FGD and Acid Gas Removal

Hot Topic Hour June 16

Free decision guide for any power plant -10 minutes

How international suppliers can benefit -5 minutes

Dry FGD overview – 5 minutes

LIFO vs. FIFO - 10 minutes

Wet FGD - 5 minutes

Eliminate sodium ponds - specific utility need -10 minutes

Sorbent injection and enlarging air pre heater -15 minutes

Novel ways to use waste heat -15 minutes (includes MIT/Calpine project to use most waste heat and CO_2 in commercial greenhouses)

How the Decision Guides and Webinars will help International Suppliers reach the Acid Gas System Purchasers in Developing Countries

- The challenge is to convince the decision maker in Vietnam that the higher efficiency blower will reduce electricity costs and more than offset the initial price or that the membrane bag will last enough longer to justify its higher price. There are three elements to success in this quest
- Create a clear case for the LTCO
- Identify the decision makers
- Convince the decision makers.
- McIlvaine is providing free access to recorded webinars and to certain publications for end users around the world. They are also reached with a bi-weekly Alert. The supplier can best leverage this opportunity by making sure the most favorable information is displayed.
- The end users have free access to the following publications:
- 44I Power Plant Air Quality Decisions (decision guides on mercury, FGD, DeNOx, precipitators, fabric filters, valves, pumps, and other subjects).
- 59D Gas Turbine and Combined Cycle Decisions (decision guides on GT intakes and GT emission control as well as many other subjects).
- 1ABC Fabric Filter (decision guides on cement, steel, waste to energy, and other subjects.
- 2ABC Scrubber/Adsorber/Biofilter Knowledge Systems (decision guides on sewage sludge, waste-to-energy, mining, and other subjects.
- 3ABC FGD and DeNOx Knowledge Systems (FGD and DeNOx decision guides).
- 4ABC Electrostatic Precipitator Knowledge Systems (coal particulate decision guide).
- 9ABC Air Pollution Monitoring and Sampling Knowledge Systems (decision guides on use of CEMs as well as water monitoring subjects

Important Questions for the Industry

- How do you determine the lowest total cost of ownership LTCO?
- Can U.S. and European suppliers leverage knowledge of the LTCO to penetrate markets in developing countries?
- How does the need to remove NO_x, PM, and mercury shape the decision on which acid gas removal system should be chosen?
- What efficiency improvements e.g. flue gas heat recovery are possible and how will that shape the acid gas decision?
- How do the needs differ between coal-fired power, cement, steel, and waste-to-energy?
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Dry Scrubbing

- How efficient is DSI?
- Where is sodium a better choice than calcium?
- What improvements are achieved by using special high reactivity hydrated lime?
- How widely will DSI be used in terms of which industries and which geographies?
- Is McIlvaine on the right track recommending an analysis of FIFO/LIFO to ensure that the first sorbent on the cake is pulsed and not the fresh unreacted sorbent?
- For medium sulfur coals, can a combination of DSI and a spray drier be competitive with circulating dry scrubbers?
- How much progress is being made on using DSI solid waste and converting it into bricks and building materials?
- Should every power plant using high sulfur coal consider DSI ahead of the air heater to reduce SO_3 and to be combined with an air heater upgrade to further reduce gas temperature?
- Can DSI with ceramic catalytic filters replace all the other APC devices?
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Dry scrubber considerations

- A continuing analysis is provided in a separate subsidiary website **Dry Scrubbing** of the main website **Power Plant Air Quality Decisions**.
- One of the decisions is the type of dry scrubber that is best. Originally SDA was the main option. Now CDS is popular. DSI with the more reactive sorbents has become an option even when higher efficiency is required.

DSI for MATS and CSAPR by Jim Dickerman, Lhoist / Chemical Lime - Hot Topic Hour January 29, 2015

- The catalytic filter with DSI promises one stop shopping. Combinations such as DSI and SDA are also an option.**FSI + Catalytic Filtration + Condensing Heat Exchangers (CHX) - How to make Pollution Control Profitable by Martin Schroter, Durr Systems - Hot Topic Hour March 19, 2015.**
- The dry scrubber is necessarily part of a multi pollutant removal system that addresses particulate, acid gases and toxic metals. As a result, evaluation of the impact of the dry scrubber on the removal of pollutants such as mercury is important. The changing regulations in the U.S., China and the EU all need to be addressed.
- Solid waste is an issue. Can the sorbent/acid/ash combination be used as construction materials? What about leaching of toxic metals? The loss of flyash and gypsum revenues need to be evaluated. The benefits of lower water use and elimination of wastewater are also important
- There are many process factors. One is the sulfur content of the fuel versus the required efficiency. Another is the temperature of the air leaving the heat exchanger and the potential for DSI ahead of the air heater to allow greater heat recovery.

Dry scrubbing child web in PPAQD

- Air Preheater
- Ceramic Filter
- Circulating Dry Scrubber
- Consumables
- Continuous Emissions Monitor
- Conveying
- Cyclone
- Direct Injection System
- Direct Sorbent Injection
- Dry FGD
- Dry Injection
- Dry Sorbent Injection
- DSI
- Dual Fluid Nozzle
- Electrostatic Precipitator
- Entrained Flow
- Fabric Filter 袋式除尘器
- FGD 烟气脱硫
- Filter Media
- Gas Suspension Absorber
- Hydrated Lime
- Injection Equipment
- Lime
- Limestone
- Pneumatic Conveyor
- Rotary Atomizer
- Screw Conveyor
- SDA
- Slaker
- SO3 Monitoring
- Sodium Bicarbonate
- Spray Dryer 喷雾干燥器
- Spray Dryer Absorber
- Trona 天然碱

