
ZEROS



Photo depicts a prior generation to ZEROS and is for illustration only

**Coal - Oil - Gas – Bio-energy
Generation of Electrical Power & Bio-fuels
“Without Emissions”**

System Due Diligence

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Executive Summary

The ZEROS System technology is an innovative closed system process for recycling and optimizing energy. The process is comprised of mature technology that is patented and proven. This process is based on oxidation, which is the process of altering compounds by adding an electro-positive oxygen atom to that compound. This process differs from incineration, which is the process of reducing a compound to ash. The main difference is oxidation relies on total mass balance. This means no product from the ZEROS System is vented to the atmosphere. Instead all products of combustion are captured and marketed as process products. The products from the system are highly refined and have a higher than average market price and qualifies the system as a recycling system.

The oxidation process is unique in that the system utilizes no ambient air therefore no nitrous oxides or sulfur dioxides are formed in the combustion process. Since nitrogen is approximately eighty percent of air the total mass through the system is eighty percent less than a system using ambient air and meaning the system can be fifty percent smaller and have the same process capacity as a system of standard technology. Also since the purpose of nitrogen in the air is to retard combustion and they're being no nitrogen present in the system, much higher temperatures are obtained quicker with less fuel energy. This oxygen-carbon dioxide synthetic air in the system also has a higher heat transfer rate for boiler efficiency than air at the same temperature. With higher boiler temperatures achievable greater efficiencies can be seen in electrical generation without the negative effect of nitrous oxides discharged into the atmosphere as is the problem with gas or coal fired plants having smoke stacks.

The ZEROS System when used to consume coal, dirty coal, low grade fuels and scrap tires as fuels becomes a very efficient process for generating electricity or water purification. The oxidation process recovers a much higher percentage of recoverable heat energy by nature of its process that do other systems that utilize ambient air in the combustion process. There are also operating cost advantages by virtue of not have to process and control large amounts of stack gas pollutants.

With no smoke stack, no health dispersion model, no regulated compounds and no incineration the system has qualified as requiring no air quality permit from state or federal EPA under current statutes. This also means that under title 40 CFR there is no mandate to open the environmental impact statement to public comment. This reduction in regulatory and permitting process means a system can be brought into operation an average of three years sooner than other technologies. Additionally location of the facility is not as great an issue with local communities since there are no emissions associated with the system.

Within the ZEROS System the flue gas is brought to a complete halt in the purification process. This allows for certification of process quality and is much different than other technologies that run flue gas up a smoke stack at a high velocity. Further benefits of the process are all of the process products are marketed which is a factor that substantially offsets the cost of system operation and improves profitability. **The specific case study information is developed from specific projects and used in this document for information purposes only. Other specific project information will change various results and scientific formulas may change specific chemical results.**

The system enjoys other benefits by virtue of its design. Internal Revenue Codes allow businesses utilizing technology such as ZEROS tax credits for recycling, energy optimization, pollution free and pollution abatement.

Risk Assessment

**Risk Assessment
&
Risk Analysis**

For Operation Of

**"Zero-emission Energy Recycling Oxidation System"
ZEROS System Electrical Generation**

Prepared For:

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Compliance Statement

This document is prepared to the standard and format as set out in Title 40, Code of Federal Regulation of The United States of America. (Section I.) Environmental Protection Agency and (Section V.) Council on Environmental Quality. It sets out the standards for construction and operations and risks if any to the public health and safety and the risks to the environment.

Introduction

This document details as a matter of scientific estimate the risks to human health and to the environment associated with the operation of a Zero-emission Energy Recycling Oxidation System for optimizing and energy recycling as the primary process in an electrical generation facility. Human health risks are based on possible human exposure to fuels, handling and processing discharged bottom ash and fly ash, handling discharged liquid and solid reactants from the scrubbing columns, handling reagents utilized in the scrubbing process, and the hazards associated with the storage and use of oxygen for the combustion of fuel. Additionally, a boiler is employed in the process and consideration must be given to the hazards associated with pressurized steam. The system also utilizes a steam turbine and gearbox assembly as a means of driving an electrical generator. Environmental risks are based on the possibility of spills and discharges of chemicals that could, if not contained and remediated, accumulate in soils and ground water. Additionally, discharges into the air (releases) will be considered which would be transported from the facility site to other areas before settling onto surface structures as contamination.

The Zero-emission Energy Recycling Oxidation System does not have a stack and does not discharge a gaseous plume; therefore, no consideration need be given for flue gas dispersion and the risks associated with exposure to the hazardous constituents of flue gas. This fact is the major advantage of the Zero-emission Energy Recycling Oxidation System over conventional combustion processes for electrical generation. The system has as a feature of its design an integral vacuum holding tank that will evacuate the system in the event of a system upset. Every effort has been made to avoid accidental releases and backup systems are employed along with fail-safe system interlocks to prevent the occurrence of operational situations that might lead to such releases. This document will however consider accidental inadvertent releases for the purpose of assessing the possible consequences from such events as related to human health and the environment. **It must be stated that under current regulations the system neither consumes nor produces any regulated compounds and the system is operated as a non-incineration oxidation process.**

Facility Design and Construction:

The design parameters and methods of construction as well as the materials requirements for construction of this facility are governed by the various industry and federal code regulations in existence at the time of construction. Compliance will conform to the standards of

International Standards Organization (ISO)

ISO 9000

ISO 9001

ISO 9002

American National Standards Institute (ANSI)

ANSI A13.1 Identification of Piping Systems

ANSI B31.1 Code for pressure piping

ANSI B31.2 Fuel gas piping

ANSI B31.3 Petroleum piping

ANSI C1-71 National Electrical Code

American Society of Mechanical Engineers

ASME Section VIII Boiler and Pressure Vessel Code

American Society for Testing And Materials

ASTM A53 Welded pipe

ASTM TC1A Testing specifications

American Welding Society

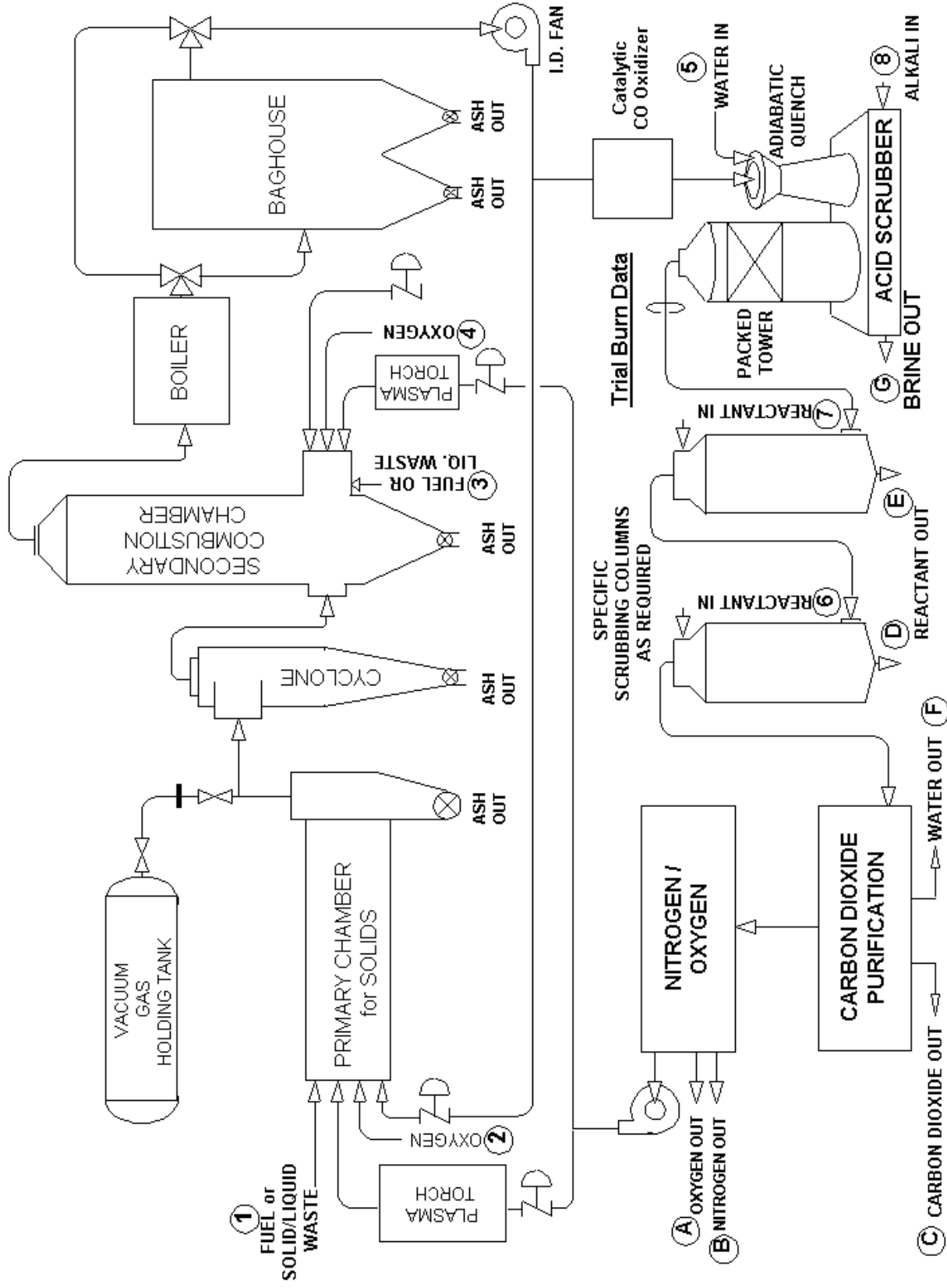
AWS B3 Standard Qualification Procedure

AWS D1.1 Standard for power pipe

AWS D10.9 Standard Qualification of welding procedures and welders for piping and tubing.

