GASIFICATION VS. INCINERATION

EPA Determination Says MaxWest Gasifier Is Not an Incinerator

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Revision 1

Introduction

Thermal conversion of wastes and residuals remains one of the more confusing technical and divisive regulatory arenas in the United States (US). All stakeholders in waste conversion, for or against, have struggled with the lack of clear guidance defining applicability of rules to specific technologies and methods. This is especially true when attempting to separate "gasification" from "incineration." Despite decades of technical and operational advances, detractors have long held that gasifiers are simply "incinerators in disguise."[1] Since this mantra continues to be an impediment to advanced waste conversion, it is imperative that a clear separation be carefully defined.

One US based gasification system developer, MaxWest Environmental Systems, Inc of Lake Mary, Florida, recently announced success[2] in seeking and receiving just such a clear and definitive determination from the US Environmental Protection Agency (EPA). In response to a formal request, the EPA issued a Determination to MaxWest that their gasification system is not an incinerator, providing specific reasoning and pertinent legal justifications. While the question was raised regarding thermal processing of sewage sludge, the implications of this formal determination extend well beyond gasification of any single type of feedstock.

Applicability: MaxWest and its strategic partner, CPH Engineers, Inc., had permitted, constructed, and commissioned a commercial scale wastewater treatment sludge gasification system in September 2009 that focused on reducing sludge disposal costs and requirements for their client, the City of Sanford, Florida. Questioning federal compliance requirements, MaxWest submitted a Request for Applicability Determination[3] to the EPA. MaxWest's counsel[4] filed the request regarding processing of sewage sludge on the basis that use of their gasification technology should not be required to comply with federal rules and compliance timelines governing Sewage Sludge Incineration (SSI)[5]. When more than a year lapsed and no federal resolution was offered, MaxWest sought and obtained the support of the Central Florida Congressional Delegation.

Congressional Support: On November 14, 2013, a joint letter of support was submitted to EPA Administrator Regina McCarthy by Congressman John Mica and Congresswoman Corrine Brown, asking that the EPA review of MaxWest's request be expedited, seeking exclusion from compliance with the SSI. The congressional representatives noted "MaxWest's gasifier solves an important problem for wastewater treatment; it eliminates dewatered sewage sludge in a sustainable way." The petition for resolution continued: "We submit that the gasifier should not be classified and regulated as a sewage sludge incinerator … the gasifier is, by definition, not an incinerator as it does not combust sewage sludge within the meaning of the [SSI] rule."[6]

The EPA Determination: The EPA responded with a formal letter to MaxWest on December 19, 2013. The letter focused on technical design and operational parameters that worked together to disallow flame combustion of the feedstock, and to define the separation of gasification from incineration. The EPA determined that the MaxWest thermal conversion system was a gasifier, not an incinerator, and as such

[1] Global Alliance for Incinerator Alternatives (GAIA), 2006. http://www.no-burn.org/article.php?id=283
[2] Press Release, 1-2-2014: http://www.prnewswire.com/news-releases/epa-ruling-on-sludge-gasification-process-opens-door-to-environmentally-beneficial-waste-treatment-technology-238478871.html
[3] EPA Applicability Determination Index; see: http://www.epa.gov/compliance/monitoring/programs/caa/adi.html
[4] McGuireWoods LLP, Washington D.C. Cameron Prell, Bernadette Rappold. http://www.mcguirewoods.com
[5] SSI: 40 CFR Part 60, subpart MMMM, Emissions Guidelines and Compliance Times for Existing Sewage Sludge Incineration Units. See: http://www.epa.gov/ttn/atw/129/ssi/ssipg.html
[6] Congressional Letter of Support, November 14, 2013.

was not required to comply with the SSI rules and timelines. The finding was based primarily on the following:

> "… no flame is applied or propagated in the gasifier and the gasifier prevents combustion by limiting the air to sludge ratio such that combustion cannot occur. Therefore, we do not believe that the gasifier is an SSI, because it does not combust sewage sludge."[7]

Thermal Conversion 101

Applying enough thermal energy to molecular structures in a closed vessel will eventually break the bonds and decompose the material into progressively smaller molecules of lighter molecular density. When that outside application of energy causes molecular bonds to be broken, recombination occurs. Carbon and hydrogen atoms "liberated" from prior molecular configurations can now combine with oxygen and this process releases more energy than it took to break the larger molecules apart in the first place. If more energy must be applied than is released overall, the process remains "endothermic", and continues to require energy input to be sustained. If more energy can be released as recombination (oxidation) occurs, the process is termed "exothermic" and once initiated, the reaction can be self-sustaining.

