US EPA‘s Air Toxics Standards (Status 2011)

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VDI Fachkonferenz
“Messung und Minderung von Quecksilber-Emissionen”
April 13 - 14, 2011, Düsseldorf
Agenda

• Links to the NESHAP (National Emission Standards for Hazardous Air Pollutants)
  • Portland Cement MACT (final since September 9, 2010)
  • Industrial Boiler MACT (final since March 21, 2011)
  • Utility MACT (draft proposal, still open for discussion until May 16, 2011)
  • Activated Carbon Injection (ACI) and Boiler Chemical Addition (BCA)
• Conclusion
National Emission Standards for Hazardous Air Pollutants NESHAP

All information on the final Portland Cement MACT is at
http://www.epa.gov/ttn/atw/pcem/pcempg.html

All information on the final Industrial Boiler MACT is at
http://www.epa.gov/ttn/atw/boiler/boilerpg.html

And all information on the development of the Utility MACT, as drafted and proposed on March 16th, 2011, is at
http://www.epa.gov/ttn/atw/utility/utiltypg.html
The States are adopting International Units (metric system) - but only „inch by inch“.

Some US-American Abbreviations, Indices and Units related to MACT = Maximum Achievable Control Technologies

MACT = BAT (or BACT) Best Available (Control) Techniques ? *)

*) US terminology: MACT (Maximum Achievable control technology) applies to hazardous air pollutants (189 species) and for both new and existing sources as well as attainment and non-attainment areas. BACT (Best Available control technology) applies to all other pollutants except HAPs and only in attainment areas.

M = 10^3 (thousand), MM = 10^6 (million), T = 10^12 (trillion)

a = actual, d = dry, w = weight, v = volume, hour = h

But also kW, MW, GW and kWh, MWh, GWh as elsewhere

Btu = British thermal unit = 1.055 kilojoule
TBtu = 293.11 GWh (thermal)

U.S. liquid gallon is defined as 231 cubic inches and is equal to 3.7854 litres

dscf = dry standard cubic foot = 0.028 dscm
dscm = dry standard cubic meter

standard temperature in USA (NIST): 68 °F = 20 °C = 293.15 K
Standard temperature in Europe (IUPAC) : 0 °C = 273.15 K = 32 °F

lb = pound = 0.4536 kg; gr = grain = 0.065 gram
Tonne = metric ton = 1000 kg = 2,204.623 lb
ton = short ton = 2000 lb = 907.185 kg, long ton = 2,240 pounds = 1,016.047 kg
tpy = short tons per year
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• Conclusion
Preheater Kiln

- Modern cement kilns use preheaters (and precalciner – not shown) to achieve good energy efficiency

- Flue gas passes through mill (Raw Mill On-Line) most of the time
- Cement Kiln Dust (CKD) usually recycled back into feed

Salonit Anhovo (Slovenia) tried already in 2005 to measure mercury mass flow rates within the plant (see next slide)

Source: Tanja L. Ljubic Mlakar et al.: „The role of fuels in mercury mass flows and cycling processes in the process of cement clinker production“, MEC 6, April 22-24, 2009, Lubljana
Evaluation of measurements from January 2005 until June 2006

Source: Tanja L. Ljubic Mlakar et al.: „The role of fuels in mercury mass flows and cycling processes in the process of cement clinker production“, MEC 6, April 22-24, 2009, Lubljan
# Portland Cement MACT

**lb/MM tons clinker // µg/dscm @ NA % O₂ // ng TEQ/dscm**

## Table 1—Emissions Limits for Kilns (Rows 1–8), Clinker Coolers (Rows 9–12), Raw Material Dryers (Rows 13–15), Raw and Finish Mills (Row 16)

