Table A105 Boiler Code – PM - WFB21; Bark Boiler Burning 100% Wood-Bark

Fuel & Source Description	Pollutant	lb/MMBtu
Spreader Stoker, 527 MMBtu/hr, ESP	1,1,2-Trichloroethane	*2.40E-04*
	1,2,4-Trichlorobenzene	*1.10E-04*
	Acetaldehyde	*5.35E-05*
	Acrolein	*1.00E-04*
	Benzene	2.27E-03
	Carbon Tetrachloride	*1.10E-03*
	Chlorobenzene	*6.80E-05*
	Chloroform	*8.70E-04*
	Methanol	*2.30E-04*
	Methyl Ethyl Ketone	*1.80E-05*
	Methyl Isobutyl Ketone	*6.10E-05*
	Methylene Chloride	*4.70E-04*
	n-Hexane	*5.20E-05*
	Styrene	*6.30E-05*
	Toluene	*5.60E-05*
	Trichloroethylene	*3.00E-04*
	Xylenes (mixed isomers)	*6.50E-05*

Reference: EPA AP-42, Section 1.6, Wood Waste Combustion, Background Data.
Italicized entries denote NDs shown at detection levels.

Roseburg Forest Products, Anderson, CA

Table A106 Boiler Code – WPM - B100; Bark Boiler Burning 100% Wood-Bark

Fuel & Source Description	Pollutant	lb/MMBtu
Sugar pine SD, ponderosa pine bark & SD - Dutch oven boiler, 45 KPPH, Wet Scrubber	2,4,6-Trichlorophenol	*1.26E-07*
	2,4-Dinitrophenol	*1.35E-06*
	2-Chlorophenol	*1.26E-07*
	2-Nitrophenol	9.71E-07
	4-Nitrophenol	*1.03E-06*
	Acetaldehyde	3.93E-05
	Benzene	9.95E-04
	Chromium^{+6}	*1.19E-05*
	Copper	3.12E-05
	Naphthalene	1.30E-04
	Pentachlorophenol	*2.52E-07*
	Phenol	3.05E-05
	Zinc	6.03E-04

Reference: EPA AP-42, Section 1.6, Wood Waste Combustion, Background Data.
Italicized entries denote NDs shown at detection levels.

Sierra Pacific, Burney, CA

Table A107 Boiler Code – WPM - B101; Bark Boiler Burning 100% Wood-Bark

Fuel & Source Description	Pollutant	lb/MMBtu
Hog fuel & chips of white fir, Douglas fir, Stoker, 200 KPPH, APCD - ESP	2,4,6-Trichlorophenol	*2.45E-08*
	2,4-Dinitrophenol	*1.64E-07*
	2-Chlorophenol	5.70E-08
	2-Nitrophenol	*4.04E-07*
	4-Nitrophenol	2.90E-07
	Acetaldehyde	6.17E-04
	Benzene	1.61E-03
	Chromium^{+6}	*5.00E-06*
	Copper	5.02E-06
	Naphthalene	2.82E-04
	Pentachlorophenol	*4.89E-08*
	Phenol	2.43E-05
	Zinc	3.80E-05

Reference: EPA AP-42, Section 1.6, Wood Waste Combustion, Background Data.
Italicized entries denote NDs shown at detection levels.

Webster Industries, Inc., Bangor, WI

Table A108 Boiler Code – WPM - B128; Bark Boiler Burning 100% Wood-Bark

Fuel & Source Description	Pollutant	lb/MMBtu
WFB, 25 KPPH, Multiclone	Copper	4.65E-05
	Zinc	1.27E-04

Reference: EPA AP-42, Section 1.6, Wood Waste Combustion, Background Data

Wood Ecology, Inc., Eau Claire, WI

Table A109 Boiler Code – WPM - B137; Bark Boiler Burning 100% Wood-Bark

Fuel & Source Description	Pollutant	lb/MMBtu
Wood-fired Boiler - Hogged Pallets, 7.9 MMBtu/hr, Multiclones	Copper	1.02E-04

Reference: EPA AP-42, Section 1.6, Wood Waste Combustion, Background Data

Big Valley Lumber Company, Bieber, CA

Table A110 Boiler Code – WPM - B14; Bark Boiler Burning 100% Wood-Bark

Fuel & Source Description	Pollutant	lb/MMBtu
Pine and Fir Hog fuel - Hog Fuel Stoker, 60 KPPH, Multiclones	2,4,6-Trichlorophenol	*2.32E-08*
	2,4-Dinitrophenol	*2.64E-07*
	2-Chlorophenol	*2.32E-08*
	2-Nitrophenol	*2.32E-08*
	4-Nitrophenol	*1.16E-07*
	Acetaldehyde	2.37E-04
	Benzene	2.91E-05
	Copper	3.83E-05
	Pentachlorophenol	*4.64E-08*
	Phenol	3.37E-07
	Zinc	2.94E-04

Reference: EPA AP-42, Section 1.6, Wood Waste Combustion, Background Data
Italicized entries denote NDs shown at detection levels.

