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Dear John and Katie,

This letter and accompanying technical paper are follow-ups to our conversation on June 29, 2018 about the appropriateness of using dioxin/furan and polycyclic organic matter (POM) emission factors for wood-fired boilers to estimate emissions from direct-fired dryers and lumber kilns.

As discussed during our conversation, the combustion conditions in direct-fired dryers and lumber kilns are unlike those in wood-fired boilers as these wood-products sources fire wood particles like sander dust in suspension. More details on the implications of formation of products of incomplete combustion (PICs) (long-chain organic intermediates within the combustion zone) – the precursors for dioxin/furan and POM formation – are provided in the attached technical paper, prepared by Dr. Arun Someshwar, with support from Messrs. Rob Crawford and Ric Law.

Please do not hesitate to contact me if you have additional questions on this information.

Sincerely,



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Applicability of Dioxin/Furan and POM Emissions Data for Industrial Biomass Boilers to Direct-Fired Wood Products Dryers and Lumber Kilns

NCASI was recently made aware that a few of the responses to EPA's Information Collection Request (ICR) for the wood products industry, in conjunction with the ongoing PCWP MACT II and RTR process, included emissions estimates for dioxin/furan and polycyclic organic matter (POM) from direct wood-fired process units, such as rotary dryers and lumber kilns. We also understand that, in most of these ICR responses, these emission rates were estimated from test data for wood-fired or natural gas-fired boilers reported in NCASI Technical Bulletins and databases. As explained in the discussion below, NCASI believes these emission factors are not applicable for the estimation of dioxin/furan and POM emissions from process equipment in the wood products industry.

Dioxin Formation and Emission from Direct-Fired Dryers and Lumber Kilns

Polychlorinated dibenzo-p-dioxins (PCDDs) and polychlorinated dibenzofurans (PCDFs), collectively known as dioxins, are formed in minor quantities and emitted from industrial wood-fired boilers. For most, if not all, of the cases where dioxins were reported on the ICR, the congener-specific PCDD/F emissions rates were derived from tests on 31 wood-fired boilers that principally burned wood residues. These test results are summarized in NCASI Technical Bulletin No. 1013 (NCASI 2013).

There is a vast amount of published literature dealing with the mechanisms of dioxin/furan formation in thermal and combustion operations. For example, the paper by Huang and Buekens (1995) "On the mechanism of dioxin formation in combustion processes" and another by Altarawneh et al. (2009) "Mechanisms for formation, chlorination, de-chlorination and destruction of polychlorinated dibenzo-p-dioxins and dibenzofurans (PCDD/Fs)" provide excellent reviews on this subject. The gist of the current understanding is that there are two principal pathways through which dioxins can be formed and emitted from industrial boilers: ***precursor formation and de novo synthesis***. Precursor formation is relevant in cases where the fuels used for combustion contain significant levels of organic compounds which would be considered precursors for dioxin formation in the boiler combustion zone. This pathway is generally discounted as being largely irrelevant today because fuels tend to undergo increased scrutiny relative to contaminants, such as those which could potentially be dioxin precursors. The de novo synthesis pathway is operative in the low temperature post-combustion zones of boilers/incinerators, typically in the range of 250 to 400°C. It involves heterogeneous catalytic reactions in the flue gas - fly ash environment. It is generally agreed upon today that dioxin formation in industrial boilers is predominantly a "post-combustion" phenomenon through the de novo synthesis pathway. The reactions involve a catalytic surface (typically fly ash), products of incomplete combustion (PICs) and chlorine atoms, all within the temperature zone of 250 to 400°C. Here, the PICs refer to long chain hydrocarbon byproducts (including phenols and benzenes) that get chlorinated by Cl atoms in the post-combustion zone, thus becoming available as chlorophenols and chlorobenzenes for dioxin formation in the post economizer temperature zone of 250 to 400°C.

These prerequisite conditions, i.e., a requisite temperature zone and the concurrent presence of PICs along with adequate levels of atomic chlorine, are not prevalent in direct-fired

dryers or lumber kilns in the wood products industry. The types of wood residues, and the manner in which they are fired to generate hot flue gases for drying wood chips or lumber, differ from the combustion of wood residues on grates in most industrial boilers. These differences are expected to result in much lower levels of PIC formation in direct-fired dryers and lumber kilns than in industrial boilers.

Most direct-fired dryers are heated by 100% suspension burners that combust very fine, dry wood particles, such as sander dust. This type of burner is designed to rapidly combust the fuel to completion. The rapid combustion, along with the resulting high temperatures, is expected to produce drastically lower levels of PICs (the precursors for PCDD/F formation) than the combustion of wet fuel on the grates of industrial boilers.