<table>
<thead>
<tr>
<th>Source Type</th>
<th>Operating Mode</th>
<th>Location</th>
<th>Emissions Limit</th>
<th>Units of Emissions Limit</th>
<th>Oxygen Correction Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Existing kiln</td>
<td>Normal operation</td>
<td>At a major or area source</td>
<td>PM—0.04</td>
<td>lb/ton clinker</td>
<td>NA</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>D/F—0.2¹</td>
<td>ng/dscm (TEQ)</td>
<td>7 percent</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Mercury—55</td>
<td>lb/MM tons clinker</td>
<td>NA</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>THC—24²</td>
<td>ppmvd</td>
<td>7 percent</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>HCl—3</td>
<td>ppmvd</td>
<td>7 percent</td>
</tr>
<tr>
<td>2. Existing kiln</td>
<td>Startup and shutdown</td>
<td>At a major or area source</td>
<td>PM—0.004</td>
<td>gr/dscf</td>
<td>NA</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>D/F—0.2¹</td>
<td>ng/dscm (TEQ)</td>
<td>NA</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Mercury—10</td>
<td>ug/dscm</td>
<td>NA</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>THC—24²</td>
<td>ppmvd</td>
<td>NA</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>HCl—3⁴</td>
<td>ppmvd</td>
<td>NA</td>
</tr>
<tr>
<td>3. Existing kiln</td>
<td>Startup and shutdown</td>
<td>At a major or area source</td>
<td>PM—0.01</td>
<td>lb/ton clinker</td>
<td>NA</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>D/F—0.2¹</td>
<td>ng/dscm (TEQ)</td>
<td>7 percent</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Mercury—21</td>
<td>lb/MM tons clinker</td>
<td>NA</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>THC—24²</td>
<td>ppmvd</td>
<td>7 percent</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>HCl—3⁴</td>
<td>ppmvd</td>
<td>7 percent</td>
</tr>
<tr>
<td>4. Existing kiln</td>
<td>Startup and shutdown</td>
<td>At a major or area source</td>
<td>PM—0.0008</td>
<td>gr/dscf</td>
<td>NA</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>D/F—0.2¹</td>
<td>ng/dscm (TEQ)</td>
<td>NA</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Mercury</td>
<td>ug/dscm</td>
<td>NA</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>THC—24²</td>
<td>ppmvd</td>
<td>NA</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>HCl—3</td>
<td>ppmvd</td>
<td>NA</td>
</tr>
<tr>
<td>5. New kiln</td>
<td>Normal operation</td>
<td>At a major or area source</td>
<td>PM—0.02</td>
<td>lb/ton clinker</td>
<td>NA</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>D/F—0.2¹</td>
<td>ng/dscm (TEQ)</td>
<td>7 percent</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Mercury—21</td>
<td>lb/MM tons clinker</td>
<td>NA</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>THC—24²</td>
<td>ppmvd</td>
<td>7 percent</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>HCl—3⁴</td>
<td>ppmvd</td>
<td>7 percent</td>
</tr>
<tr>
<td>6. New kiln</td>
<td>Normal operation</td>
<td>At a major or area source</td>
<td>PM—0.008</td>
<td>gr/dscf</td>
<td>NA</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>D/F—0.2¹</td>
<td>ng/dscm (TEQ)</td>
<td>NA</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Mercury</td>
<td>ug/dscm</td>
<td>NA</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>THC—24²</td>
<td>ppmvd</td>
<td>NA</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>HCl—3</td>
<td>ppmvd</td>
<td>NA</td>
</tr>
<tr>
<td>7. New kiln</td>
<td>Startup or shutdown</td>
<td>At a major or area source</td>
<td>PM—0.02</td>
<td>lb/ton clinker</td>
<td>NA</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>D/F—0.2¹</td>
<td>ng/dscm (TEQ)</td>
<td>7 percent</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Mercury—21</td>
<td>lb/MM tons clinker</td>
<td>NA</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>THC—24²</td>
<td>ppmvd</td>
<td>7 percent</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>HCl—3⁴</td>
<td>ppmvd</td>
<td>7 percent</td>
</tr>
<tr>
<td>8. New kiln</td>
<td>Startup and shutdown</td>
<td>At a major or area source</td>
<td>PM—0.02</td>
<td>lb/ton clinker</td>
<td>NA</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>D/F—0.2¹</td>
<td>ng/dscm (TEQ)</td>
<td>7 percent</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Mercury—21</td>
<td>lb/MM tons clinker</td>
<td>NA</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>THC—24²</td>
<td>ppmvd</td>
<td>7 percent</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>HCl—3</td>
<td>ppmvd</td>
<td>NA</td>
</tr>
</tbody>
</table>

¹ If the average temperature at the inlet to the first particulate matter control device (fabric filter or electrostatic precipitator) during the D/F performance test is 400°F or less this limit is changed to 0.4 ng/dscm (TEQ).

² Measured as propane.

³ Any source subject to the 24 ppmvd THC limit may elect to meet an alternative limit of 9 ppmvd for total organic HAP. If the source demonstrates compliance with the total organic HAP under the requirements of § 63.1349 then the source's THC limit will be adjusted to equal the average THC emissions measured during the organic HAP compliance test.