Birchwood Lumber & Veneer, Birchwood, WI

Table A111 Boiler Code – WPM - B15; Bark Boiler Burning 100% Wood-Bark

Fuel & Source Description	Pollutant	lb/MMBtu
SD/sanderdust mixture (red oak & some aspen) - Suspension Burner, 400 HP, Cyclone	Acetaldehyde	1.67E-05
	Acetophenone	3.23E-09
	Benzoic Acid	4.68E-08
	Bis(2-ethylhexyl)phthalate	4.65E-08
	Copper	1.00E-07
	Naphthalene	5.95E-08
	Phenol	3.12E-09
	Zinc	2.11E-06

Reference: EPA AP-42, Section 1.6, Wood Waste Combustion, Background Data

Birchwood Lumber & Veneer, Birchwood, WI

Table A112 Boiler Code – WPM - B16; Bark Boiler Burning 100% Wood-Bark

Fuel & Source Description	Pollutant	lb/MMBtu
Sawdust/sanderdust - Auger stoker fired; Suspension Burner, 100 HP, APCD - None	Acetaldehyde	2.89E-04

Reference: EPA AP-42, Section 1.6, Wood Waste Combustion, Background Data

Bohemia, Inc., Rocklin, CA

Table A113 Boiler Code – WPM - B19; Bark Boiler Burning 100% Wood-Bark

Fuel & Source Description	Pollutant	lb/MMBtu
Pine sanderdust - Wood-fired Suspension Burner, 62 KPPH, Multiclone	Acetaldehyde	*1.56E-05*
	Benzene	2.90E-03
	$Chromium^{+6}$	6.61E-06
	Copper	3.00E-05
	Zinc	2.79E-04

Reference: EPA AP-42, Section 1.6, Wood Waste Combustion, Background Data.
Italicized entries denote NDs shown at detection levels.

Catalyst Hudson, Anderson, CA

Table A114 Boiler Code – WPM - B26; Bark Boiler Burning 100% Wood-Bark

Fuel & Source Description	Pollutant	lb/MMBtu
Pine and Cedar hog fuel - Hogged wood waste boiler, Stoker, 90 KPPH, Wet Scrubber	2,4,6-Trichlorophenol	*2.24E-08*
	2,4-Dinitrophenol	4.03E-07
	2-Chlorophenol	*2.97E-08*
	2-Nitrophenol	*4.21E-08*
	4-Nitrophenol	*1.12E-07*
	Acetaldehyde	1.59E-04
	Benzene	2.72E-04
	Copper	1.60E-05
	Naphthalene	3.06E-04
	Pentachlorophenol	*4.48E-08*
	Phenol	3.98E-05

Reference: EPA AP-42, Section 1.6, Wood Waste Combustion, Background Data
Italicized entries denote NDs shown at detection levels.

Georgia Pacific, Fort Bragg, CA

Table A115 Boiler Code – WPM - B45; Bark Boiler Burning 100% Wood-Bark

Fuel & Source Description	Pollutant	lb/MMBtu
Redwood bark - WFB, Stoker, 140 KPPH, Wet Scrubber	Acetaldehyde	2.34E-04
	Benzene	4.23E-03
	Copper	2.78E-11
	Naphthalene	1.86E-04
	Zinc	3.11E-10

Reference: EPA AP-42, Section 1.6, Wood Waste Combustion, Background Data

Georgia Pacific Corporation, Phillips, WI

Table A116 Boiler Code – WPM - B50; Bark Boiler Burning 100% Wood-Bark

Fuel & Source Description	Pollutant	lb/MMBtu
Wet Wood - FBC, APCD - Multiclone	Acetaldehyde	1.22E-04
	Acetone	2.15E-04
	Acrolein	2.30E-02
	Benzene	3.92E-05
	Bromomethane	2.38E-06
	Chloromethane	2.31E-05
	Methyl Ethyl Ketone	5.39E-06
	Propionaldehyde	6.11E-05
	Toluene	2.48E-06

Reference: EPA AP-42, Section 1.6, Wood Waste Combustion, Background Data

Louisiana Pacific Waferboard, Tomahawk, WI

Table A117 Boiler Code – WPM - B74; Bark Boiler Burning 100% Wood-Bark

Fuel & Source Description	Pollutant	lb/MMBtu
Wood/bark- Ram stoker, 30 MMBtu/hr, FF	Benzene	*1.13E-04*
	Phenol	*2.41E-03*

Reference: EPA AP-42, Section 1.6, Wood Waste Combustion, Background Data.
Italicized entries denote NDs shown at detection levels.