"ZEROS" - Zero-emissions Energy Recycling Oxidation System - Process Schematic

Mass Balance: $1 + 2 + 3 + 4 + 5 + 6 + 7 + 8 = A + B + C + D + E + F + G + \text{TOTAL ASH OUT}$



Facility Description And Operation:

Figure One on the preceding page depicts the Zero-emission Energy Recycling Oxidation System in schematic representation. The system employs a rotary kiln primary combustion chamber followed by a cyclone separator where entrained particulate matter is removed from combustion gases exiting the rotary kiln before their entry into the secondary combustion chamber. Combustion gases are exposed to a high temperature, high turbulence, oxidative environment for at least two seconds in the secondary combustion chamber providing ample opportunity for extremely high process oxidation efficiency. Both the primary and secondary combustion chambers are oxygen fired. No air with its burden of 80% nitrogen is introduced in either of these combustion chambers. Instead, a portion of the cleaned and cooled combustion gas is returned from the outlet of the baghouse fabric filter and re-introduced to the process along with the pure oxygen providing for thermal oxidation of fuel and fuel. Both combustion chambers are operated at pressures below barometer during normal operations. Special seals are installed on the rotary kiln to prevent air infiltration. These same seals additionally prevent the expulsion of combustion gases should the rotary kiln primary combustion chamber become slightly pressurized due to inadvertent over feeding or the introduction of highly volatile fuel stock. As a backup for failsafe operation a vacuum tank is provided to automatically scavenge excessive combustion gas during an inadvertent kiln pressurization.

In the unlikely event that inorganic inert compounds are present in the fuel being used to fire the system consideration must be given to the removal of this trace amount of ash. Risk to human health and the environment can arise from improper handling and disposal of this ash. Proper handling and disposal procedures will be employed to avoid such risk. All personnel involved in the handling and disposal of the combustion process ash will be trained and made cognizant of the risks and their responsibility to follow all safety and environmental protection protocols. These individuals will be supervised and guided in the conduct of their work to insure the lowest probability of human error possible. The highest risk to human health associated with this ash lies with these workers. Ingestion by breathing airborne particulate into their lungs is the nature of the risk and respiratory protection, as well as proper containment are required when handling this material as a dry product.

Upon exiting the secondary combustion chamber the combustion gases are routed into a heat recovery boiler. The combustion gases exit the boiler at temperatures ranges between 450 degrees and 1500 Fahrenheit depending on configuration and uses of steam energy. Steam produced by the heat recovery boiler has many uses on site and can be used as pure steam energy to water purification units and desalinization plants or can even be used to generate electricity by driving a turbine generator. The electrical power generated will be marketed in the commercial market. This boiler system is constructed and operated in accordance with ASME standards and the rules and regulations imposed

by local authority governing the operation of boilers. Personnel working around or directly operating the boiler system are trained, supervised, and licensed as required for boiler operation.

Upon exiting the boiler the combustion gases are routed into the baghouse fabric filter where particulate matter entrained in the gas flow is removed. This particulate matter is commonly referred to as fly ash because it so readily takes flight with a moving gas. Once discharged from the baghouse fabric filter this fly ash presents a hazard to both human health and the environment. If not properly contained this very light and fine powder will be blown with the wind and scattered around the facility and possibly transported to areas outside the facility boundary. This fly ash is readily ingested by breathing and typically contains trace levels of metals that are harmful to human health and the environment. Personnel working with or around this fly ash must wear respiratory protection. To prevent accidental discharge and the consequential dispersion of fly ash into the air a wetting process is used to convert the fine dry powder into a paste. Cement is mixed with the paste formed by mixing water with the baghouse fly ash. The cement and fly ash is then mixed with a portion of the bottom ash from the cyclone separator. This mixture is formed into cinder blocks for storage on site. Walk-ways, barricades, fences, small storage buildings, and fire walls separating fuel storage areas can all be constructed from the cinder blocks produced over time from the ash discharged from the facility.

Upon exiting the baghouse fabric filter the cleaned combustion gases enter the induced draft fan that provides the motive force keeping the gases moving through the process. At the exit of the induced draft fan the gases split into two streams of flow. A portion of the cleaned and cooled combustion gas is returned to both combustion chambers where it mixes with the products of combustion there and is re-heated. Re-heating the returned combustion gas moderates the combustion temperatures in the combustion chambers. In fact, the combustion temperature in the combustion chambers is readily controlled by the amount of cooled combustion gas returned and mixed with the products of combustion being generated there. This is another of the advantages that the Zero-emission Energy Recycling Oxidation System has over conventional combustion processes that introduces a constant four parts nitrogen with each one part oxygen delivered for combustion. To increase temperature these conventional combustion processes increase fuel and firing rate. The Zero-emission Energy Recycling Oxidation System can simply reduce the amount of re-circulated combustion gas to increase combustion chamber temperature without increasing fuel consumption and firing rate. This factor provides an extra measure of control to enhance the safety and quality of operation of the Zero-emission Energy Recycling Oxidation System facility.

Cleaned and cooled combustion gas which is not returned to the combustion chambers are routed into the wet scrubbing system to remove acidic constituents such as SO_2 and HCL before the gas enters the CO_2 recovery plant. The first component of the wet scrubbing system is an adiabatic

quench & low pressure drop Venturi. Combustion gas temperature is dropped from approximately 400 degrees Fahrenheit to roughly 175 to 180 degrees Fahrenheit in the Venturi quench by direct contact with and evaporation of water. This direct contact with water spray also provides for absorption of HCL from the gas into the water. Approximately 90 percent of the HCL in the combustion gas will be removed by this first mechanism in the wet scrubbing process. SO₂ and additional HCL are removed from the combustion gas by contact with reagents in the packed bed scrubber and in additional scrubbing columns added to insure optimum scrubbing efficiency before the gas enters the CO₂ recovery system. There is also an activated carbon packed bed absorber immediately before the inlet of the CO₂ recovery system. This device is to remove trace levels of residual organic compounds and metal fume such as mercury that might find its way into the process with certain fuel streams.

The wet scrubbing process requires that liquid brine be produced and discharged from the scrubber. The amount of brine discharge depends on the level of chlorine and sulfur present in the fuel being processed. This brine is mixed with the ash product and cement described earlier to form cinder blocks. In the event that fuel with very high chlorine and / or sulfur content is processed and more liquid brine discharge is produced than can be mixed with ash and cement, the excess will be filtered and steam from the boiler will be utilized to evaporate water from this filtered brine to produce a marketable fracturing or completion fluids for the oil industry. If required a solid salt cake can be produced from this brine.

Entering the CO₂ recovery unit will be a mixture of moisture, CO₂, excess oxygen, and nitrogen. Nitrogen is liberated from the combustion of natural gas, fuel oil, and some of the other fuel streams. The proportions of these constituents will be approximately as follows:

CO₂ => 52%

H₂O => 42%

O₂ => 5%

N₂ => 1%

The CO₂ recovery unit condenses and discharges the moisture as a liquid. This water is then used as make-up to the wet scrubber system to replace the water that is discharged there as a brine. The amount of water recovered from the moisture in the combustion gas will be in the order of 10 gallons per minute. In the event that the scrubber does not require this amount of blow-down due to a very low chlorine and sulfur content in the fuel, the excess water will be contained, filtered, treated, sampled and analyzed as required to allow for its discharge into the fuel heat boiler.

