Accelerating Mercury Control

The Latest Advancements in Activated Carbon Technology

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"Driving the critical aspects of activated carbon to optimize performance in your emission train"

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Discussion Outline

- Overview history of mercury control development in the U.S.
- Mercury control compliance implementation in the U.S.
- The science of flue gas mercury control
- Applying the science in the plant
- Tuning activated carbons for Hg removal
- Preserving fly ash value
- SO_3 tolerant PAC development example
- Avoid re-emission: PAC for wet scrubbers
- Guiding Principles for Hg Control
- ADA Carbon Solutions and Activated Carbon Innovation

Genesis of Activated Carbon Injection (ACI) for Mercury Capture

1990s

- Multiple-pollutant control laboratory and pilot-scale studies to evaluate co-benefits and sorbent injection
- Technology transfer of ACI from Municipal Solid Waste over to Coal Firing, but capture conditions different and mercury concentrations much lower from coal
- Major issues with measurement of Hg at these low levels in actual flue gas matrix

Early 2000s

- Significant field studies and demonstrations of same PACs used for water treatment and MSW plants
- Introduction of halogen-treated activated carbons
- Measurement improvements and options expanded
- Issues such as ash disposal identified & studied

Today

- PAC manufacturers focused attention on serving the coal-fired EGU market
- Identification of critical aspects of carbon that drive performance in mercury capture
- Focused product development in specific application challenges
- Measurements still challenging and high-maintenance
- Compliance at low levels of 1.2 and 4 lb/TBTU achieved

Ongoing Development

- Meaningful quality criteria that correlate with mercury capture performance
- Rapid innovation targeting specific application challenges
  - High Acid Gases
  - Concrete Compatibility
  - Faster Kinetics
- Solutions tailored for specific circumstances to achieve optimal compliance solutions

- Coal-fired mercury control studied by EPRI, EPA, DOE and others since 1990
- Activated Carbon Injection **commercial** in coal fired power plants since 2007
- As of late 2014, there were >135 GW of ACI (ICAC) – considered as

Best Available Control Technology and Maximum Achievable Control Technology

MATS Update – Coal-Fired EGU Compliance Plans

Institute of Clean Air Companies survey that covered 181 GW of coal-fired power generation revealed:

	Number of Generating Units	Size of Generating Units, GW (%)
ACI	310	137 (76%)
Boiler Oxidant	49	26 (14%)
Non-carbon Sorbents	3	1.6 (1%)
Wet FGD Additives	36	16.5 (9%)
Totals	**398**	**181 (100%)**

Data based on late 2014 survey results. Source: Institute of Clean Air Companies; Power Magazine, April 2015
http://www.powermag.com/the-state-of-u-s-mercury-control-in-response-to-mats/

Activated Carbon Injection is considered as Best Available Control Technology and Maximum Achievable Control Technology

Science of Efficient Mercury Capture

Three Critical Mechanisms

Conversion

of elemental mercury (Hg^0) to an oxidized state (Hg^+ or Hg^{++}) to enhance mercury's receptivity to the capture media

Contact

of mercury, which is in very dilute concentrations in the flue gas, with the capture media