Endothermic reactions conserve more of the molecular structure than do exothermic reactions. If more complex molecules are to be recovered from breakdown of feedstock, less splitting is initiated and less oxidation results. If more heat is wanted, additional molecular breakdown and subsequent oxidation is encouraged. The control of the breakdown of the molecules of feedstock and the degree of oxidation energy released define the function of the system and the ability to manage this reaction is dictated by the design and operation of the thermal conversion equipment.

The speed and degree of completion of the conversion reaction can be adjusted by varying the amount of heat, the amount of oxygen allowed and the retention time of the feedstock in the retort. The three factors of Retention Time, Processing Temperature, and Oxygen provide the basis for controlled thermal decomposition.

A system designed to *gasify* feedstock differs from one designed to *incinerate* material by facilitating access to the intermediary products of the thermal decomposition prior to final usage. Heat initiates a phase change from solid to gas. The char, any liquid recondensed from vapors, and the gaseous raw products may be separated, modified, cleaned, upgraded, or reformed according to the desired "refined" final products. Gasification allows *molecular recovery*; incineration "renders to ash."

Regulatory Background: Gasification vs. Incineration

The process of *incineration* is defined as "the act of burning something completely; reducing it to ashes."[8] An *incinerator* is a device that uses controlled flame combustion to directly "burn" feedstock, and an *incineration unit* is that part of any facility that processes waste by incineration. A Waste-to-Energy (WtE) facility applies combustion to solid waste-sourced feedstock to maximize and recover thermal energy, or heat. That heat can then be used directly for process heat, can create useful steam, and/or can drive power generation equipment.

RCRA: Most of the EPA's rules regarding thermal conversion have been developed for safe treatment of hazardous waste. When Congress enacted the Resource Conservation and Recovery Act (RCRA) in 1976, it directed the EPA to establish performance, design, and operating standards for all hazardous waste treatment, storage, and disposal facilities (TSDFs). The EPA promulgated both general facility standards that apply to all TSDFs, and requirements for specific types of units (e.g., incinerators, landfills, and surface impoundments) in 40 CFR Parts 264 and 265.

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[7] EPA Determination of Applicability, December 19, 2013.
[8] Incineration, defined: Prinston University web-based WorldNet. See: http://wordnetweb.princeton.edu/perl/webwn?s=incineration

CAA: Section 129 of the Clean Air Act (CAA §129) required the EPA to develop and adopt performance standards for solid waste incineration units, including emission limitations, and defined the term, *solid waste incineration unit*:

"a distinct operating unit of any facility which combusts any solid waste material from commercial or industrial establishments or the general public".[9]

The EPA recognizes seven types of flame combustion systems, or incinerators, regulated under CAA §129, and two additional types of combustors that fall under provisions of the Resource Conservation Recovery Act (RCRA) and the Toxics Substances Control Act (TSCA).[10] These include: 1) large municipal waste combustors; 2) small municipal waste combustors; 3) hospital/medical/infectious waste incinerators; 4) commercial and industrial solid waste incineration units; 5) other solid waste incinerators; 6) sewage sludge incinerators; 7) hazardous waste incinerators and manufacturing waste incinerators; 8) boilers and industrial furnaces that burn solid waste; and 9) industrial, commercial, and institutional boilers that do not burn solid waste.

California's Query to EPA R9: The California Department of Toxic Substances Control submitted a letter on July 24, 1995 to EPA Region 9 (R9) seeking the federal regulatory differentiation between "gasification" and "incineration" thermal conversion technologies and clarification of various associated terminology. The request was forwarded to the national EPA Office of Solid Waste and Emergency Response, which assessed the series of questions for over two years and finally returned a letter (RO 14238) to EPA R9. Two years of assessment prompted the EPA to provide this clarification:

"Controlled flame combustion refers to a steady-stare, or near steady-state, process wherein fuel and/or oxidizer feed rates are controlled. Controlled flame combustion is the defining character of incineration. If the system discussed operates outside the limits of flammability, such that a flame is never formed, it is reasonable to conclude that it is not an incinerator."[11]

SSI: The EPA published its Final Rule for Sewage Sludge Incineration (SSI)[12] in the Federal Register on March 21, 2011, and resolved all outstanding challenges about a year later. This formally amended Title 40 of the Code of Federal Regulations (CFR), Part 60 (40 CFR Part 60). SSI reinforces the definitions of the CAA for an incineration unit and for solid waste, and relies on CAA's methodology for setting and enforcing performance standards. The preamble to the final Rule describes an SSI unit as

"an enclosed device or devices using controlled flame combustion that burns sewage sludge for the purpose of reducing the volume of sewage sludge by removing combustible matter."