LIFO vs. FIFO

- The recent regulation of many pollutants combined with new technology which makes it possible to remove all the pollutants in one device has greatly increased the use of fabric filters. However, there has not been a recognition of what McIlvaine describes as "***The importance of FIFO vs. LIFO in Dust Cake creation.***"
- Direct sorbent injection (DSI) and embedded catalyst dictate a new approach to bag cleaning. In addition to discrete particle capture, bag filters are being tasked with:
- Mercury removal
- Acid gas absorption
- Dioxin destruction or capture
- NO_x reduction
- The importance of the method of bag cleaning can be illustrated by use of the accounting approach to inventory. Two options are first in first out (FIFO) and last in first out (LIFO). If the price paid stays the same, the choice between the two accounting methods makes no difference. But, if the cost of recent inventory is greatly different than the past, then the accounting method makes a big impact on profits.
- The capture of discrete particles is the equivalent of price parity. Let's say that when you pulse a bag you are always discharging the latest particles to arrive and the remaining cake consists of the earliest. Since the ability of a matrix of dust particles to act as a filtration medium does not change, it does not matter which particles remain. In fact, maintaining a somewhat permanent layer of cake protects the fabric from wear. Also a more permanent cake provides higher dust capture. It has been shown that on-line cleaning results in some re-deposit of dust particles. But this is does not impact discrete particle capture efficiency.

Lifo vs Fifo continued

- The new paradigm with DSI is a big price difference. The newly arrived lime particle has the capability to absorb acid gases. The lime particle deposited earlier is already converted to calcium sulfate and provides no additional absorption capability. The semi-permanent cake layer is very undesirable for acid gas capture. Mercury re-emission is also a risk for an activated carbon cake which is semi-permanent. So it is very important to adopt FIFO and not LIFO.
- This leads to the obvious question as to which are the best cleaning methods to achieve LIFO? The long running debate about surface filtration vs. depth filtration needs to be reviewed in light of FIFO. Also, the pulsing method itself needs to be reviewed. Do some methods result in more re-entrainment of particles in the previous cake than do others? Should more of the cake be removed with each pulsing
- It could be argued that the reaction takes place in the ductwork and not on the bag. But the big difference in performance of bag filters vs. precipitators with DSI proves that the cake absorption is substantial.
- There may be lots of research on this subject but if so, McIlvaine would appreciate feedback on it. If there is not, it is an area deserving lots of attention.
- Bag cleaning is also made more challenging by the increasing use of ceramic filter elements. The advantage of these elements is the ability to remove dust at 850°F. The older generation rigid ceramic has been replaced by ceramic fiber media which can be pulsed. However, this media cannot necessarily be pulsed with the identical system used for synthetic bags. An alumina refinery in Australia was having cleaning problems with a ceramic filter. **Pentair Goyen** analyzed the situation and provided a more robust pulsing system. This solved the problem.
- Ceramic, glass and even synthetic media are incorporating catalyst in the media to reduce NO_x or oxidize dioxins. Do these designs require a different cleaning approach? The catalyst in the Clear Edge design is not on the surface. So, the dust cake will not affect performance except if it causes maldistribution of the gas. If more gas flows through one area than another, the reactivity of the system is reduced.
- A broader subject is the whole approach to cleaning. High pressure/low volume is the most popular option. Does capture of these other pollutants open the door for high volume /medium pressure or even for reverse air cleaning?
- The potential for the one-stop shopping is great. Costs of pollution control can be reduced for new installations. The small footprint makes a big difference in the cost of upgrading existing plants to meet new air pollution rules. It is, therefore, important to understand and then maximize FIFO potential

Pentair-Goyen: The dust collector and cleaning system design and parameters can be carefully tailored to achieve specific dust cake behaviour to maximise the acid gas removal with the most efficient sorbent usage.

Dust Cake Properties & Acid Gas Removal

- Dust cake thickness
- Total dwell time of the sorbent on the bag
- Are there many sorbent types?
- What is the optimal cake behaviour?
- Does the incoming gas concentration vary much over time? Should the cake behaviour vary?

Cleaning System Parameters

- Pulse Strength
- Pulse Duration
- Peak Cleaning Pressure vs Cleaning Flowrate
- For high differential pressures, devices such as venturis are necessary

The Dust Cake Properties During a Pulse

- Dust cake agglomeration & strength
- Dust dislodgment
- Dust suspension
- Dust re-entrainment
- Dust migration down bag
- Possible FIFO behaviour

Collector Design Parameters

- Forward flowrate
- Filtration velocity
- Differential Pressure
- Filter spacing
- Updraft velocity
- Pulsing patterns

Q. What is the optimal dust cake/sorbent bed characteristics & behaviour?

Wet Calcium FGD

- What about the European approach in waste-to-energy which includes two scrubber stages including one to capture hydrogen chloride and make 30 percent hydrochloric acid?
- Why not leach out rare earths with the acid?
- The Chinese are touting a technology similar to the rod deck scrubber for wet limestone SO_2 removal. How do rod decks and trays compare to spray towers in terms of lowest total cost of ownership?
- Can lime be competitive with limestone as a reagent based on lower capital cost and higher efficiency?
- Can lime or other reagents be used along with limestone?
- Is the double alkali approach worth considering particularly if you have a high magnesium lime and can make magnesium hydroxide?
- Where are the ammonium sulfate and sulfuric acid options attractive?
- Should powdered limestone replace ball mills (this is popular in China)
- How efficient should mist eliminators be?

