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carbon capture journal

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Oxyfuel for CCS - dispelling the myths

CO2-EOR as a 'soft start' for CCS in the UK

CEFCO's pilot plant

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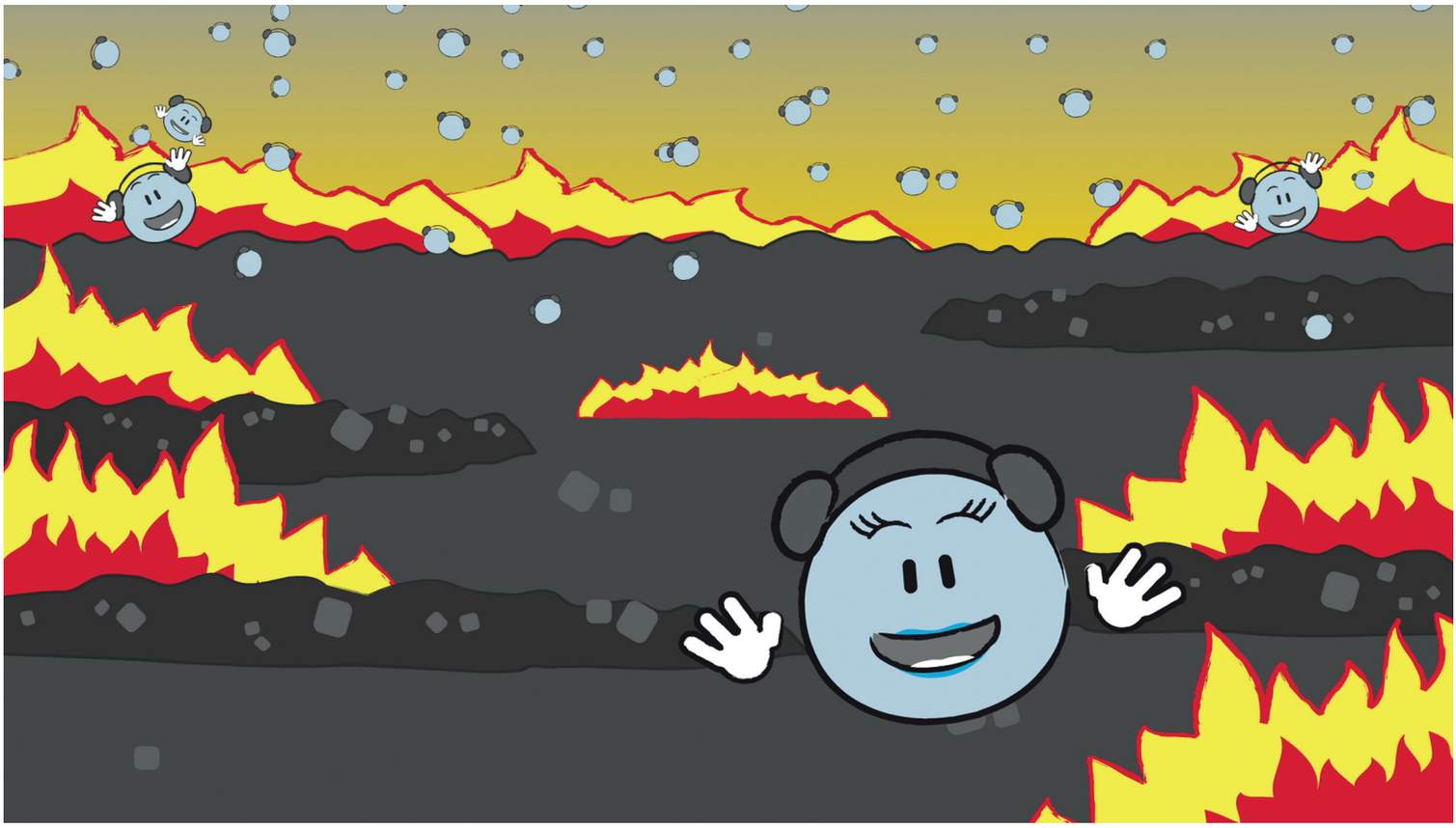

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Lower energy penalty CO2 capture system

In the second part of the article, the authors discuss recent results from CEFCO's process pilot plant and the generation of value added products such as fertilizers.