The gaseous combination of roughly 4 parts oxygen and 1 part nitrogen that is discharged from the CO₂ recovery unit cannot be reintroduced into the Zero-emission Energy Recycling Oxidation System process because the nitrogen would accumulate and grow in proportion to the other gases until the process was overwhelmed. The gaseous mixture is recovered as a separate product from the CO₂ and sold for oxygen enrichment to metal smelters or used on site to fire a small clean fuel burner for a recycling process for scrap metal or glass.

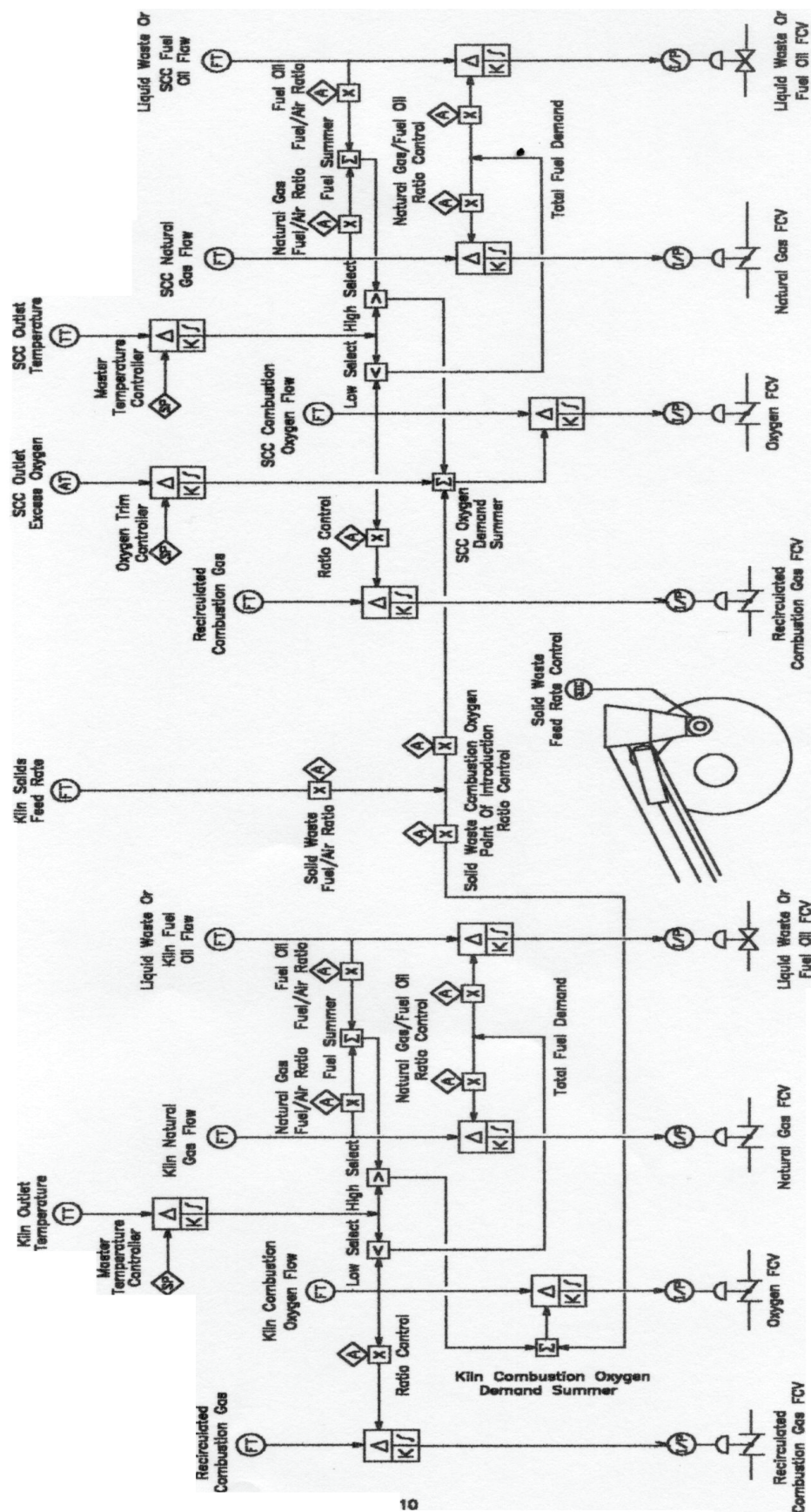
Process Control and Automatic Operational Interlock Logic:

Figure Two on a following page is a schematic diagram of the burner control scheme developed for the Zero-emission Energy Recycling Oxidation System. The system is a chamber-coupled arrangement that allows oxygen to be routed into both combustion chambers for fuel being fed into the rotary kiln primary chamber. With this mode of control the primary combustion chamber can be operated in a slightly sub-stoichiometric mode to enhance stability and dampen the process response to fluctuations in fuel feed characteristic. This mode of operation is widely accepted for dual chamber combustion processes requiring stability and high combustion efficiency.

The control scheme noted is implemented utilizing a computerized data acquisition and control system with field mounted I/O modules and a control room operator's station. The system is referred to as distributive control and represents the state of the art in process control systems. From a risk assessment standpoint this type of control system provides the best available technology to insure the lowest probability of a run-away process. Automatic interlocks prevent the feeding of fuel when any of several critical operating parameters are not sensed to be at conditions appropriate for the highest efficiency fuel oxidation. Additionally, the control room operator has manual means of stopping fuel feed when any factor in his judgment leads him to conclude that he should stop fuel feeding. The operator does not however have manual means to start fuel feed when the automatic operational protocols have fuel feeding interlocked out. Even when the automatic operational protocols allow fuel feeding, the operator must initiate that feeding after making the judgment that all conditions are appropriate. Either human judgment or the computer system can stop fuel, but both must be in agreement to start fuel feeding.

Primary Chamber

Secondary Chamber



Zero-emission Energy Recycling Oxidation System Control Scheme
Figure Two

Automatic interlocks are in place for two secondary purposes. Some interlocks are implemented to simply protect equipment from damaging operating conditions. Other interlocks are implemented to insure that no fuel is processed unless operating conditions are appropriate for the thorough oxidation of that fuel and the proper handling of the products of that oxidation. The primary purpose of both of these interlock types is to provide protection to human health and the environment. The following is a list of detail operational protocol interlocks that automatically oversee the Zero-emission Energy Recycling Oxidation System facility operation and minimize the risk to human health and the environment associated with its operation.

Interlocks that are implemented to prevent equipment damage include the following:

1. Stop fuel feed. Stop burner fuels flow. => Loss of boiler feed water and boiler water level in low alarm.
2. Stop fuel feed. Stop burner fuels flow. => Boiler water level in **low** alarm.
3. Vent Steam Drum Pressure. => Boiler Pressure Above 350 PSIG or as determined for interlock by local boiler codes or manufacturer.
4. Stop fuel feed. Start emergency quench. => Baghouse inlet temperature above 500 degrees Fahrenheit or as recommended by specific fabric filter manufacturer.
5. Stop fuel feed. Stop oxygen flow. Stop fuels flow. Re-circulate total gas volume. => Loss of CO₂ recovery system operation or loss of Adiabatic quench or any failure of operation in the acidic constituent scrubbing system.
6. Rotary kiln primary chamber combustion gas temperature greater than 2,400degrees Fahrenheit (Or as determined by the refractory manufacturer to be the upper temperature limit allowed for the primary combustion chamber refractory)
7. Secondary combustion chamber combustion gas temperature greater than 2,600 degrees Fahrenheit (Or as determined by the refractory manufacturer to be the upper temperature limit allowed for the secondary combustion chamber refractory)

More automatic operational protocol interlocks for equipment protection will be added as deemed appropriate from experience gained with operation at a specific facility. In addition to these

automatic interlocks the control room operator and personnel working as outside operators are trained to recognize and respond to equipment problems of all varieties. Routine hourly check list inspections will be made to monitor the physical condition of the facility during operation and a daily inspection is required by the facility engineer or a skilled representative of the facility engineer in his absence. Routine preventative maintenance, such as lubrication of bearings and drive chains, is carried out by daily and weekly checklist to prevent equipment failures to the extent possible. The Zero-emission Energy Recycling Oxidation System facility is operated under the watchful eyes and ears of highly trained and skilled personnel with a constant effort applied to recognizing and dealing with impending problems before they become actual problems with impact on human health or the environment. If equipment failure occurs in spite of these efforts, these same personnel are trained and equipped to respond to minimize the impact of the failure. Safety and preservation of human health are the first considerations of any action whether in response to a failure or a normal operating procedure.