98 plus % SO_2 removal with Turbulator: Turbulent rod deck scrubbing is competing with spray towers

The Anqing Phase II project incorporated highly advanced flue gas treatment technologies, based on an ultra-low emission technology roadmap. The roadmap includes an electrostatic precipitator (ESP) with a low-temperature economizer, spin exchange coupling FGD, and a rotary tube bundle PM demister. Several of these flue gas treatment devices offer co-benefits that further reduce net emissions.

There are three separate processes in the power plant that remove PM from the flue gas. The high-frequency ESP with three chambers and five electric fields forms the first segment of particulate emissions control. The removal efficiency of PM in the ESP is up to 99.86–99.9 percent with a concentration around 25 mg/Nm^3. The secondary PM removal segment is the efficient spin exchange coupling FGD that removes 60% of the remaining PM. The third approach to PM removal is the low-temperature economizer + rotary tube bundle PM demister, which has a PM removal efficiency of more than 70%. Compared to other PM capture options, the investment and operating costs for the advanced tube bundle PM removal technology were lower, it takes up less space, and it fits well into the general layout of new construction and retrofit projects. In total, the final target of an outlet concentration of PM less than 3 mg/Nm^3 can be achieved—exceeding the requirement for a natural gas power plant in China.

The efficient spin exchange coupling wet FGD removes SO_2 with an efficiency of 97.8–99.7 percent. In the spin exchange coupling efficient-FGD technology, a device termed a “turbulator” has been added between the entering flue gas and first level of the FGD tower, which changes the flow state of the incoming gas from laminar to turbulent and reduces the gas film resistance, so as to increase the liquid-gas contact area, increase the gas-liquid mass transfer rate, and thus increase FGD and PM removal efficiency. This system also requires less power consumption than other FGD systems. In the compulsory 168-hour unit test run, the FGD efficiency reached 99.7 percent.

Broader implications; Chinese are developing their own designs and at least one approach uses the rod deck to create a turbulent zone. Andritz now has a version of this technology. In general it is an extension of the tray concept as opposed to spray towers.

Utility participating today wants to eliminate sodium sulfate ponds

- A utility participating in this discussion has contacted us and asked for our recommendations on how to eliminate the sodium sulfate pond.
- One option would be a double alkali system. Neumann says that their Colorado Springs installation has the right chemistry to eliminate excess sodium sulfate (see next several slides).
- Another option would be to switch to Thioclear (see following slide). The benefits are a magnesium oxide by product as well as gypsum
- What about ZLD using forward osmosis?

Sodium

- **NeuStream - DR: Improving the Effectiveness of DSI while substantially Reducing the Chemical Cost by Jean-Philippe Feve - Neuman Systems Group - Hot Topic Hour August 1, 2013**
- Discussed a process for recycling injected sorbents
- **Advanced wet flue gas desulfurization technology known as NeuStream®, by Rob Fredell - Hot Topic Hour November 8, 2012**
- The Colorado Springs Drake 6 & 7 use a double alkali system with sodium as the scrubbing agent.   The units began successful operation in March 2016. The question relevant to the utility wanting to eliminate the sodium ponds is whether the Colorado ‘Springs technology can be economically applied to the existing utility scrubbing system?

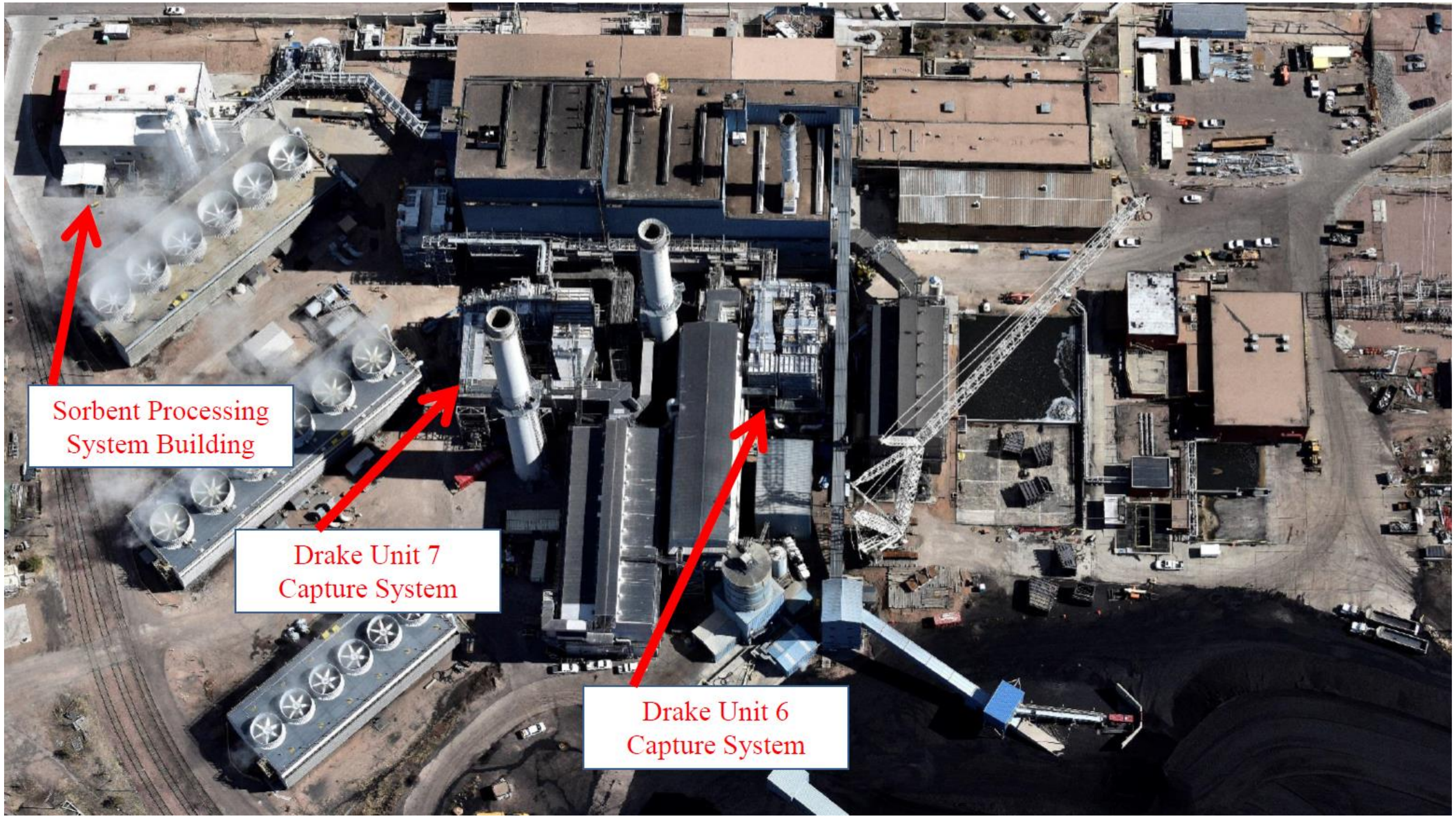
Neumann system making gypsum in dual alkali mode-Drake 6 & 7 operating as of March 2016