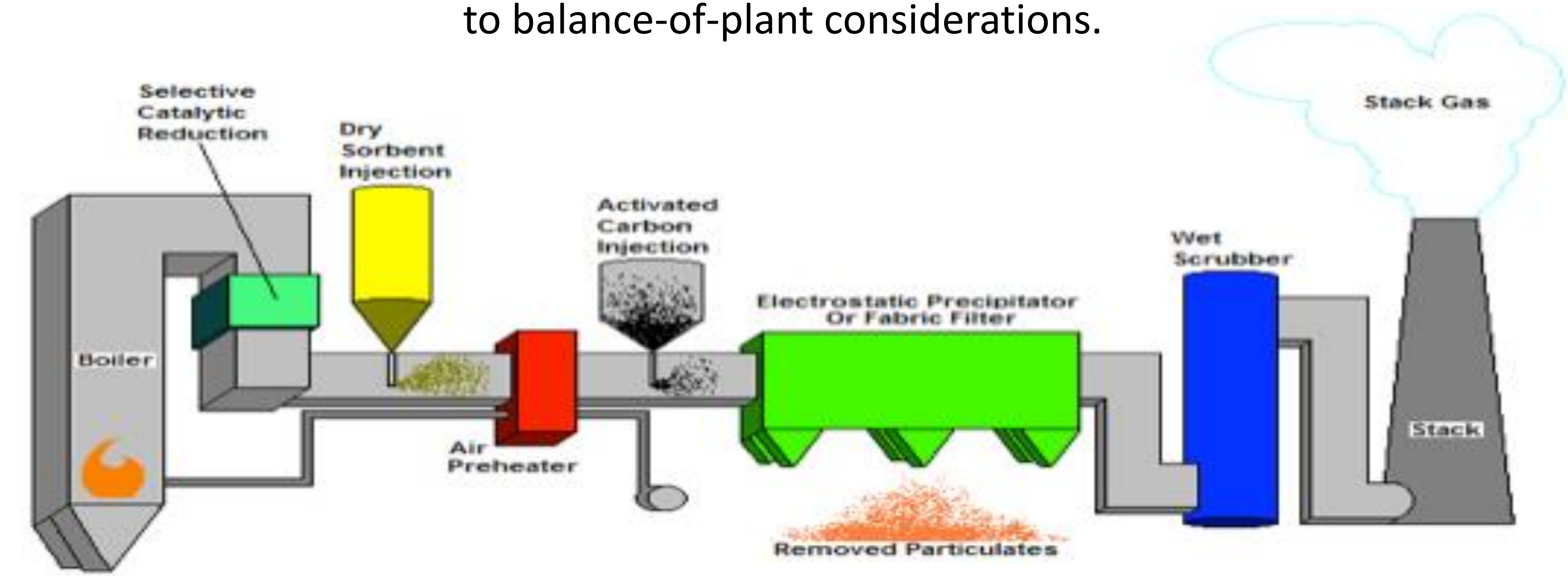
Capture

of the mercury in the capture media's structure for removal from the system

All three mechanisms must occur in seconds or less to achieve compliance.

Applying Science in the Plant

Technology solutions need to be cost effective for Hg control and favorable to balance-of-plant considerations.



Coal Pretreatment | Combustion Oxidation | Dry Sorbent Injection | Sorbent Injection | Wet Scrubber Additives | Post Scrubber Treatments

- Integrate technology options and actively manage mercury control.
- Maximize native capture of mercury.

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What are the conditions at the specific plant?

- Mercury in coal levels and target emissions rate
- High sulfur? Coal variability?
- Totality of reagents affecting byproducts and discharge
- Dry Sorbent Injection (DSI)? Dry scrubber?
- Wet scrubber? – Limestone Force Oxidation (LSFO)? materials of construction and inventory
- Hg oxidation level due to coal, SCR, additives?
- Byproduct utilization? What uses?
- Discharge issues or sensitivities – water, solid waste
- Load cycling or base-load plant?
- Baghouse (fabric filter) or ESP?
- Materials of construction in back end?
- Process conditions at injection point? Residence time/contact?

Integrating the Technology Landscape

Effective management strategies integrate technology options and actively manage emissions control.

Pollutant	Common Controls	Reagents
NOx	Low NOx burners, Staged Combustion, SNCR & SCR	Ammonia, Urea, *unburned carbon*
SOx	DSI, dry or wet scrubber	Lime, Limestone, Sodium
PM	ESP, Baghouse	SO_3
Hg	ACI, wet scrubber w/ or w/o enhanced oxidation	ACI, Br_2
HCl	DSI, dry or wet scrubber	Lime, Limestone, Sodium

Achieving All Mercury Capture Mechanisms in the Full Life Cycle of Mercury Capture

		Predominant Mercury Capture Mechanisms		
		Conversion to Oxidized Mercury	Contact with Capture Media	Capture & Removal
Emission Treatment	Pre- & Post Combustion Oxidation	Effective		
	Fly Ash / LOI		Effective	*Effective or not?*
	Selective Catalytic Reduction	Effective		
	Activated Carbon Injection	Effective	Effective	Effective
	Non-carbon Sorbents	Effective	Effective	*Effective or not?*
	Wet Scrubber		Effective	*Effective or not?*

- Technology treatments that do not fulfill all three mechanisms require supplemental process steps.
- Avoiding unintended consequences or negative Balance of Plant (BOP) impacts for each option are also key to success.

What is the most economic alternative?

- ✓ Achieve emission targets
  1. Consistently meet all emissions limits in a synergistic manner
  2. No surprises
- ✓ Minimize all sorbent / reagent costs
  1. The combination of all emissions control reagents / sorbents is optimized
  2. Each sorbent work synergistically with other sorbents / reagents / technologies
- ✓ Maximizes the value of the byproducts
  1. Maintains the maximum value of the byproducts for beneficial use
  2. Avoids leaching issues if temporary storage is necessary