By Robert E. Tang, President, CEFCO Global Clean Energy and Dr. Anupam Sanyal, President, International Environmental & Energy Consultants

Part 1 of the article (CCJ Jan/Feb 2012) introduced an innovative low cost CO2 Removal technology; case histories of its U.S. EPA, DOE and DOD approved application in Hazardous Waste Combustion ("HWC") Maximum Achievable Control Technology ("MACT"); its recently patented process for application to coal/oil fired boilers, cement and petro-chemical industries; and the description of its demonstration in a 1-3 MW thermal unit and energy penalty comparison with that of a traditional amine process.

This part aims to describe the recent results of the CEFCO Process pilot plant, compliance with the U.S. EPA Power MACT, NESHAPs, and CSAPR ("Cross-State Transport Rule"), and generation of value added end-products making the CEFCO Process a profit center in contrast with the high energy penalty traditional processes.

A ground-level photo of the pilot facilities with two of the five co-inventors: Donald Degling and Robert Tang

Current status of the CEFCO testing at Pilot Plant

The supersonic shockwave technology (often described in EPA literature as "tandem nozzle", "free-jet scrubbing" or "free-jet collision" technology) previously invented by the CEFCO co-founder Thomas Ewan and incorporated into the present CEFCO patented technology, produces the superior 99+% Particulate Capture.

It has already been recognized by the EPA as a HWC[1] MACT technology from 1997 onward and has been published as HWC MACT compliant on May 22, 2002 under EPA's "Guide to Phase I MACT Compliance" for HWC Maximum Achievable Control Technology. Ewan's Technology was codified in Federal Statute under 40 CFR §63.109 et al.

CEFCO has deemed that Particulate Capture and all Acidic Gases Capture have been proven and put into commercial and governmental usage; therefore, additional work need not be spent on testing on this pollutant capture aspect of the CEFCO Process. All future testing will focus on the co-production of valuable and sellable products of the CEFCO Process. The capture capability will be offered to the licensed users of the CEFCO Process in the market place for compliance with the upcoming MACT, CSAPR and NESHAPs rules of the EPA.

Furthermore, both CEFCO and Peerless Mfg. Co. ("PMFG", the licensed manufacturer of the CEFCO Process Equipment in the territory of the USA) announced on November 9, 2011the successful completion of large scale prototype tests associated with the first two pollution control modules of the CEFCO Process equipment.

They further announced that PMFG and CEFCO are seeking a sponsor to conduct a pilot program at a potential customer facility, inviting all end-user operators in the following industries to contact the respective company to initiate a pilot-demonstration program: Cement Producers, Oil & Gas Processors and Refiners, and Power Generators."

Status of the SO2 capture and co-incidental CO2 capture and product-conversion testing at Pilot Plant

While developing and demonstrating the CEFCO Process to the U.S. Power Industry in mid-2011, it was requested by certain U.S. power producers to minimize the CO2 Capture ability of the CEFCO Modules in the earlier reactors in order to reduce the operating, transportation and handling costs of

1 The Ewan's free-jet collision HWC MACT technology is used for radioactive waste and particulate capture by the Nuclear Regulatory Commission of the DOE and for hazardous chemical weapons incineration by DOD and for EPA's Superfund remediation programs.

Capture and Conversion

CO_2 Capture (and the Bicarbonate-Carbonate Regeneration Cycle[2]) — i.e., in the Sulfur Reactor System ("SRS") and the Nitrogen Reactor System ("NRS") Modules, thereby leaving CO_2 Capture to be primarily performed in the Carbon Reactor System ("CRS") Module, the last module, if and when it is required.