Automatic operational protocol interlocks that prevent the feeding of fuel when conditions are perceived to be inappropriate include the following:

1. Secondary combustion chamber outlet temperature below 2,200 degrees Fahrenheit.
2. Available oxygen in combustion gas at the secondary combustion chamber outlet less than 2 percent of wet volume.
3. Sum of total hydrocarbons and carbon monoxide at the baghouse inlet greater than 100 parts per million of wet volume (Or as determined by operating experience to provide indication of less than optimum processing).
4. Rotary kiln primary combustion chamber outlet draft level less than 0.1 inches water column.
5. Rotary kiln primary combustion chamber outlet temperature less than 1,400 degrees Fahrenheit (Or as determined by operating experience to provide indication of less than adequate detoxification of the fuel being fed).
6. Loss of kiln rotation or loss of ash drag operation.
7. Low or high pressure drop across the baghouse fabric filter (limits to be determined as recommended by manufacturer).

8. ID Fan high vibration or high motor amperage (limits to be determined as recommended by manufacturers).
9. Loss of re-circulation flow in the packed bed absorber.
10. Loss of acidic constituent scrubbing efficiency as determined by pH of condensate discharged from the CO₂ recovery system.

Statement Of Risks:

Fuel Storage and Handling

The greatest risk to human health encountered with the operation of the Zero-emission Energy Recycling Oxidation System facility occurs due to the necessity of workers to come into close contact with the fuel when off loading, placing into temporary storage, and later preparing the fuel for processing. To lessen the effects of this type of accident, all personnel, where the possibility of contact with fuel exists, must wear protective clothing, eye protection, and respirators. Additionally, emergency showers are situated throughout these areas to provide quick decontamination in the event a worker comes in contact with fuel deemed hazardous.

All fuel off loading and storage areas are constructed to provide secondary containment. Emergency spill response kits are stationed in all areas where fuel handling occurs. These kits contain adsorbent, shovels, plastic drums, and protective gear for workers who might be required to use them. All spills of hazardous fuel require immediate response and remediation. No such spills will be left uncontained in the environment for any period of time longer than is necessary to call out the response team and effect an immediate clean-up. With this approach a spill associated with the operation of the Zero-emission Energy Recycling Oxidation System Facility has only a very short term and temporary effect on human health or the environment.

Kiln Bottom Ash & Fly Ash Handling and Containment

Ash, from the fuel combustion processes typically contains no trace elements and therefore present minimal risk to humans or the environment. The normal mode of facility operation will eliminate dust by wetting the ash with the blow-down from the wet scrubber and / or the condensate from the CO₂ recovery system. The highest probability of releases of ash into the air occurs during periods of facility shutdown and maintenance. The oxidation chambers and baghouse assembly will be opened for inspection during those periods and residual fly ash can become airborne and escape at

these times. Workers, who carryout these inspections, must be protected with particulate filtering respirators and special precautions must be taken to avoid releases. Temporary airlock entries will be constructed during these inspection and maintenance periods to prevent releases of fly ash from the facility.

Liquid Discharge Handling

No liquid from the Zero-emission Energy Recycling Oxidation System facility will be discharged into the environment. Both the blow-down from the wet scrubbing system and the condensate from the CO₂ recovery unit will be used to the extent possible to quench the ash products and react with the cement mixed with the ash. In this role the liquid discharge constitutes no known risk to human health or the environment. An effort will be made to market concentrated brine from the scrubber process. This brine will be filtered and sold to the oil industry as a frac brine or completion fluid. In this role as is the case with mixing with ash and cement no known risk to human health or the environment exists for the liquid discharge from the Zero-emission Energy Recycling Oxidation System.

Residual Oxygen & Nitrogen From The CO₂ Recovery Unit

These gaseous products representing roughly 5 percent of the input to the CO₂ recovery system will be rejected. This rejected gas will be approximately 80 percent oxygen and 20 percent nitrogen. With a means of separating these two components in place there is no concern with their presence. The oxygen will be reintroduced into the Zero-emission Energy Recycling Oxidation System and the nitrogen will be utilized as the inert blanketing gas for the fuel input area or sold as a product. This is the preferred means of dealing with this gas stream and represents no additional risk to human health or the environment beyond that already discussed.

Accidents and Fires

As with any industrial process involving combustible chemicals or materials and human labor, the potential for accidents resulting in injury or death is present with the operation of the Zero-emission Energy Recycling Oxidation System Facility. Because we are aware of this potential and conscience of the human suffering created by accidents, safety is the most important consideration given to any aspect of the facility operation. A safety program is in place to maintain that awareness and to provide monitoring and training continuously. That training is aimed at both preventing accidents and preparation for response to accidents. The risk to human health and the environment due

to accidents at the Zero-emission Energy Recycling Oxidation System Facility will be no greater than that noted from other well run chemical process facilities of its size.

Conclusions:

The greatest risk to human health and the environment associated with the operation of the Zero-emission Energy Recycling Oxidation System Facility lies with the handling of fuel at the site. This risk is no greater than the risk that any other storage and handling facility would encounter with the same fuel. Once the fuel has been oxidized that risk is eliminated and the oxidation process itself presents minimal risk to human health or the environment.



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United States Patent [19] Clark

[11] Patent Number: 5,906,806
[45] Date of Patent: May 25, 1999

[54] REDUCED EMISSION COMBUSTION
PROCESS WITH RESOURCE
CONSERVATION AND RECOVERY OPTIONS
"ZEROS" ZERO-EMISSION ENERGY
RECYCLING OXIDATION SYSTEM

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[21] Appl. No.: 08/730,974

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F25J 1/00; F01K 17/00

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39.55, 278, 297, 648; 423/220, 437.1

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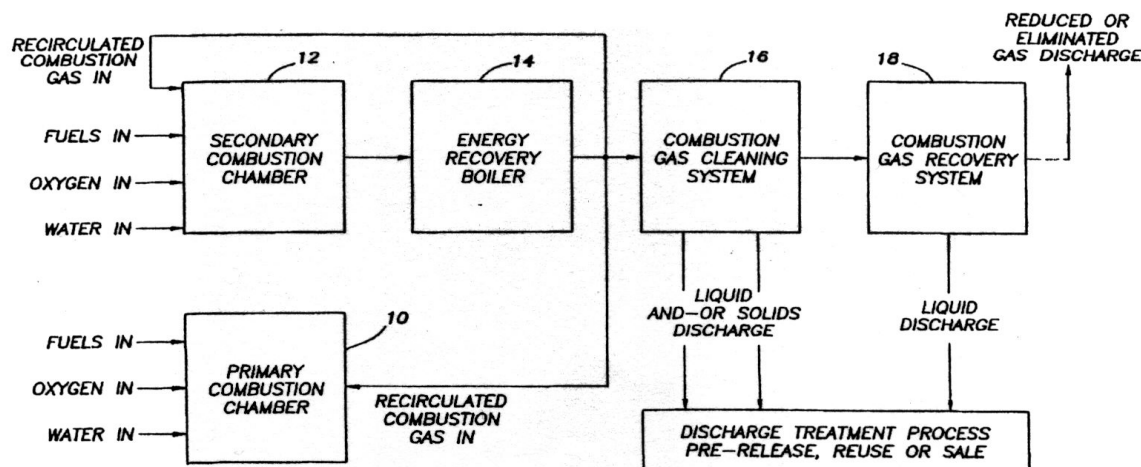
Assistant Examiner—Ljiljana V. Ciric

Attorney, Agent, or Firm—Pravel, Hewitt & Kimball

[57] ABSTRACT

A system and a process for combusting hydrocarbons to recover energy and the carbon dioxide resulting from the combustion is provided. The process utilizes a two-stage combustion process, each stage utilizing water injection and a recirculation stream to increase the efficiency of combustion to generate larger proportions of carbon dioxide. An energy recovery boiler is used to recover heat energy from the combustion product. Combustion product is then cleaned and the carbon dioxide is separated and condensed into a useable liquid carbon dioxide product.