We Tune Key Activated Carbon Features to Enhance PAC Performance

Surfaces

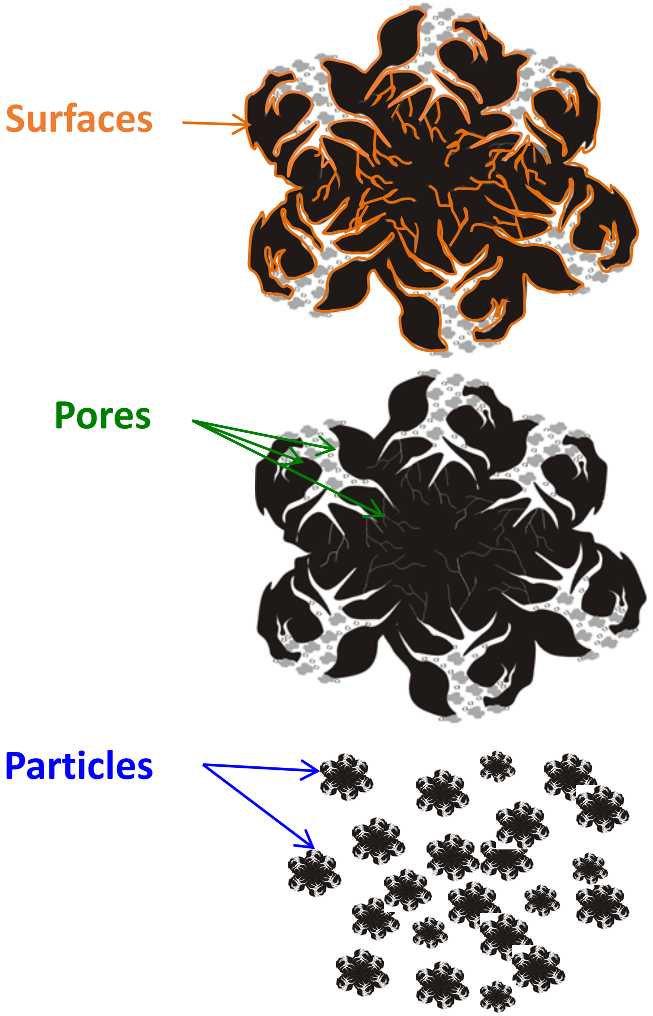
- Host for chemical reactants, catalysts and chemical functionalities

Pores

- “Holes” of varying sizes to “transport” and “capture” target molecules to be removed

Particles

- Transportation medium to deliver desired properties to the right location at the right time



Modifying carbon surface, pores and particles creates improved Hg removal properties

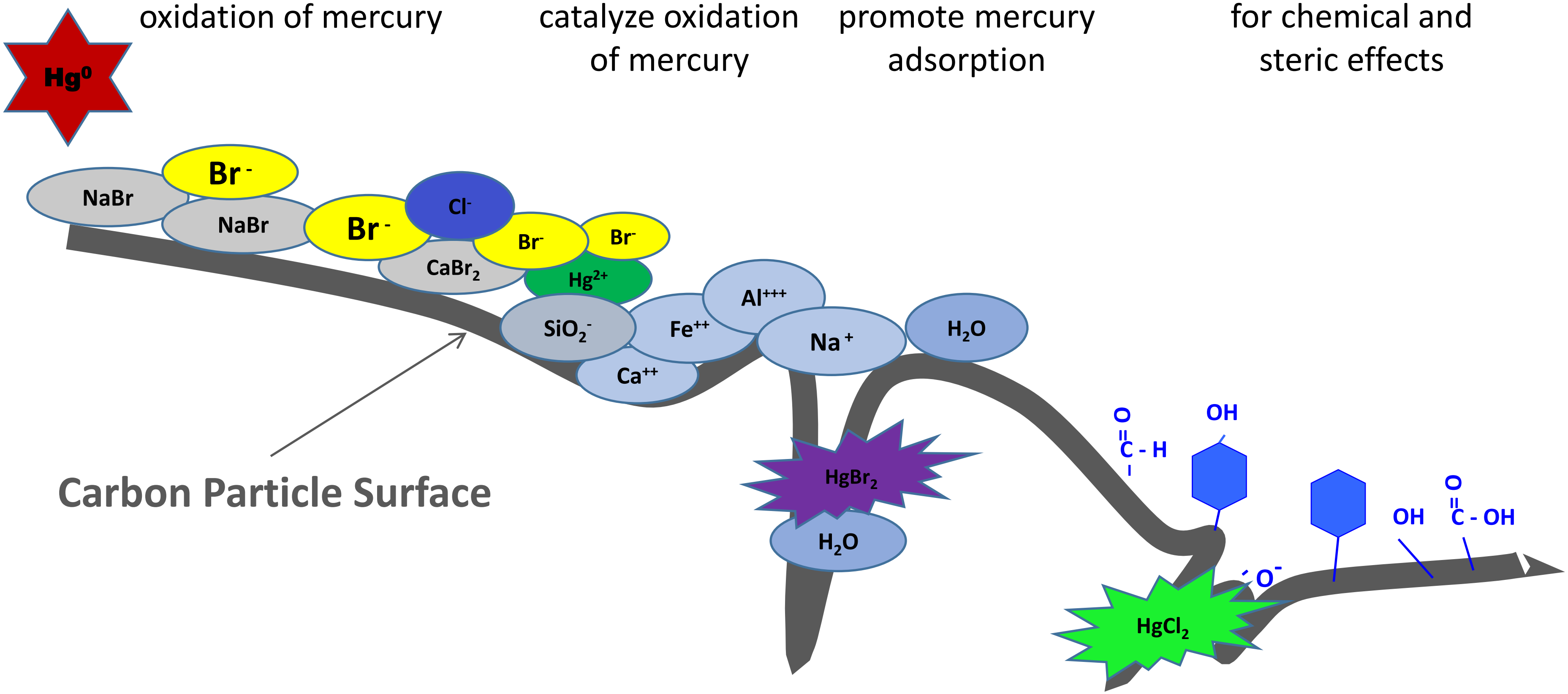
Tuning the Activated Carbon Surface is One Key Approach