CEFCO Global Clean Energy responded affirmatively and successfully for the SRS Module represented by Eq. 7(see later), by forcing the product-forming capture reaction into the supersonic shockwave and exiting through a subsonic nozzle into the sub-atmospheric adiabatic zone. Thus, the CEFCO Process circumvented the need for the steps in Eqs. 2 through 4, and Eq. 6, and obtained the desired result of capturing virtually all of the SO_2 to produce the valuable Potassium Sulfite-Sulfate Fertilizer product i.e., in an alternative reaction condition without using a combination of KOH and K_2CO_3 to lessen the CO_2 Capture capability, as it was specifically requested by the client.

The following equations[3] show the chemistry involved in traditional and well-known removal of SO_2 and CO_2, except for the last equation, whose appearance here clearly illustrates the application of the CEFCO Process for a superior result. In honoring the request by potential users, CEFCO Global Clean Energy has suppressed the CO_2 Capture and Product-Conversion by eliminating the use of K_2CO_3 as a reagent in the SRS Module. This action specifically negated Eqs. 3 and 4 (as shown below). K_2CO_3 is known to be a more powerful reagent (reacting faster) for capturing CO_2 than KOH.

However, the supersonic shockwave employed by the CEFCO Process is also a very powerful source of energy and acts as the catalyst to allow the traditionally slower KOH to also capture a fair amount of CO_2 very simply and swiftly (as shown in Eqs. 5 and 6, below). Consequently, CEFCO Global Clean Energy has altered the pH level and other parameters to reduce the amount of CO_2 Capture so that the bulk of CO_2 Capture is deferred and will take place in the CRS Module.

The typical chemical reactions of the CEFCO Process inside the SRS Module are provided below:

Eq. 1: $SO + H_2O_2$ (or ½ O_2 only from any oxidation source) → $SO_2 + H_2O$
Eq. 2: $SO_2 + H_2O_2 \rightarrow H_2SO_4$
Eq. 3: $H_2SO_4 + K_2CO_3 + KOH \rightarrow K_2SO_4 + KHCO_3 + H_2O$ (net result – Exothermic)
Eq. 4: $CO_2 + K_2CO_3 + H_2O \rightarrow 2KHCO_3$ (more effective Carbon Capture)
Eq. 5: $CO_2 + KOH \rightarrow KHCO_3$ (effective Carbon Capture)
Eq. 6: $4KHCO_3$ + Heat (200 deg F) → $2K_2CO_3 + 2CO_2 + 2H_2O$

CO_2 in Carbon Capture will be liberated as a purified gas and sent to compression or storage, or to make biofuels, etc. and the same Reagent K_2CO_3 is once again re-generated in a cyclic re-circulated operation continually. The CEFCO Process can make its own reagent K_2CO_3 to be used subsequently in the CRS Module.

The CEFCO Process is also a net-generator of new water, by liberating prehistoric water previously trapped in fossil-fuels, in a "water-constrained" environment:

Eq. 7: $SO_2 + 2KOH \rightarrow K_2SO_3 + H_2O$ (net result — Exothermic)
Eq. 8: $K_2SO_3 + ½ O_2 \rightarrow K_2SO_4$ (solid crystals)

This equation proves SO_2 Capture and the conversion of the capture into Potassium Fertilizer as a valuable product.

This result is produced by the recognition and application of Hess's Law:

SO_2 + 2 KOH (reagent) → $K_2SO_3 + H_2O$ (Reaction Product – Liquid Potassium Sulfite Fertilizer)
$SO_2 + H_2O \rightarrow H_2SO_3$ (Intermediate-Transient Product)
H_2SO_3 + 2 KOH (reagent) → K_2SO_3 + 2 H_2O (Liquid Reaction Product)

Conventional Oxidation Reactions Forming Final Stable Solid Product:

2 $K_2SO_3 + O_2$ (or + $2H_2O_2$) → 2 K_2SO_4 (or + $2H_2O$) (Reaction Product – Solid Potassium Sulfate Fertilizer Crystals)

Therefore, the production of valuable Potassium Sulfate fertilizer is achieved from the exceeding 99% capture of the targeted sulfur content in coal and other fossil-fired flue gases.