For direct-fired lumber kilns, the heat source is typically a gasifier-type burner that has a 2-stage combustion process. The first stage heats green saw dust to generate an organic rich gas stream under low oxygen conditions. In the second stage, the organic rich gas is completely burned under excess oxygen conditions to generate hot air temperatures around 1100°C (2000°F). This combustion process is expected to also generate essentially zero PICs.

Another distinction in direct-fired dryers and lumber kilns is that, even if PICs were formed during combustion, there is limited potential for PCDD/F formation through the de novo synthesis pathway. In both process unit types, the amount of time that post-combustion gases spend in the range of 250°C to 400°C is minimal in comparison to boilers. The green (wet) wood chips in rotary dryers quickly absorb the heat from combustion gases, and overall temperature decreases rapidly due to evaporative cooling as the chips are dried. In direct-fired lumber kilns, the heat associated with the combustion gases is rapidly quenched in the blend chamber where the combustion gases are mixed with wet, relatively cool air (about 75°C) recirculated from the lumber kiln, which brings the temperature of the combined gases down to about 150°C before they are routed into the kiln.

A final point to consider is that most of the PCDD/F emissions data from the wood-fired boiler tests summarized in NCASI Technical Bulletin No. 1013 have been shown to be of questionable accuracy. In the context of developing PCDD/F emission limits from industrial boilers (Boiler MACT), NCASI has previously established that most of the PCDD/F data generated using EPA Method 23, are below applicable practical quantitation limits (PQL). EPA decided not to promulgate PCDD/F limits on industrial boilers due to this reason, instead finalizing a work practice standard.

PAH/PAC/POM Formation & Emission from Direct-fired Dryers and Lumber Kilns

Polycyclic organic matter (POM) emission rates were also reported for some direct wood-fired dryers and lumber kilns in the responses to EPA's ICR. These emission estimates were primarily derived from test data available for several wood-fired boilers in the background document for Section 1.6 of AP-42 and summarized in Table 4.5 of NCASI Technical Bulletin No. 1013 (NCASI 2013).

POM is composed of compounds which are inadvertently manufactured and emitted during combustion of wood, or fossil fuels, in industrial boilers. The formation of POM is the result of

combustion of carbonaceous material, either under reducing conditions or suboptimal combustion conditions, once again resulting in the formation of products of incomplete combustion (PICs). The presence of POM in flue gases emitted to the atmosphere is related to the generation of PICs during combustion of the fuel that generates the hot flue gases. As described above in the discussion related to dioxins, the level of PICs in hot flue gases are expected to be much less for direct-fired dryers (suspension burners, rapid, complete combustion) and direct-fired lumber kilns (organic rich stream burned in a high oxygen environment) than for industrial grate-fired biomass boilers. Thus, the level POM emissions are expected to be much smaller for direct-fired dryers and lumber kilns when compared to those from industrial boilers. NCASI has very limited POM data for direct-fired units at particleboard, hardboard and OSB plants – majority of the data are non-detects (to the extent POMs were detected, the data typically come from limited testing at one facility).

POM emissions were also reported in EPA's ICR for some direct natural gas-fired process units such as plywood veneer dryers, and for some natural gas-fired thermal oxidizers used as pollution control devices, e.g., regenerative thermal oxidizers (RTOs) and regenerative catalytic oxidizers (RCOs). In most of these cases, the reported emissions were derived from emission factors for natural gas-fired boilers in AP-42 (EPA 1995). The natural gas emission factors for POMs given in AP-42 are dated and of questionable quality. Also, it is inappropriate to apply these factors to natural gas combustion in thermal oxidizers which are designed to destroy VOCs, including POM.

For the above stated reasons, it is our assessment that PCDD/F and POM emission factors for boilers firing wood residues are inappropriate for estimating PCDD/F and POM emissions from direct-fired process units in the wood products industry.

References

National Council for Air and Stream Improvement, Inc. (NCASI). 2013. *A comprehensive compilation and review of wood-fired boiler emissions*. Technical Bulletin No. 1013. Research Triangle Park, NC: National Council for Air and Stream Improvement, Inc.

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Huang, H. and Buekens, A. (1995). 1995. *On the mechanism of dioxin formation in combustion processes*. Chemosphere. Vol. 31, No. 9. pp. 4099-4117.

Altarawneh, M., Dlugogorski, B. Z., Kennedy, E.M., Mackie, J. C. 2009. *Mechanisms for formation, chlorination, dechlorination and destruction of polychlorinated dibenzo-p-dioxins and dibenzofurans (PCDD/Fs)*; Progress in Energy and Combustion Science 35 245–274.