Bromine to facilitate oxidation of mercury

Minerals to catalyze oxidation of mercury

Moisture to promote mercury adsorption

Functional groups for chemical and steric effects



The activated carbon surface can be modified in different ways to maximize Hg capture

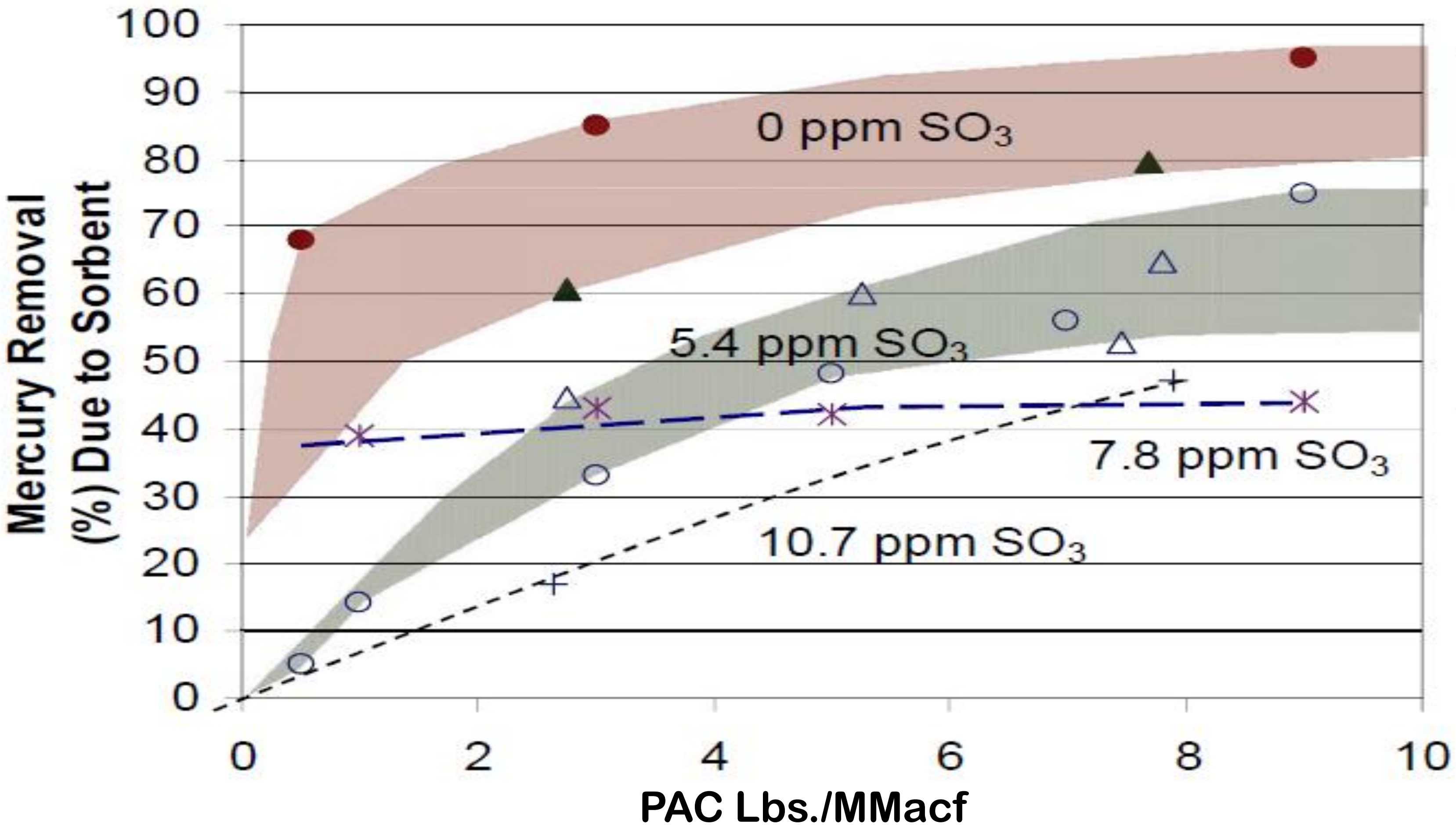
Effective Solutions Maximize Flyash Value

1. Solution considers all aspects of emissions train design
2. Product tailored to benefit operational issues such as **ash specifications**
   I. Cement/concrete market – highest value
   II. Cement raw materials – next highest
   III. Structural fill (e.g. roads – beneficial use) / mine fill (exclusion) – revenue source, landfill cost avoidance
3. Maximizing ash value requires careful emission reagent **selection** and **dosage**
4. Consistent, reliable **manufacturing** maintains PAC specs to enable control and **predictability** of performance
5. Third generation PACs provide **improved Hg adsorption** with lower dosage, steeper capture curves and effective beneficial uses of ash
6. Power plant operational management can contribute significantly to maintaining **ash consistency** through **collaboration**
7. When PAC impacts are larger and/or in tight markets, **passivation / masking agents** can be used to maintain ash quality