9 Claims, 7 Drawing Sheets





US006024029A

United States Patent [19]

Clark

[11] **Patent Number:** **6,024,029**[45] **Date of Patent:** **Feb. 15, 2000**[54] **REDUCED EMISSION COMBUSTION SYSTEM**[76] **Inventor:** **Steve L. Clark**, 1730 Hillcrest,
Baytown, Tex. 77520[21] **Appl. No.:** **09/181,110**[22] **Filed:** **Oct. 28, 1998****Related U.S. Application Data**

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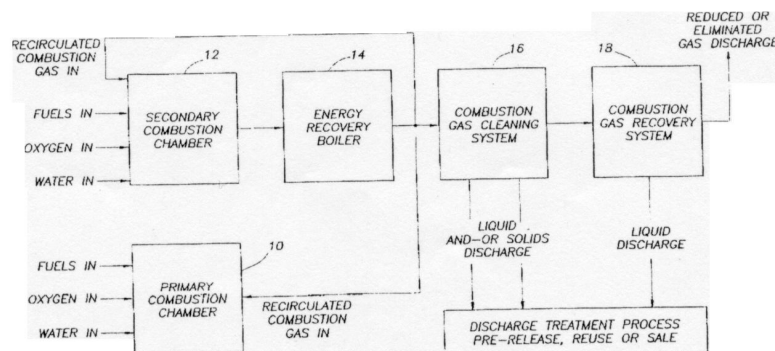
[51] **Int. Cl.**⁷ **F23J 3/00**[52] **U.S. Cl.** **110/216; 110/203; 110/204;**
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423/210[58] **Field of Search** 110/203, 204,
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344, 345; 60/648, 39.182; 423/210, 244;
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Primary Examiner—Ira S. Lazarus**Assistant Examiner**—Ljiljana V. Ciric**Attorney, Agent, or Firm**—Akin, Gump, Strauss, Hauer &
Feld, L.L.P.[57] **ABSTRACT**

A system and a process for combusting hydrocarbons to recover energy and the carbon dioxide resulting from the combustion is provided. The process utilizes a two-stage combustion process, each stage utilizing water injection and a recirculation stream to increase the efficiency of combustion to generate larger proportions of carbon dioxide. An energy recovery boiler is used to recover heat energy from the combustion product. Combustion product is then cleaned and the carbon dioxide is separated and condensed into a useable liquid carbon dioxide product.

15 Claims, 7 Drawing Sheets



US006119606A

United States Patent [19]
Clark

[11] **Patent Number:** **6,119,606**
[45] **Date of Patent:** ***Sep. 19, 2000**

[54] **REDUCED EMISSION COMBUSTION PROCESS**

[75] Inventor: **Steve L. Clark**, Baytown, Tex.

[73] Assignee: **M. Ltd.**, Highlands, Tex.

[*] Notice: This patent is subject to a terminal disclaimer.

[21] Appl. No.: **09/243,036**

[22] Filed: **Feb. 3, 1999**

Related U.S. Application Data

[63] Continuation of application No. 08/730,974, Oct. 16, 1996, and a continuation of application No. 09/181,110, Oct. 28, 1998.

[51] Int. Cl.⁷ **F23B 7/00; F23J 3/00**

[52] U.S. Cl. **110/345; 110/344; 110/348; 431/2; 423/220; 62/617; 62/928**

[58] **Field of Search** 110/341, 342, 110/344, 345, 346, 203, 204, 208, 210, 212, 216, 233, 234, 348; 431/2, 3, 5; 62/600, 602, 606, 611, 617, 928; 60/39.52, 39.55, 278, 297, 648; 423/220, 437.1

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Primary Examiner—Ira S. Lazarus

Assistant Examiner—Ljiljana V. Ciric

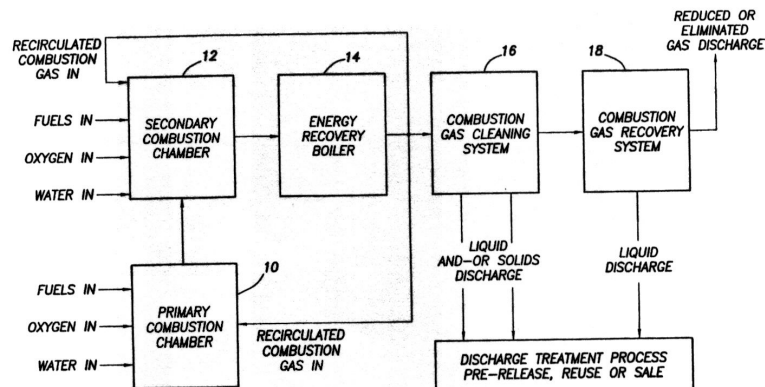
Attorney, Agent, or Firm—Akin, Gump, Strauss, Hauer & Feld, L.L.P.

[57]

ABSTRACT

A system and a process for combusting hydrocarbons to recover energy and the carbon dioxide resulting from the combustion is provided. The process utilizes a two-stage combustion process, each stage utilizing water injection and a recirculation stream to increase the efficiency of combustion to generate larger proportions of carbon dioxide. An energy recovery boiler is used to recover heat energy from the combustion product. Combustion product is then cleaned and the carbon dioxide is separated and condensed into a useable liquid carbon dioxide product.

10 Claims, 7 Drawing Sheets





US006137026A

United States Patent [19]
Clark

[11] **Patent Number:** **6,137,026**
[45] **Date of Patent:** ***Oct. 24, 2000**

[54] **ZEROS BIO-DYNAMICS A ZERO-EMISSION
NON-THERMAL PROCESS FOR CLEANING
HYDROCARBON FROM SOILS ZEROS BIO-
DYNAMICS**

[76] **Inventor:** **Steve L. Clark**, 1730 Hillcrest,
Baytown, Tex. 77520

[*] **Notice:** This patent issued on a continued prosecution application filed under 37 CFR 1.53(d), and is subject to the twenty year patent term provisions of 35 U.S.C. 154(a)(2).

[21] **Appl. No.:** **08/864,597**

[22] **Filed:** **May 28, 1997**

[51] **Int. Cl.⁷** **A62D 3/00**

[52] **U.S. Cl.** **588/205; 588/206; 588/207;
588/208; 588/209; 588/213; 588/223**

[58] **Field of Search** **405/128, 129,
405/263; 588/206, 207, 209, 223, 205,
208, 213**

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Primary Examiner—Steven P. Griffin

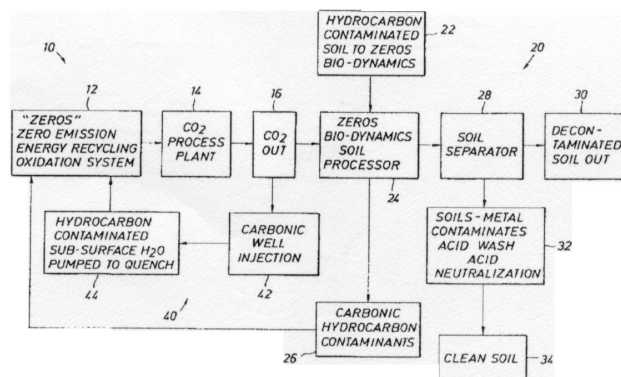
Assistant Examiner—Eileen E. Nave

Attorney, Agent, or Firm—Akin, Gump, Strauss, Hauer & Feld, L.L.P.

[57] **ABSTRACT**

A combination of parallel processes is disclosed to provide optimal remediation operations for contaminated soil. Soils with high levels of heavy petroleum hydrocarbons are directed to a thermal process for destruction in a combustion process. Carbon dioxide generated and recovered in the thermal process is employed as a solvent in a solvent process to clean other soils of petroleum hydrocarbons and certain chlorinated hydrocarbon compounds. In the solvent process, contaminated soils are run through a closed soil separator where the soils are washed with carbon dioxide. The carbon dioxide is then dried from the soil and the soil is sent for segregation. Soils with the lightest forms of hydrocarbon contamination (gasoline, etc.) are subjected to a vaporization process utilizing heat energy generated in the thermal process to heat the soil, under a partial vacuum, and the vapors generated are captured, condensed, and recovered as product.

20 Claims, 4 Drawing Sheets



Texas Water Resources Institute



October 22, 2008

Mr. Stan Schlueter
The Schlueter Group
P. O. Box 2227
Austin, TX 78768

Dear Mr. Schlueter:

This is in response to your request for information concerning Texas Water Resources Institute's (TWRI) efforts to verify the technical feasibility of the Zero-Emission Energy Recycling Oxidation System (ZEROS).

In 2004, TWRI hosted two meetings between Mr. Steve Clark, inventor of ZEROS, and six senior Texas A&M University System engineers and economists. The consensus of the faculty was that ZEROS is technically feasible to oxidize animal wastes like dairy manure.

Also, since 2004 TWRI has consulted with Mr. Tom Boyd of Triencon Services, Inc. on the technical and economic feasibility of using ZEROS technology to power both electrical generation and produce liquid fuels. Mr. Boyd, an early skeptic of the technology, has developed sophisticated engineering and economic models of ZEROS and, as a result, has become a strong proponent of and advocate for the system. I have examined and discussed with him his analyses and trust his conclusions regarding both the technical and economic feasibility of the ZEROS process. In general, I believe that his assumptions are conservative, and commercial ZEROS facilities could easily prove even more profitable than he projects.