SSI methodology centers on an on-going assessment of the *most achievable control technology* (MACT Standard) for each type and category of technology, establishing a minimum level of emissions control stringency. Thus relevant emissions standards are *technology* specific and applicability of the standards to any one application depend on a reasonable determination that the technology used fits the MACT standard technical basis.

CISWI: Following years of Rulemaking, the EPA finally issued "Commercial and Industrial Solid Waste Incineration Units: Reconsideration and Final Amendments; Non-Hazardous Secondary Materials that are Solid Waste" (the CISWI Rule) on February 7, 2013.[13] The final rule defines a CISWI unit, in part, as *any combustion unit at a commercial or industrial facility that is used to combust solid waste*. Further, systems were only deemed to be "incinerators" while they are indeed burning solid waste, while the system was actually being used to *incinerate* waste. The CISWI Rule indicates that it is not the technology alone that

[9] CAA §129 (g)(1) as amended November 15, 1990. See: http://www.epa.gov/ttn/uatw/129/sec129.pdf
[10] EPA Region 1 New England - Combustion Units; see: http://www.epa.gov/region1/eco/combustion/kindsofunits.html
[11] RO 14238; http://yosemite.epa.gov/osw/rcra.nsf/0/2E168ED0CE00B713852568E3004682CF/$file/14238.pdf
[12] Ibid; SSI: 40 CRF Part 60. Standards of performance for New Stationary Sources and Emissions Guidelines for Existing Sources: Sewage Sludge Incineration Units; Final Rule. Federal Register. V.76, No.54. 3/21/2011. See: http://www.epa.gov/ttn/atw/129/ssi/fr21mr11.pdf
[13] Federal Register: CISWI Final Rule; Notice of Final Action on Reconsideration (CISWI). Docket ID Number EPA-HQ-OAR-2003-0119. See: https://www.federalregister.gov/articles/2013/02/07/2012-31632/commercial-and-industrial-solid-waste-incineration-units-reconsideration-and-final-amendments

determines what is or is not an incineration unit; one must consider both the system and its operational process.

Gasification Rule: Gasification is a centuries-old technology. Much of our modern technical knowledge and corresponding regulatory framework comes from usage of gasification for materials conversion and recovery by the petroleum industries to separate crude oil and its myriad refinery-sourced residuals into the chemical building-blocks of modern manufacturing. In January of 2008, the EPA amended the RCRA to address use of thermal conversion of oil-bearing secondary materials from petroleum refining for the recovery of additional resources from materials otherwise considered wastes.[14]

Years of public debate drew thousands of comments, for and against. Legal challenges were mounted, most notably by the Sierra Club. On April 17, 2012, the EPA answered the last of these challenges, and issued the final Rule amending Title 40 of the Code of Federal Regulations (40 CFR parts 260 and 261): "Regulation of Oil-Bearing Hazardous Secondary Materials From the Petroleum Refining Industry Processed in a Gasification System To Produce Synthesis Gas; Final Determination To Deny Administrative Petition."[15] is commonly known as the Gasification Rule.

Although not strictly true for all gasifier system designs and modes of operation, the federal Gasification Rule provides this definition:

"Gasification is a chemical process that converts carbon-containing material into a synthesis gas that can be used for energy production or as a building block for other chemical manufacturing process. Gasifiers operate at high temperatures and pressure in an oxygen limited environment. Gasification is a chemical process, not a combustion process. The synthesis gas product from the gasifier is comprised primarily of carbon monoxide and hydrogen and is similar to natural gas. Gasification also can produce a concentrated carbon dioxide stream that may have a significant role in carbon sequestration in the future."[16]

Environmental Technology Verification of MaxWest Gasification

The EPA administers the Environmental Technology Verification (ETV) program that provides third-part technology assessment and validation of efficacy. One of the ETV activities is the GHG Center[17], a public/private partnership between the EPA National Risk Management Research Laboratory (NRMRL) and the Southern Research Institute. The GHG Center verifies the performance of technologies that produce, mitigate, monitor, or sequester GHG emissions, including technologies for advanced energy production, waste-to-energy conversion, oil and gas production and transmission, and other energy efficiency technologies.