Example: Next-Generation SO_3 Tolerant PACs

1. The SO_3 problem: Hg capture historically hindered
2. Taking a fundamental scientific view...potential mechanisms that impact Hg capture
3. Development process from lab to field
4. Product generations / SO_3-specific evolution
5. Full-scale field test results

Typical Impact of SO_3 on PAC Hg Capture

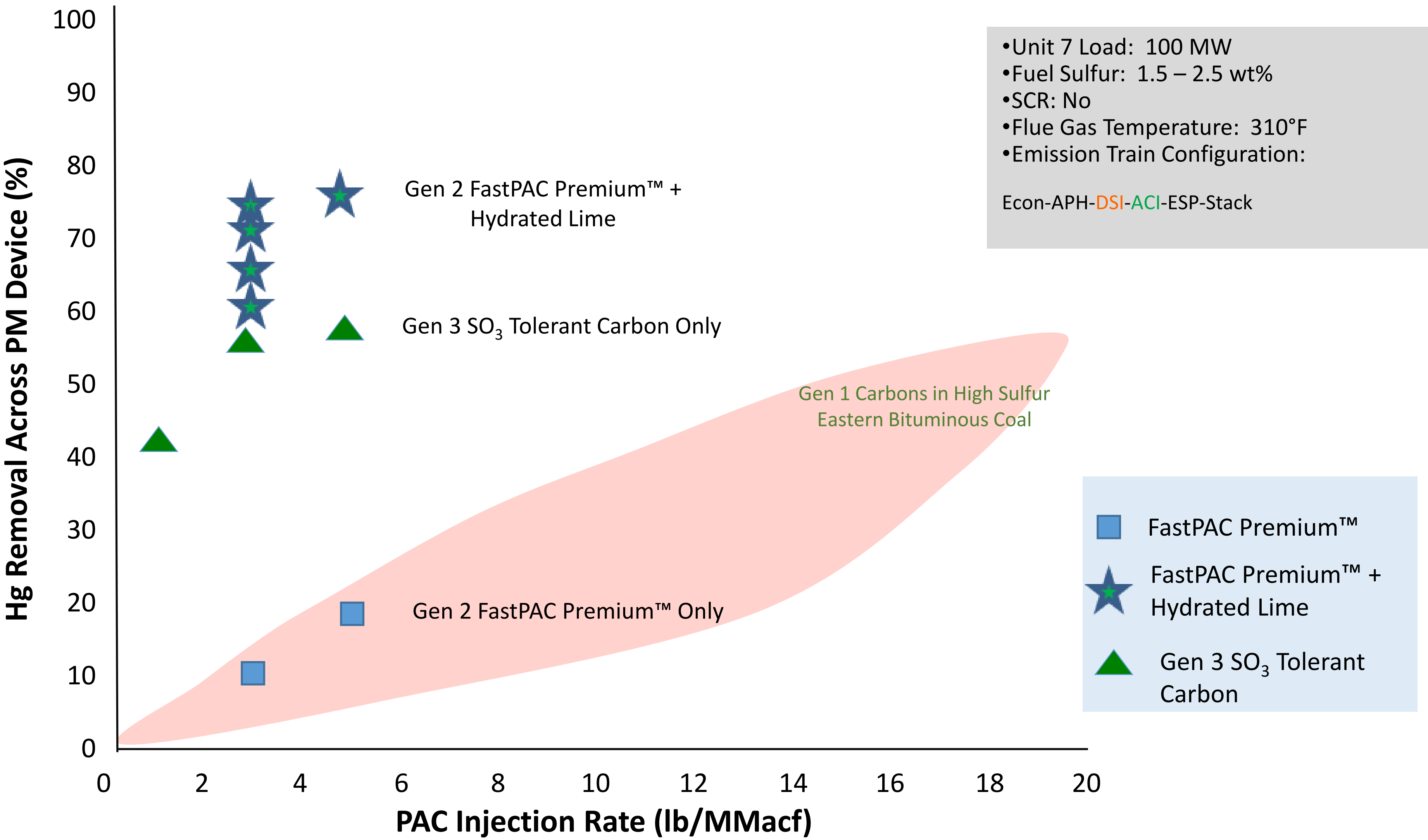


SO_3 levels greater than 3 ppm in the flue gas reduce PAC efficiency, but can be tempered by the right choice of PAC.

