Mercury Removal from Sewage Sludge Incinerators

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Overview

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Overview

- U.S. sewage sludge incinerators must meet new mercury emission rules by March 2016
- Older multiple hearth units have limits which are 100 times greater than those for coal fired power plants.
- Older Fluid bed units have emission limits 10 x higher than coal fired power plants
- new units have limits equivalent to existing coal fired power plants
- Activated carbon and absorber modules are being used for mercury removal
- Some plants are shutting down incinerators and disposing of the sludge offsite
- States have not been entirely successful in their efforts to ensure compliance. As a result EPA has a new plan to try to resolve this problem.

Questions to be Resolved

- Can wet scrubbers remove some mercury if chemicals were injected into incinerator for the purpose of oxidation of the mercury?
- How does the carbon bed compare with the Gore module in terms of total cost of ownership?
- Can the carbon beds be used with just a scrubber and heat exchanger or would too much particulate be generated and thus plug the carbon bed?
- Are WESPS needed in front of carbon beds but not the Gore module?

Regulations

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Regulations

- There are nation wide rules to meet MACT in the U.S. but some question as to the enforcement efforts by States
- Rules in the U.S. China, and Europe also address the MACT reduction requirements when sewage slude is burned in cement kilns and power plants
- A number of power plants in Europe burn sewage sludge
- Distinctions are made between multiple hearth and fluid bed combustors and between old units and new ones

EPA has proposed plan to ensure States meet sewage sludge limits

- IN April 2015 The U.S. Environmental Protection Agency released a proposed plan to ensure states are meeting federal emissions standards for sewage sludge incinerators, adding that the agency is still working on addressing issues raised by the D.C. Circuit when it remanded the federal standards in 2013.
  The proposed plan, which will help states that did not submit an approved plan to implement the standards, includes emissions limits for all regulated pollutants, requirements for annual inspections of emissions control devices, and annual testing, monitoring, recordkeeping and reporting requirements.

  It's intended to be an interim measure until states assume their role as the preferred implementers of the emissions guidelines, according to the EPA.

  In the proposed plan, the EPA said it is evaluating the appeals court's decision and intends to address the concerns. The agency noted that its response to the decision may require further evaluation of the calculations outlined in the appeals court's opinion.

  "In the meantime, the agency believes it is appropriate to propose the federal plan at this time because the [sewage sludge incinerator] rule remains in place following the court's decision and the federal plan is needed to implement the rule in states without an approved state plan," according to the rule.

EPA SSI rules cover sewage sludge incinerators but also cement kilns

- In 2011 the Environmental Protection Agency (EPA) finalized new air emissions regulations of air toxics and criteria pollutants, as well as new operating and monitoring requirements, for new and existing sewage sludge incineration (SSI) units. Concurrently, EPA also finalized a definition of non-hazardous solid waste to include sewage sludge. This second action by EPA established that facilities, like cement kilns, that burn dried sewage sludge, will also be regulated like incinerators under the more onerous Clean Air Act (CAA) §129. If these facilities that use biosolids as an alternative fuel can demonstrate that the sewage sludge they are burning is a “legitimate fuel” they can remain regulated under the reasonable air quality emissions requirements that they currently comply with in CAA §112. These rules are expected to impact sewage sludge.

234 systems with FB and MH design

- In terms of sheer numbers, there are many more MH systems in the United States, some dating back to the 1930s. FB systems were introduced to the municipal market in the early 1960's and became popular due to their simpler operation, reduced emissions and improved efficiency in terms of fuel consumption. Virtually all new thermal oxidation systems built in municipal applications over the past two decades use FB technology, but a substantial number of MH systems remain in operation and it is expected that these will continue to be operated for years to come.
- Thermal oxidation is often the least expensive biosolids handling alternative for medium and large scale facilities and, therefore, satisfies the economic criteria which is a very important to most owners and operators. Fluid bed emissions have been shown to be favorable with land application, drying, and composting when transportation emissions are considered. Additionally, the product is pathogen free and inert and suitable for beneficial use, thereby making thermal oxidation an environmentally sound and sustainable biosolids management technique. Since traffic is a problem in most cities, a reduction in hauling vehicle traffic could be considered an improvement in the quality of life for the neighbors to the facility.

MACT 129 in perspective

- **Authors:** Queiroz, Gustavo; Cheslek, Heather; Rowan, James; Patrick Schlotzhauer, C.; Welp, James
- **Source:** Proceedings of the Water Environment Federation, Residuals Biosolids 2014, pp. 1-14(14)
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- Abstract:
- Sewage sludge incinerators (SSIs) located at Publicly Owned Wastewater Treatment Works (POTWs) are subject to the recently enacted US Environmental Protection Agency (USEPA) 129 emission limits, often referred to as the MACT 129 rule. These regulations set a time limit of March 21, 2016 for compliance with emission limits for both multiple hearth incinerators (MHIs) and fluidized bed incinerators (FBIs). They also establish new, more restrictive limits for “new” MHIs and FBIs. As a result, owners of existing incinerators have been evaluating compliance strategies to continue incineration or to shut down their incinerators and determine alternatives for the future processing of their sludge. Although most utilities currently operating SSIs fall under the MACT rule’s “existing” category for compliance, some are being classified as “new” per the MACT’s “50 percent rule” (Rowan et al., 2011) and are required to meet stricter “new” MHI emission limits.

  This paper discusses both operational considerations and emission control equipment that may be required for “new” MHIs and FBIs. This paper discusses recent experience with emissions control compliance for MHIs and how this knowledge may be applied to other MACT compliance projects, particularly those POTWs faced with a decision on implementing emission controls to meet “new” MACT limits to continue operating, or who want to understand potential future emission limits that may be implemented for “existing” MHIs.

Lower Hg Limits for Existing U.S. Multiple Hearth Incinerators

New Federal Limits

Effective March 21, 2016

2016 Hg EMISSION LIMITS*		
	Existing	**New**
Fluidized Beds:	0.037	0.001
Multiple Hearths:	0.28	0.001
Units:	mg/dscm @ 7% O_2	

*40 CFR 60 – Subparts LLLL (New/Modified) & MMMM (Existing)

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Sewage Sludge MACT limits

SSI Emissions Limits

TABLE 1—EMISSION LIMITS FOR EXISTING SSI UNITS

Pollutant	Units	Emission limit for MH incinerators	Emission limit for FB incinerators
Cd	mg/dscm @ 7% O_2	0.095	0.0016
CO	ppmvd @ 7% O_2	3,800	64
HCl	ppmvd @ 7% O_2	1.2	0.51
Hg	mg/dscm @ 7% O_2	0.28	0.037
NO_X	ppmvd @ 7% O_2	220	150
Pb	mg/dscm @ 7% O_2	0.30	0.0074
PCDD/PCDF, TEQ	ng/dscm @ 7% O_2	0.32	0.10
PCDD/PCDF, TMB	ng/dscm @ 7% O_2	5.0	1.2
PM	mg/dscm @ 7% O_2	80	18
SO_2	ppmvd @ 7% O_2	26	15

TABLE 2—EMISSION LIMITS FOR NEW SSI UNITS

Pollutant	Units	Emission limit for MH incinerators	Emission limit for FB incinerators
Cd	mg/dscm @ 7% O_2	0.0024	0.0011
CO	ppmvd @ 7% O_2	52	27
HCl	ppmvd @ 7% O_2	1.2	0.24
Hg	mg/dscm @ 7% O_2	0.15	0.0010
NO_X	ppmvd @ 7% O_2	210	30
Pb	mg/dscm @ 7% O_2	0.0035	0.00062
PCDD/PCDF, TMB	ng/dscm @ 7% O_2	0.045	0.013
PCDD/PCDF, TEQ	ng/dscm @ 7% O_2	0.0022	0.0044
PM	mg/dscm @ 7% O_2	60	9.6
SO_2	ppmvd @ 7% O_2	26	5.3

EPA approves Michigan plan in November 2015

- The Environmental Protection Agency (EPA) is approving Michigan's State Plan to control air pollutants from “Sewage Sludge Incinerators” (SSI). The Michigan Department of Environmental Quality (MDEQ) submitted the State Plan on September 21, 2015. The State Plan is consistent with the Emission Guidelines (EGs) promulgated by EPA on March 21, 2011. This approval means that EPA finds that the State Plan meets applicable Clean Air Act (Act) requirements for subject SSI units. Once effective, this approval also makes the State Plan Federally enforceable. EPA is also notifying the public that we have received from Michigan a negative declaration for Small Municipal Waste Combustors (SMWC). The MDEQ submitted its negative declaration onJuly 27, 2015. MDEQ notified EPA in its negative declaration letter that there are no SMWC units subject to the requirements of the Act currently operating in Michigan

Savannah moving away from incineration

- **<u>Savannah to spend $25 Million Plus to Upgrade Sewage Treatment Plant</u>**
- Savannah is upgrading its main sewage treatment plant, moving away from incineration and toward a process that could ultimately result in the sale or giveaway of its "Class A biosolids" for agricultural or backyard use.
-
- Instead of burning the sludge that remains after wastewater is processed, the city will be harnessing the power of bacteria to render that waste harmless, said John Sawyer, who heads the public works and water resources bureau. The sludge will be processed in an enclosed container that allows anaerobic bacteria to do its work.
-
- The conversion, which has been in the planning stage for more than three years, is expected to cost about $25 million to $26 million. The President Street facility is permitted for an average daily flow of 27 MGD and typically sees 20 MGD, about 75 percent of the city's wastewater. It serves about 60,000 residential and industrial customers. Savannah also operates wastewater treatment plants in Georgetown, Wilshire and Crossroads.
- Savannah's upgrade, however, is motivated by an air quality issue, Sawyer said.
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System Options

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Conventional Approach in N.J is Carbon Adsorption in a Six Stage System-Chavond-Barry Engineering Corp.

1. Remove The Heat

- Goal: Prepare the gas for the demister
- Here in NJ every location uses a wet scrubber.
  - Venturi scrubber
  - Tray scrubber
  - VenturiPak scrubber
  - Ring Jet scrubber
  - Packed bed scrubber
- Sometimes preceded by energy recovery units, e.g., heat exchanger
- Results in a saturated gas at 80°F - 100°F.

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Table 1 Sewage Sludge Production and Beneficial Utilization Rates in Selected Countries

Country or Region	Sludge Utilization Rate (%)	Sludge Production (Million tons dry solids per year)	Main Sludge Applications
United Kingdom	85	1.05	Land application, energy recovery
Australia	80	0.36	Land application
South Africa	80	1.0	Land application
India	80	...	Land application
Japan	74	2.2	Energy recovery, construction products (including products of incineration ash)
Germany	60	2.3	Land application, energy recovery
United States	55	17.8	Land application
European Union	40	9.0	Land application
Republic of Korea	6	1.9	Land application, construction products
Singapore	0	0.12	...
Hong Kong, China	0	0.3	...

... = information not available.

Source: East Asia Department, ADB.

Remove Large Particles (CB)

2. Remove The Large Particulate

Goal: Remove particulate, metals, and acid gases

- This is most often done in the wet scrubber system. Results in an ash slurry
- Frequently, a Wet Electrostatic Precipitator (WESP) is added following the scrubber.

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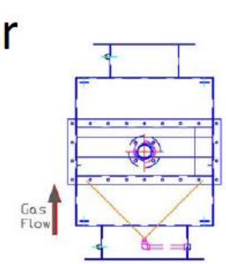
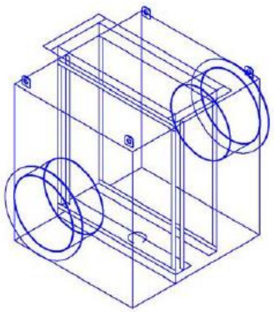
Remove Water Droplets
(not necessary with Gore module)

3. Remove Water Droplets

<u>Goal</u>: Dry gas is needed for optimized operation of adsorber





- Mist Eliminator
- Coalescer-Demister
- Chevron Separator
- Mesh pad Separator

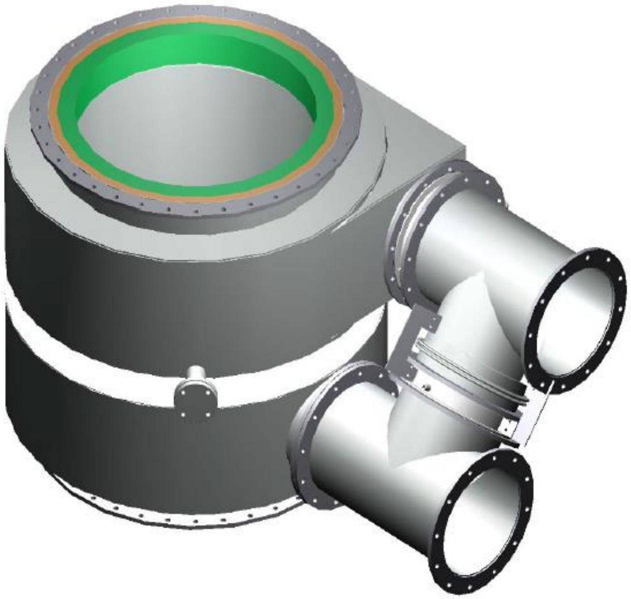
Heat the Gas
(not necessary with Gore module)

4. Heat The Gas

Goal: Raise gas temperature above dew point

- Dry Gas
- Better mass transfer

- Heat Exchanger
- Direct mixing with hot gases
- Duct heaters



Remove Ultrafine Particles (CB)

5. Remove Ultra-Fine Particles

Goal: Prevent mechanical failure of carbon column (Clog)

- Remove additional droplets
- Protect from dust buildup

Ultra-High Efficiency Filter

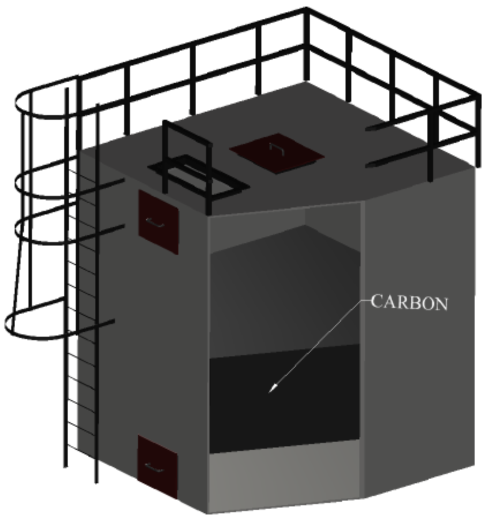
Absorb Hg with Activated Carbon (CB)

6. Adsorb the Hg

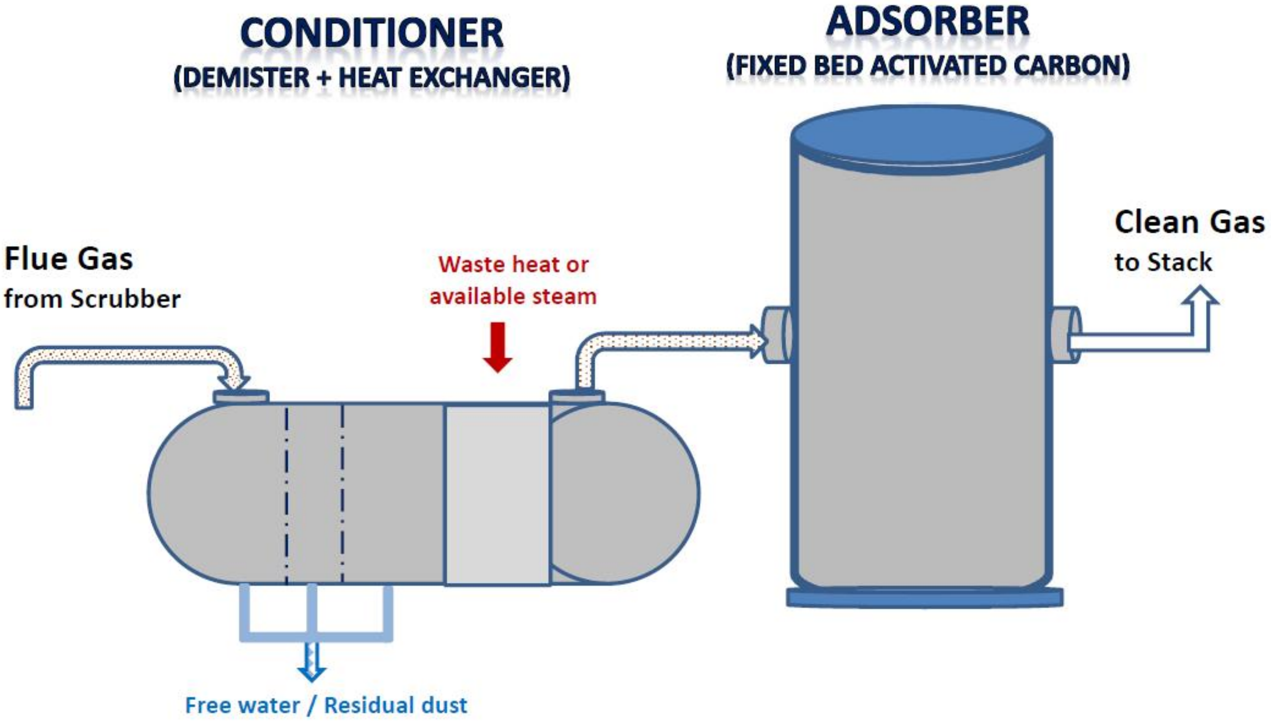
<u>Goal:</u> Expose incinerator exhaust gases to sulfur impregnated carbon