⁴ If the kiln does not have a HCl CEM, the emissions limit is zero.
Portland Cement MACT
emission limits as 30 day mean values
calculated by Vosteen under the assumption of 2000 - 2200 dscm/metric ton clinker

Existing kiln in normal operation:
55 lb/MM short tons clinker
which corresponds to
10.3 – 11.3 μg Hg/dscm @ 12 % O$_2$

New kilns in normal operation:
21 lb/MM short tons clinker
which corresponds to
3.9 – 4.3 μg Hg/dscm @ 12 % O$_2$
DIRECTIVE 2010/75/EU OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL
of 24 November 2010
on industrial emissions (integrated pollution prevention and control)

Official Journal of the European Union, ANNEX V, pages L 334/59
Technical provisions relating to combustion

2. Special provisions for cement kilns co-incinerating waste

2. Special provisions for cement kilns co-incinerating waste

\[ \text{2. C - total emission limit values (mg/Nm}^3\text{ except for dioxins and furans) for the following polluting substances} \]

\[ \begin{array}{|c|c|}
\hline
\text{Polluting substance} & \text{C} \\
\hline
\text{Total dust} & 30 \\
\text{HCl} & 10 \\
\text{HF} & 1 \\
\text{NO}_x & 500 (f) \\
\text{Cd + Ti} & 0.05 \\
\text{Hg} & 0.05 \\
\text{Sb + As + Pb + Cr + Co + Cu + Mn + Ni + V} & 0.02 \\
\text{Dioxins and furans (mg/Nm}^3\text{)} & 0.1 \\
\hline
\end{array} \]

\(^{(*)}\) Until 1 January 2016, the competent authority may authorize exceptions from the limit value for NO\textsubscript{x} for Lepel kilns and long rotary kilns provided that the permit sets a total emission limit value for NO\textsubscript{x} of not more than 800 mg/Nm\textsuperscript{3}.

50 \mu g Hg/dscm@10 \% O\textsubscript{2}
Measurements of Stack Emissions

- Data from German Preheater Kiln
  - CEM to measure stack Hg concentration
  - Sampling of ESP dust
- Stack temperature and Hg emission change with Raw Mill on- or off-line


Gaseous Emissions in Cement Production

Emissions:
- SO\textsubscript{2}
- NO\textsubscript{x}
- Dust
- HCl
- HF
- TOC
- Hg
- Dioxine and Furan

NO\textsubscript{x} and NH\textsubscript{3} Reduction (if SNCR or SCR are implemented)

SO\textsubscript{x}, Dust, HCl, HF, and Hg Reduction

Dust Reduction

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First shocking confrontation with drafted Industrial Boiler MACT:

US-Limits for dust 5 times higher than in EU
US-Limits for HCl 4 times higher than in EU
but
US-Limits for Hg 10 times lower than in EU
## Table 1—Emission Limits for Boilers and Process Heaters