Furthermore, by not using the more powerful and more expensive K_2CO_3 and only using the cheaper KOH reagent, the CEFCO Process succeeded in capturing much less CO_2 within the SRS Module than originally planned in accordance with the performance instruction from the power producers.

As described above, the capture of virtually all SOx is achieved in the SRS together with a smaller quantity of CO_2 than originally designed (in the form of Bicarbonate-Carbonate). The resulting Bicarbonate-Carbonate end-product (as shown in Eq. 5) can be sold to various industrial users as an incremental cost-reduction or a cost recovery step for the power producers.

The following are equations showing CO_2 Capture under the CEFCO Process:

CO_2 + KOH (reagent) → $KHCO_3$ (Carbon Capture)
CO_2 + K_2CO_3 (reagent) + H_2O → 2 $KHCO_3$ (Carbon Capture)

Transient Reactions (Effect of Hess's Law):

$CO_2 + H_2O \rightarrow H_2CO_3$
KOH (reagent) + $H_2CO_3 \rightarrow KHCO_3 + H_2O$ (Carbon Capture)

Conventional Decarbonation = Liberation of CO_2 Dioxide Reaction:

Heat (205 deg F) + 2 $KHCO_3$ →K_2CO_3 (regenerated) + CO_2 ↑(liberated gas) + H_2O

Note: K_2CO_3 re-generation process, supra, liberates CO_2 as gas and produces a supply of recovered water for many subsequent uses. This liberated "new water" may be returned to the Plant to repay the "borrowed water" as previously described. The regenerated K_2CO_3 may be returned to the system to capture additional CO_2, or may be sold for high value to industrial users, such as to the petro-refinery industry, as a reagent for their processes.

Current status of the CO_2 capture and product-conversion testing at Wichita Falls Pilot Plant

As to current technical progress at Peerless' Wichita Falls Facilities in Texas, CEFCO Global Clean Energy operates the SRS Module consuming only the "net use of KOH" on a stoichiometric molar basis to achieve superior capture and conversion into Potassium Sulfite fertilizer showing the most cost-efficient result in a cyclic recirculating-regenerating mode.

Thus, the CEFCO Technology minimized premature CO_2 Capture by deliber-

2. The use of Bicarbonate-Carbonate in the CEFCO Process must be distinguished from the Honeywell UOP Benfield™ Process (a 1954 conventional thermodynamic process), which uses repeatedly heated and cooled Sodium Bicarbonate-Carbonate cycles and is extremely energy and time consuming, and cannot offer the same energy and cost efficiency. The 2010 CEFCO™ Process is dramatically different from the 1954 Benfield™ Process.
3. These Carbon Capture Eqs. 3 thru 6 have been well-known and proven by chemists to work with NaOH + Na_2CO_3, as well as with KOH + K_2CO_3. Under conventional thermo-chemistry, they involve the use of adding expensive heat, pressure and catalyst at a cost commonly referred to in the Power Industry as the "energy penalty". CEFCO uses shockwaves (generated by "spent steam" or "post-production steam" in the Steam Return-Loop) and aerodynamic reactors as a low cost substitute, and thereby to minimize any "energy penalty".

Heavy viscous liquid exiting the bottom of the Aero-Coalescer of the SRS Module is showing the captured and converted sulfur compounds and the CO2 (as KHCO3) flowing continuously into the product settling tank. Samples are taken and tested periodically

ately not using any K2CO3 as capturing reagent in its SRS reaction process. The CEFCO Process' reactor is powerful enough that there is "No Need" to go through any K2CO3 step and will save substantial OPEX for its users. The end-product is sellable and valuable liquid K2SO3 (and eventually oxidising into K2SO4 solid crystal) fertilizer for the American agricultural cooperative market.