Miller Redwood Company, Crescent City, CA

Table A118 Boiler Code – WPM - B81; Bark Boiler Burning 100% Wood-Bark

Fuel & Source Description	Pollutant	lb/MMBtu
Redwood and fir sawdust - Wellons fuel cell, 20 KPPH, APCD - NA	Acetaldehyde	5.23E-04
	Benzene	*4.25E-05*
	$Chromium^{+6}$	*3.10E-04*
	Copper	1.11E-04
	Naphthalene	4.87E-04
	Zinc	2.20E-04

Reference: EPA AP-42, Section 1.6, Wood Waste Combustion, Background Data.
Italicized entries denote NDs shown at detection levels.

Pacific Lumber Company, Scotia, CA

Table A119 Boiler Code – WPM - B91; Bark Boiler Burning 100% Wood-Bark

Fuel & Source Description	Pollutant	lb/MMBtu
Hog fuel - redwood and fir bark - WFB Stoker, 150 KPPH, ESP	Acetaldehyde	5.93E-05
	Benzene	6.66E-04
	$Chromium^{+6}$	*7.48E-06*
	Copper	2.82E-06
	Naphthalene	*1.00E-03*
	Zinc	4.38E-05

Reference: EPA AP-42, Section 1.6, Wood Waste Combustion, Background Data.
Italicized entries denote NDs shown at detection levels.

Pacific Lumber Company, Scotia, CA

Table A120 Boiler Code – WPM – B92; Bark Boiler Burning 100% Wood-Bark

Fuel & Source Description	Pollutant	lb/MMBtu
Redwood & fir - Traveling grate, spreader stoker, 450 KPPH, ESP[1]	Acetaldehyde	5.01E-05
	Benzene	5.70E-04

Reference: EPA AP-42, Section 1.6, Wood Waste Combustion, Background Data.
[1]This plant had 3 identical boilers rated at 150 KPPH ducted to a common ESP.

Roseburg Forest Products, Weed, CA

Table A121 Boiler Code – WPM - B99; Bark Boiler Burning 100% Wood-Bark

Fuel & Source Description	Pollutant	lb/MMBtu
Hog-wood (pine & fir) - Dutch type oven, 80 KPPH, ESP	Acetaldehyde	2.33E-04
	Benzene	1.54E-05
	Chromium^{+6}	7.33E-06
	Copper	1.35E-04
	Naphthalene	*1.13E-08*
	Zinc	1.18E-03

Reference: EPA AP-42, Section 1.6, Wood Waste Combustion, Background Data.
Italicized entries denote NDs shown at detection levels.

Temple-Inland, Pembroke, Ontario

Table A122 Boiler Code – WPM - WFB22; Bark Boiler Burning 100% Wood-Bark

Fuel & Source Description	Pollutant	lb/MMBtu
Spreader Stoker, 137-172 MMBut/hr, ESP	Methanol	4.86E-04
	Naphthalene	8.13E-06
	Phenol	5.29E-04

Reference: EPA AP-42, Section 1.6, Wood Waste Combustion, Background Data

REFERENCES

National Council for Air and Stream Improvement, Inc. (NCASI). 2004. *Compilation of criteria air pollutant emissions data for sources at pulp and paper mills including boilers.* Technical Bulletin No. 884. Research Triangle Park, NC: National Council for Air and Stream Improvement, Inc.

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APPENDIX B

DETAILED PM, $PM_{2.5}$ AND CPM DATA FOR WOOD-FIRED BOILERS

Table B1 provides the details of results for $PM_{2.5}$ test runs performed concurrently with filterable PM and/or condensable PM. ADL designated lab results are above the detection limit of the stack test Method (1.35 mg for $PM_{2.5}$ by method 201A, 2mg for FPM by Method 5, and 4mg for CPM by Method 202). ND designated lab results below those detection limits. Each run also included a designation of whether or not that value met the Practical Limit of Quantitation (PLQ), which is three times the detection limit for each method. The actual mass measured by the lab (lab catch) for each fraction is also included.