<table>
<thead>
<tr>
<th>Subcategory</th>
<th>Particulate Matter (PM)</th>
<th>Hydrogen Chloride (HCl)</th>
<th>Mercury (Hg)</th>
<th>Carbon Monoxide (CO) (ppm @ 3% oxygen)</th>
<th>Dioxin/Furan (TEQ) (ng/dscm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Existing—Coal Stoker</td>
<td>0.039</td>
<td>0.035</td>
<td>0.0000046</td>
<td>270</td>
<td>0.003</td>
</tr>
<tr>
<td>Existing—Coal Fluidized Bed</td>
<td>0.039</td>
<td>0.035</td>
<td>0.0000046</td>
<td>82</td>
<td>0.002</td>
</tr>
<tr>
<td>Existing—Pulverized Coal</td>
<td>0.039</td>
<td>0.035</td>
<td>0.0000046</td>
<td>160</td>
<td>0.004</td>
</tr>
<tr>
<td>Existing—Biomass Stoker/other</td>
<td>0.039</td>
<td>0.035</td>
<td>0.0000046</td>
<td>490</td>
<td>0.005</td>
</tr>
<tr>
<td>Existing—Biomass Fluidized Bed</td>
<td>0.039</td>
<td>0.035</td>
<td>0.0000046</td>
<td>430</td>
<td>0.02</td>
</tr>
<tr>
<td>Existing—Biomass Dutch Oven/Suspension Burner</td>
<td>0.039</td>
<td>0.035</td>
<td>0.0000046</td>
<td>470</td>
<td>0.2</td>
</tr>
<tr>
<td>Existing—Biomass Fuel Cells</td>
<td>0.039</td>
<td>0.035</td>
<td>0.0000046</td>
<td>690</td>
<td>4</td>
</tr>
<tr>
<td>Existing—Biomass Suspension/Grate</td>
<td>0.039</td>
<td>0.035</td>
<td>0.0000046</td>
<td>3,500</td>
<td>0.2</td>
</tr>
<tr>
<td>Existing—Liquid</td>
<td>0.0075</td>
<td>0.00033</td>
<td>0.0000035</td>
<td>10</td>
<td>4</td>
</tr>
<tr>
<td>Existing—Gas 2 (Other Process Gases)</td>
<td>0.043</td>
<td>0.0017</td>
<td>0.00013</td>
<td>9.0</td>
<td>0.08</td>
</tr>
<tr>
<td>Existing—non-continental liquid</td>
<td>0.0075</td>
<td>0.00033</td>
<td>0.0000078</td>
<td>160</td>
<td>4</td>
</tr>
<tr>
<td>New—Coal Stoker</td>
<td>0.0011</td>
<td>0.0022</td>
<td>0.0000035</td>
<td>6</td>
<td>0.003</td>
</tr>
<tr>
<td>New—Coal Fluidized Bed</td>
<td>0.0011</td>
<td>0.0022</td>
<td>0.0000035</td>
<td>18</td>
<td>0.002</td>
</tr>
<tr>
<td>New—Pulverized Coal</td>
<td>0.0011</td>
<td>0.0022</td>
<td>0.0000035</td>
<td>12</td>
<td>0.003</td>
</tr>
<tr>
<td>New—Biomass Stoker</td>
<td>0.0011</td>
<td>0.0022</td>
<td>0.0000035</td>
<td>160</td>
<td>0.005</td>
</tr>
<tr>
<td>New—Biomass Fluidized Bed</td>
<td>0.0011</td>
<td>0.0022</td>
<td>0.0000035</td>
<td>260</td>
<td>0.02</td>
</tr>
<tr>
<td>New—Biomass Dutch Oven/Suspension Burner</td>
<td>0.0011</td>
<td>0.0022</td>
<td>0.0000035</td>
<td>470</td>
<td>0.2</td>
</tr>
<tr>
<td>New—Biomass Fuel Cells</td>
<td>0.0011</td>
<td>0.0022</td>
<td>0.0000035</td>
<td>470</td>
<td>0.003</td>
</tr>
<tr>
<td>New—Biomass Suspension/Grate</td>
<td>0.0011</td>
<td>0.0022</td>
<td>0.0000035</td>
<td>1,500</td>
<td>0.2</td>
</tr>
<tr>
<td>New—Liquid</td>
<td>0.0013</td>
<td>0.00033</td>
<td>0.000002</td>
<td>3</td>
<td>0.002</td>
</tr>
<tr>
<td>New—Gas 2 (Other Process Gases)</td>
<td>0.0067</td>
<td>0.0017</td>
<td>0.0000078</td>
<td>3</td>
<td>0.08</td>
</tr>
<tr>
<td>New—non-continental liquid</td>
<td>0.0013</td>
<td>0.00033</td>
<td>0.0000078</td>
<td>51</td>
<td>0.002</td>
</tr>
</tbody>
</table>
Industrial Boiler MACT

Existing plants:
0.0000046 lb/MMBtu = 4.6 lb/TBtu
which corresponds
- in case of a bituminous coal –
  5.3 \( \mu g \) Hg/dscm @ 6 % \( O_2 \)
  (or 3.5 \( \mu g \) Hg/dscm @ 11 % \( O_2 \))

New Plants:
0.0000035 lb/MMBtu = 3.5 lb/TBtu
which corresponds
- in case of a bituminous coal –
  4.0 \( \mu g \) Hg/dscm @ 6 % \( O_2 \)
  (or 2.7 \( \mu g \) Hg/dscm @ 11 % \( O_2 \))
Technical provisions relating to waste incineration and waste co-incineration plants

Air emission limit values for waste incineration plants

1. All emission limit values shall be calculated at a temperature of 273.15 K, a pressure of 101.3 kPa and after correcting for the water vapour content of the waste gases.

They are standardised at 11 % oxygen in waste gas except in case of incineration of mineral waste oil as defined in point 3 of Article 3 of Directive 2008/85/EC, when they are standardised at 3 % oxygen, and in the cases referred to in Point 2.7 of Part 6.