Case Study: Southern Plant Gorgas Developmental Gen-3 SO_3-Tolerant PAC For Bituminous Coal (~10 ppm SO_3) [2012 data]

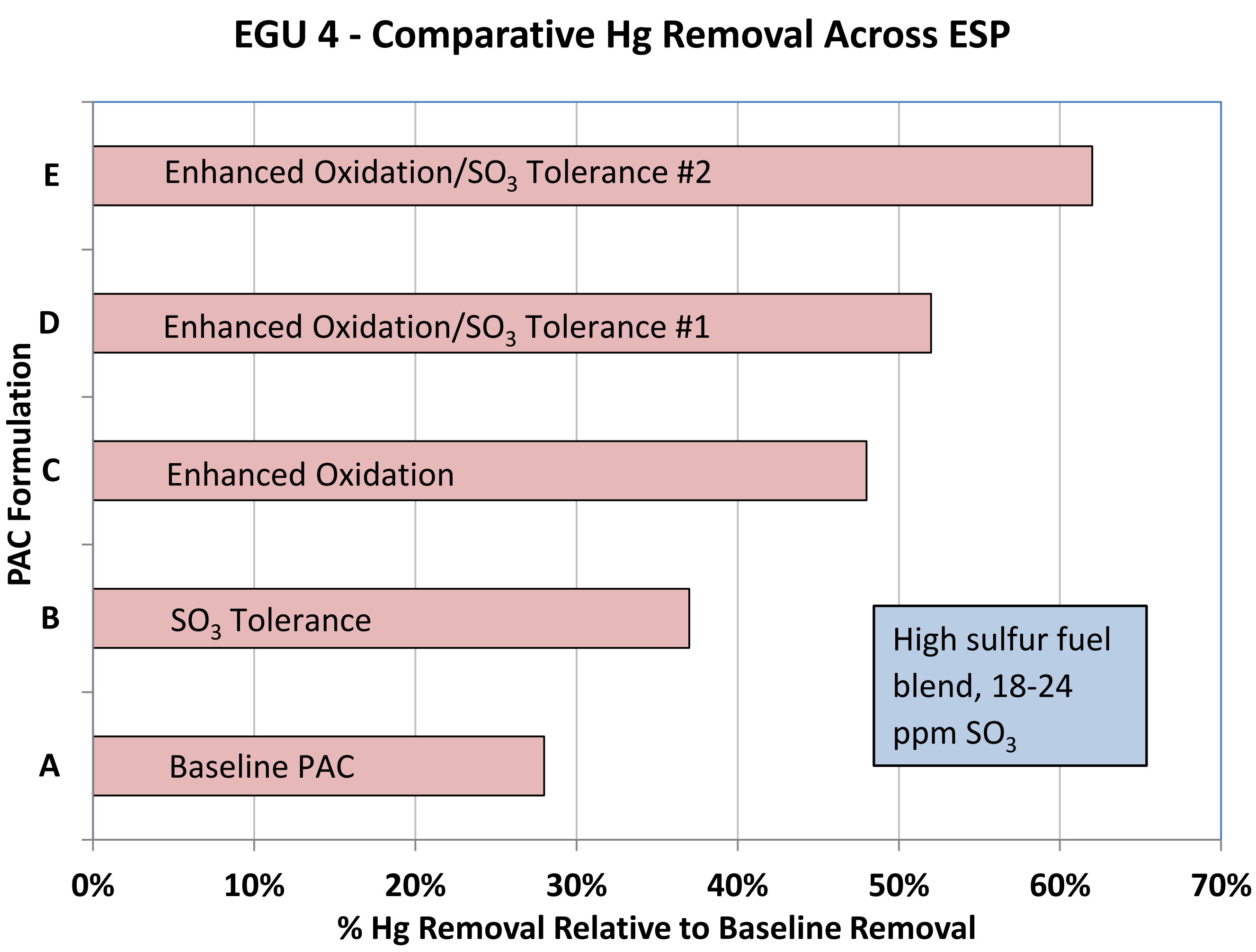
- Unit 7 Load: 100 MW
- Fuel Sulfur: 1.5 – 2.5 wt%
- SCR: No
- Flue Gas Temperature: 310°F
- Emission Train Configuration:

Econ-APH-DSI-ACI-ESP-Stack



Next-Generation Product Performance: EGU 4 - High Sulfur Fuel Blend

Stepwise mechanistic formulation enhancements



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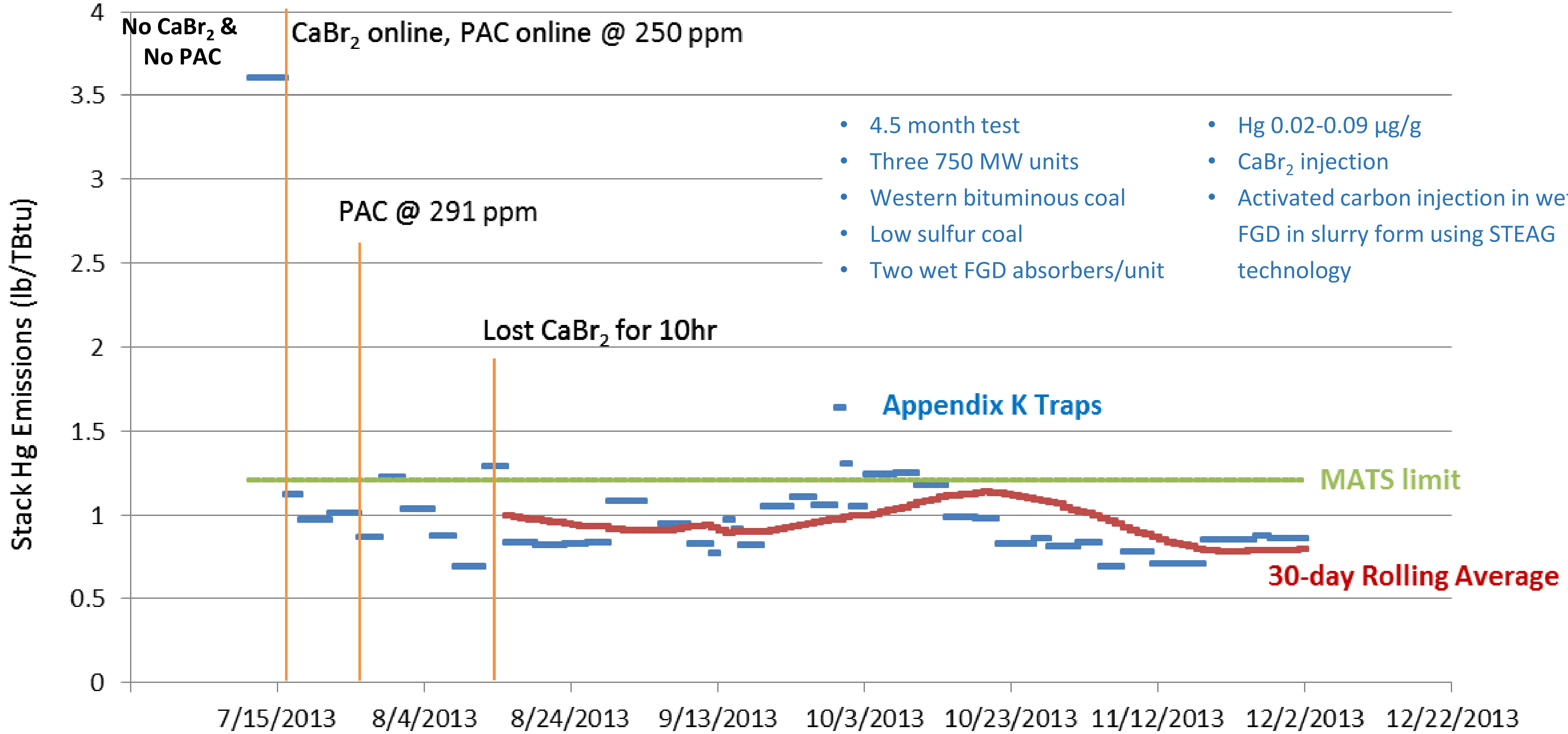
Summary - Next-Generation SO_3 Tolerant PACs

1. The SO_3 problem is better understood mechanistically leading to rigorous R&D technology roadmaps for building the next-generation SO_3 Tolerant PACs
2. Rapid PAC prototyping from lab to field is available to advance technologies and achieve lower mercury emissions
3. Next-generation ADA Carbon Solution SO_3 Tolerant PACs have been introduced and demonstrated high Hg removal efficacy in full-scale utility tests
4. Additional PAC product generations for SO_3-specific systems are in development

Stable Capture without Re-emission of Mercury

- Mercury re-emission from wet scrubbers is well documented
  - Southern Company - EPRI/URS paper #57 from 2014 MEGA describes oxidized Hg being reduced to elemental in the wet scrubber and re-emitting
    - Stack Hg exceeds inlet Hg under changing process conditions
    - Good example of Contact-Conversion-Capture not succeeding
- The same concept applies to other temporary capture techniques
  - Fly ash LOI can result in re-emission or leaching; oxidation without stable capture does not achieve compliance goals
- Activated carbon injection can be used in flue gas or slurried into a scrubber
- Scrubber additives include sulfides that precipitate mercury
- Removal from the system is also key; these solids need to be separable
- Good results have been reported with either PAC or sulfides in scrubbers

MATS compliance levels achieved– Salt River Project Navajo Generating Station



- 4.5 month test
- Three 750 MW units
- Western bituminous coal
- Low sulfur coal
- Two wet FGD absorbers/unit
- Hg 0.02-0.09 µg/g
- $CaBr_2$ injection
- Activated carbon injection in wet FGD in slurry form using STEAG technology

Met 30-Day Rolling Average for MATS Compliance with Calcium Bromide Treatment on Coal and PowerPAC WS in Wet FGD *(A&WMA MEGA 2014 Paper #90)*