After two weeks of continuous operation of the NeuStream® desulfurization unit at the Colorado Springs Utilities’ (CSU) Martin Drake Power Plant, Unit 7. NSG VP of Operations, Dr. JP Feve said:

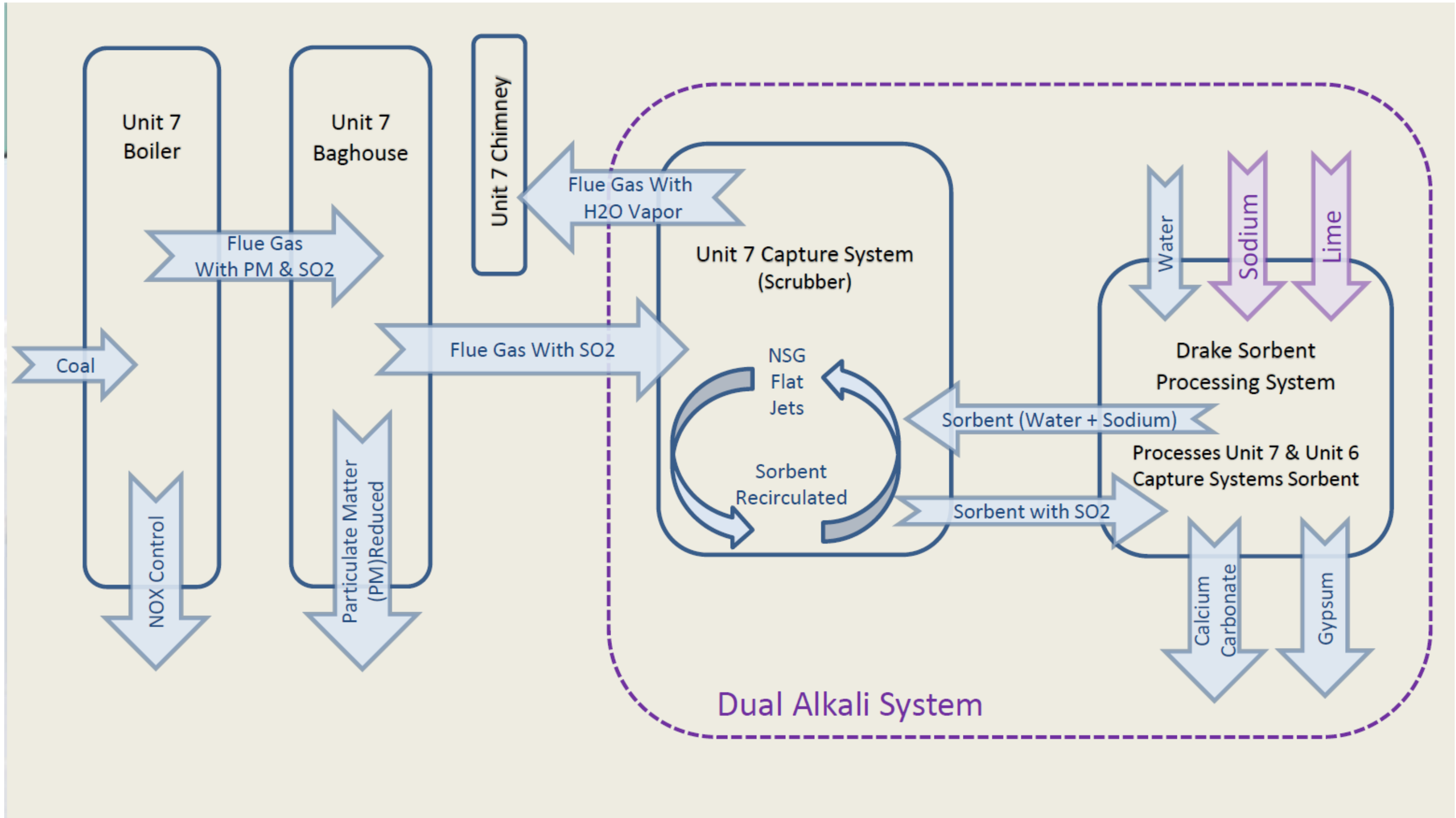
“The NeuStream® scrubber has operated now for almost two weeks and has continuously removed sulfur dioxide at a higher level than predicted. To date over 135,000 lbs of sulfur have been removed from the flue (exhaust) gas from the Drake 7 Unit. Additionally, we are now producing gypsum from the captured sulfur dioxide.”