In 2007, Mr. Clark and I met with a number of senior engineers working with Federal and State agencies in Washington, D.C., Dallas and Austin. These included: Robert C. Marlay, Director of the EPA Office of Science and Technology Policy; David Schanbacher, Chief Engineer of TCEQ, Carl Edlund, Multi-Media Planning and Permitting Division Director of EPA Region 6; and Vic Der, Deputy Assistant Secretary for Clean Coal, DOE. My conclusion after speaking with these and many other experts in alternative energy production is that the ZEROS technology is the only oxy-fuel technology that has operated successfully for an extended period at a commercial scale producing electric power while capturing and sequestering 100% of the CO₂ produced.

Also, in 2007 Dr. Kalyan Annamalai, Paul Pepper, Professor of Mechanical Engineering, and Dr. Kenneth Hall, Jack E. and Frances Brown, Chair Professor of Chemical Engineering at Texas A&M

Texas Water Resources Institute
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2118 TAMU
College Station, TX 77843-2118

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<http://twri.tamu.edu>



University evaluated the technical feasibility of ZEROS for TXU Power Generation Company. They reported to TXU, TWRI, and Mr. Clark that their analyses indicated that the ZEROS process is technically feasible using several possible fuels, though their calculations of the amount of fuel required to produce 50 MW of electricity were somewhat higher than those proposed by Mr. Clark. I do not consider this to be a serious concern since the ZEROS waste-to-energy facility would receive a tipping fee for disposing of the waste. The additional income from greater fuel tipping fees, as well as the sale of additional CO₂, nitrogen, argon, and distilled water byproducts would more than offset the cost of additional O₂ required to produce 50 MW of electricity.

Finally, in 2008 Arrendondo, Zepeda & Brunz, LLC (AZ&B) reviewed a proposal to build a ZEROS municipal solid-to-energy facility at a proposed regional land fill in Grimes County. AZ&B concluded, based on their analyses as well as discussions with Drs. Annamalai and Hall, that the project is technically feasible, though they questioned the economic benefits to the land fill operator.

Additional information is available at (zerosinc.com/Due-Diligence.pdf) concerning details of the theory, engineering, operations, and economics of ZEROS facilities; risk assessments; environmental impacts; patents; Florida and Texas environmental agency permit exemptions; legal opinions; actual test results from waste remediation applications; and EPA verification that ZEROS can be used to "delist" hazardous wastes.

Mr. Schlueter, my conclusion based on the studies and other information cited above, as well as many discussions with experts in the field, is that ZEROS has operated effectively at a commercial scale as a waste remediation technology; and it is technically and economically feasible as a zero-emission waste-to-energy technology.

Sincerely,



Dr. C. Allan Jones
Director,
Texas Water Resources Institute

CAJ/rp

cc: Steve Clark
B. L. Harris

Barry R. McBee, *Chairman*.
R. B. "Ralph" Marquez, *Commissioner*
John M. Baker, *Commissioner*
Dan Pearson, *Executive Director*



TEXAS NATURAL RESOURCE CONSERVATION COMMISSION

Protecting Texas by Reducing and Preventing Pollution

April 29, 1997

Mr. Steve Clark
Zeros, Inc.
P.O. Box Z
Highlands, Texas 77562

Re: Permit Requirements
ZEROS Recycling System
Highlands, Harris County

Dear Mr. Clark

This is in response to your letter dated March 26, 1997 concerning the proposed construction and testing of your Zero-Emission Energy Recycling Oxidation System. We understand this unit will use natural gas only during the tests, and that the unit has no emissions to the atmosphere.

After evaluation of the information which you have furnished, we have determined that your proposed construction and testing will not create a new source of air contaminants or increase emissions of air contaminants from existing sources. On this basis, no permit will be required from the Office of Air Quality. You are reminded that regardless of whether a construction permit is required, this facility must be in compliance with all air quality rules and regulations of the Texas Natural Resource Conservation Commission at all times.

Your cooperation in this matter is appreciated. If you have further questions, please contact me at (512)239-1079.

Sincerely,

A handwritten signature in black ink, appearing to read "Skeet Payne".

Lawson L. (Skeet) Payne
Coatings and Combustion Section
New Source Review Permits Division

LP/bg

cc: Ms. Karen Atkinson, Air Program Manager, Houston
Mr. Rob Barrett, Director, Harris County Pollution Control Department, Pasadena
P.O. Box 13057 • Austin, Texas 78711-3057 • 512/239-1000 • Internet address: www.tnrcc.state.tx.us



Jeb Bush
Governor

Department of Environmental Protection

Marjory Stoneman Douglas Building
3900 Commonwealth Boulevard
Tallahassee, Florida 32399-3000

David B. Struhs
Secretary

October 3, 2001

Mr. Ray Molina, President
ZEROS Energy Systems International, Inc.
815 Ponce de Leon Boulevard
Coral Gables, Florida 33134

Dear Mr. Molina:

Thank you for your August 26 letter in regards to Zero-emission Energy Recycling Oxidation System (ZEROS) technology. Both the Division of Air Resources Management and the Division of Waste Management have been asked to review your submittal.

Based on the information submitted, the ZEROS system is an oxidation process which generates no emissions or pollution discharged to the environment. If the system's emissions performance is as proposed, no air permit would be required.

Staff from the Division of Waste Management contacted Mr. Steve Clark for clarification of proposed feed stock for the ZEROS system. While the literature provided identifies potential waste feedstocks (such as waste tires), I understand that only natural gas would fuel the system you are proposing for Florida. With these proposed fuels, no solid waste permits would be required. However, if you intend to change your proposed fuel to any type of solid waste, your system will be subject to solid waste permitting. It would be advisable, at that time, to engage in a pre-permitting review to determine what testing and analysis would be required to obtain a permit or a beneficial use approval for the by-products of your process.

Thank you for the opportunity to review your technology description. If you have questions in the future about permitting procedures or our solid waste rules and standards, please contact Mr. Richard Tedder, Administrator of our Solid Waste Management Section at 850/921-9976.

Sincerely,

Howard Rhodes
Director
Division of Air Resource Management

AFB/jrc
cc: John M. Ruddell

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**THE LAW OFFICES
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FAX: 972-771-7204
www.jimchoate@aol.com

15 September 2001

ZEROS, INC.
P.O. Box 888
Highlands, Texas 77562

Attention: Mr. Steve Clark

Re: Tax Credits, Applicability of
26 USC Section 29
"Credit for producing fuel from a
nonconventional source."

Dear Mr. Clark;

You have asked me to opine as to the applicability of the above referenced provision of the Internal Revenue Code as it now exist. In specific regard to the use of LIGNITE (as a subclassification of the generic term "coal") for the production of energy. You have furnished me with copies of your patents and lengthy descriptions of the process described within such patents, as well an explanation of the actual functioning process. You have shown me visual and historic data compiled by you from your prior field test of the subject equipment, although such test was not intended for the production of energy by use of lignite.

Based upon this information I have researched the implications of the above stated Code provision as applied to the Zero system when configured for the production of energy using lignite as a source material. The following sets forth my legal opinion based upon the conditions stated.

Section 29 of the Internal Revenue as suggested by it's caption applies to the production of fuel (not electricity or other end products). It is further restricted by the term nonconventional source. Section 29 (c) (1) (C) defines "qualified fuels" to include "liquid, gaseous, or solid synthetic fuels produced from coal [(including lignite)], including such fuels when used as feedstocks."

When a ZERO system is configured to produce electricity, it is my understanding that the ZERO system would produce a "CO synthetic fuel gas" which in turn would be used as a fuel to generate energy. (In the contemplated configuration of the system, that energy would be produced as electricity.)

I was unable to find any case law or Internal Rulings dealing directly with the production of such energy from lignite. This however, in the present case, would not be unusual as your patented system has never been otherwise duplicated.

A simple straight forward analysis of the provision itself would fairly place the ZERO system as contemplated, within it's ambit and that the owner/producer would be entitled to the tax credits as set forth. (Other provisions of the Code could permit a pass through of such credits to upstream owners.)

In addition it is important to note that lignite is specifically grouped with other forms of nonconventional sources which includes forms of hydrocarbons not normally economically usable for production of energy. (i.e. shale, tar sands, tight seam coal). Lignite is likewise specifically excluded from organic material which could be covered other provisions of the Code.

This would be in harmony with the legislative history of this provision and several other interrelated tax incentives for the production of energy as well as investment tax credits for such equipment. (See 26 USC Sections 38, 45 and 48.)

While there are many other potential uses for different source materials (organic and waste) this opinion is limited to the use of lignite as delineated above.