- $\geq$ 2 second RT

- Fixed bed adsorber
- Powdered activated carbon injection



Heat Exchanger and AC Bed



Carbon Pellets

Activated Carbon

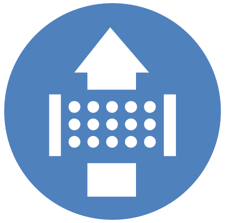
- Extremely porous with very large surface area available for adsorption and/or chemical reactions.
- Sulfur Impregnated
- Mercury Sulfide (HgS)

Hg Removal – Various Solutions

- Fixed Bed System (FB)
  - Granular Activated Carbon
  - Pelletized Activated Carbon
- Activated Carbon Injection (ACI)
  - Powdered Activated Carbon (FLUEPAC®)

Flue Gas

Liquid Natural Gas

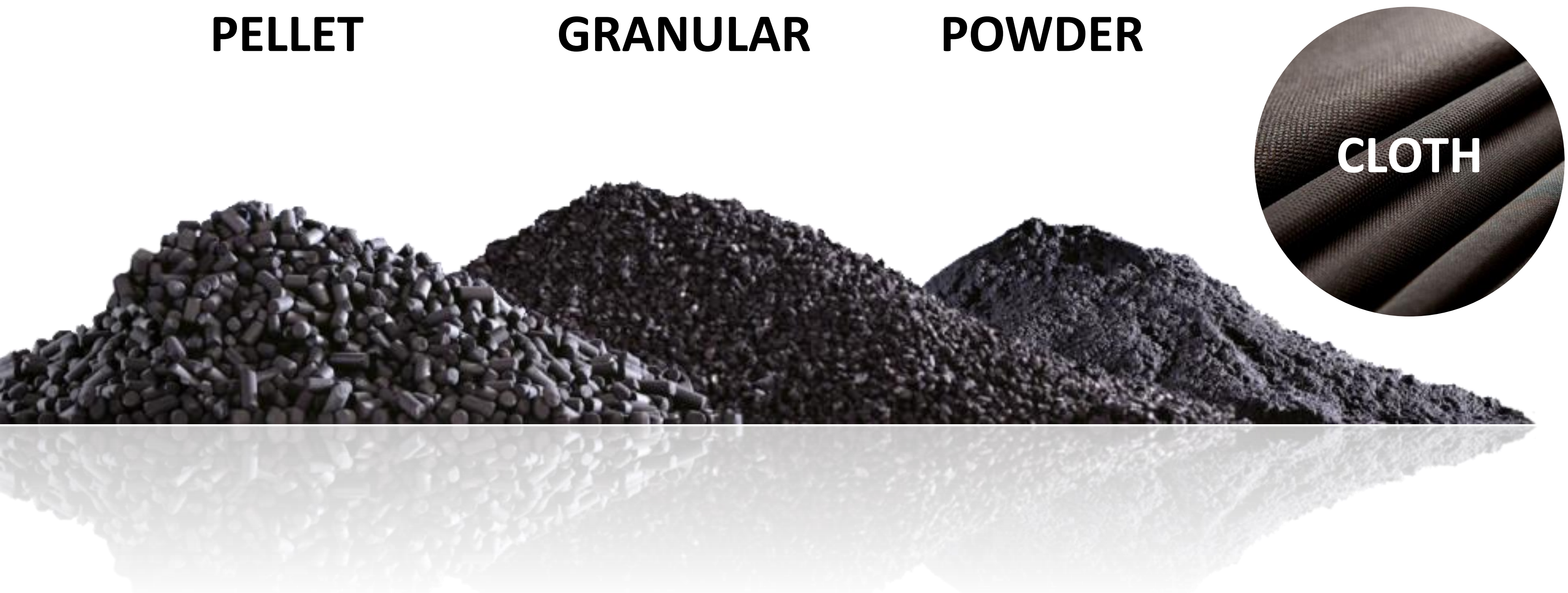


Industrial Air Treatment

Various applications:

- Coal fired power plants
- Sludge incinerators
- Cement plants
- Industrial boilers
- Liquefied natural gas

Forms of Activated Carbon



Activated Carbon Starting Materials

Not All Are Created Equal

Raw material dictates all product possibilities

- – Ash impurities inherited
- – Density and hardness linked
- – Differing overall porosities
- gle u y of prc

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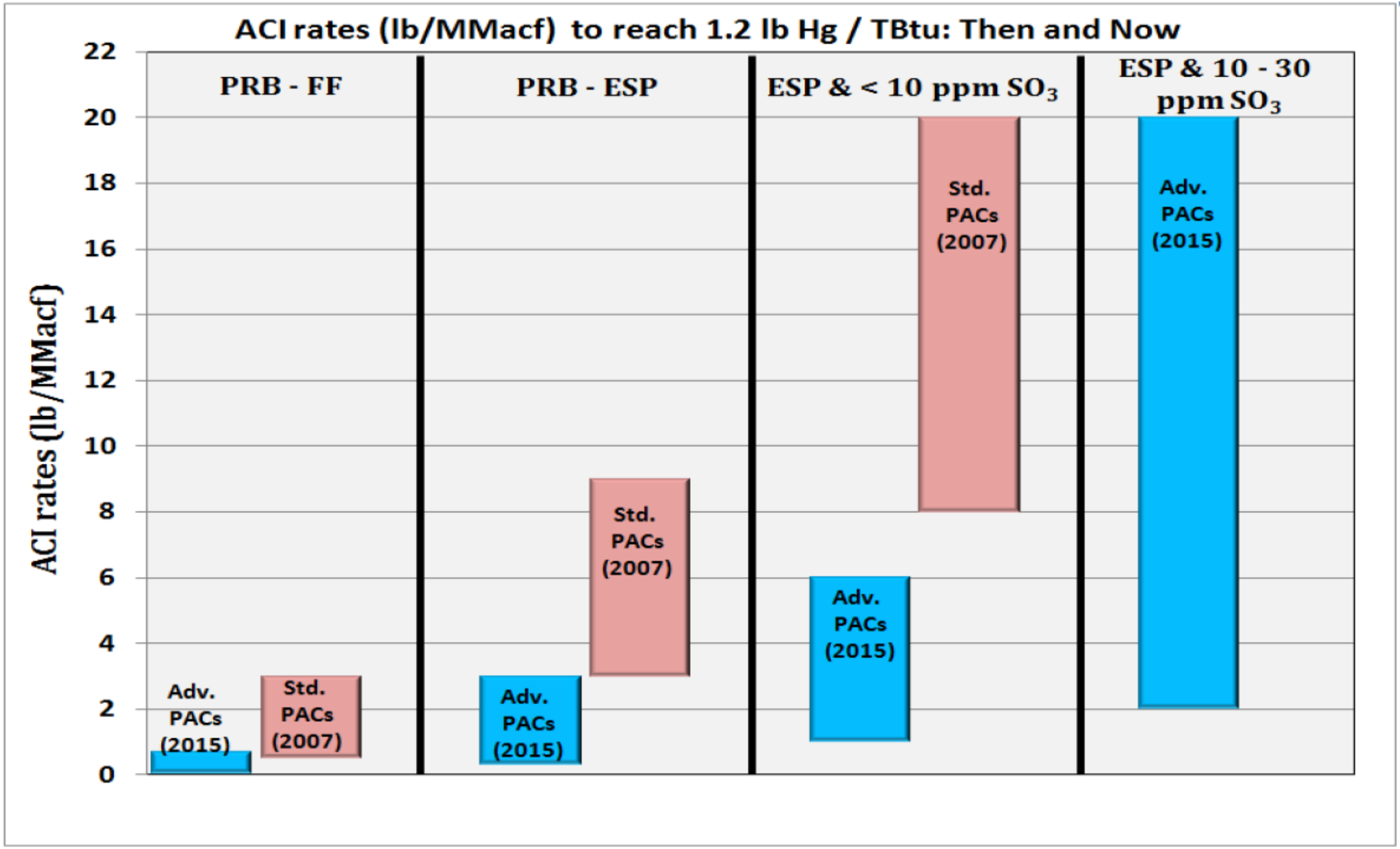
Bituminous Coal | **Lignite Coal** | **Coconut Shells** | **Wood**

Higher mercury adsorption capacity
Superior concrete compatibility

Impact of Advanced Products

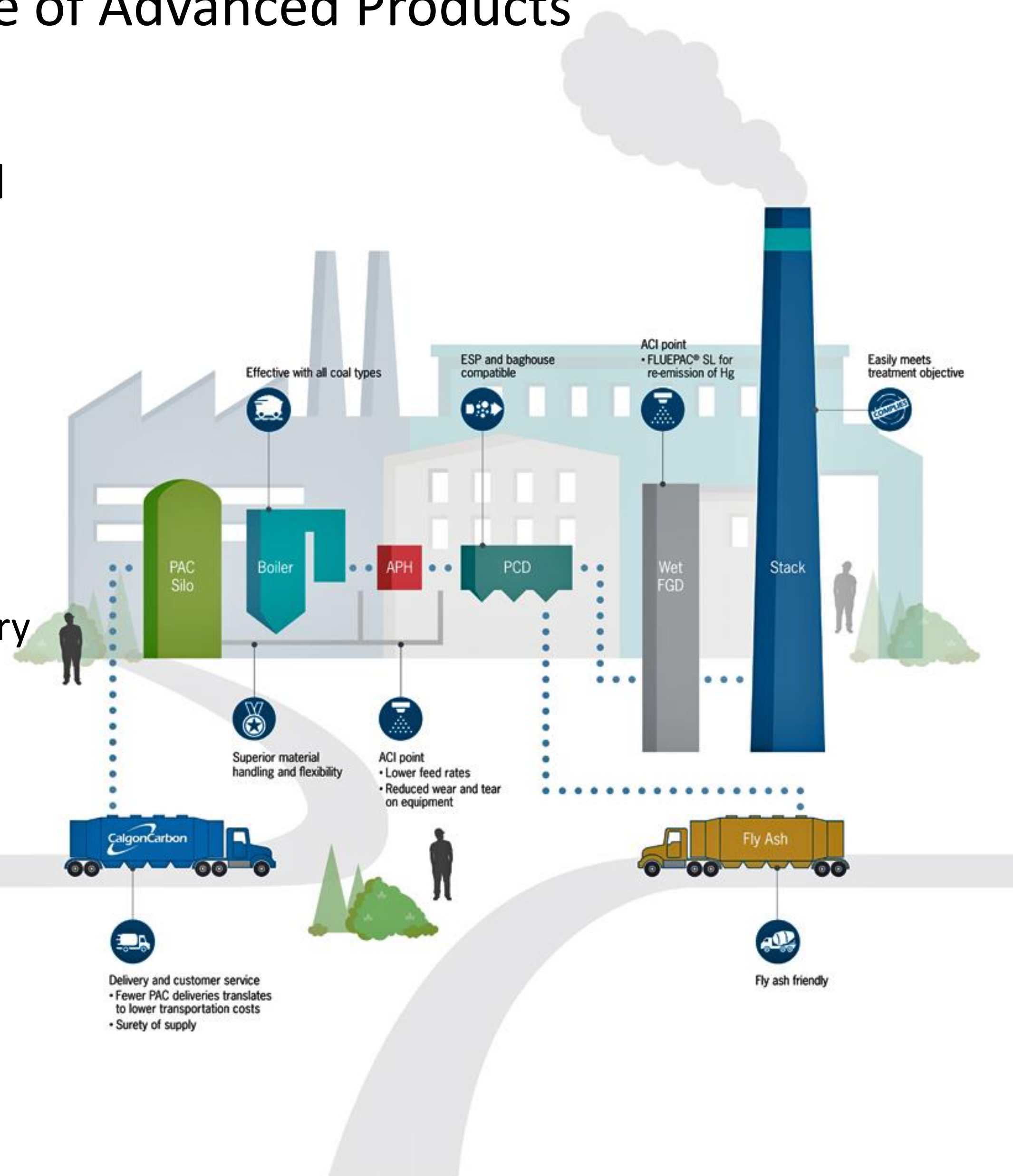


- ACI rates will vary based on the plant configuration and carbon performance
- Standard products will NOT meet compliance objectives in 100% of scenarios

Understanding the Total Treatment Cost…

The Importance of Advanced Products

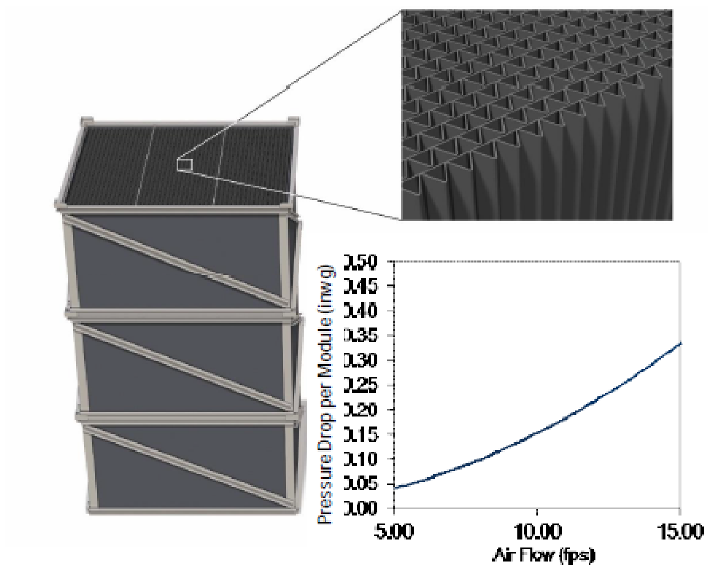
- **Vendor comparison testing will help you make the most informed choice possible and save you money**
- Advanced carbons have huge performance advantages over standard products…
  – Yet, standard carbons are still very present in the marketplace
- PAC demand volumes may depend largely on the extent to which advanced products are adopted.