Spokesperson Amy Trinidad of Colorador Springs Utility said : "We are collecting the gypsum in a storage facility at the Drake site. Once we collect enough gypsum, it will be transported to our Clear Spring Ranch facility for disposal as currently there is no commercial market for this by-product."

Drake system layout



Materials flow at Drake



Thioclear - magnesium lime double alkali system

- This project represents the first industrial application of Dravo Lime Company's patented Thioclear® process. AES Beaver Valley Inc. has used Dravo's first generation process since 1988. That first-generation, magnesium-enhanced, scrubbing process represents one of the most efficient chemistries for sulfur dioxide (SO_2) removal from stack gases. Its major drawback was that it created a throwaway product (calcium sulfite) which had to be landfilled. Additionally, due to the generation of this solid material in the scrubber vessels, the threat of build-ups and pluggages requiring downtime and clean-up expense were an ongoing concern.
- The second generation Thioclear® process uses the same scrubber chemistry to maintain outstanding SO_2 removal rates, but removes the clean-liquor scrubbing solution to remote vessels before solids are generated. An additional chemical reaction (oxidation) creates two salable byproducts, gypsum (calcium sulfate) which is used in the cement industry and magnesium hydroxide which is used in water treatment applications.
- By converting the station to this process, the amount of material going to landfill as a result of the coal combustion and subsequent flue gas desulfurization process will be decreased by some 115,000 tons annually. This represents a 60 percent reduction from current levels. The conversion will annually produce 60,000 tons of gypsum which will be sold to two local cement manufacturers as well as 1,500 tons of magnesium hydroxide sold to a local chemical supplier. The electric power needed to run the new equipment will be available thanks to the increased availability of the existing generating system because the new, cleaner process will greatly reduce downtime due to build-ups. Thus, the amount of electric power for sale to West Penn Power will not be affected.
- **HH 00 04 15 "Review of 18 Months of ThioClear® FGD Operation at AES Beaver Valley Cogeneration"** by K. Smith, M. Babu and E. Goetz, Dravo Lime Co., Pittsburgh, PA and G. Leckonby, AES Beaver Valley Cogeneration, Monaca, PA. 15 p.
- In a joint effort between AES Beaver Valley and Dravo Lime Co., the magnesium enhanced lime FGD system at AES Beaver Valley Cogeneration station was converted to Dravo's forced oxidation FGD process known as ThioClear® in September of 1997. Operation of the 130 Mwe installation continues up to the time of this writing. This project represents the first full-scale operation of the process since pilot plant operation was conducted at the Miami Fort station from 1990 to 1993. The status of the retrofit of ThioClear FGD in Allegheny Power's 1300 Mw Pleasants station is also briefly discussed.
- C DRAVO LIME, IH 680 COGENERATION, IH 223 THIOSORBIC LIME, IH 222 MAGNESIUM ADDITION, IH 215 FORCED OXIDATION

Mercury Options and integration with acid gas removal

E = experience, P = potential
H = high, M = medium, L = low, U = unknown

	Coal-fired Power	Waste-to-Energy	Sewage Sludge Incineration	Cement	Natural Gas	Non-Ferrous Smelting
Activated carbon injection	EH PH	EH PM	EL PL	EL PM	EL PL	EM PM
	300 million pounds for coal-fired boilers in the U.S. with other markets being lower. New carbons provide higher efficiency per pound. Big potential market in China. Will more cost effective AC result in stricter emission rates using the MACT concept and history of continuous lowering of limits? Most efficient when injected ahead of fabric filter. The unanswered question is the impact on either pressure drop across the bags or cleaning frequency. How much selenium is captured with the mercury?					
Activated carbon pellets	EL PM	EM PL	EM PM	EL PL	EH PH	EM PM
	Can achieve 99 percent removal of mercury from sewage sludge incinerator. Non-ferrous mining industry is also using this approach. It is a common approach for natural gas.					
Scrubber chemicals	EM PH	EL PM	EL PM	EL PM	EL PL	EH PH
	Bromine is proving effective when added to the fuel in coal-fired boilers. Sewage sludge incinerators should pursue this option. Chemicals or PAC added to the scrubber slurry are effective in preventing re-emissions. Will sorbent injection ahead of the air heater eliminate the corrosion problem from bromine in the fuels? Could this sorbent be added in the furnace e.g., Clear Chem process?					
Gore module	EL PH	EL PH	EM PH	EL PM	EL PL	EL PH