In June of 2012 the Center published the peer and administratively reviewed Technology Assessment Report on Aqueous Sludge Gasification Technologies[18], evaluating over forty gasifier technologies. The Gasification Technology Assessment Report "aimed to summarize the anticipated benefits and limitations of commercial or near commercial sludge gasification systems, screen out systems with limited promise, and identify significant information gaps necessary to properly evaluate the gasification systems."

The study focused on gasification of two types of industrial sludge that are generated by the pulp and paper industry and biosolids sludge from wastewater treatment plants. The work was prompted by the rapidly increasing tonnages of sludge requiring management, and on encouraging results of prior demonstrations:

"…the process of gasification has been successfully shown to convert numerous types of carbon based feedstocks into a synthesis gas (syngas) which can be directly combusted for heat and energy production, or further processed into a variety of liquid fuels and other chemicals. By significantly reducing the volume

[14] Regulation of Oil-Bearing Hazardous Secondary Materials From the Petroleum Refining Industry Processed in a Gasification System To Produce Synthesis Gas. EPA, 2008. http://www.epa.gov/fedrgstr/EPA-WASTE/2008/January/Day-02/f25240.htm
[15] EPA-HQ-RCRA-2008-0808; FRL 9658-3; see: http://www.gpo.gov/fdsys/pkg/FR-2012-04-13/html/2012-8921.htm
[16] Environmental Protection Agency (EPA), 2008. http://www.epa.gov/wastes/hazard/wastetypes/wasteid/gas.htm
[17] Greenhouse Gas Technology Center. See: http://www.epa.gov/ordntrnt/ORD/NRMRL/std/etv/center-ggt.html
[18] Technology Assessment Report on Aqueous Sludge Gasification Technologies. EPA/600/R-12/540; see: http://nepis.epa.gov/Adobe/PDF/P100EM1Q.pdf

of the residual biosolids, gasification also reduces the costs associated with transportation and disposal in a landfill."

Considerable detail is provided that describes the thermal conversion of sludge waste to syngas, tracing the progression of the feedstock from drying through pyrolysis to full gasification. As molecular bonds are broken, partial oxidation of carbon and hydrogen proceeds and energy is released, temperatures rise to around 250° C and 60 to 70% of the sludge feedstock is volatilized with liquid and gaseous phases, and un-reacted char and ash. As volatiles are oxidized heat is again generated and temperatures rise to around 1100° C. A key phrase from the report:

"The oxidation reactions of the volatiles are very rapid and the oxygen is consumed before diffusing to the surface of the char. *No combustion of the solid char can, therefore, take place* … The products, including CO2, CO, H2, H2O, high chain hydrocarbon gases, residual tars and char, then pass on into the gasification zone." (emphasis added)

Emphasizing that an understanding of both technology and operation are crucial, the report points out the importance of the opportunity with a gasification system to remove compounds from the product gas through simple cleaning and scrubbing which would later form pollutants during the combustion process. With gasification, unlike incineration, the design allows the operator to *access and modify the intermediary products prior to final usage*.

Forty-four gasification system vendors were selected by the EPA for assessment in the Report. Four installations were chosen for in-depth case study comparison. Two applications were still at the pilot to demonstration stage, while only two were identified as running consistently at commercial levels for sludge gasification. The commercial sludge gasification systems included the Germany based and demonstrated Kopf gasifier, and the Florida-based MaxWest Environmental Systems gasifier. As noted in the Congressional support letter:

"Of the forty-four gasifiers EPA studied for the Gasification Report, it awarded only one U.S.-based system the highest possible "Technology Readiness Level"[19]: the MaxWest gasifier. Further, the ETV report clearly distinguishes between gasifiers and incinerators, and calls for an end to the regulatory barriers (such as application of the Rule) that prevent the broader proliferation of gasification technology."

The ETV Report found that, "Gasification is capable of providing a clean and manageable process with the possibility of net energy gains. Unlike incineration, there is potential for sludge gasification to deliver negative GHG emissions. This is accomplished through energy production from biogenic sources and avoiding GHGs which would have been created in a different process."