Applying Your Results to the Bid…

- ACI is not a commodity product
  - It is essential to look beyond simple $$/lb pricing
- Normalize your results for each product by feed rate to obtain a Removal Efficiency Index (REI)
- Calculate freight costs using REI
- Calculate costs of additional products such as $CaBr_2$ or DSI.
- Factor in ash sales or disposal where appropriate
- **Compute the TOTAL TREATMENT COST**

New Approach for Gas Phase Remediation



GORE SPC Technology

- Low Pressure Drop Modules
  - No booster fan, minimal energy requirements
- Passive Control System
  - No injection of sorbents or chemicals
  - No moving parts
  - No regeneration
- Tailpipe solution

Mercury Control Modules

- High efficiency for Hg removal
- High capacity for Hg sequestration
- Scalable Hg removal (20-90+%)
- SO_2 removal co-benefit

SO_2 Control Modules

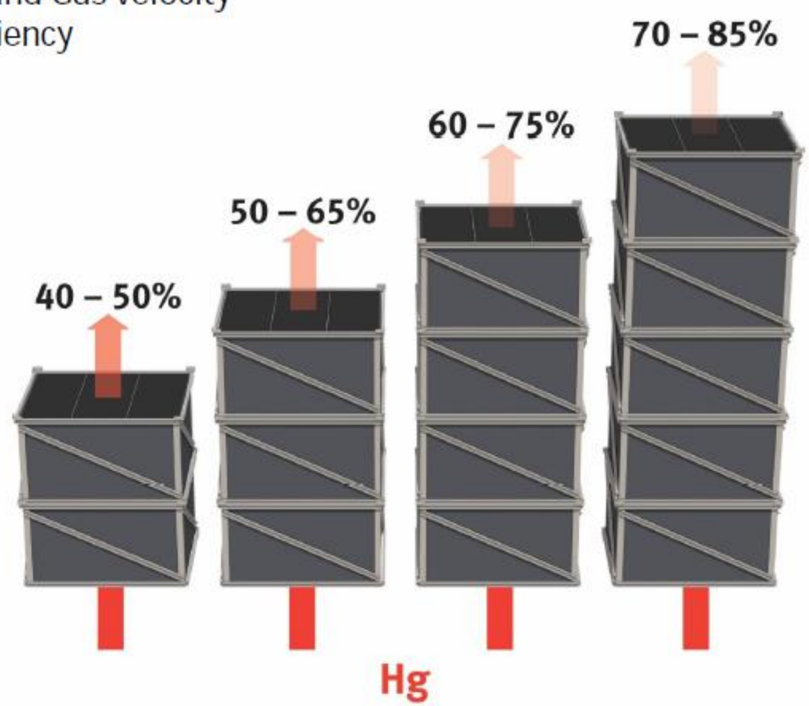
- Scalable SO_2 polishing (10-80+%)
- Generates dilute sulfuric acid instead of solid waste
- Hg removal / sequestration co-benefit

Sequestration and Removal efficiencies are scalable

Module Stack Height and Gas Velocity
Impacts Removal Efficiency

Example of Mercury Removal Efficiencies at Gas Velocities of 8-16 feet per second

Higher Removal Efficiencies possible with reduced gas velocities



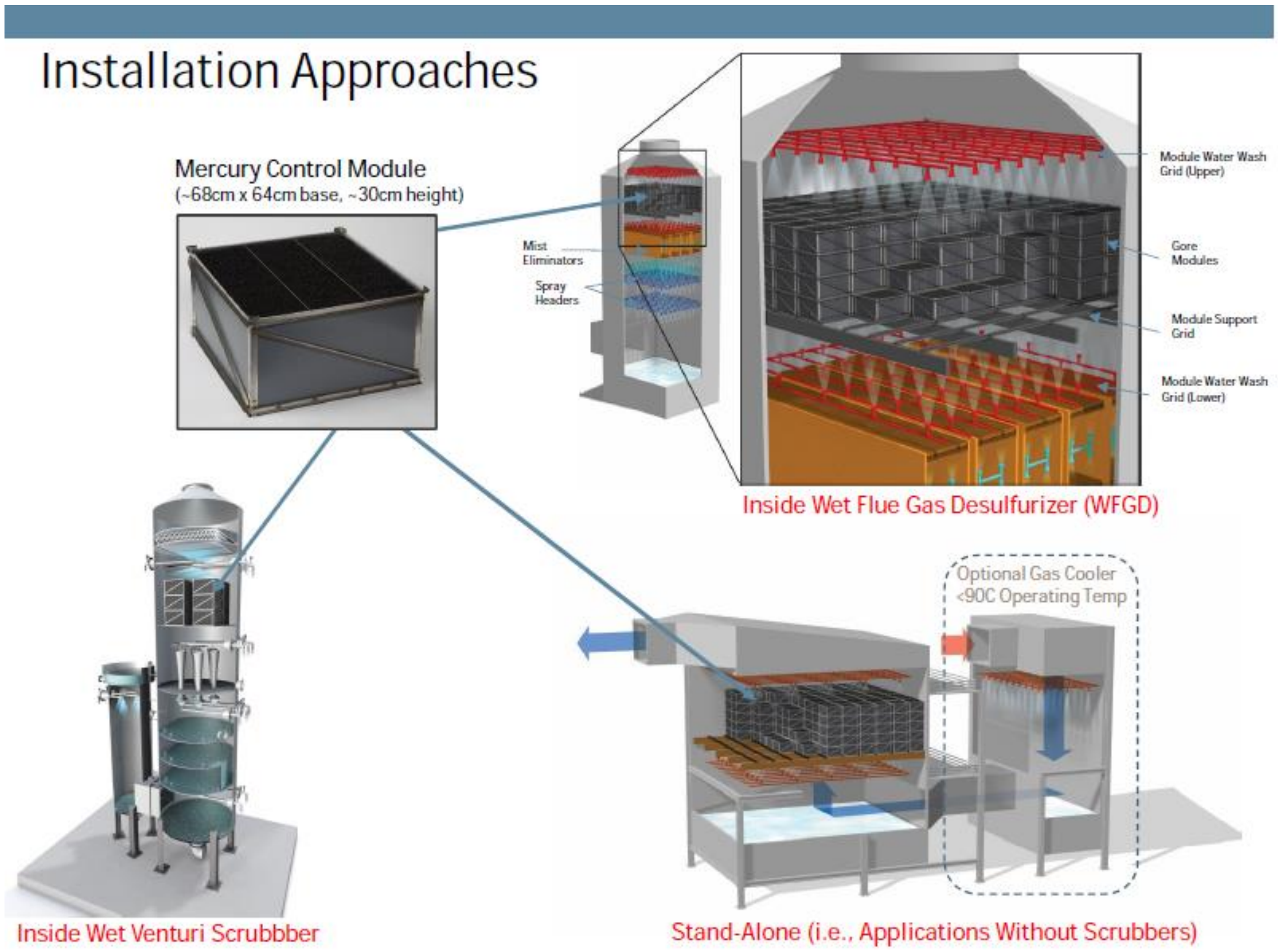
W. L. Gore & Associates

GORE™ Mercury Control System

Fixed Sorbent Technology

- An alternative to carbon injection
    - No contamination of process dust
    - Simple system, no moving parts
    - Low operating cost
- An alternative to oxidizing chemicals
    - No risk of upstream process corrosion
- An alternative to carbon fixed beds
    - Low pressure drop
    - No gas pre-conditioning requirement
    - Can be installed inside a wet scrubber
- Ideally Suited for Low Hg Concentration Gas Streams
    - Up to 250 μg/Nm3 inlet concentrations
    - Scalable solution: <1 μg/Nm3 outlet demonstrated

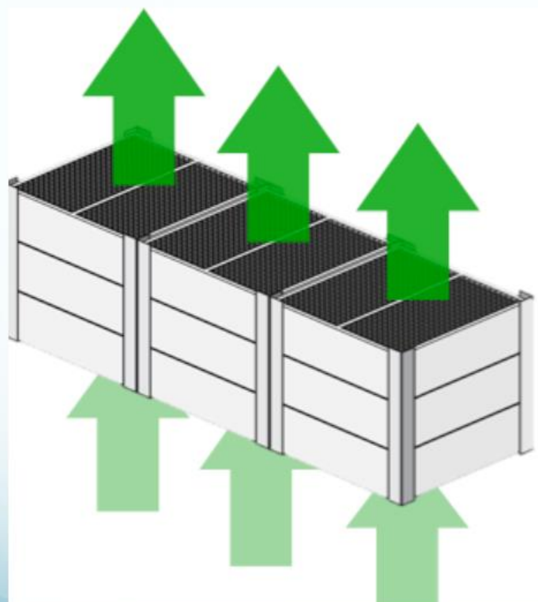
Options for Gore Module Location



EnviroCare VenturiPak with Integral Gore Module

Gore Media Basics

SPC Media by W. L. Gore



- Sorbent Polymer Composite (SPC)
  - Removes elemental mercury from gas stream (oxidized mercury can be removed by efficient wet scrubbers)
  - Media has high capacity for mercury storage
  - Small footprint (in-scrubber)
- Simple
  - No moving parts
  - No regeneration of media (replacement is required)
  - VenturiPak provides required pre-conditioning
    - Compliance with PM regulations is req'd
  - No auxiliary equipment (i.e. gas conditioning unit, radiant tube heat exchanger)
- Cost-Effective
  - Low capital cost
  - O&M cost roughly equal to carbon adsorption
  - Low pressure drop (no upgrade to blowers req'd)
  - SO_2 is removed (no caustic system req'd)

Case Histories and Examples

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FB Incinerators N.J

NJWEA

Addressing the Emission Requirements for Fluid Bed Sludge Incinerators

Howard Hurwitz
Executive Director
NORTHWEST BERGEN COUNTY UTILITIES AUTHORITY

Christopher Doelling
Vice-President
CBE
CHAVOND-BARRY ENGINEERING CORP.

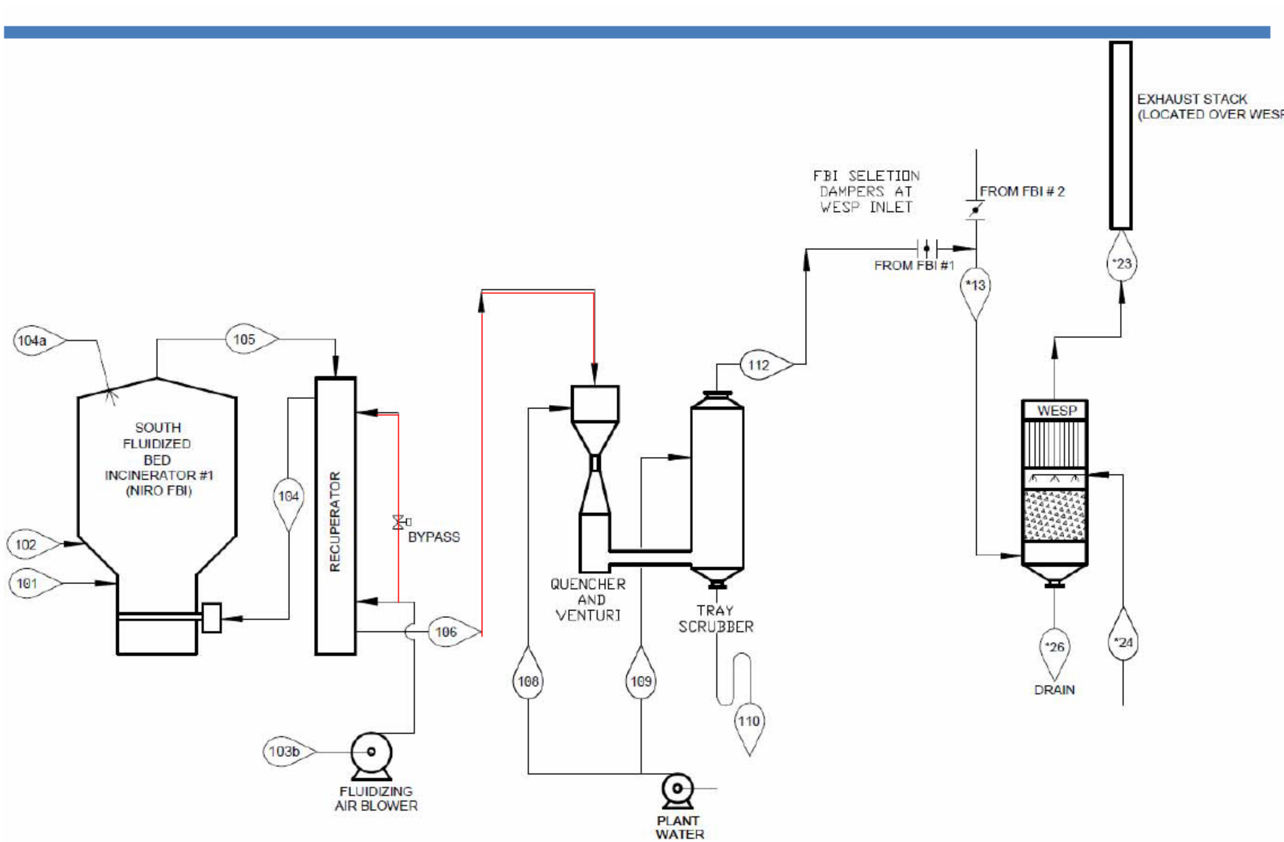
North Bergen WWTP

Two Incinerators

- Original Facility Included Fluid Bed Incinerator
- Circa 1990, a Niro incinerator was installed.
- Circa 1995, a more modern IDI incinerator was installed.
- Feed rates:
  - IDI: 2250 dry lbs/hr
  - Niro: 2000 dry lbs/hr
- Combined Exhaust: single WESP and stack installed with IDI incinerator

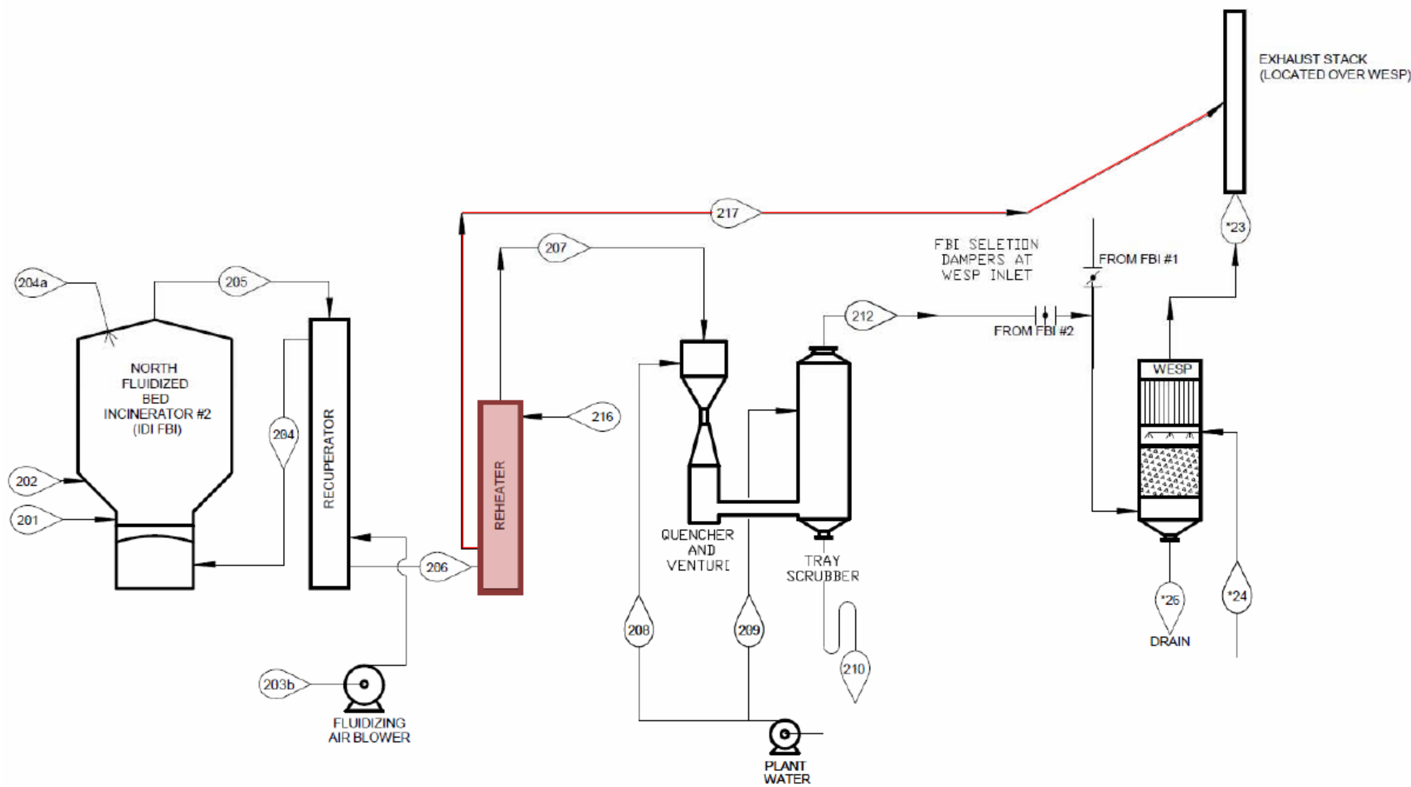
North Bergen Niro Incinerator

Niro Incinerator



Northwest Bergen IDI Incinerator

IDI Incinerator



Northwest Bergen County

IDI unit @ 85% load

IDI Unit					
Pollutant	MMMM Limit		NBCUA Result		% of limit
Cd	0.0016	mg/dscm@7%O2	9.20E-04	PASS*	58%
CO	64	ppmvd/dscm@7%O2	1.991	PASS	3%
HCl	0.51	ppmvd/dscm@7%O2	0.100	PASS	20%
Hg	0.037	mg/dscm@7%O2	7.44E-02	FAIL	201%
NOx	150	ppmvd/dscm@7%O2	43.765	PASS	29%
Pb	0.0074	mg/dscm@7%O2	2.02E-03	PASS	27%
CDD/CDF TEQ	0.1	ng/dscm@7%O2	6.42E-03	PASS	6%
CCD/CDF TMB	1.2	ng/dscm@7%O2	1.20E-01	PASS	10%
PM	18	mg/dscm@7%O2	1.477	PASS	8%
SO2	15	ppmvd/dscm@7%O2	1.327	Pass	9%

Niro Performance

Niro Unit @110% load

NIRO Unit					
Pollutant	MMMM Limit		NBCUA Result		% of limit
Cd	0.0016	mg/dscm@7%O2	3.44E-04	PASS	22%
CO	64	ppmvd/dscm@7%O2	4.52	PASS	7%
HCl	0.51	ppmvd/dscm@7%O2	0.061	PASS	12%
Hg	0.037	mg/dscm@7%O2	9.52E-02	FAIL	257%
NOx	150	ppmvd/dscm@7%O2	16.69	PASS	11%
Pb	0.0074	mg/dscm@7%O2	5.40E-03	PASS	73%
CDD/CDF TEQ	0.1	ng/dscm@7%O2	3.17E-03	PASS	3%
CDD/CDF TEQ	0.1	ng/dscm@7%O2	2.64E-03	PASS	3%
CCD/CDF TMB	1.2	ng/dscm@7%O2	9.46E-02	PASS	8%
PM	18	mg/dscm@7%O2	12.03	PASS	67%
SO2	15	ppmvd/dscm@7%O2	28.97	FAIL	193%