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Table B1 Results of Analyses for $PM_{2.5}$, Filterable PM and Condensable PM Data For Wood-Fired Boilers

Boiler Code	Sampling Date	PM 2.5 Run	PM2.5 (gr/dscf)	DL (1.35mg)	PLQ (4.05 mg)	PM2.5 lab catch (mg)	PM Filter-able Run	PM Filterable (gr/dscf)	DL (2mg)	PLQ (6mg)	Filterable PM lab catch (mg)	CPM Run	CPM (gr/dscf)	DL (4mg)	PLQ (12mg)	CPM lab catch (mg)
PM - BB16	04-Aug-09	A1	3.72E-03	ADL		15.1	A1	2.31E-02	ADL		245	A1	6.71E-03	ADL		27.2
PM - BB16	04-Aug-09	A2	4.71E-03	ADL		17	A2	2.56E-02	ADL		252.1	A2	4.57E-03	ADL		16.5
PM - BB16	05-Aug-09	A3	3.12E-03	ADL		12.4	A3	1.56E-02	ADL		161.2	A3	1.53E-02	ADL		61
WPM - BB24	01-Sep-09	A1	2.66E-02	ADL		112	A1	6.29E-02	ADL		612.4	A1	3.67E-03	ADL		15.4
WPM - BB24	01-Sep-09	A2	2.77E-02	ADL		115	A2	5.60E-02	ADL		537.7	A2	3.02E-03	ADL		12.5
WPM - BB24	02-Sep-09	A3	3.32E-02	ADL		142	A3	5.80E-02	ADL		540	A3	3.26E-03	ADL		13.9
PM - BB17	18-Nov-09	A1	4.30E-04	ADL	<PLQ	2.2	A1	2.23E-03	ADL		15	A1	9.11E-03	ADL		46.57
PM - BB17	19-Nov-09	A2	5.44E-05	ND	<PLQ	0.3	A2	1.30E-03	ADL		9.3	A2	1.60E-02	ADL		88.35
PM - BB17	19-Nov-09	A3	1.97E-04	ND	<PLQ	1	A3	1.11E-03	ADL		10.2	A3	2.93E-02	ADL		148.5
PM - BB18	15-Sep-09	A1	4.47E-03	ADL		18.8	A1	1.07E-01	ADL		1125.1	A1	2.57E-03	ADL		108
PM - BB18	15-Sep-09	A2	2.71E-03	ADL		11.1	A2	2.65E-02	ADL		276.2	A2	2.37E-03	ADL	< PLQ	9.7
PM - BB18	16-Sep-09	A3	1.75E-03	ADL		7.5	A3	6.40E-03	ADL		67.7	A3	1.70E-03	ADL	< PLQ	7.3
PM - BB1	14-Jul-09	C1	3.98E-04	ADL	<PLQ	1.5	A1	9.98E-04	ADL		9.2	C1	1.83E-03	ADL	< PLQ	6.9
PM - BB1	14-Jul-09	C2	6.63E-04	ADL	<PLQ	2.4	A2	1.14E-03	ADL		10	C2	2.16E-03	ADL	< PLQ	7.8
PM - BB1	14-Jul-09	C3	3.06E-04	ND	<PLQ	1.1	A3	8.63E-04	ADL		8.2	C3	1.64E-03	ADL	< PLQ	5.9
PM - BB24	05-Aug-09	A1	9.64E-05	ND	<PLQ	0.5	A1	2.76E-03	ADL		20.5	A1	4.44E-03	ADL		23.4
PM - BB24	06-Aug-09	A2	3.72E-04	ADL	<PLQ	1.9	A2	3.26E-03	ADL		26.8	A2	5.32E-03	ADL		27.3
PM - BB24	06-Aug-09	A3	2.21E-04	ND	<PLQ	1.1	A3	1.44E-03	ADL		11.3	A3	3.29E-03	ADL		16.8
WPM - BB30	11-Aug-09	C1	2.20E-04	ND	<PLQ	1	A1	9.74E-04	ADL		9.9	C1	1.14E-02	ADL		55.39
WPM - BB30	12-Aug-09	C2	1.31E-03	DLL		6.5	A2	1.00E-05	ND	<PLQ	0.1	C2	6.72E-03	ADL		33.15
WPM - BB30	12-Aug-09	C3	6.19E-05	ND	<PLQ	0.2	A3	5.60E-04	ADL	<PLQ	5.8	C3	1.51E-03	ADL	< PLQ	7.137
PM - BB25	19-Aug-09	A1	2.80E-04	ADL	<PLQ	1.57	A1	6.70E-04	ADL		6.4	A1	1.38E-03	ADL	< PLQ	7.72
PM - BB25	20-Aug-09	A2	2.25E-04	ND	<PLQ	1.17	A2	7.28E-04	ADL		6.9	A2	1.47E-03	ADL	< PLQ	7.65
PM - BB25	20-Aug-09	A3	4.91E-04	ADL	<PLQ	2.54	A3	4.61E-04	ADL	<PLQ	4.3	A3	1.42E-03	ADL	< PLQ	7.34