1.1. Daily average emission limit values for the following polluting substances (mg/Nm³)

<table>
<thead>
<tr>
<th>Substance</th>
<th>Limit Value (mg/Nm³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total dust</td>
<td>10</td>
</tr>
<tr>
<td>Gaseous and vaporous organic substances, expressed as total organic carbon (TOC)</td>
<td>10</td>
</tr>
<tr>
<td>Hydrogen chloride (HCl)</td>
<td>10</td>
</tr>
<tr>
<td>Hydrogen fluoride (HF)</td>
<td>1</td>
</tr>
<tr>
<td>Sulphur dioxide (SO₂)</td>
<td>50</td>
</tr>
<tr>
<td>Nitrogen monoxide (NO) and nitrogen dioxide (NO₂), expressed as NO₂ for existing waste incineration plants with a nominal capacity exceeding 6 tonnes per hour or new waste incineration plants</td>
<td>200</td>
</tr>
<tr>
<td>Nitrogen monoxide (NO) and nitrogen dioxide (NO₂), expressed as NO₂ for existing waste incineration plants with a nominal capacity of 6 tonnes per hour or less</td>
<td>400</td>
</tr>
</tbody>
</table>

In USA the dscm is related to 68 °F
(= 20 °C = 293.15 K)
Technical provisions relating to waste incineration and waste co-incineration plants

Air emission limit values for waste incineration plants

1.3. Average emission limit values (mg/Nm³) for the following heavy metals over a sampling period of a minimum of 30 minutes and a maximum of 8 hours

<table>
<thead>
<tr>
<th>Metal and its compounds, expressed as</th>
<th>Limit Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cadmium and its compounds, expressed as cadmium (Cd)</td>
<td>Total: 0.05</td>
</tr>
<tr>
<td>Thallium and its compounds, expressed as thallium (Tl)</td>
<td>0.05</td>
</tr>
<tr>
<td>Mercury and its compounds, expressed as mercury (Hg)</td>
<td>Total: 0.5</td>
</tr>
<tr>
<td>Antimony and its compounds, expressed as antimony (Sb)</td>
<td>0.5</td>
</tr>
<tr>
<td>Arsenic and its compounds, expressed as arsenic (As)</td>
<td></td>
</tr>
<tr>
<td>Lead and its compounds, expressed as lead (Pb)</td>
<td></td>
</tr>
<tr>
<td>Chromium and its compounds, expressed as chromium (Cr)</td>
<td></td>
</tr>
<tr>
<td>Cobalt and its compounds, expressed as cobalt (Co)</td>
<td></td>
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<tr>
<td>Copper and its compounds, expressed as copper (Cu)</td>
<td></td>
</tr>
<tr>
<td>Manganese and its compounds, expressed as manganese (Mn)</td>
<td></td>
</tr>
<tr>
<td>Nickel and its compounds, expressed as nickel (Ni)</td>
<td></td>
</tr>
<tr>
<td>Vanadium and its compounds, expressed as vanadium (V)</td>
<td></td>
</tr>
</tbody>
</table>

These average values cover also the gaseous and the vapour forms of the relevant heavy metal emissions as well as their compounds.

50 μg Hg/dscm@11%O₂
Official Journal of the European Union, ANNEX V, pages L 334/59
Technical provisions relating to combustion

Emission limits shall be reconsidered regularly
and can be lowered ...

(21) In order to take account of developments in best available
techniques or other changes to an installation, permit con-
ditions should be reconsidered regularly and, where neces-
sary, updated, in particular where new or updated BAT
conclusions are adopted.
Calculation Vosteen (2011) starting from ultimate analysis data only
(applied on a data set from Kast/Krischer / Kröll, 1978)

Gross Heating Value HHV (Btu/lb as received) and Ho (kJ/kg as received) as measured and as calculated with the statistical Michels HHV formula (developed for wastes) based on the ultimate analysis of different coals (ash, water, c, h, s, n and o)

<table>
<thead>
<tr>
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<tbody>
<tr>
<td></td>
<td>Ho (kJ/kg)</td>
<td>HHV (Btu/lb)</td>
<td>Ho (Michels)</td>
<td>a (Gew.%)</td>
<td>w (Gew.%)</td>
<td>c (Gew.%)</td>
<td>h (Gew.%)</td>
<td>s (Gew.%)</td>
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<td>15413</td>
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<td>0,80</td>
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<td>1,90</td>
<td>88,60</td>
<td>3,60</td>
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<td>1,00</td>
<td>78,80</td>
<td>3,90</td>
<td>1,30</td>
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<td>Mittelgut</td>
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<td>12615</td>
<td>24391</td>
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<td>16575</td>
<td>32412</td>
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<td>78,00</td>
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<td>1,00</td>
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<td>15776</td>
<td>30882</td>
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<td>5,70</td>
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<td>13940</td>
<td>7182</td>
<td>13598</td>
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<td>30,00</td>
<td>33,70</td>
<td>3,30</td>
<td>1,00</td>
</tr>
<tr>
<td>Holz (lufttrocken)</td>
<td>16410</td>
<td>8455</td>
<td>16449</td>
<td>0,40</td>
<td>18,00</td>
<td>40,80</td>
<td>4,90</td>
<td>35,90</td>
</tr>
</tbody>
</table>
Calculation Vosteen (2011) starting from ultimate analysis data only
(applied on a data set from Kast/Krischer / Kröll, 1978)