This opinion has been prepared for your use and such others as you may authorize. No other person or entity is entitled to rely on any statement or expression of opinion set forth herein.

Should you require further support please don't hesitate to call upon me.

Sincerely yours,

A handwritten signature in black ink, appearing to read "Jim K. Choate", with a large, stylized flourish extending to the left.

Jim K. Choate, Attorney
United States Tax Court
Bar Number: CJ 1484

New Technology Week

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Monday, June 9, 2003

NTW Volume 17, Number 23

Waste In, Clean Electricity Out Adds Up To ZEROS

The power plant will generate electricity and a number of marketable byproducts, while emitting no pollution. The plant's primary fuel supply will be free. When that supply runs out after several years, the plant owners can pick up and move their facility elsewhere.

No fantasy. Entrepreneur industrialist Ray Wright anticipates operating just such a facility at—among other places—a tire dump. The plant will make power and other products out of the tires, thus getting rid of them. Then—because the plant is portable—on to another dump.

Wright numbers among the first buyers of ZEROS, a newly commercialized system that has its origins as a means of cleaning up messes such as oil spills, but that has evolved into a multiple-problem solver—a converter of waste into electricity and other high-quality products—with remarkable promise.

That promise is proven, through the technology's long first phase as a clean-up tool, through Environmental Protection Agency (EPA) review, and through the tough scrutiny of knowledgeable buyers such as Wright, president of Nevada-based Greenway Minerals, Inc.

ZEROS, an acronym that stands for zero-emission energy recycling oxidation system, uses a combination of technologies and subsystems to process incoming material (including hydrocarbon waste matter of almost any sort), separate the organic from the inorganic content, and feed the organic portion into a specially designed chamber for burning.

Key to ZEROS is its use of oxidation, rather than ordinary incineration, for the burning phase, according to Ed Blair, president of ZEROS Technology Holdings, LLC, a Dallas-based company that markets the system. (See www.zerosinc.com.)

Combining one part waste matter with two parts pure oxygen, and then igniting the mix, ZEROS leverages basic chemistry to rearrange the molecules: the hydro-

BY RICHARD MULLEN

gen and carbon in the waste matter are oxidized, splitting apart and clamping onto oxygen atoms as their new partners. The result: water and carbon dioxide.

ZEROS can harness the water as steam for turning a turbine, thus generating electricity. It also can capture the water for other uses, or for sale. As for the resulting carbon dioxide, it is of an extremely pure, high grade suitable for industrial purposes. The system also makes nice, neat packages of the inorganic part of the waste, such as the metals in tires, for easy recycling.

But the greatest significance of the oxidation system, in Wright's view, is the ingredient it does not include: nitrogen.



Most incineration processes use ambient air—which is about 80 percent nitrogen—in order to burn. But, as ZEROS inventor Steve Clark explained, the

nitrogen doesn't burn: rather, it retards combustion and becomes a waste product that, readily combined with oxygen or other elements, becomes nitrous oxide or some other noxious form of pollution.

Using pure oxygen rather than nitrogen-laden ordinary air for combustion yields critical advantages, according to Clark. Taking the nitrogen out of the equation lowers the overall mass of the combusted material by three-fourths, while greatly increasing the energy output. With oxidation, Clark said, "I can get as much energy with one-fourth the amount of fuel [as] you can with [a conventional] incineration process."

ZEROS brings these advantages to a tightly closed system that captures all of the combusted material: "Equal mass in, equal mass out," Blair noted, contrasting ZEROS with the traditional incineration plant in which a great quantity of nitrogen-based emissions "goes up the smokestack."

In stark contrast, the company states flatly, "The ZEROS system has no emissions."

(Continued on next page)

Waste In, Clean Electricity Out... (Continued from page one)

Wide applicability

ZEROS is a modular system, Blair said: a set of components designed to suit the needs of each specific customer. Those specifications will depend on variables such as the kind of waste—whether tires, oil spills, sewage, or something else—that the customer wants to eliminate. For instance, ZEROS offers tire recyclers a front-end grinder that minces tires to aid processing.

Standard to the system is its proprietary oxidation chamber, which—thanks to the extreme combustive efficiency of pure oxygen—must withstand temperatures ranging up to 2,500 degrees Fahrenheit, Blair said. The chamber meets that requirement by means of special tiles similar to those used on the space shuttle, he said.

The customer may opt for a facility capable of producing up to 50 megawatts of electricity—currently the upward limit for ZEROS—or may choose not to produce electricity at all. While it might not need the power production capacity, a hospital might use the system for disposing of its biological wastes and for generating carbon dioxide and water for its own use, Blair said.

The system's price falls in the neighborhood of "about \$1 million a megawatt," said Blair.

"The plant pays for itself in five years by the sale of the water and carbon dioxide and electricity," not counting the tax credits operators could earn for emissions-free power generation, he said.

A full-size system, 150 feet by 150 feet on its sides and 18 feet tall, could process 250,000 pounds of raw waste material per day, Blair said.

Not only modular, ZEROS is mobile: a full-size system would fit on five tractor trailers, Blair said. The system's mobile aspect traces directly to its early iterations and decades of use by Clark as a clean-up tool, capable of moving to the site of oil spills or other disasters.

Its combination of features—emission-free waste disposal, power production, mobility, and more—makes ZEROS highly applicable to a growing number of situations, in the view of Wright, whose company specializes in disposing of waste for clients.

"We have a crisis in waste management in this country," he said.

"Our country's overflowing with tire dumps everywhere," for instance, Wright said. "There's hundreds of millions of tires" in dumps around the United States, said Wright, who has contracted to purchase three of the 17 systems ZEROS Technology

Holdings has sold so far. Wright expects to have the first of his three systems running by early 2004.

He anticipates that one of his applications for ZEROS will be a tire dump that, to his customer, looks like a disposal problem, but, to Wright, means "three years of fuel." When those tires are gone, he said, his company can disassemble ZEROS and "in less than 10 days [we] can have it operating in another location."

Tires are just the beginning, however. ZEROS, Blair said, can make a good product out of oil-drenched dirt, biosolids, sludge, carpeting, paint cleaners, scrap nylon, and much else.

"We can go into a landfill and literally reclaim that landfill," Wright said. With ZEROS, he said, "we can turn the landfill into useful products. That's enormous," he said, given that in many fast-developing communities around the country, "they've run out of places to put their trash."

ZEROS has rural applications as well, Wright said. A dairy farm could use it to dispose of cow manure, while generating steam for cleaning and carbon dioxide for refrigeration, he said. Orchard growers could use ZEROS to remove unwanted biomass, such as almond or walnut shells, which they are no longer allowed to burn conventionally. And in disposing of the biomass, Wright said, "we can turn that into a positive product."

Wright speaks from evidence-based conviction. Before investing in ZEROS, his company performed due diligence on the product and its manufacturers.

"We researched this very thoroughly," said Wright, a former employee of Texas Instruments with an engineering background. "We've gone over their documentation every way from Sunday."

"We took our time" in researching ZEROS, Wright said, because he didn't want to face the prospect of colliding with tough emissions standards such as those of California, where his company has many clients.

"The concept in general was wonderful," Wright said of ZEROS, "but would it really stand the test of EPA regulations?"

It would. In 1999, Blair said, the EPA issued a letter saying that ZEROS is, in fact, emission-free and that, as such, it would not require permits in order to operate. Florida and Texas have issued similar letters, he said.

Beyond the "brilliant" nature of the ZEROS technology itself, Wright said, what "really sold us" was that its maker "also got EPA approval before they went to the market with this thing."

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**US Government Endorsement
&
System Test Data**



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PORT HUENEME, CA 93043-4301

IN REPLY REFER TO:
4330/2716
April 10, 1998

ZEROS, Inc.
Attn: Mr. Steve Clark
P.O. Box Z
Highlands, TX 77562

Ladies and Gentlemen:

This letter pertains to the abstract that you submitted in response to Broad Agency Announcement N47408-96-R-6342 "Innovative Technologies Addressing Various Environmental Problems", including Topics BAA 96-003, -004, -005, and -006.

Your abstract "Zero Emission Energy Recycling Oxidation System on Topic BAA 96-006, was reviewed by a Technical Evaluation Board of engineers and scientists, established by the Naval Facilities Engineering Service Center (NFESC). The evaluation was in accordance with the criteria stated in Commerce Business Daily synopses of May 10, 1996, August 27, 1996, October 31, 1996, and August 15, 1997.

Your overall rating was acceptable. Although the technology is of interest to the Navy and is ready for field application, the Navy does not currently have a suitable application site or appropriate funding. Your abstract will be entered into the Book of Abstracts which is available for review by the field activities in seeking possible applications to an environmental problem.