Table B1 Continued

Boiler Code	Sampling Date	PM 2.5 Run	PM2.5 (gr/dscf)	DL (1.35mg)	PLQ (4.05 mg)	PM2.5 lab catch (mg)	PM Filter-able Run	PM Filterable (gr/dscf)	DL (2mg)	PLQ (6mg)	Filterable PM lab catch (mg)	CPM Run	CPM (gr/dscf)	DL (4mg)	PLQ (12mg)	CPM lab catch (mg)
WPM - BB23	28-Jul-09	C1	4.67E-04	ADL	<PLQ	2.5	C1	7.77E-04	ADL		8.03	C1	8.14E-04	ADL	< PLQ	4.36
WPM - BB23	28-Jul-09	C2	1.17E-04	ND	<PLQ	0.7	C2	5.34E-04	ADL	<PLQ	5.91	C2	9.38E-04	ADL	< PLQ	5.6
WPM - BB23	29-Jul-09	C3	4.34E-04	ADL	<PLQ	2.1	C3	6.44E-04	ADL		6.72	C3	7.44E-04	ND	< PLQ	3.6
WPM - BB25	09-Sep-09	A1	1.37E-02	ADL		64.5	A1	1.86E-02	ADL		246.2	A1	1.87E-03	ADL	< PLQ	8.8
WPM - BB25	09-Sep-09	A2	1.50E-03	ADL		6.7	A2	2.80E-03	ADL		38.8	A2	2.24E-04	ND	< PLQ	1
WPM - BB25	10-Sep-09	A3	8.54E-04	ADL		4.2	A3	1.95E-03	ADL		27	A3	1.30E-03	ADL	< PLQ	6.4
WPM - BB38	05-Aug-09	A1	2.09E-03	ADL		8.2	A1	3.36E-03	ADL		37.3	A1	2.47E-03	ADL	< PLQ	9.7
WPM - BB38	05-Aug-09	A2	2.48E-03	ADL		8.5	A2	4.07E-03	ADL		46.5	A2	2.75E-03	ADL	< PLQ	9.4
WPM - BB38	05-Aug-09	A3	1.66E-03	ADL		5.9	A3	2.07E-03	ADL		23.4	A3	2.93E-03	ADL	< PLQ	10.4
WPM - BB20	22-Jul-09	A1	8.00E-04	ADL		5.1	A1	1.35E-03	ADL		17	A1	4.09E-03	ADL		26.1
WPM - BB20	23-Jul-09	A2	6.15E-04	ADL	<PLQ	3	A2	1.64E-03	ADL		19	A2	3.93E-03	ADL		19.2
WPM - BB20	23-Jul-09	A3	5.90E-04	ADL	<PLQ	3.1	A3	1.75E-03	ADL		20	A3	5.46E-03	ADL		28.7
WPM - BB21	11-Aug-09	A1	2.69E-04	ADL	<PLQ	1.37	A1	4.63E-04	DLL	<PLQ	4.62	A1	5.49E-04	ND	< PLQ	2.79
WPM - BB21	11-Aug-09	A2	1.76E-04	ND	<PLQ	0.99	A2	5.94E-04	ADL		6.26	A2	6.05E-04	ND	< PLQ	3.4
WPM - BB21	12-Aug-09	A3	1.88E-04	ND	<PLQ	1.03	A3	1.96E-04	DLL	<PLQ	2.06	A3	1.10E-03	ADL	< PLQ	6.02
WPM - BB26	04-Aug-09	A1	6.46E-02	ADL		106	A1	9.72E-02	ADL		830.18	A1	1.11E-02	ADL		18.15
WPM - BB26	04-Aug-09	A2	5.32E-02	ADL		115	A2	1.00E-01	ADL		843.18	A2	8.62E-03	ADL		18.59
WPM - BB26	05-Aug-09	A3	6.35E-02	ADL		131	A3	1.15E-01	ADL		948.68	A3	7.81E-03	ADL		16.17
PM - BB4	27-Jul-09	C1	2.40E-03	ADL		9.8	A1	4.00E-03	ADL		36.7	C1	3.70E-03	ADL		15.1
PM - BB4	28-Jul-09	C2	2.34E-03	ADL		8.9	A2	3.63E-03	ADL		35	C2	9.07E-03	ADL		34.48
PM - BB4	28-Jul-09	C3	3.53E-03	ADL		14.2	A3	2.90E-03	ADL		28.9	C3	2.63E-03	ADL		10.57