EPA: Gasification, not Incineration

The EPA response of December 19, 2013 reiterated key elements of MaxWest's system and process descriptions, noting:

- The gasifier processes feedstock in an oxygen-starved environment at about 704 degrees Celsius (°C).
- No flame is applied to the sludge in the gasifier, nor is a flame propagated as a result of the heating.
- The gasifier produces synthetic gas or "syngas." Once the syngas exits the gasifier, it is routed through a particulate matter cyclone and then to a process heater and heat exchanger for heat recovery.
- The syngas is combusted in the process heater to generate the heat to dry new incoming sludge.

[19] Technology Readiness Level (TRL): John C. Mankins 1995. Office of Advanced Concepts, Space Access & Technology, North American Space Administration (NASA). TRLs are a systematic metric/measurement metric that supports assessments of the maturity of a particular technology and the consistent comparison of maturity between different types of technology. ETV's determination that the MaxWest gasifier was *commercial* placed the system at TRL Level 9, the "actual application of the technology in its final form. In almost all cases, this is the end of the last “bug fixing” aspects of true system development. Examples include using the system under application and market conditions, such as those encountered in operational test and evaluation." See: http://www1.eere.energy.gov/manufacturing/financial/trls.html

- Flue gas exiting the process heater and heat exchanger is routed to a baghouse and a wet scrubber.

The EPA response states that the SSI Rule (Section 60.5250) applies to an incineration unit combusting sewage sludge, a feedstock which is defined as the solid, semi-solid, or liquid residue generated during the treatment of domestic sewage at a treatment works. Lack of feedstock combustion by the design and operation of the MaxWest gasifier for conversion of sewage sludge convinced the EPA that the system was not a "Sewage Sludge Incinerator."

The EPA extended their assessment to the thermal oxidizer process heater, a critical element of the MaxWest sewage sludge processing train or "gasifier unit." This crucial separation of all combustive processes from the actual gasification stage within the main retort allows operation of the MaxWest system to include modification of the syngas as a function of the "unit", in this case, processing through a particulate matter cyclone prior to final combustion of the syngas to generate process heat.

Further, SSI's definition of sewage sludge and "materials derived from sewage sludge" includes only solid, semi-solid and liquid materials; any gaseous phase (such as the product syngas) is *not* included in the definition. "Therefore, EPA believes that the combustion of the syngas in MaxWest's thermal oxidizer process heater is not subject to the SSI EG [Emissions Guidelines] Rule."

Conclusions

Incineration is direct combustion of feedstock by rapid flame oxidation, resulting in ash. Gasification is a chemical process that occurs at high temperatures in the absence of sufficient oxygen to propagate and maintain a flame (also "starved air" combustion). The heat converts solids to syngas that can be used directly as a fuel or refined to meet final product specifications.

Differentiation of *gasification* from *incineration* must take into account both the design and the operational process of a thermal conversion system.

The entire processing train from feedstock supply to final delivery of syngas for intended use is referred to as the "gasification unit". The central thermal conversion chamber is the "gasifier", while the process of non-combustive thermal conversion is "gasification."

A thermal waste conversion system designed as a gasifier is not being operated as an incinerator if there is no direct flame combustion of the feedstock within the reactor. This non-combustive condition is a result of a configuration and its operation that does not use applied flame to "burn" the feedstock, and precludes sufficient oxidation of the feedstock to maintain a flame in the retort. Thus by design and process, the reactions taking place in a gasification unit include a level of direct raw product access, sensoring, and feedback sufficient to eliminate direct combustion and disallow *incineration.*

The design of a gasification unit must allow the operator to access the intermediary synthetic gas, and modify that syngas as needed prior to further combustion or other end-use. An incinerator's design need not include this functional element, instead being developed and operated to drive the thermal conversion of the feedstock by direct application and propagation of flame combustion at the surface of the feedstock.

MaxWest had been pursuing regulatory clarity regarding both the design and operation of their gasification systems for at least half of the current decade, while continuing to refine systems and market their applications. The company's level of engagement in the ongoing regulatory and verification processes is certainly commendable. The legal timelines for federal response to a formal Request for Applicability Determination are clear, yet MaxWest and their legal counsel found it necessary to seek the direct intersession of their congressional delegation to force EPA's hand. Perhaps this hard-won Determination can now provide a fulcrum for the rest of the waste conversion sector, industrial and municipal alike, with which to speed the shift from repressive regulation to inclusive, science-based resource recovery.