Northwest Bergen Options

SLUDGE DISPOSAL OPTIONS

- Dewater (20% - 25% Solids) and Truck Off-Site
  - 20 Tons/Day Dry Solids
  - 25,000 Tons/Year Dewatered Cake
  - Estimated Disposal Cost - $2.5 million per year

- Retrofit Carbon Absorption System
  - Estimated Capital Cost - $5 to $6 million
  - Estimated Debt Service - $300,000 per year

Northwest Bergen County Carbon Bed

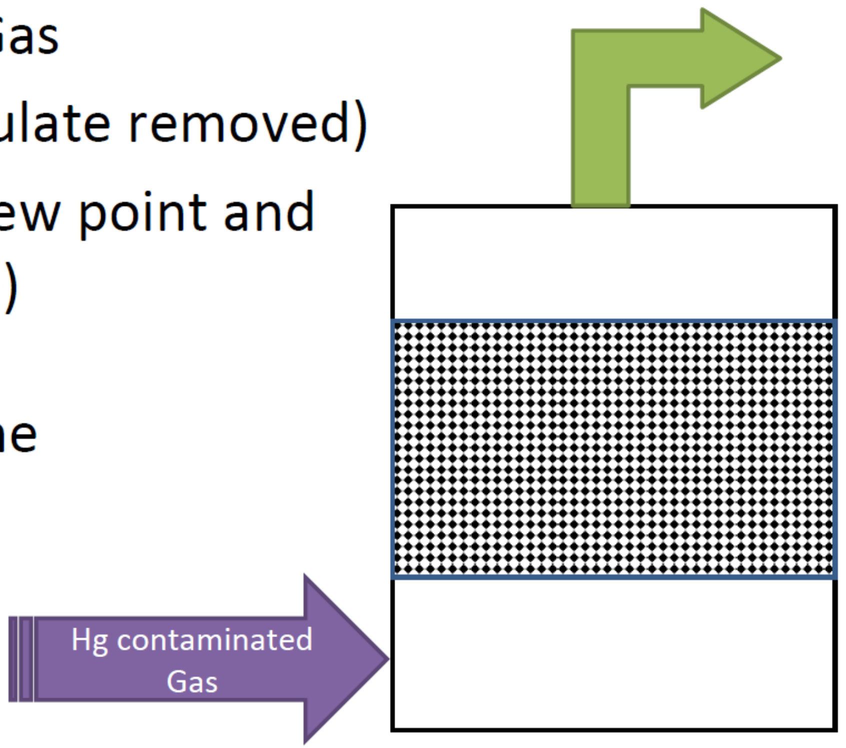
Adsorption of Hg onto Carbon

Conditioned Gas

- Clean (particulate removed)
- Dry (above dew point and droplet free)

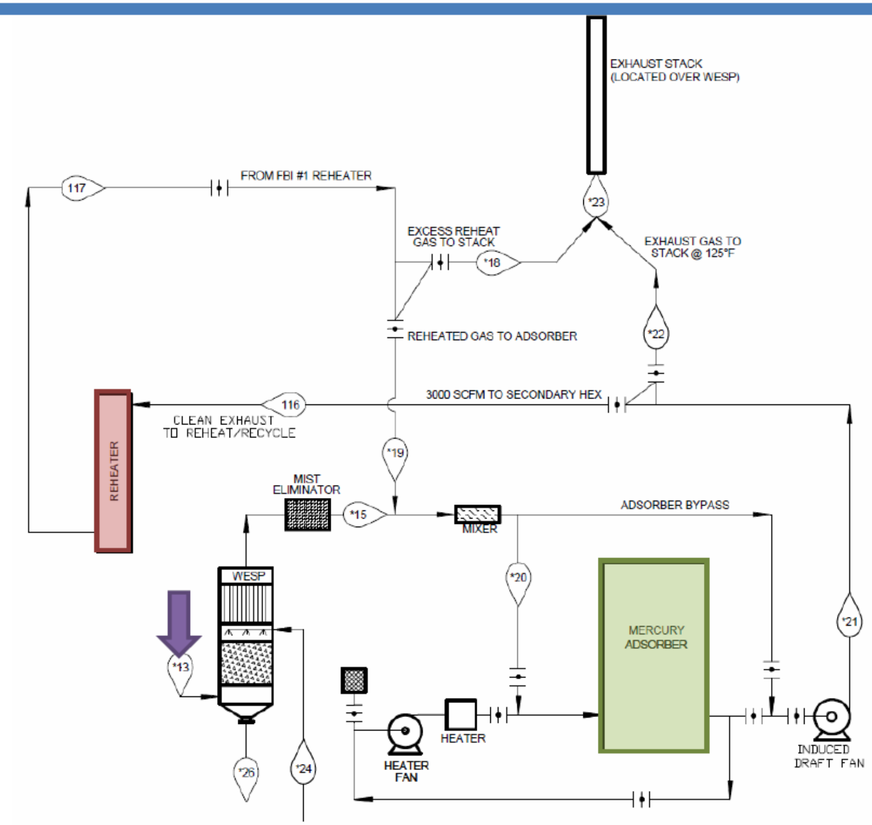
Residence Time

- 2-5 seconds



Northwest Bergen County Carbon

Hg Control: Carbon Column



Northwest Bergen County SO2

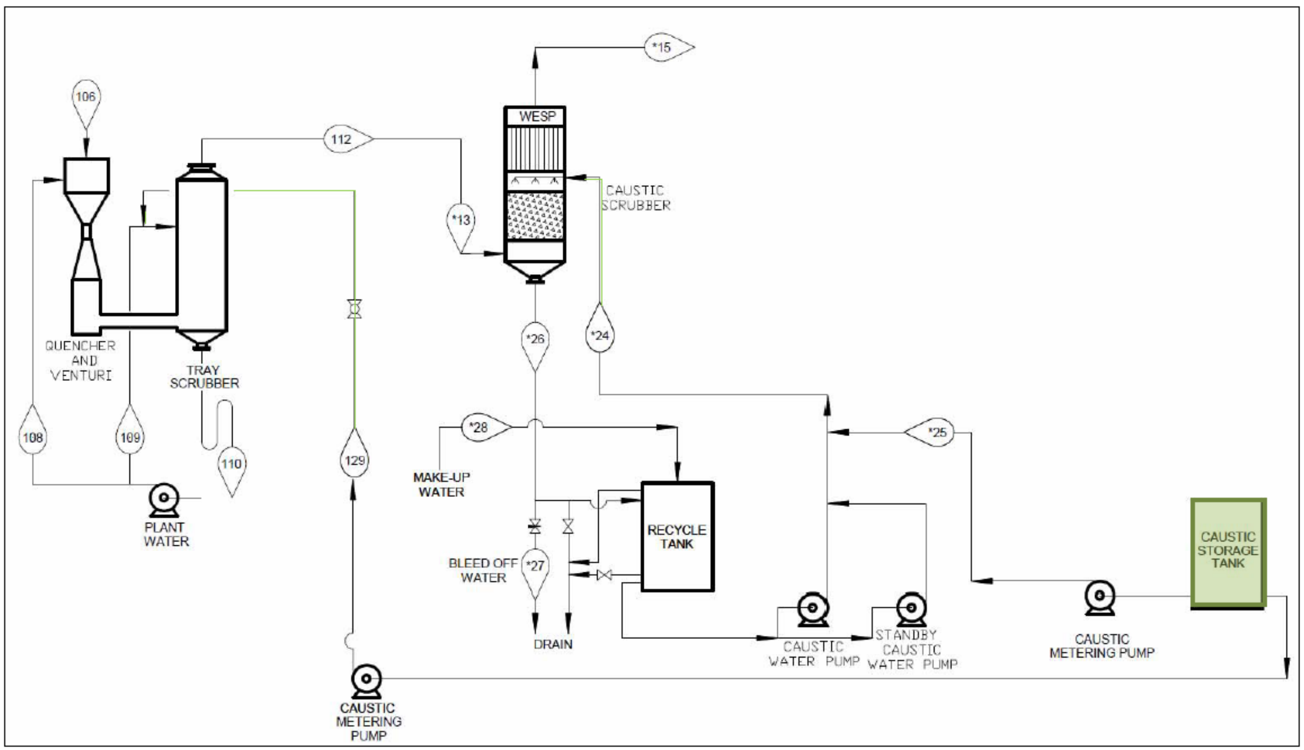
Increased SO_2 & HCl Control

- Currently have wet scrubbers
  - Venturi
  - Tray Tower
  - Packed Column

- Adding Caustic to neutralize acid gas and increase scrubber absorption efficiency
- Recycle stream to conserve caustic

Northwest Bergen County

SO2 Control: Caustic System



Buncombe County N.C. to Use Gore Module

- Part of the upcoming $5.5 million project at Buncombe County's Metropolitan Sewerage District wastewater treatment plant will involve replacing the Venturi emissions filtration system.
- The new scrubber will be installed, with a new polymer filtration system on top of it to pull out mercury emissions.
- The plant processes about 20 million gallons of sewage a day.
- The plant is upgrading the current incinerator system to meet 2016 environmental standards on mercury emissions.

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Mercury Adsorption Module

Mercury Reduction in a Wet Scrubber using Mercury Adsorption Modules

W. Hunter Carson[1], Maureen O'Shaughnessy[2], Stephen Bennett[2], Marcel Pomerleau[3*], Dave Ruggles[3], Brian Higgins[3], Jeff Kolde[4], John Knotts[4], Frank Sapienza[5], Richard Tsang[5], and Tim Ebner[6]

[1]Metropolitan Sewerage District of Buncombe County
[2]Prince William County Service Authority
[3]EnviroCare International
[4]W. L. Gore
[5]CDM Smith
[6]Element 1 Engineering

METROPOLITAN SEWERAGE DISTRICT · BUNCOMBE COUNTY, NORTH CAROLINA

SA

CDM Smith

El 1

GORE Creative Technologies Worldwide

EnviroCare International

Gore Module is Lower Cost Approach

Hg Treatment Alternatives

- Began design of carbon adsorber system and learned of a new (low-cost) alternative for mercury removal, SPC media
- Design Cost Estimate

Mercury Removal Technology	MSD Cost Estimate (Equipment Only)	PWC Cost Estimate (Equipment Only)
Carbon Adsorber Vessel & Auxiliary Equipment (i.e. gas conditioning unit, radiant tube heat exchanger)	$2,800,000 [a]	$3,700,000 [c]
Sorbent Polymer Composite Media	$225,000 [b]	$450,000 [b]
a: Quote from CPPE and Hankin	b: Quote from EnviroCare	c: Quote from CMAR 60% Design

- Potential savings were too significant; directed CDM Smith to further explore SPC media and piloting options
- Continued with carbon design in order to remain on schedule should SPC not work

MSD and PSD Mercury Capital Costs

Hg Treatment Alternatives

- Began design of carbon adsorber system and learned of a new (low-cost) alternative for mercury removal, SPC media
- Design Cost Estimate

Mercury Removal Technology	MSD Cost Estimate (Equipment Only)	PWC Cost Estimate (Equipment Only)
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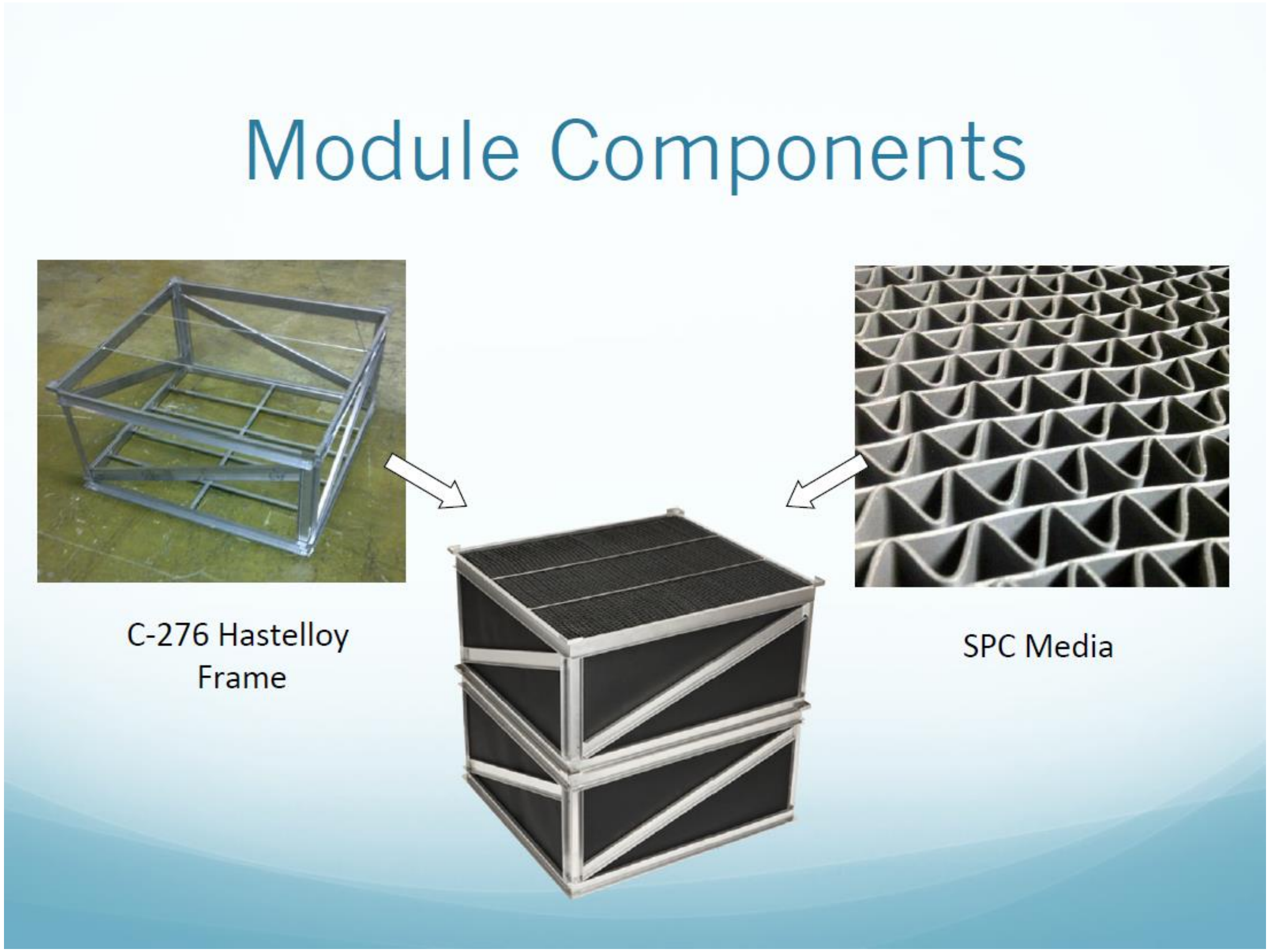
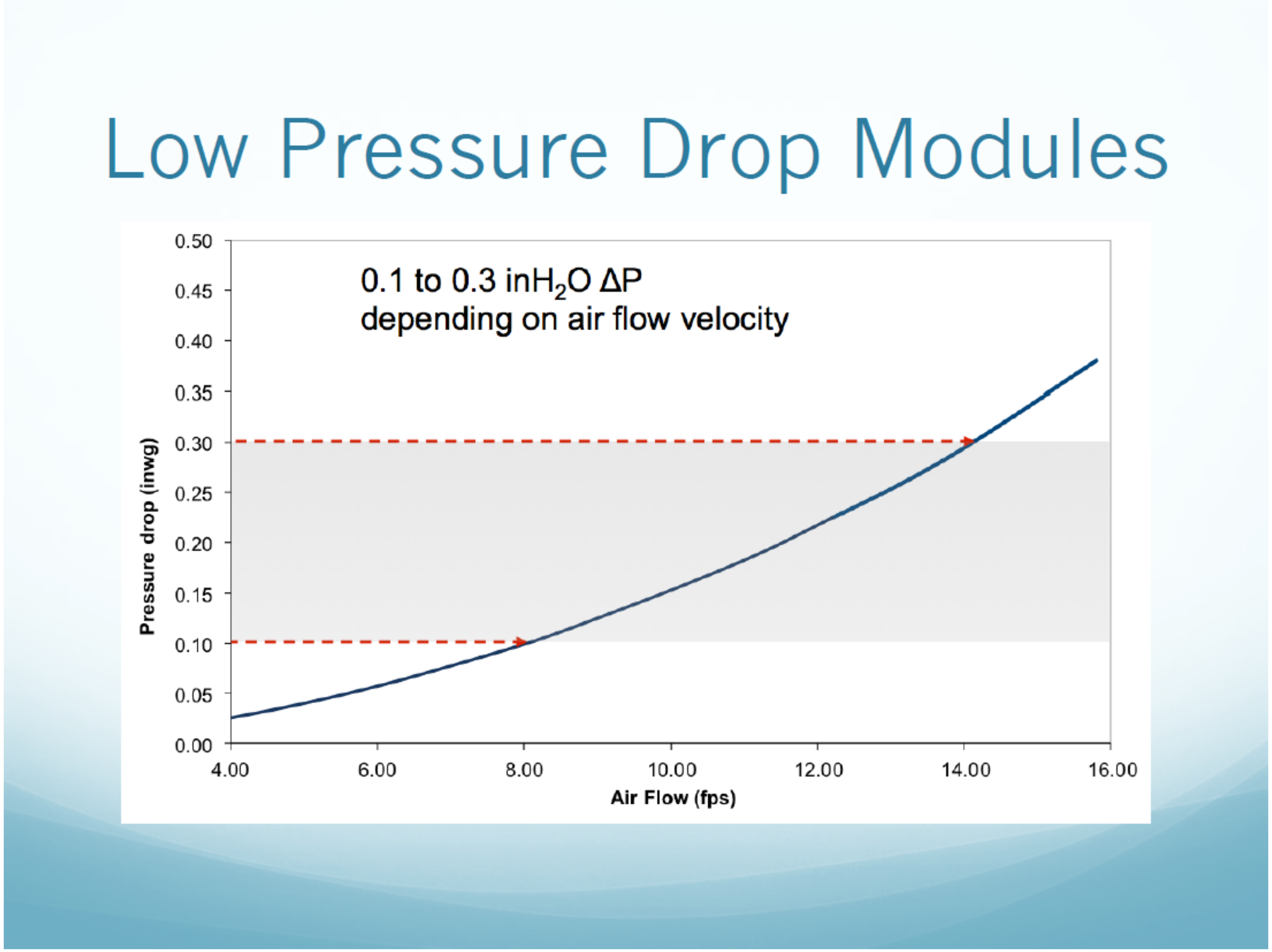
Modules with Hastelloy Frames