Gross Heating Value HHV (Btu/lb as received) and Ho (kJ/kg as received) as measured and as calculated with the statistical Michels HHV formula (developed for wastes) based on the ultimate analysis of different coals (ash, water, c, h, s, n and o)
Existing plants: 4.6 lb Hg/TBtu

c. 3.7 µg Hg/dscm@11%O₂
New plants: 3.5 lb Hg/TBtu

\[ \mu g \text{ Hg/dscm@11\%O}_2 \]

Corresponds to c. 3 \[ \mu g \text{ Hg/dscm@11\%O}_2 \]
Agenda

- Links to the NESHAP (National Emission Standards for Hazardous Air Pollutants)
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- Conclusion
In the U.S., Power Plants Emit:

- 60% of the SO₂
- 60% of the arsenic
- 13% of the NOₓ
- 30% of the nickel
- 20% of the chromium
- 50% of the mercury
- over 50% of many acid gases

Sources: NEI Trends Data (2009) and IPM (2010) (SO₂, NOₓ); Proposed toxics rule modeling platform, based on inventory used for 2005 NATA (Hg); Inventory used for 2005 NATA (other toxics)
Power Plants Are the Largest Remaining Source of Mercury Emissions in the U.S.

- In 1990 three source categories made up approximately two-thirds of total U.S. mercury emissions: municipal waste combustors, medical waste incinerators, and power plants.
- Two of the three are now subject to federal emissions standards.
- So are many other industries such as cement plants and steel manufacturers.
- Today, 20 years after 1990 CAA Amendments passed, no federal limit for toxic emissions – including mercury – exists for coal- or oil-fired power plants.

<table>
<thead>
<tr>
<th>Industrial Category</th>
<th>1990 Emissions tons per year (tpy)</th>
<th>2005 Emissions (tpy)</th>
<th>% Reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power Plants</td>
<td>59</td>
<td>53</td>
<td>10%</td>
</tr>
<tr>
<td>Municipal Waste Combustors</td>
<td>57</td>
<td>2</td>
<td>96%</td>
</tr>
<tr>
<td>Medical Waste Incinerators</td>
<td>51</td>
<td>&lt;1</td>
<td>&gt;98%</td>
</tr>
</tbody>
</table>

Source: EPA’s 2006 NATA Inventory Modified for the Toxics Rule 2006 Base Year (2010)

53 short tons = 48 metric tons
The EPA Administrator, Lisa P. Jackson, signed the following notice on 03/16/2011, and EPA is submitting it for publication in the Federal Register (FR). While we have taken steps to ensure the accuracy of this Internet version of the rule, it is not the official version of the rule for purposes of compliance. Please refer to the official version in a forthcoming FR publication, which will appear on the Government Printing Office's FDSys website (http://fdsys.gpo.gov/fdsys/search_home.action) and on Regulations.gov (http://www.regulations.gov) in Docket Nos. EPA-HQ-OAR-2009-0234; EPA-HQ-OAR-2011-0044. Once the official version of this document is published in the FR, this version will be removed from the Internet and replaced with a link to the official version.

ENVIRONMENTAL PROTECTION AGENCY

40 CFR Parts 60 and 63


BIN 2060-AP52

Utility MACT (draft proposal),
Excerpt from Table 10 on Emission limits as 30 day mean values for existing and new Coal-Fired EGUs

<table>
<thead>
<tr>
<th>Subcategory</th>
<th>Total particulate matter</th>
<th>Hydrogen chloride</th>
<th>Mercury</th>
</tr>
</thead>
<tbody>
<tr>
<td>Existing coal-fired unit designed for coal &gt; 8,300 Btu/lb</td>
<td>0.030 lb/MMBtu (0.30 lb/MWh)</td>
<td>0.0020 lb/MMBtu (0.020 lb/MWh)</td>
<td>1.0 lb/TBtu (0.0008 lb/GWh)</td>
</tr>
<tr>
<td>Existing coal-fired unit designed for coal &lt; 8,300 Btu/lb</td>
<td>0.030 lb/MMBtu (0.30 lb/MWh)</td>
<td>0.0020 lb/MMBtu (0.020 lb/MWh)</td>
<td>11.0 lb/TBtu (0.20 lb/GWh)</td>
</tr>
<tr>
<td>New coal-fired unit designed for coal &gt; 8,300 Btu/lb</td>
<td>0.050 lb/MWh</td>
<td>0.30 lb/GWh</td>
<td>0.000010 lb/GWh</td>
</tr>
<tr>
<td>New coal-fired unit designed for coal &lt; 8,300 Btu/lb</td>
<td>0.050 lb/MWh</td>
<td>0.30 lb/GWh</td>
<td>0.040 lb/GWh</td>
</tr>
</tbody>
</table>