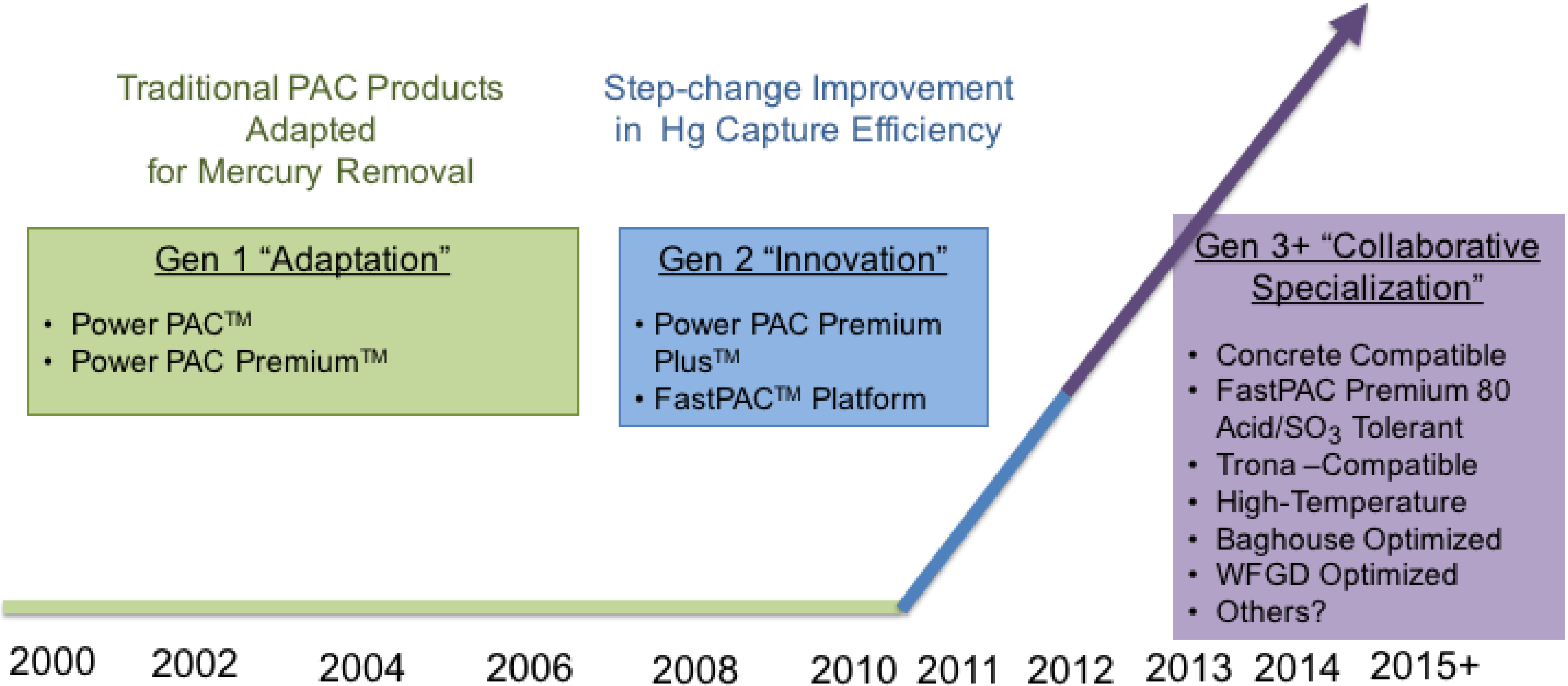
Guiding Principles for Mercury Control

- Insure that fundamental capture mechanisms of Conversion-Contact-Capture are completed as effectively as possible and ideally all at once
- Adopt true "engineering" or "active" control methods
- Capture Hg as far forward in your emission train as possible...downstream capture must contend with multiple phases, complex uncontrolled & competing chemistries, dilute Hg concentrations with lower capture driving force, etc.
- Always consider balance of plant (BOP) issues...corrosion, excess chemicals in water, re-emissions, Hg in water streams, Hg in solid wastes, ash utilization, impact on other contaminants, need for added chemicals or multiple steps, etc.
- Calculate total cost of control beyond $/lb of PAC
- Testing is critical – coal-fueled plants are unique and process differences are significant

ADA Carbon Solutions, LLC

- ADA Carbon Solutions is committed to flue gas mercury control. We manufacture powdered activated carbons and continuously drive improvement through science using our in-house RnD and collaboration
- Headquartered in Littleton CO and operating three facilities in Louisiana
  - Red River: Primary manufacturing plant
  - Five Forks Mine: Critical raw material
  - Natchitoches: Custom manufacturing
- Significant market share in the North American mercury control market
- Primary customers are public and private coal fired power generators, waste to energy incinerators and cement kilns

We've Changed the Performance Landscape by rapidly innovating impactful new PACs...



GEN 1 PACs developed in the mid-2000s are no longer the industry performance standard ... it's new Gen 2 and Gen 3 carbons

Focused on Mercury Emission Control

ADA CARBON SOLUTIONS

Expertise.

- ✓ Industry leading expertise
- ✓ Broad based emissions control perspective
- ✓ Focused on solutions optimized for mercury compliance

Reliability.

- ✓ The largest U.S. producer of PAC that is optimized for Hg removal
- ✓ Dedicated, reliable, supply chain
- ✓ Backward integration into critical raw material

Compliance.

- ✓ Collaborative product design and specification
- ✓ Optimized solutions to achieve ***Compliance….Reliable and Cost Effective…. Today and Tomorrow.***

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