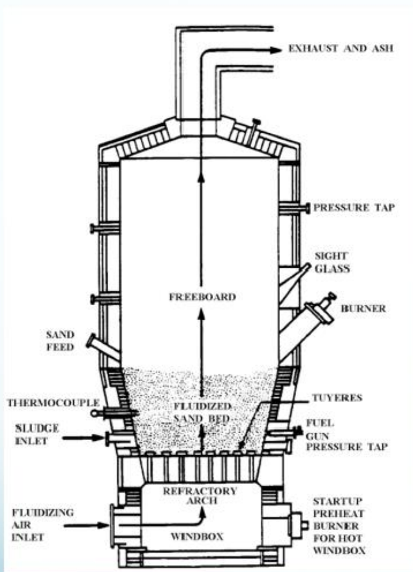


Gore Pressure Drop is Less Than 0.3 in wg



Buncombe County

MSD Buncombe County
Asheville, North Carolina



FBI

- Full load:
  - 3333 dry pounds per hour (40 dry tons per day)
- Existing Emission Controls:
  - Venturi and tray scrubber

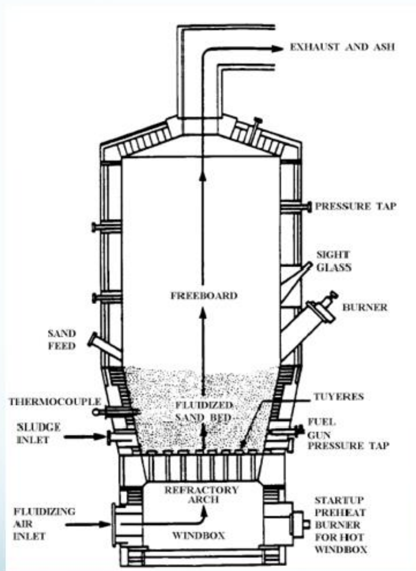
Buncombe County needs Mercury Reduction and Possible SO2 Reduction

MACT Constituent Sampling Data

Pollutant	Units (all at 7% O_2)	MACT Limit	July 2009 Data	November 2010 Data	July 2013 Data	Compliance Potential
Particulate	mg/dscm	18	18	13	13.21	Marginal
Cadmium (Cd)	mg/dscm	0.0016	0.06	0.0003	0.00018	Marginal
Lead (Pb)	mg/dscm	0.0074	0.0013	0.002	0.0033	High
Hydrogen Chloride (HCl)	ppmvd	0.51	0.13	No data	0.14	High
Carbon Monoxide (CO)	Ppmvd	64	4	No data	1.8	High
Mercury (Hg)	mg/dscm	0.037	0.12	0.08	0.099	Low
Nitrogen Oxides (No_x)	ppmvd	150	86.8	143	105.2	Marginal
Sulfur Dioxide (SO_2)	ppmvd	15	13	No data	48.9	Marginal
Dioxin/Furan (mass)	ng/dscm	1.2	No data	0.03	No data	High
Dioxin/Furan (TEQ)	ng/dscm	0.1	No data	0.003	No data	High

PWCSA has Traditional Scrubber

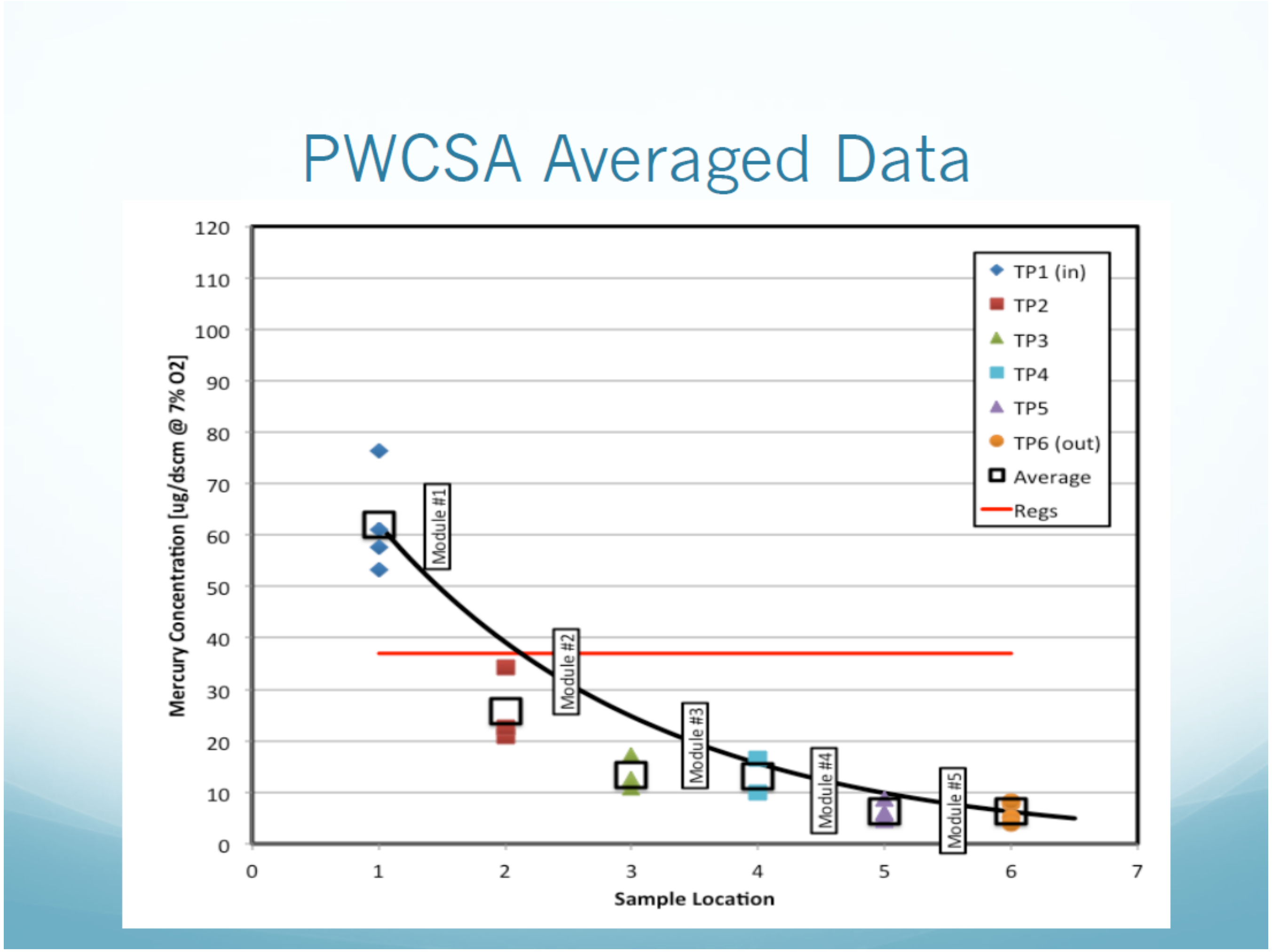
PWCSA
Woodbridge, Virginia



FBI

- Full load:
  - 2200 – 2800 dry pounds per hour
- Emission Controls:
  - Traditional scrubber

PWCSA- Adsorber Easily Meets Mercury Requirement

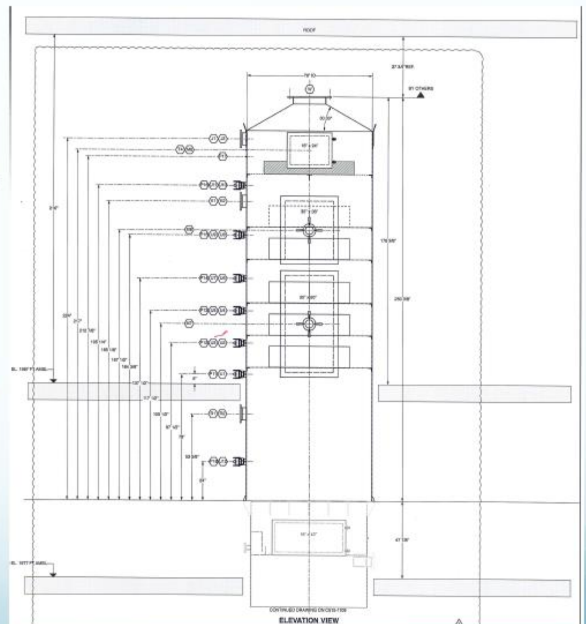


Full Scale MSD will have Four Layers

Full-Scale Design MSD

- MSD is currently in fabrication stage
- Single-vessel design; SPC modules

  located above EnviroCare VenturiPak
- 4-layer design, 16 modules total
  - ACFM = 6700
  - Hg loading = 0.078 mg/dscm
  - 24 – 36 month life (18 mo. guarantee)
- Sample ports for compliance testing and operational efficiency
- Mercury scrubber cost ~ $225,000



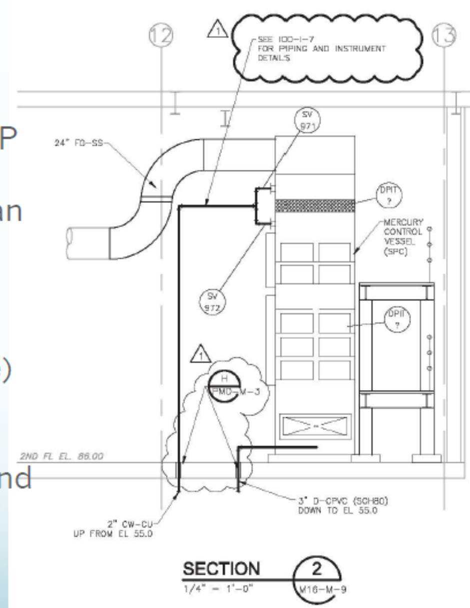
PWCSA has Room for 5th Layer

Full-Scale Design PWCSA

- PWCSA is currently in design stage
- Single-vessel design; SPC modules

  located in stand-alone unit after WESP
- 4-layer design, 16 modules total with an empty 5th layer for future
  - ACFM = 7217
  - Hg loading = 0.080 mg/dscm
  - 24 – 36 month life (12 month guarantee)
- Sample ports for compliance testing and

  operational efficiency
- Mercury scrubber cost ~ $450,000

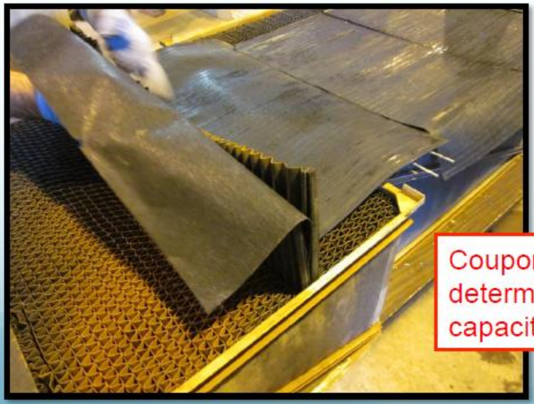


Guaranteed Media Life Span of One Year or More

Media Life Span

- Manufacturer's Guaranteed Life Span*
  - MSD: 18 months
  - PWCSA: 12 months
    - Replacement modules offered at pro-rated discount
- Expected Life Span: 24-36 months

* Guarantee based on mercury loading and gas flow



Coupon taken to determine remaining capacity

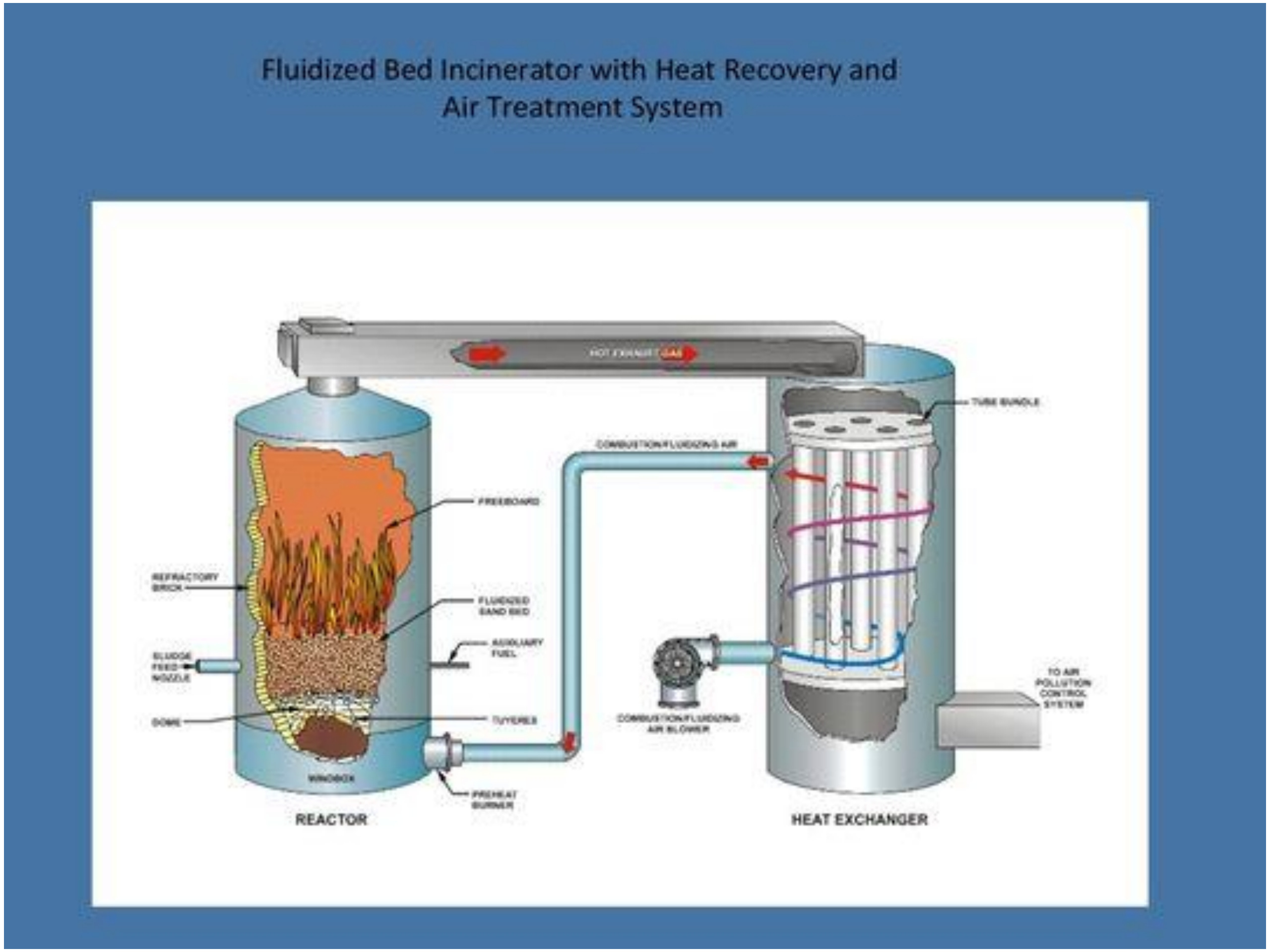
Hastelloy Frames Reusable

Disposal

- Module life spans are typically 1 to 2 years for leading modules and 3 to 5 years for trailing modules
  - Mercury capacity exceeds two pounds of Hg per module
- Disposal options:
  - Hazardous Waste Hauler (Cleanventure, MD)
  - Subtitle C Landfill (Emelle, AL) / Hazardous Waste Encapsulation
    - Approx. $165/module disposal cost (does not include hauling costs)
  - EPA Facility with Part B Permit (Cycle Chem Inc., Lewisberry, PA)
  - Ultimate disposition based on Total Hg (ppm), TCLP
    - Recycle (mercury retort) or encapsulation
- Current plan is to hire a third-party disposal company to take modules
  - Replacement modules are new
  - Frames can be reused for new modules

Testing at Edmonds Wa, Asheville MSD and PWSA VA

Gore Module to Follow Heat Exchanger at N.C Incinerator



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T.Z Osborne Incinerator Replacement in Greensboro N.C

- Wastewater is treated at two wastewater treatment facilities. T.Z. Osborne Water Reclamation Facility has the capacity to treat 40 million gallons per day (mgd), while North Buffalo Creek Water Reclamation Facility can treat 16 mgd. The fluidized bed incinerator replacement project is nearly complete at the T.Z. Osborne Water Reclamation facility. The equipment is an integral component in the daily disposal of waste.