Mercury Options and integration with acid gas removal
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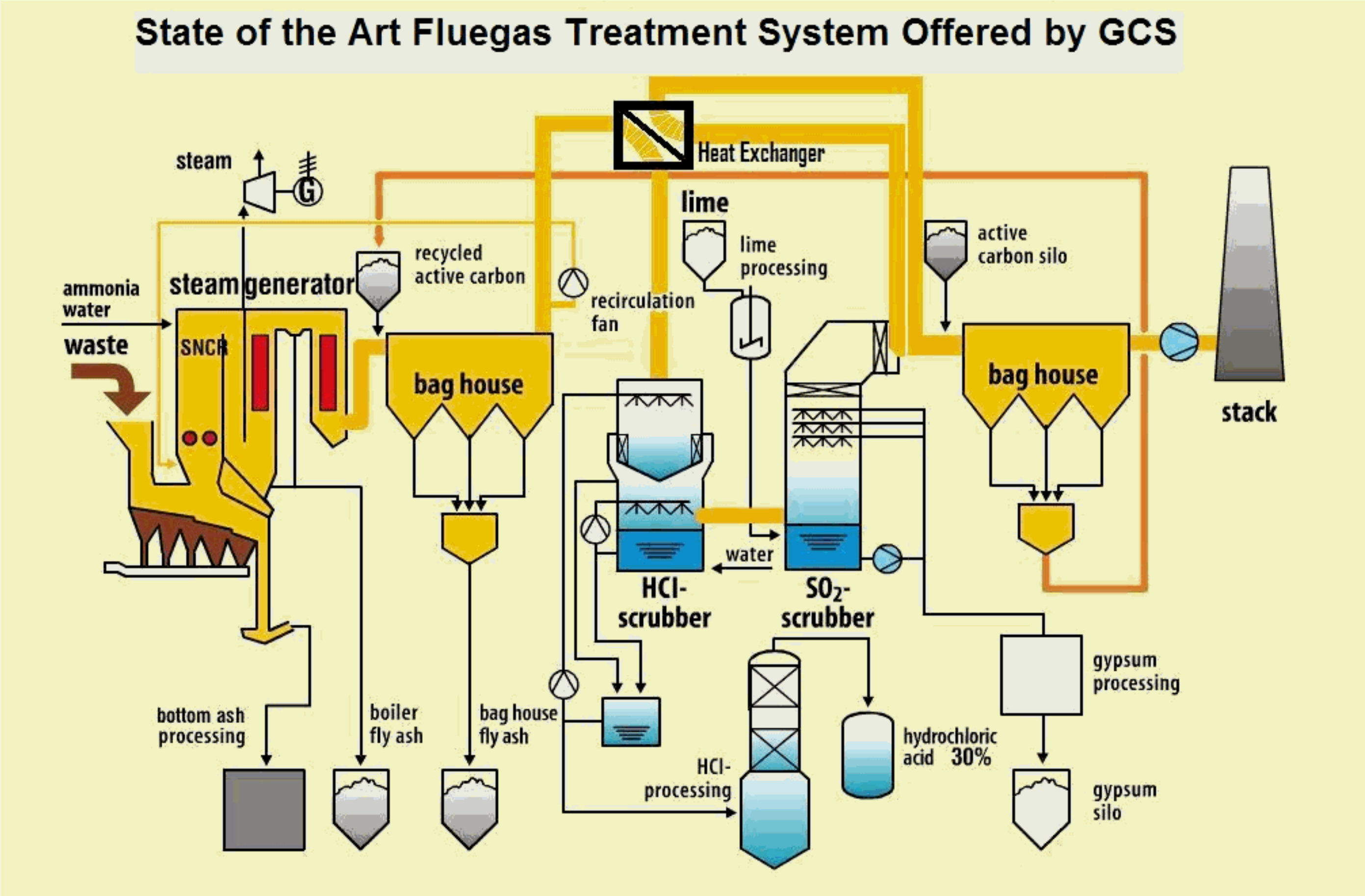
	Coal-fired Power	Waste-to-Energy	Sewage Sludge Incineration	Cement	Natural Gas	Non-Ferrous Smelting
Gore module	EL PH	EL PH	EM PH	EL PM	EL PL	EL PH
	23 systems now sold for coal-fired power plants and sewage sludge incinerators. Works best following a wet scrubber but can be used following a dry scrubber if exit temperature reduced. Very cost-effective compared to carbon bed for an existing sewage sludge incinerator where modest mercury reduction is needed.					
Metal sorbent	EL PL	EL PL	EL PL	EL PL	EM PM	EH PM
	UOP, Johnson Matthey, and Axens all have metal oxide or metal sulfide sorbents being used in natural gas mercury removal. Non-ferrous smelters have used metal sorbents as well.					
Molecular sieve	EL	PL	EL PL	EL PL	EH PH	EL PL
	UOP molecular sieves can combine dehydration and mercury removal from natural gas. They can also be regenerated.					
Ionic liquid	EL PL	EL PL	EL PL	EL PM	EL PH	EL PL