**Misprint!**
To be corrected: 0.008 lb/GWh (electrical!)

**Crazy!**
0.00001 lb/GWh <<<< 0.008 lb/GWh (factor 800 smaller)
To compare
lb Hg/TBtu (thermal input, based on HHV)
with
lb Hg/GWh (electrical output):

1 TBtu (thermal) = 293.11 GWh (thermal)

In case of an electrical efficiency of
$\eta_e = 42.6\%$ (based of HHV as Energy Input):

1 TBtu (thermal) = (in the sense of „corresponds to“)
293.11 GWh (thermal) * 42.6/100 = 124.86 GWh (electrical)

With this follows:
1 lb Hg/TBtu (thermal) = (in the sense of “corresponds to“)
1 lb Hg/124.86 GWh electrical = 0.008 lb Hg/GWh (electrical)

The equivalency of the mercury emission factors in line 1 of table 10 of the utility
MACT draft proposal,
i.e. 1 lb/TBtu and 0.008 lb/GWh (electrical),
relates exactly to a mean electrical efficiency of $\eta_e = 42.6\%$
as based on HHV for coal fired EGUs
Utility MACT
Existing Plants (EGUs)
1 lb Hg/TBtu

1 lb Hg/TBtu or 0.008 lb/GWh, electrical
Agenda

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form. Units with wet FGD scrubbers can achieve high levels of Hg control – provided that the Hg is present in the oxidized (i.e., the soluble) form. A selective catalytic reduction (SCR) catalyst can enhance the Hg removal by catalytically converting Hg$^0$ to Hg$^{+2}$, making it more soluble and more likely to be captured in the scrubber solution. **Halogen additives** (usually bromide salts, but chloride salts may also be used) can also be added directly to the coal or injected into the boiler to enhance the oxidation of Hg.

Activated carbon injection (ACI) is the most successfully demonstrated Hg-specific control technology.
The drafted Hg- emission limits for existing and newly designed plants is open for discussion until May 16, 2011.

The reason why US EPA is proposing such values is based on a procedure (12 % mean of the utility MACT floor), as prescribed by US law.

– To be explained –

The recently established utility MACT floor seems to be based mainly on applications of ACI at small units –

Often much too expensive and technically questionable (see example further down)
TOXECON™ Clean Coal Demonstration for Mercury and Multi-Pollutant Control

EUEC 2008
Tucson, Arizona

Steven Derenne

January 29, 2008
**TOXECON™ Configuration**

Presque Isle Power Plant

Coal → Heat Side Electrostatic Precipitator → APH → Sorbent Injection → PJFF → Fly Ash (99%) → Fly Ash (1%) + PAC
TOXECON™ - 270 MW Demonstration

- Presque Isle Power Plant, Marquette MI
  - Units 7-9
  - PRB Coal from Antelope and Spring Creek Mines

- $53.3M
  - $24.9M DOE
  - $28.5M We Energies

- 90% Hg Control
- 70% SO₂ Control
- 30% NOₓ Control
Economics – Cont.

- Capital Costs (2005$)
  - $34.4 million, 270 MW
  - $128/kW

- O&M Costs (estimate)
  - $0.81/MWh

- Hg Removal - 82 pounds/year
  - $11,000/lb – Variable
  - $62,000/lb – All In
„Technology commercially available“
Smoldering Filterbags, Hot Spots in 2 of 10 Chambers

Steve Derenne, DOE NETL Conference, Pittsburg, Dec. 2006

Hot-Spot Problems shall be minimized today (2008)
KNX™ Coal Additive – Addition on coal conveyor belt

Coal Conveyor (shown in black)

Injection Spray Header

KNX™ Additive Storage Tank

Metering Pump
Bromine > 25 times more effective for Hg$^{\text{met}}$ oxidation than chlorine, in waste incineration as well as in coal combustion

(BAYER patent applications pending world wide)

Synergistic Effect of KNX + Mer-Cure

500 MW PRB with Particulate Scrubber

55% incremental performance improvement

ALSTOM
License granted in 2008 to WE Pleasant Prairie Unit 1 and Unit 2 (2 x 600 MWe with SCR, ESP, WFGD) -
In commercial operation since January 1, 2010