- The sludge produced from both wastewater facilities flows into a fluidized bed incinerator located at the T.Z. Osborne Facility, and the ash remaining is hauled to the City sanitary landfill for disposal..
- Purchased in 1996, the old incineration unit had reached the end of its design life resulting in the need for replacement. This piece of equipment is critical in the wastewater treatment process, and replacement is a beneficial step in maintaining cost efficiency in the daily operations of the facility.

Naugatuck Incinerator Hg Options

- The Borough of Naugatuck's Wastewater Treatment Plant operates a 3.5 dry ton per hour (DTPH) fluidized bed sewage sludge incinerator (SSI) system. The existing system consists of a thermal sludge dryer (TDU), fluidized bed combustor (FBC), air preheater, hot oil heat recovery unit, wet venturi scrubber (VS), multi-stage wet impingement tray scrubber (ITS), induced draft fan, and a wet electrostatic precipitator (WESP).
- Mercury (Hg) stack emission data is available from all stack tests between 2004 and 2013, and averages 0.0899 mg/dscm at 7% O2. The new regulatory limit under subpart MMMM is 0.037 mg/dscm at 7% O2, so this will require a 59% reduction from the average. Unlike historic Pb emissions, Hg emissions from the Naugatuck SSI system are consistently above the new regulatory limit, so there is no doubt that additional APC equipment for mercury control is required. TRC explored some chemical oxidant chemistry options in the wet scrubbers for mercury control and put together a trial plan, but several factors caused that pursuit to be abandoned, including the logistical complexity and low expectation for success. Advancing to the commonly used mercury sorbent capture options was instead recommended.
- TRC approached seven vendors to solicit budgetary proposals for APC equipment solutions for mercury capture. Only five responded, and two declined to make a proposal. Of the three that did, the common control technology was sorbent capture. Sorbent injection, usually activated carbon, with a fabric filter dust collector (i.e. baghouse) is not an attractive option due to high relative capital cost and huge relative waste of sorbent, unless there is an existing baghouse or if there is separate justification to install one. Fixed beds are more cost effective. The next slide summarizes the mercury control options from the three APC vendors who made budgetary proposals.

Gore vs AC Bed at Naugatuck

Company	Bionomic Industries	Cameron Great Lakes	EnviroCare Industries / Alpine Technology
Contacts	Dave Meier / Ken Schifftner	Joe Battaglia	Marcel Pomerleau / Peter Brady
Technology	Fixed bed, with sulfurized activated carbon adsorbent	Fixed bed, with sulfurized activated carbon adsorbent	Fixed bed, with W.L. Gore & Associates/ECI novel sorbent
Additional Details	• Series 3000 dual bed carbon adsorber • Loose fill carbon • Suggested ¾″ FRP	• Model SA3H3W • 3 x 3 modules • 24″ x 24″ x 2″ deep trays • 8 trays per module x 9 =72 trays per pass x 3 passes = 216 trays total • Transition pieces included	• 4 or 5 layers with 4 to 6 modules per layer, 16 layers assumed for installed cost • Can be retrofitted and included on top of the wet ITS scrubber or as a standalone unit (latter more likely) • Capture media is expanded PTFE impregnated with a proprietary Gore sorbent
Approximate Overall Size	30 ft tall x 8 ft diameter, single tower	6.5 ft tall x 6 ft wide x 12.2 ft long, single unit	12 ft tall x 8 ft diameter, single tower
Guarantee	0.025 mg/dscm at 7% O_2 for 12 months	90% reduction per stage x 3 stages = 99.9% removal which will far exceed the requested guarantee of 0.025 mg/dscm at 7% O_2, duration unknown	0.025 mg/dscm at 7% O_2 for 18 months

McILVAINE

Gore Module Slightly Lower Capital Cost

Company	Bionomic Industries	Cameron Great Lakes	EnviroCare Industries / Alpine Technology
Budgetary Installed Capital Cost [3]	$1,124,000	$1,043,000	$955,000
Estimated Media Life before Replacement	10 years	10 years	3 years
Media Replacement Duration	1 day	1 day	1 day
Media Replacement Cost [4]	$47,918 ($2.47/lb for contractor to remove and dispose of spent carbon and replace with new)	$16,019 ($4.12/lb for contractor to remove and dispose of spent carbon and replace with new)	$172,560 ($8,500/replacement module; $128/module for disposal)
Budgetary Annual Operating Cost [1]	$213,000	$201,000	$215,000
Other Maintenance	• Periodic draining of any condensed water (no shutdown required)	• Periodic draining any condensed water (no shutdown required)	• Recommended yearly 3-4 days inspection by EnviroCare (~$4,200 and a 2 day shutdown required) • Additional inspection tasks and frequencies will be provided with individualized operation and maintenance manual
Pros	• Simple, proven technology • Small footprint	• Simple, proven technology	• Stream does not have to be dry before passing through the media • Less frequent media change-outs • Some coincidental SO_2 removal

McILVAINE

Can Gore Module Meet Efficiency Needs?

Company	Bionomic Industries	Cameron Great Lakes	EnviroCare Industries / Alpine Technology
			• Lower pressure drop (1.3″wg), so should require no fan modification • Vendor claims direct experience designing and troubleshooting for wastewater incinerators
Cons	• Stream must be dry before passing through the media, so may require a drying heat exchanger • Higher pressure drop (5″wg), so may require a new or modified fan	• Large footprint • Stream must be dry before passing through the media, so may require a drying heat exchanger • Higher pressure drop, so may require a new or modified fan	• Newer technology with less runtime history available • Naugatuck's reduction target is on the edge of technology's reduction capability

McILVAINE

Gloucester County Upgrade

- In the early 1970's, The Gloucester County Utilities Authority installed a fluidized bed incinerator to burn sewage sludge produced at its sewage treatment facility
- As part of a 2000 upgrade, the fixed metal throat venturi scrubber was replaced with a “plumb bob” design variable throat venturi. The high velocity through the old venturi continuously eroded the bottom cross over section causing shutdowns and excess maintenance costs. The replacement was specifically installed to eliminate this problem. However, the replacement eroded through just above the throat inlet area.
- After several repairs and no advice from the manufacturer, it was surmised that the sharp turn into the venturi throat caused the particulate to bombard one side of the inlet. Ironically, the old venturi, using the same inlet duct did not experience this problem. A long radius, refractory lined duct was installed to direct the flow of particulate laden gas straight into the venturi. This eliminated the problem. The lesson learned is that stream lines into a venturi are a critical design consideration.

St Paul

- All FBI exhaust gases will be treated in a four-step process consisting of a mercury control system, dry ESP, wet scrubbing, and wet ESP. The mercury control system is expected to be comprised of an activated carbon injection system.
- The dry ESP will remove up to 99 percent of the particulates in the exhaust stream including the activated carbon granules onto which mercury is absorbed.
- Wet scrubbing will then lower the temperature of the gas stream to condense volatile compounds and remove acid gases, such as sulfur dioxide (SO2) and hydrogen chloride.
- The wet ESP will remove volatile compounds condensed in the wet scrubbers and the remaining particulates and heavy metals, such as lead (Pb) and cadmium (Cd). The exact details of the air pollution control system may vary depending upon which contractor is selected to design and build the FBIs. However, any design alternatives proposed by the FBI design/build contractor must meet the same performance specifications.

New Orleans

- The FBI system was added to the East Bank Plant during 1978 for disposal of waste activated sludge (WAS) removed fiom the plant secondary treatment process. The system is designed for 24 hourdday, 7 daydweek options with scheduled shutdowns for system PIM, inspections, and maintenance repairs.
- The Dorr-Oliver FBI has a design capacity of 40.65 tons dry solids per day at 20% cake solids. The system design criteria and flow diagram are included at the end of this chapter. Dewatered WAS from the plant sludge dewatering units is pumped (Schwing Pump) to the FBI on a continuous basis (not to exceed 1.66 dry tons per hour). The FBI is a refhidory brick lined vessel that allows mixing of the cake into the hot fluidizing bed of sand at the bottom of the bed. The FBI Sand Bed temperature is maintained around 1300 degrees F to 1500 degrees F for complete burning of the sludge solids to inorganic ash. The Fluid Bed Incinerator has three zones in operation. The Windbox is the zone where the fluidizing air goes into the incinerator. This zone is also where the incinerator is heated. The BED is the zone where the sand and sludge are pumped. This zone is also where we inject fuel oil or gas to maintain the system temperature. The last zone is the Freeboard. This zone is where all the off gases are burned up. The sand bed is fluidized (kept in suspension) by a continuous supply of air fiom the fluidizing air blower.
- Under normal sludge burning operating conditions, this airflow is approximately 6000 - 8500 sch. The fluidized sand bed is heated by the burning sludge and grease solids and also by auxiliary. fuels (oil or gas), which are pumped into the bed. The action of the fluidized bed burns and grinds the sludge cake to small particles, which are more easily and completely burned.

New Orleans Scrubber

- The Venturi provides cooling of the gases and the removal of the ash particles in the Incinerator exhaust gas flow. The solids (ash) are trapped in the venturi throat area where water is injected at 170 to 210 GPM. The ash slurry drains to the base of the Scrubber and then to the Ash Pumps and discharge to the Ash Lagoons where it is dewatered. Water for the Venturi operation is provided from the Plant Utility Water Pumps, The Scrubber provides the last stage of the removal of the smaller particulate matter through four (4) water tray sections. The particulate matters are trapped in the water as it passes through each stage of the water trays. The Plant Utility water is injected at 650 to 850 GPM and is discharge into the effluent water channel.

Black & Veatch Designing Sewage Sludge APC Systems for St Louis and has Systems in Detroit and Indianapolis

- -- A new $35 million incinerator air emissions upgrade program is underway at the Metropolitan St. Louis Sewer District (MSD) \The project is expected to bid to contractors in March of 2015, while construction is projected to begin by May 1, 2015. Completion is set before the compliance deadline to allow testing for the scrubbers..
- The project will entail installing advanced wet scrubbers on MSD's Bissell Point and Lemay plants in order to meet the Maximum Achievable Control Technology (MACT) standards. Together, the Bissell Point and Lemay plants incinerate 75 percent of all solids generated by the MSD service area.
- The project will employ a single, adjustable venturi scrubber followed by train impingement scrubbers on each of the incinerators, according to Tom Ratzki, P.E., M.ASCE, a project director for Black & Veatch.
- Black & Veatch is currently completing similar work in Detroit and Indianapolis. In addition, the company is providing design, permitting and construction management for a new incinerator facility for the Little Blue Valley Sewer District in Eastern Jackson County, Missouri. It is the first in the state to be permitted under the new MACT SSI standards.
- "Retrofitting existing facilities always presents unique challenges," said Tom Ratzki, Black & Veatch project director for the St. Louis proposal. “

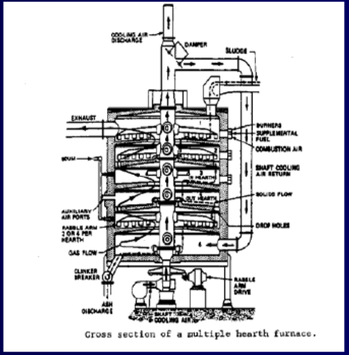
MaxWest in Sanford FL Modified in 2013

- final air permit modification, authorizes replacement of an existing gasifier and modification to the existing thennal oxidizer. This construction permit modification allows the permittee, MaxWest, to replace t.he existing gasifier with one of two possible options; option" A" is a fluidized bed gasifier and option "B# is a rotary style gasifier. Each option for the replacement gasifier can be instaJled and tested during the construction permit modification period until March 30, 2013. . The proposed work. will be conducted at MaxWest EnvironnentaJ Systems/City of Sanford Biosolids Gasification Facility, which is waste-to-energy gasfication system (). The facility is located in Seminole COW1ty at 3540 Cameron Avenue (at the wastewater treatment plant) in Sanford, Florida. The UTM coordinates are Zone 17, 479.08 km East and 3181.11 km North.
- The system consists of the materials handling system. the continuous dryer heated Indirectly by a thermal fluid., the baghouse (BCE Model SW-256-12~IX), the primary gasifier, the thermal oxidizer, and the thermal energy transfer system. There is a scrubber/secondary heat exchanger.

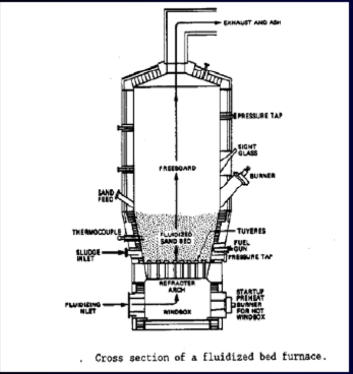
NEORSD Southerly

Southerly Biosolids

Replace 4 existing Multiple Hearth Incinerators



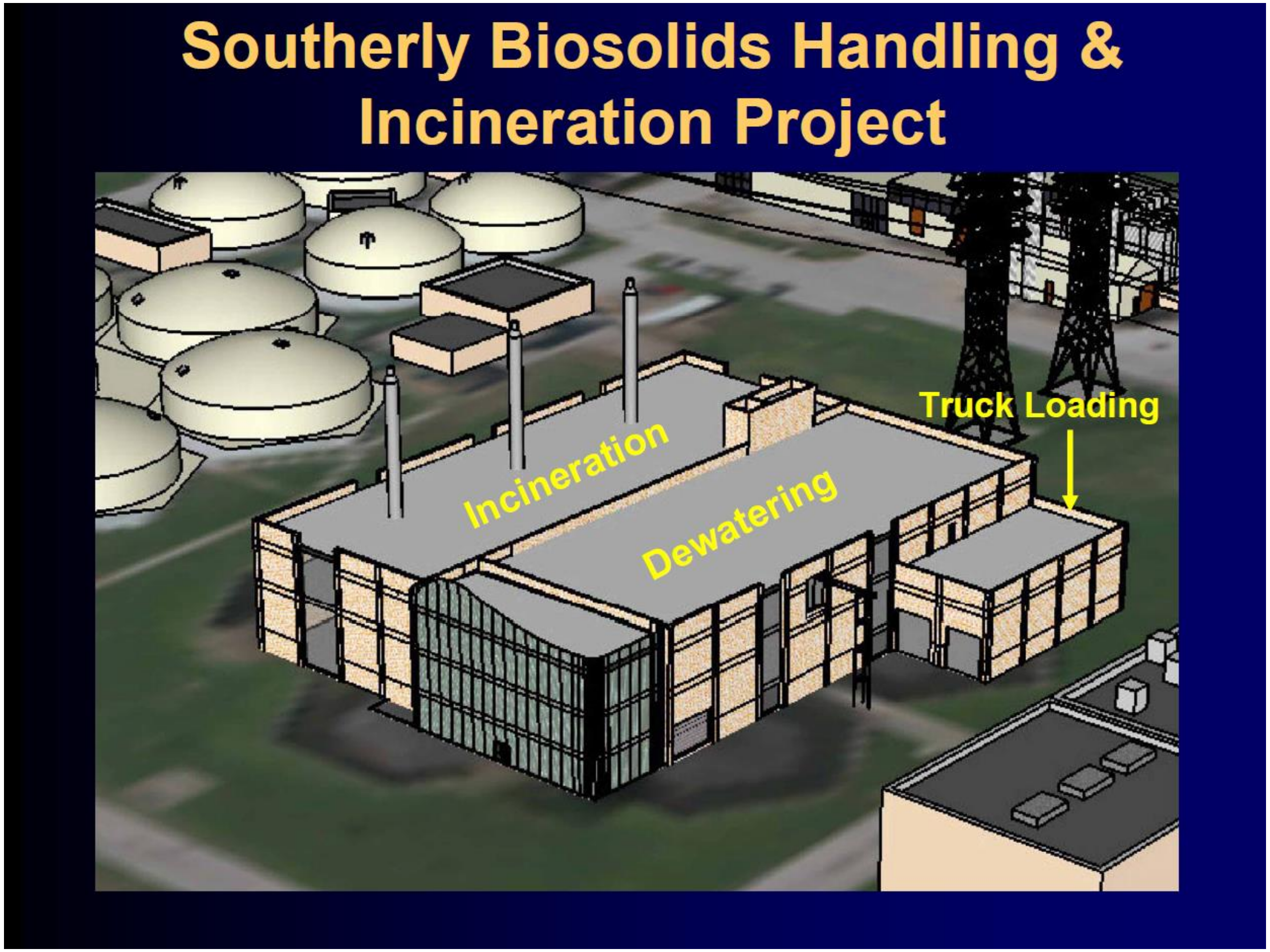
Cross section of a multiple hearth furnace.