The CEFCO System has operated at a temperature range and atmospheric condition that avoided premature CO2 Capture and, thus, minimized the extraneous consideration of the "Bicarbonate and Carbonate Cycle" at a significant saving in energy and reagent costs. (Compare: earlier Footnotes).

The CEFCO Technology's parametric testing of the modules continues at Wichita Falls, and CEFCO Global Clean Energy will work on other capture aspects to achieve overall cost-efficiency. The next task as requested by the Power Industry will be to operate and achieve the same desirable result of NOX Capture in the NRS Module by obtaining the valuable KNO3 fertilizer as the end-product, while reducing significantly the expected CO2 Capture. This progress will be reported in the future.

Thus, CEFCO Global Clean Energy is working to achieve the U.S. Power Industry's aim of deferring the vast majority of CO2 Capture into the last Module alone, the CRS, as the specifically-dedicated CO2 Capture and Conversion Module. Overall OPEX would have been minimized as a result. The economics are being tested and results will be reported in the future.

Furthermore, CEFCO Global Clean Energy is proactively working on full and comprehensive compliance with the current MACT, NESHAPs and CASPR Transport Rule . . . and the eventual GHG or Carbon Rules in the future.

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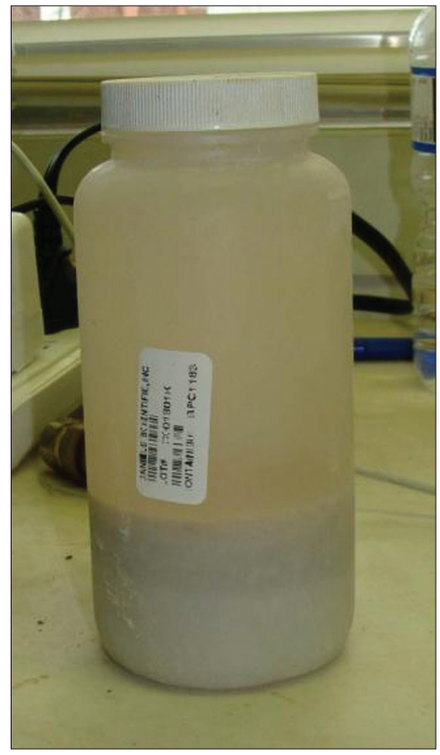

Shown in a translucent amber coloured bottle: The bottle shows the captured pollutants settled down and turned into 3-layers of sellable end-products: white Potassium Bicarbonate crystals at the bottom layer, the grayish off-white Potassium Sulfate Fertilizer crystals in the layer above it, and the dull viscose opaque liquid layer of Potassium Sulfite Fertilizer above them

More information

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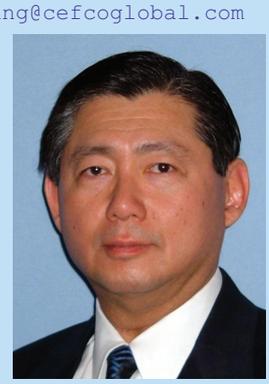

Robert Tang is the Chief Executive Officer of CEFCO Global Clean Energy, LLC, and is a co-inventor of the CEFCO Process. He also serves on the Board of Directors of several major specialty engineering and construction companies, one of which has great emphasis and experience in the utility power industry and air pollution control (AQCS) industry, and the other is in the petro-chemical and refining industry. Tang received his B.A. from Columbia University in 1971 and two additional graduate degrees from Oxford University in England in 1973 and 1979. Tang led all the five co-inventors to invent and apply for the newly patented technology. US Patent and Trademark Office issued Patent #7,842,264 on Nov. 30, 2010.

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