2 x 600 MWe
Base Load
(24 hours/day)

PRB coal
2 x 315 tons/hour
0.11 ppm Hg

KNX (as CaBr$_2$)
25 ppm Br on coal

H$_{\text{total}}$ at stack
< 1 µg/dscm
(both units)
Pleasant Prairie (P4) Units 1 & 2 – Unit Operations Scheme

Air Pollution Control System

SO₂

NOₓ and NH₃

Opacity

Flow

Stack Emission Monitor: OPSIS

Feed Forward

Makeup Water

Electrostatic Precipitator

Ammonia or Amea

A/P Ash

Flyash

Limestone

Ash Silo

Boll Mill

Coal Feed

Bottom Ash

Comb. Air

Flyash

Limestone

Gypsum

ALSTOM
License granted in 2008 to WE Pleasant Prairie (2 x 600 MWe Units) with SCR, ESP, WFGD - In commercial operation since January 1, 2010

Test July - September 2008, with 25 ppm Br per PRB-coal, while SCR was in service with NH₃
<table>
<thead>
<tr>
<th>OWNER</th>
<th>FACILITY / STATION</th>
<th>UNIT ID</th>
<th>Size (MW)</th>
<th>AQCS</th>
<th>KNX™ Startup</th>
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<tr>
<td>We Energies</td>
<td>Pleasant Prairie</td>
<td>1</td>
<td>605</td>
<td>SCR / ESP / WFGD</td>
<td>1/1/10</td>
</tr>
<tr>
<td>We Energies</td>
<td>Pleasant Prairie</td>
<td>2</td>
<td>605</td>
<td>SCR / ESP / WFGD</td>
<td>1/1/10</td>
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<tr>
<td>MDU Resources</td>
<td>Lewis &amp; Clark</td>
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<td>WFGD</td>
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<td>NN</td>
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<td>ESP</td>
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Enhanced Mercury Abatement
CaBr$_2$ to Bituminous Coal and PAC to WFGD
with Selective Mercury Precipitation in WWT

Large Scale Tests in 2009 and 2010
Enhanced Mercury Abatement
CaBr$_2$ to Bituminous Coal and PAC to WFGD with Selective Mercury Precipitation in WWT

Large Scale Tests in 2011
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• Conclusion
Conclusions

The US EPA air toxics rules will reduce US mercury emissions drastically.

In the drafted Utility MACT, EPA has proposed for existing coal-fired plants mercury emission limits in the “1 µg/dscm range”.

Such low values are highly ambitious, but might be attained by enhanced mercury capture technologies as Activated Carbon Injection (ACI) or/and by Boiler Chemical Addition (BCA) – the latter preferably in its highly efficient and cost-effective form of Precombustion Bromide Addition to coal.

EPA has proposed for newly designed coal-fired plants even lower mercury emission limits – here in the “2 ng Hg/dscm range” only. Such values appear over-ambitious (if not “crazy”) and fairly unrealistic – with respect to commercial operations and to economics, as well.

Though over-ambitious values might be achieved somewhere – e.g. in the rare case of strictly limited Hg-contents of the fired coals, and at the same time applying e.g. both BCA and ACI technologies in series, such minimal limits don’t make sense – except that EPA intends to drive the costs for /stop investments into new coal-fired power plants.

What about costs?
Conclusions (continued)

EPA is setting forth its mercury emission limits in the utility MACT (table 10) as related freight values – for existing plants e.g. in the form of 1 lb Hg/TBtu (based on the energy input, HHV) or in the equivalent form of 0.008 lb Hg/GWh (based on the energy output).

The EPA proposed these emission limits independent of any given range of possible coal mercury contents. Further, EPA is staying extremely restrictive when not demanding minimum mercury removal rates only (e.g. as > 90% from coal to stack) and thus not permitting variable mercury emissions in the range of e.g. < 10 % of the coal mercury.

Up to now, only a limited number of tests have been done on precombustion bromide addition at plants firing Eastern bituminous coals: More tests with Ebit coals are needed.

Precombustion bromide addition is commercially applied in USA to low-chlorine PRB coals at > 5500 MWe – realizing cost-effective co-benefit mercury capture at wet and dry APCs.

Some countries like China are installing step by step modern APCs with high-dust SCR-DeNOx catalysts and wet FGD. Such systematique APC-installation will allow for impressive co-benefit mercury capture by precombustion bromide addition – also when firing own low-chlorine coals of higher mercury content.
THANK YOU FOR YOUR ATTENTION

QUESTIONS?