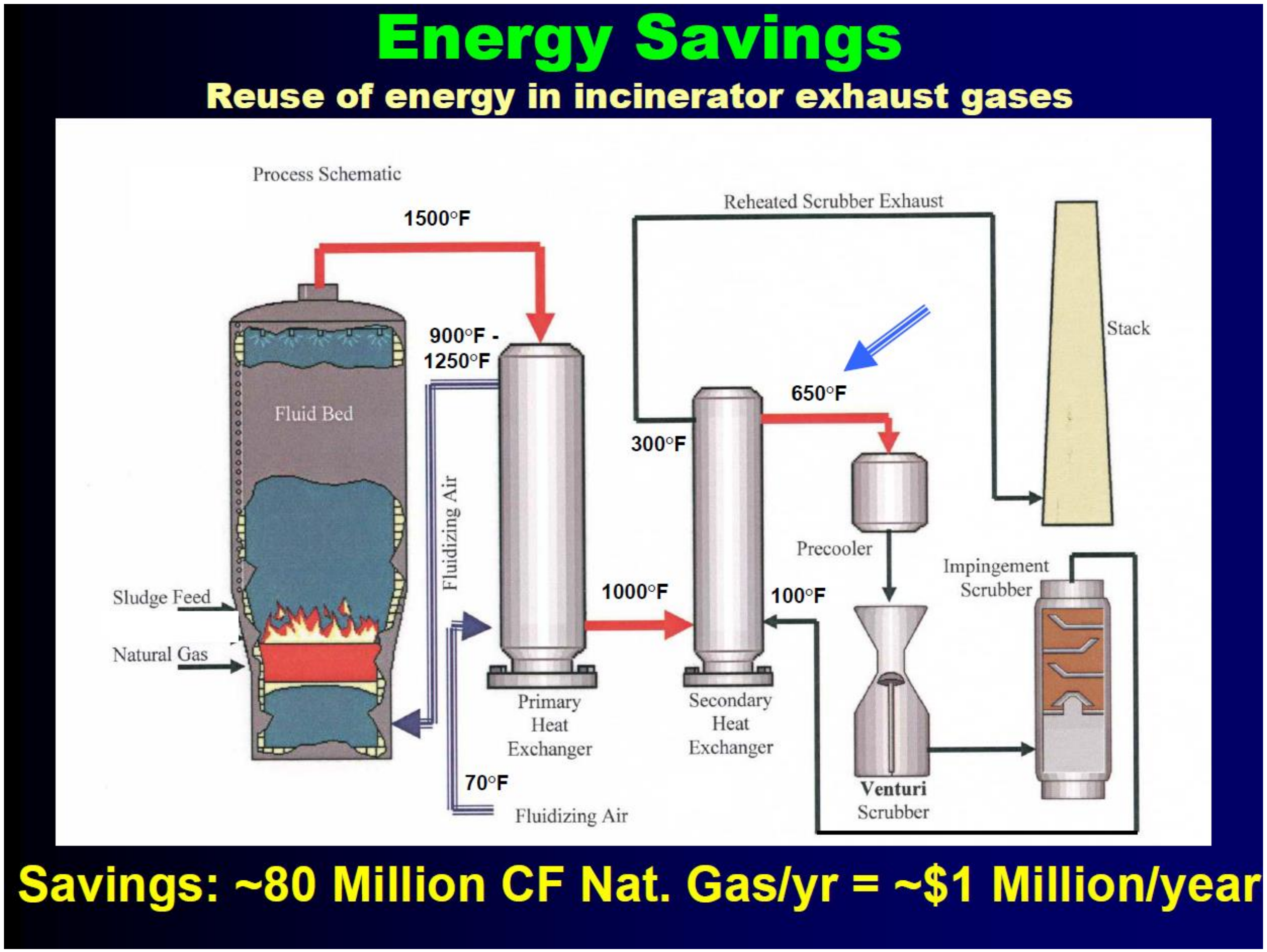
Cross section of a fluidized bed furnace.

with 3 new 100 dry ton/day Fluidized Bed Incinerators

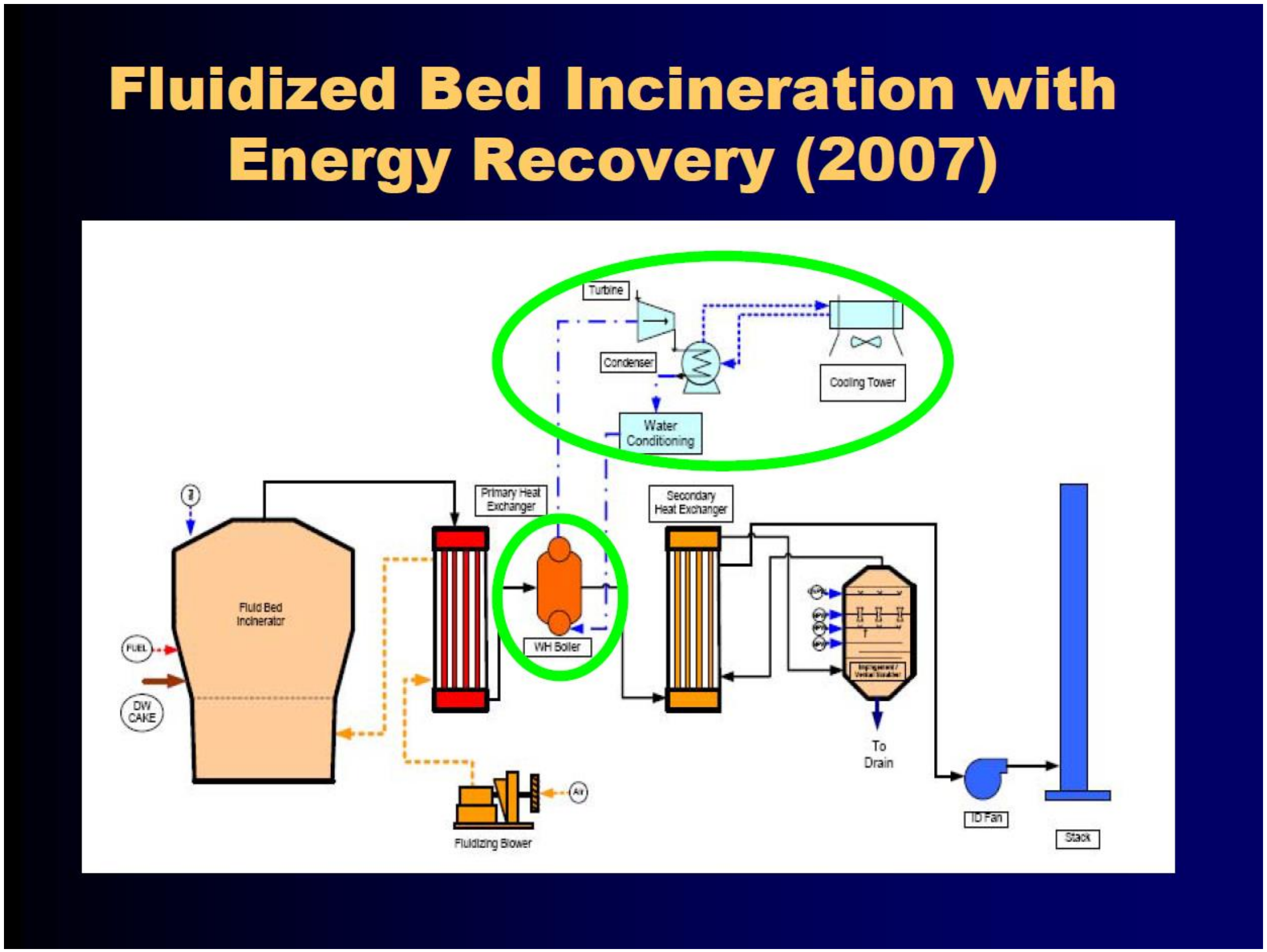
NEORSD Southerly



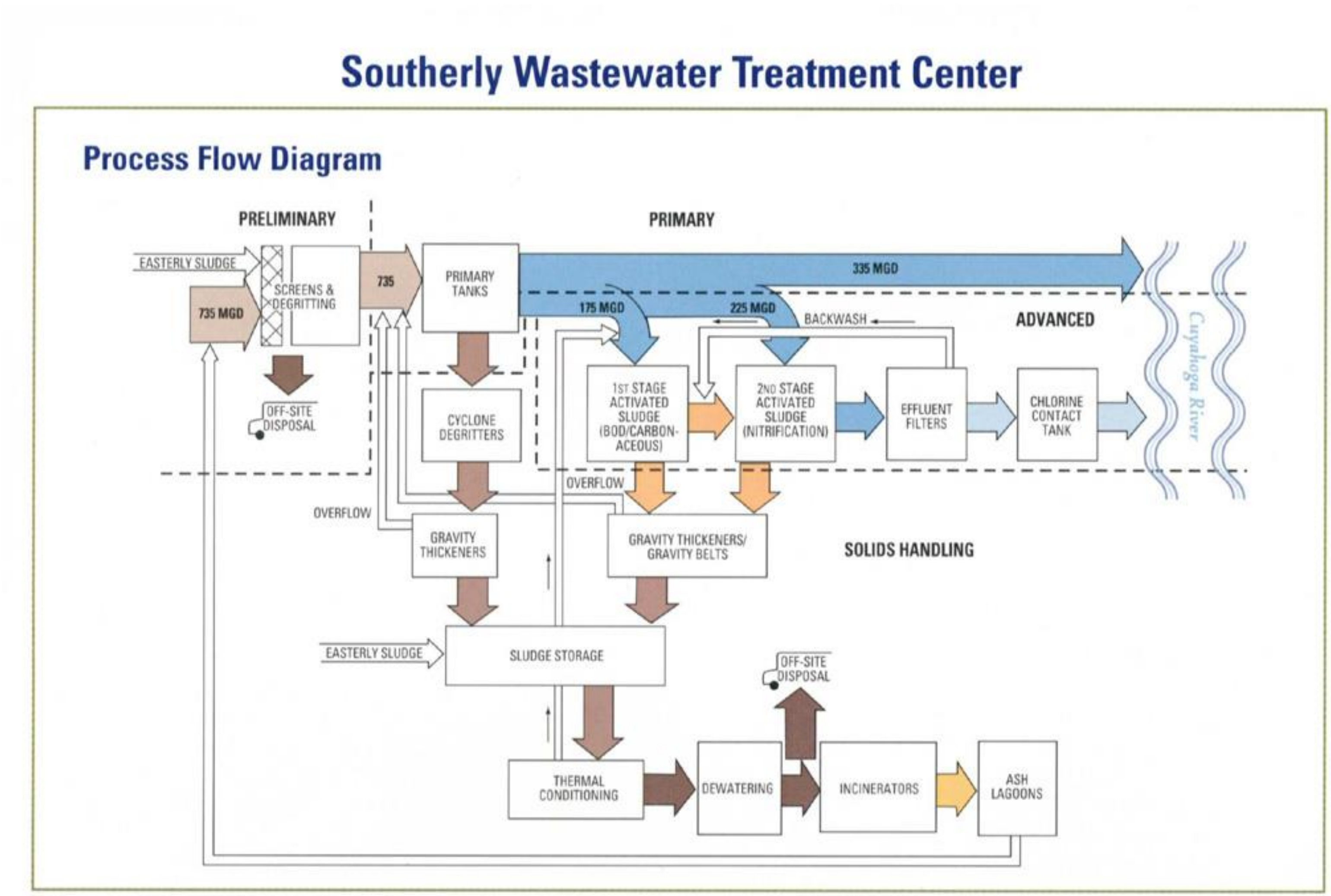
NEORSD Southerly



NEORSD Southerly



NEORSD Southerly Plant Schematic



New Jersey Bayshore Incinerator Renovation

- **<u>BRSA moves forward with $42.8 Million WWTP Project</u>**
- The commissioners of the Bayshore Regional Sewerage Authority (BRSA) authorized a $16.45 million contract for repairs and mitigation to the wastewater plant's incinerator building, moving the first phase of a $42.8 million project forward.

- The contract was awarded to Stone Hill Contracting Inc., which will likely begin work in the near future, according to BRSA Executive Director Robert Fischer.

- The incinerator repairs are part of a four contract, $42.8 million restoration and mitigation project for 12 buildings damaged at the plant during superstorm Sandy, when the 14-acre facility in Hazlet was inundated with 3 feet of water from the Raritan Bay. In addition to the incinerator building, the facility's blower building and sludge pumps, as well as various authority buildings, are included in the project.

- Despite the needed repairs and upgrades, the wastewater treatment facility is currently operating at full capacity.

- Contracts on the various authority buildings and pump stations have been advertised, and Fischer said he expects the agency to receive all bids by March 26 and award the contracts in April.

- Following the repairs, work will continue on protections such as 6-inch-thick walls and floodgates for some buildings. Those floodgates would be lowered in advance of a hurricane or severe storm in order to seal off the buildings, Fischer has said. The remaining facilities will be made "wet-floor proof," meaning the equipment will be elevated out of harm's way and floodwaters will be allowed to enter during a storm. The incinerator building, used for destroying the sludge that is a byproduct of the plant's operations, will also be the focus of upgrades intended to meet new federal emissions standards, which are set to go into effect in 2016

Stonybrook NJ uses RTO and WESP

- **RTO Technology reduces Operating Costs at New Jersey WWTP**
- The Stony Brook Regional Sewerage Authority (SBRSA) in Princeton, NJ's River Road Wastewater Treatment Plant receives flow from Princeton Borough and Township, South Brunswick Township, and West Windsor Township.
- The sludge generated by the plant is de-watered and then incinerated in one or two multiple hearth incinerators. The sewage sludge incineration (SSI) process is continuous and averages approximately 6.0 wet tons per hour, operating 6 days per week and 52 weeks per year.
- To control odors and carbon monoxide (CO) at SBRSA, the exhaust from the incinerator was originally conveyed to a direct fired afterburner system, before passing through a wet venturi scrubber for removal of coarse particles. The Authority recognized that approximately 50 percent of the natural gas used in the incineration process was consumed by the direct fired afterburner. This became the focus of the Authority's initiative to reduce operating costs.
- SBRSA consulted Chavond-Barry Engineering (CBE) in Blawenburg, NJ. After extensive review of the process, CBE recommended a Regenerative Thermal Oxidizer (RTO) to obtain the greatest reduction in operating costs.
- CBE recommended Dürr Systems of Plymouth, MI, based on their successes at similar facilities in Wayne, NJ and Fitchburg, MA. High thermal efficiency, high destruction efficiency and a proven track record were some of the reasons used to formulate CBE's equipment and supplier recommendation. In addition to Durr's experience in the industry, CBE specified Dürr's Ecopure RL RTO system for the added benefit of the single rotary valve that allows for high destruction efficiency, low system maintenance as well as the compact footprint offered by the skid-mounted design.
- The project included the addition of a Wet Electrostatic Precipitator (WESP) for a total system install cost of $4.9 million. Since going online with the Durr RL RTO, SBRSA has realized an average monthly savings in natural gas usage of 49 percent. That equates to over $2,500,000 thus far in energy cost savings. The return on investment for the entire project stands at just under 3.5 years.
- Risk was greatly reduced by employing an RTO technology that was previously proven in difficult situations where odor and CO destruction were critical project objectives. The Ecopure design features a single rotary diverter valve, twelve heat recovery chambers enclosed in a single tower, and a pre-piped, pre-wired, skid-mounted package. The single rotary valve isresistant to particulate and condensables while few moving parts reduce maintenance and improve system uptime.The RL features a continuous purge which makes it well-suited for any performance emission reduction application. An RTO without a purge feature will "puff" untreated emissions which can be detected locally. Rotary valve RTO's eliminate the "puffing" which occurs during valve switching, a common problem with conventional regenerative thermal oxidizers.