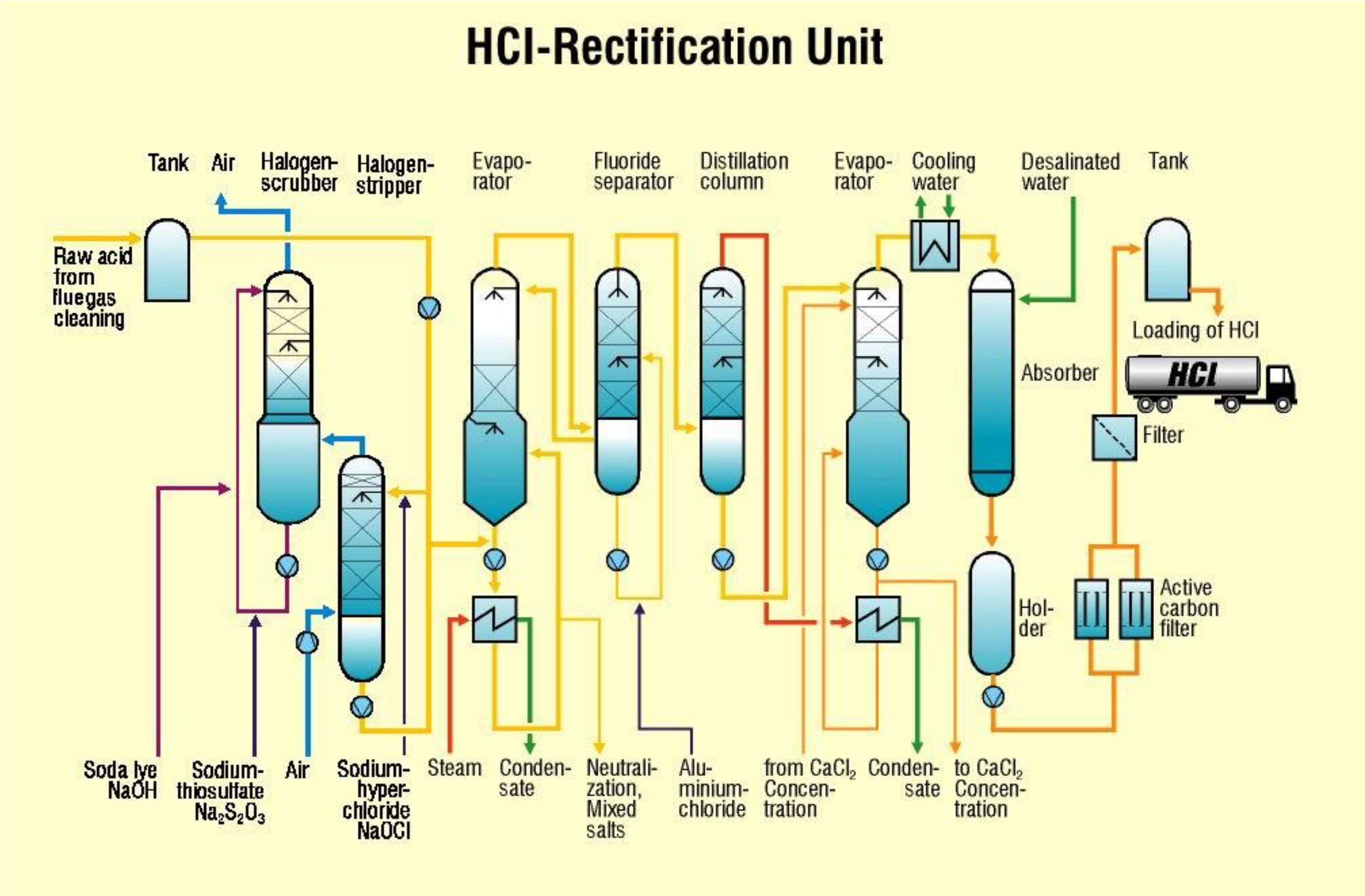
Harm from CO_2 vs. Other Pollutants

- ***Harm from CO_2 vs. Other Pollutants***
- An editorial in the January 2, 2016 *New York Times* was titled "The Dirty Truth About 'Clean Diesel'." It documents deterioration in air quality in Europe as a result of a program to increase the use of diesel-powered vehicles because they emit less CO_2 than those powered with gasoline. The substantial increase in NO_x and fine particulate emissions are leading European policy makers to belatedly view "diesel as a devil's bargain."
- China has just started a $20 billion pipeline to transfer clean coal gas to cities across the nation. The hope is to eliminate the smog caused by burning solid fuels. So China has concluded that increasing CO_2 in order to reduce NO_x and particulate is worthwhile.
- Every pollution control decision may not be a "devils bargain" but there is a negative aspect. It may just be cost but typically the reduction of one pollutant increases another. Water purification is an example. Substantial energy is needed to purify water with reverse osmosis. The investor has decided that increased CO_2 is offset by the clean water value.
- Informally the world is functioning with a common metric to measure all harm and good. Every government, business and personal decision involves use of this metric.
- The problem is that the metric values differ widely among decision makers. The decision to donate to a charity or buy a new coat is individualized based on life quality perceptions. Life quality, in turn, is shaped by tribal values and differing views on discounting future values.
- The European facing vehicle smog vs. CO_2 at home will have a different preference than if asked to choose between CO_2 and smog for China. CO_2 causes global but not local harm. Tribal values cause us to look at every decision through a prism of our own self-interest and then the interests of our tribe (family, city, country, etc.).
- The well fed protected American will more likely put more value in creating a better life for grandchildren than the Syrian refugee who can justifiably discount any future value.
- McIlvaine has attempted to create a decision system with a harm metric which fulfills the true goal of individuals to maximize life quality and not quantity. More information is found at: **Sustainability Universal Rating System**.