Brockton Mass

- **Brockton Received $11 Million for WWTP Upgrades in 2011**
- Gov. Deval Patrick's head of stimulus funding was full of praise after touring the Brockton's sewer treatment plant, which has received $11 million in stimulus money for upgrades.

- The $11 million is being used to upgrade the plant's sludge-burning incinerator as well as manholes and pipes. Those changes follow a $74 million installation of state-of-the-art ultraviolet disinfecting technology, sand filters and other improvements at the plant.

- David Norton, who oversees the plant, said the incinerator was shut down for improvements when the city began trucking a solid sludge product called "cake" to Woonsocket, RI, for burning. Norton said the incinerator upgrade, which cost almost $4 million, will reduce emissions of particulate matter and hydrocarbons. The incinerator could be finished in a few weeks, and the system improvements are due to wrap up in December or January, 2011.

RTO and Afterburner

Return to
T of C

After Burners vs RTO

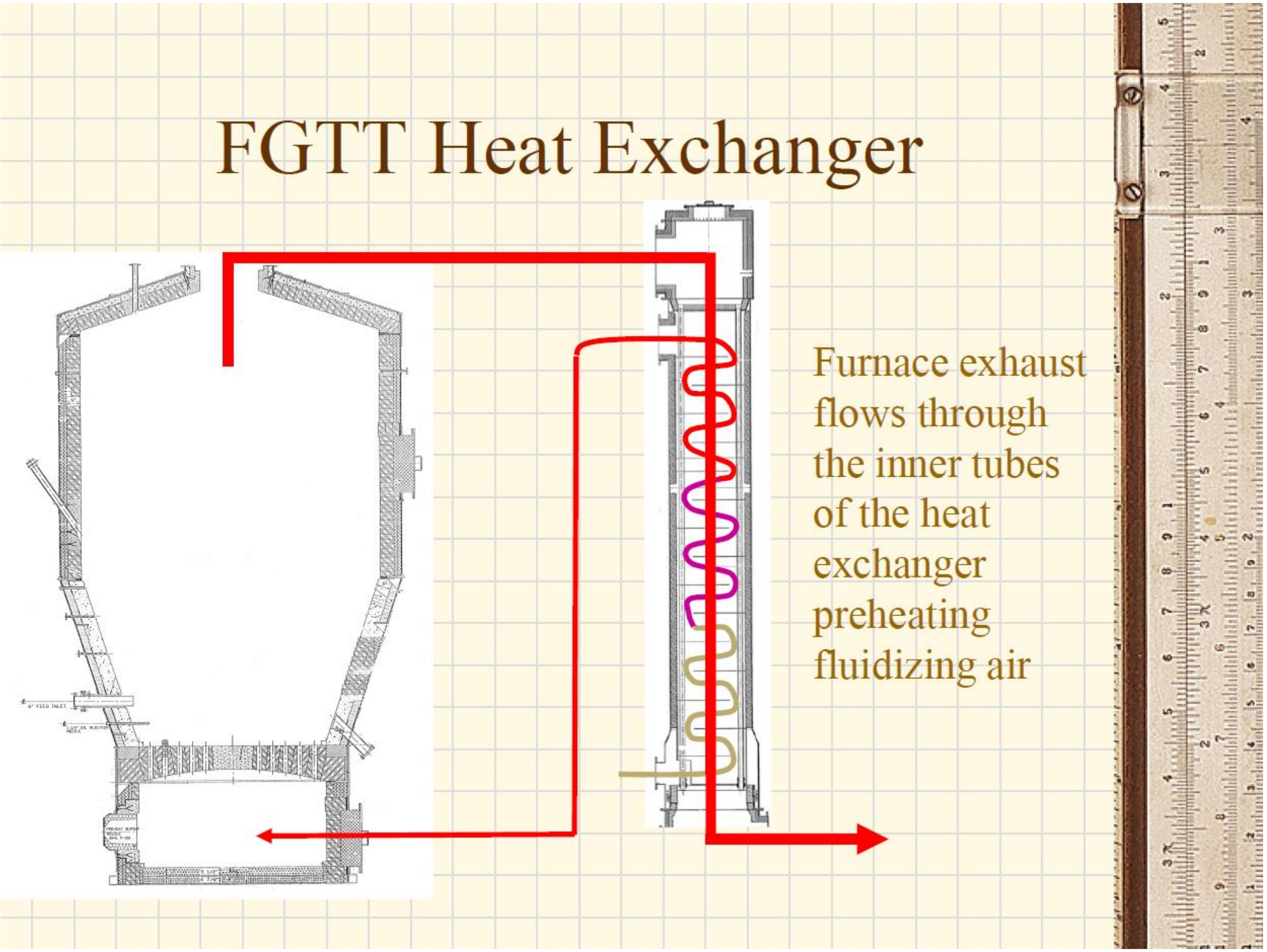
Efficiency and Design Improvements in Multiple Hearth & Fluid Bed Incinerators

CBE

Chavond-Barry Engineering

400 Rt. 518, Blawenburg, NJ 08504

FGTT Heat Exchanger (Chauvand Barry)



After Burners before APC or RTO After

RHOX – Reheat & Oxidize Process

- In NJ, all MHF are required to maintain an afterburner at >1500°F
- Typical afterburner designs include:
  - Top Hearth
  - Top heath with Jumper Flue
  - External Chamber
- Afterburners located directly after the incinerator (before APC equipment)

After Burners can Produce NOX

RHOX – Reheat & Oxidize Process

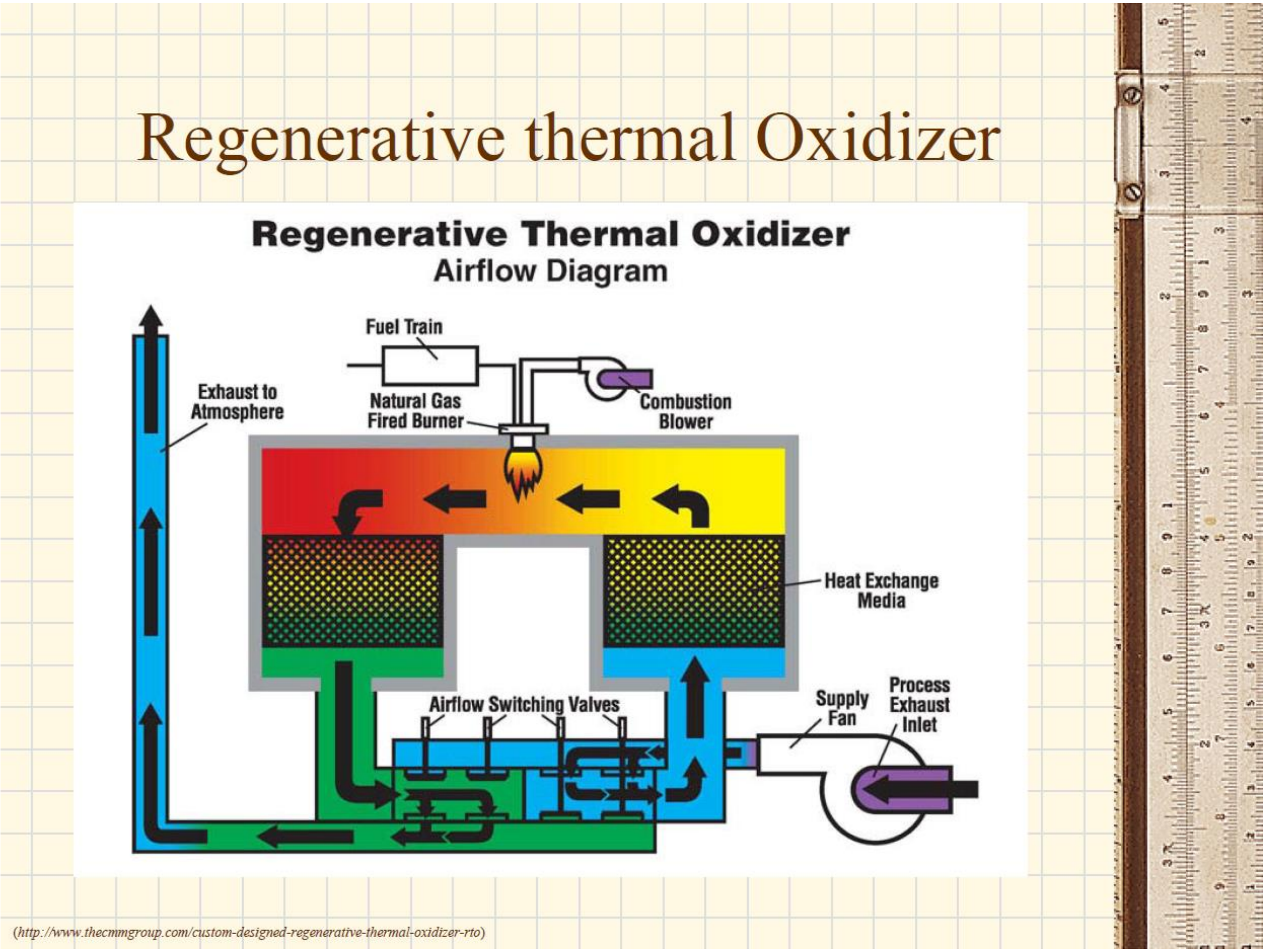
- Traditional afterburner designs require 1 or more burners
- Require high fuel usage to maintain afterburner temperature
- Additional burners can produce NOx

RHOX (Chauvand Barry)

RHOX – Reheat & Oxidize Process

- RHOX Process differs in that:
  - Occurs after the APC equipment
  - <u>Recovers heat from exiting exhaust gasses</u>
  - Requires 1 burner (less potential Nox production)
- Common RHOX process application is the Regenerative Thermal Oxidizer (RTO)

RTO Design



Regenerative thermal Oxidizer
Regenerative Thermal Oxidizer
Airflow Diagram
Fuel Train
Exhaust to Atmosphere
Natural Gas Fired Burner
Combustion Blower
Heat Exchange Media
Airflow Switching Valves
Supply Fan
Process Exhaust Inlet
(http://www.thecmmgroup.com/custom-designed-regenerative-thermal-oxidizer-rto)

RTO Utilizes Two or More Chambers

Regenerative Thermal Oxidizer

- RTO:
  - Utilizes 2 or more heat recovery chambers
  - Cold inlet gas passes through a heated chamber, preheating the gas
  - Hot exhaust exits through and heats another chamber
  - A single burner maintains gas temperature within the RTO
  - Periodically, a valve switches the inlet/outlet chambers

RTO Benefits (Chauvand –Barry)

Regenerative Thermal Oxidizer

- RTO benefits:
  - More efficient that traditional afterburners
    - The use of waste heat recovery decreases the fuel requirements
  - Provides more control than traditional afterburners
    - Less affected by furnace upsets / changes

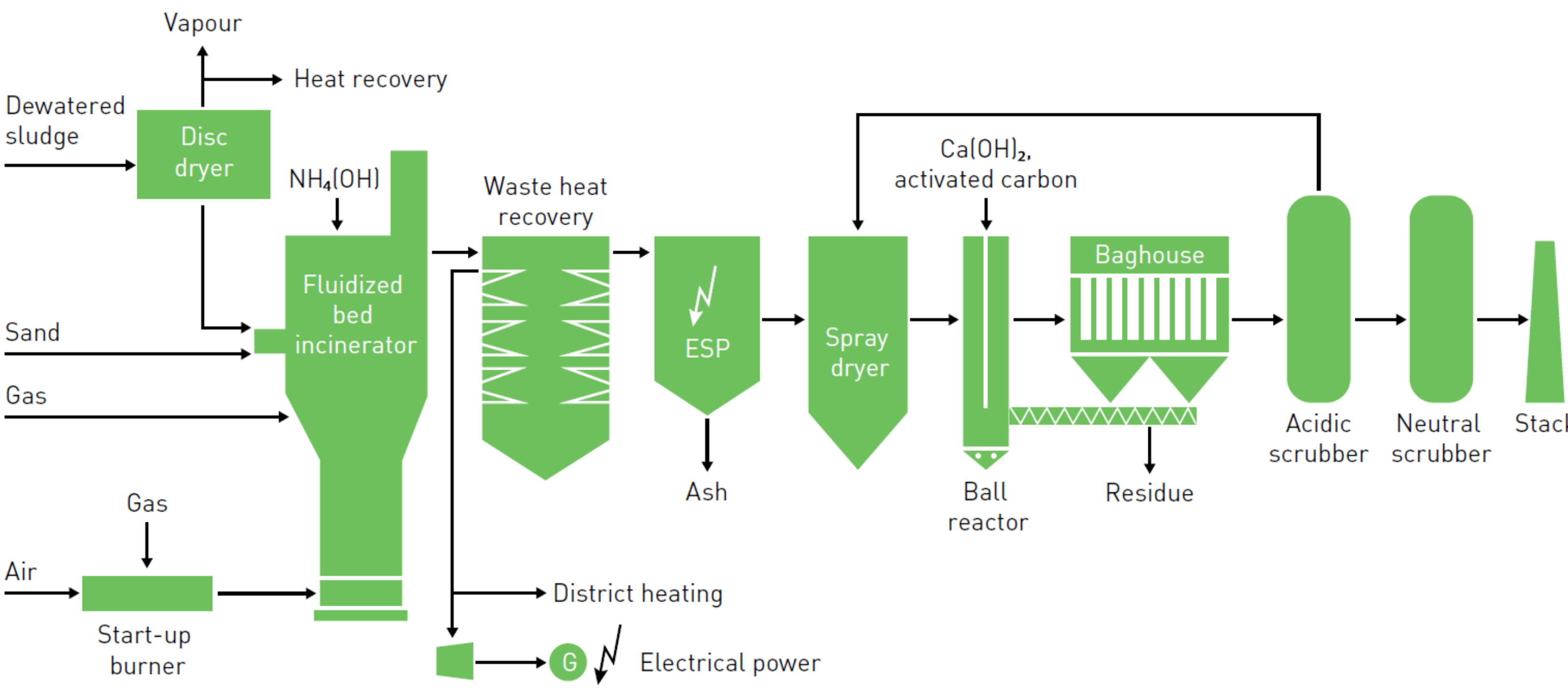
European Installations

[Return to T of C]

Outotec has Mercury Filter

- An Outotec fluidized bed Sewage Sludge Incineration Plant operates as a self-sustained process, without external fuel. It can produce a surplus of electrical power or heat and complies with all emission standards (EN 2000/76).
- Key process steps include:
- Receiving and storage
- Partial pre-drying
- Thermal treatment
- Boiler and turbine system
- De-dusting
- Scrubber and condensing system
- Mercury filter
- ASH DEC phosphate recycling system

Outotec Sewage Sludge Incinerator System



ERZ Zurich

OUTOTEC SEWAGE SLUDGE INCINERATION PLANT 100 FOR ERZ ZÜRICH, SWITZERLAND

Outotec supplied a turnkey solution, including assistance with the building permit application, design engineering, and delivery of the complete process. Outotec was also responsible for commissioning, production ramp-up, and operator training on site.

PLANT FACTS

Capacity	100,000 t/y at 22–30% dry solid content
Steam parameters	
Flow	9 t/h
Temperature	450°C
Pressure	60 bar
Electrical power output	900 kW
Completion	2015

BMG Austria

OUTOTEC SEWAGE SLUDGE INCINERATION PLANT 30 FOR BMG, AUSTRIA

Outotec was responsible for the design, manufacture, and supply of all equipment, the installation and commissioning activities, including all construction work, as well as start-up support and operator training assistance. Furthermore, Outotec was also awarded an operation and maintenance contract for the plant.

PLANT FACTS

Capacity	30,000 t/y at 20-35% dry solid content
Heat recovery boiler	
Thermal oil	230°C/180°C
Excess heat	1200 kW at 85°C
Completion	2011

Voslau, Austria

OUTOTEC SEWAGE SLUDGE INCINERATION PLANT FOR AWA BAD VÖSLAU, AUSTRIA

Outotec was responsible for the design, manufacture, and supply of all equipment. The project scope also included installation and commissioning activities. Outotec also provided the operator with additional ongoing support following the plant's commissioning.

PLANT FACTS

Capacity	14,000 t/y at 25% dry solid content
Heat recovery boiler	
Thermal oil	230°C/180°C
Excess heat	800 kW at 90°C
Completion	2005