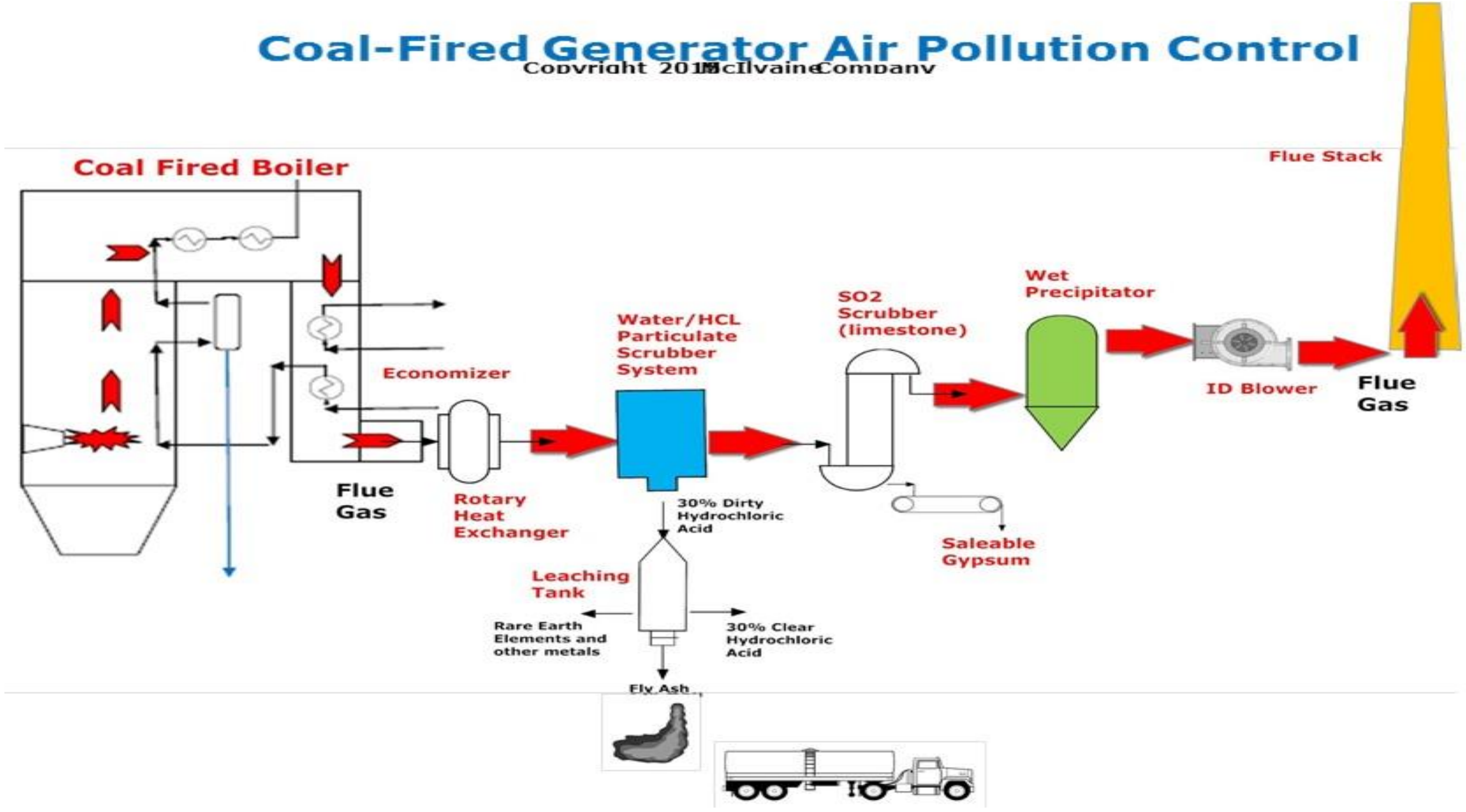
Green Conversion Systems WTE system with Hydrochloric acid manufacturer



WTE plant produces acid, metals, and gypsum with acid purification in rectification unit



Recovery of rare earths with two stage scrubbing and leaching



DOE moving forward with rare earth program but ignoring the technology which is already developed and would be much more cost effective - news release December, 2015

- The University of Wyoming earned one of 10 grants from the U.S. Department of Energy Wednesday to research separating rare earths valuable to electronics manufacturing out of coal ash.
- The DOE said that it's looking for cost-effective and environmentally benign approaches to take rare earths out of coal and coal byproducts as rare earths become more valuable to the American way of life. The agency cited unique chemical properties making rare earth elements essential to electronics, computer and communications systems, transportation, health care and national defense.
- "The demand, cost and availability of rare earth elements has grown significantly over recent years stimulating an emphasis on economically feasible approaches for … recovery," officials said in a release.
- Meanwhile, China has been all but cornering the market to feed into its industrial complex, making it difficult for other rare earth mines to succeed. The only rare earths mine in the U.S. recently went bankrupt and may need to sell assets to keep from going completely belly-up. Even so, a new player is trying to elbow into the market in Wyoming with a new rare earths mine in coal country in northeast Wyoming.
- The U.S. Bureau of Land Management points out that Wyoming produced 382 million short tons of coal from the Powder River Basin. A study presented at the 2015 World of Coal Ash Conference in Nashville identified 16 different rare earths in fly ash from PRB coal.
- "Although coal ash has been identified as a potential source for rare earth production, it still remains as an untapped source," study authors Tran Phuoc, Ping Wang and Dustin McIntyre wrote in an abstract. "This is because data on the concentrations of trace rare earth elements in various coal ash wastes are not available."
- The DOE studies could put an end to that deficiency. The UW study funded in part by the DOE will "design, develop and test a three-step bench-scale extraction process that will use carbon dioxide and ferric chloride under supercritical conditions to recover [rare earths]" from PRB coal after it has been burned.
- UW is cost sharing 27 percent of the study to value the research at about $820,000 total.
- Another project will also specifically examine PRB coal since it's such a major source for the national energy supply chain. Neumann Systems Group Inc., based in Colorado Springs, Colorado, scored a $750,000 grant to test "a supercritical carbon dioxide/co-solvent and conventional acid/base extraction process for the recovery of [rare earths]" from post-combustion PRB coal fly ash as well as Eastern coal.
- The grant awardees will compete to move to the next grant round.
- "The successful execution of these phase two projects will lead to the development and application of technology for economically recovering [rare earths] from domestic coal and coal byproducts," DOE officials said.

Other products in FGD and acid gas removal

- <u>Components</u>
- Wet: Agitators, oxidation blowers, pumps, valves, fans, hydrocyclones are all subject to severe service. How should these be designed to provide LTCO?
- Dry: Rotary atomizers, two fluid nozzles, slakers, dust valves are all in severe service. What selections provide the LTCO? How site specific is this in terms of coal type and sulfur percentages?

- <u>Materials</u>
- Should linings or high alloys be used for scrubber shells? How dependent is this on lining skills and site specific conditions?
- Where should weld overlays and hard coatings be applied to pumps and valves?

- <u>Consumables</u>
- What is the quality and availability of lime and limestone in each country?
- Should membrane or nonwoven bags be selected?
- What is the role of treatment chemicals in the fuel, flue gas and wastewater?