This office will pass on a copy of this letter to the Army Environmental Center (AEC), the Air Force Center for Environmental Excellence (AFCEE), and the Department of Energy (DOE) for their review. If AEC, AFCEE, or DOE express an interest in your abstract, they may contact you directly or through this office for contracting under this General BAA. AEC point of contact is Mr. Eric Hangeland at (410) 612-6858. AFCEE point of contact is Ms. Laura Maxwell at (210) 536-4218. DOE point of contact is Mr. Dan Krivitzky at (505) 845-4852.

We appreciate your participation in this BAA and hope that you will continue to respond on any future requirements in your field of interest. You may direct any comments or questions to e-mail address gbaa@nfesc.navy.mil or telephone (805) 982-1592.

Sincerely,

KATHERINE A. VOLPE
Contracting Officer

Copy to:
Army Environmental Center (E. Hangeland)
Air Force Center for Environmental Excellence (L. Maxwell)
Department of Energy (D. Krivitzky)

Title: Field Demonstration of ZEROS System for Remediation of Hazardous and Toxic Wastes
Prepared By: ARINC Inc.

Topic: BAA 96-006 Assessment and Remediation Technologies and Methodologies for Environmental Cleanup

Offeror: ZEROS, Inc.
PO Box 888
Highlands, TX 77562

Offer

Objective.

The primary objective of this paper is to introduce a proven, innovative, cost effective, 100 percent Destruction Removal Efficiency (DRE) waste remediation technology to the Department of the Navy. This technology is the Zero-emission Energy Recycling Oxidation System (ZEROS)®. In the last two decades the hazardous waste sites in this nation have presented a formidable challenge to our scientific, technical, economic and political institutions. As the costs associated with the cleanup of these sites have escalated, so has the mandate to lower these costs, but to do so without exposing the public to any significant risk.

Most technologies employed have many drawbacks, are extremely expensive, and take many years to actually achieve results. The biggest drawback to the technologies currently employed, is that none can attain a 100% DRE on high molecular weight hydrocarbons such as heavy oils. ZEROS meets this need to completely eliminate hazardous waste problems without many of the common problems associated with remediation, including smokestack emissions and high levels of remaining hazardous waste.

1.2 Proposal.

ZEROS, Inc. proposes to initiate a demonstration remediation effort utilizing this proven innovative technology including sampling, remediation, and testing to completely demonstrate this process. The ZEROS system is capable of disposing of any and all toxic wastes. Prime targets of the system are hydrocarbons and chlorinated wastes such as PCB's and dioxins. Although remediation at virtually any Navy sight is feasible, ZEROS, Inc. proposes the technology be applied at any one of several BRAC sights located in the San Francisco Bay Area. The technology behind the system will offer the most cost effective approach to remediation of contaminated soils, liquid wastes in metal and plastic containers, asbestos, medical and biomedical wastes, contaminated sludge, waste fuels and residues, and most any other solid waste.

Method.

The ZEROS System technology proposed includes the parallel use of two methods for remediation of wastes: the ZEROS® Thermal Process and the ZEROS Bio-Dynamics® Process. Soils will be processed through one or both processes as needed to ensure optimal and cost effective remediation. Figure 1 of the attachment details both processes and each of the processes is described in the following.

ZEROS THERMAL PROCESS

The ZEROS Thermal Process is an energy efficient combustion process that can process virtually any waste product contaminated with both inorganic and organic compounds and produce marketable products while generating no uncontrolled smokestack emissions.

The primary innovation of the ZEROS Thermal Process is that it is based on a closed thermal oxidation system. As a closed oxidation system at temperatures up to 1200° C, the ZEROS Thermal Process has the following advantages over current technology:

The exit mass from this system is brought to a complete stop and contained. There are no smokestack emissions and a complete analysis of the process is allowed. This analysis has demonstrated a complete mass balance and a one hundred percent DRE.

Marketable, salable products result from the process. Carbon dioxide, steam, distilled water, and concentrated brine are produced as usable byproducts in the ZEROS Thermal Process.

Energy is recycled during the process, resulting in increased efficiency and lower cost.

As illustrated in Figure 1, the first step of the ZEROS Thermal Process is the initial oxidation. Combustion gas is created through this oxidation process and is redirected back into the primary and secondary combustion chambers until all toxicity is destroyed, producing ash collected in the bag-house. The remaining gas is then processed through a wet scrubbing system for chlorine removal, producing brine. Approximately 90% of the acid gas is removed from the combustion gas by the wet scrubbers. Additional acid gas is removed by introducing the combustion gas to additional scrubbing columns.

Throughout the combustion process, water (with or without contaminants) is used for temperature moderation. Following its use for temperature control, the water is distilled which removes any residual contaminants. The pure water is sold as a usable product and any contaminants removed from the water are directed to the process system for proper disposition.

The combustion gas then enters the carbon dioxide (CO₂) recovery system. The CO₂ recovery system condenses the moisture from the combustion gas. This liquid is returned to the wet scrubbing system to reconcile for the liquid lost in that process. The CO₂ recovered can be used as a salable product or as a solvent to treat soils contaminated with petroleum hydrocarbons and chlorinated hydrocarbon compounds in the ZEROS Bio-Dynamics® Process.

The ZEROS Thermal Process described above partially removes metals from the soils by reducing the metals to oxides of those metals and capturing them in the ash. Soils that exhibit high levels of metals after the thermal process will be treated by acid rinsing. Soils treated with acid rinsing will be neutralized with calcium hydroxide. The metal hydroxides created will be removed from the rinsate using a clarifier and filter press before disposal.

ZEROS BIO-DYNAMICS® PROCESS

The ZEROS Bio-Dynamics® Process treats soils moderately and lightly contaminated with hydrocarbons. Contaminated soils are processed using a carbon dioxide solvent processing system which uses carbon dioxide generated from the ZEROS Thermal Process. The ZEROS Bio-Dynamics® system utilizes the recovered carbon dioxide as a solvent to clean other soils contaminated with petroleum hydrocarbons and chlorinated hydrocarbon compounds.

2. Offerors Capabilities

ZEROS, Inc. brings comprehensive environmental planning and technical support to implement site closure/turnover type projects. The ZEROS corporation brings focus and expertise on environmental remediation systems design, construction, and operation.

Direct project related experience areas include the Resource Conservation and Recovery Act (RCRA), Super Fund legislation (CERCLA), National Environmental Policy Act (NEPA), Clean Water Act (CWA), Safe Drinking Water Act (SDWA), Surface Mining Control and Reclamation Act (SMRCA), and other federal regulatory programs, as well as state and local environmental regulations.

ZEROS, Inc. holds the technology rights to the Zero-emission Energy Recycling Oxidation System ("ZEROS") and with ZEROS California Corporation, a California based ZEROS licensee bringing more than fifteen years of US Government contracting and construction experience, which will perform the site remediation service.

3. Principal Investigators -

Steve Clark: President

Mr. Clark has over twenty years of experience with oil industry failure prevention, analysis, and response. He has provided oversight and management of research, development and operations of pollution spill prevention and control and remediation of oil and chemical spills. Mr. Clark has successfully completed cleanup projects for major oil companies such as Gulf Oil, Getty Oil, Conoco Oil, and others. He has designed and developed tools and techniques for remediation of soil and water contamination and has authored quality management programs for prevention of and remediation of toxic spills.

James Winchester: Director of Engineering

Mr. Winchester has twenty years of experience with research, development and operations of combustion processes. He is currently tasked at the U.S. Air Force's Arnold Engineering Development Center. His experience ranges from coal fired Magneto hydrodynamics to thermal detoxification of soils and incineration of hazardous substances. He has provided oversight management for two superfund sites and written oversight inspection plans for three sites.

Cost/Reasonableness

Cost of the ZEROS Process is favorably comparable to existing technology. For comparative purposes the following information is provided. Costs for ZEROS processes are based on real data accumulated from ZEROS plants in the U.S. and Mexico.

Table 1 - Cost/Technology Comparison

Technology	Cost/Ton	Duration	DRE	Usable Products
Pump and Treat	\$ 990	Perpetual	5 %	None
Haul and Burn	\$1,105	12 years	87 %	None
BIO Venting	\$ 750	Perpetual	3 % w/75% re-bound	None
BIO remediation	\$ 850	Will not work	0 %	None
ZEROS	\$900	5 years	100 %	CO ₂ , Brine, H ₂ O

Data from ZEROS facilities is provided in the information attached. Also attached are calculated results from a hypothetical ZEROS installation at Hunters Point in the San Francisco Bay Area. Data includes information concerning contaminants, DRE, and cost.

ATTACHMENT -
SUPPORTING DATA

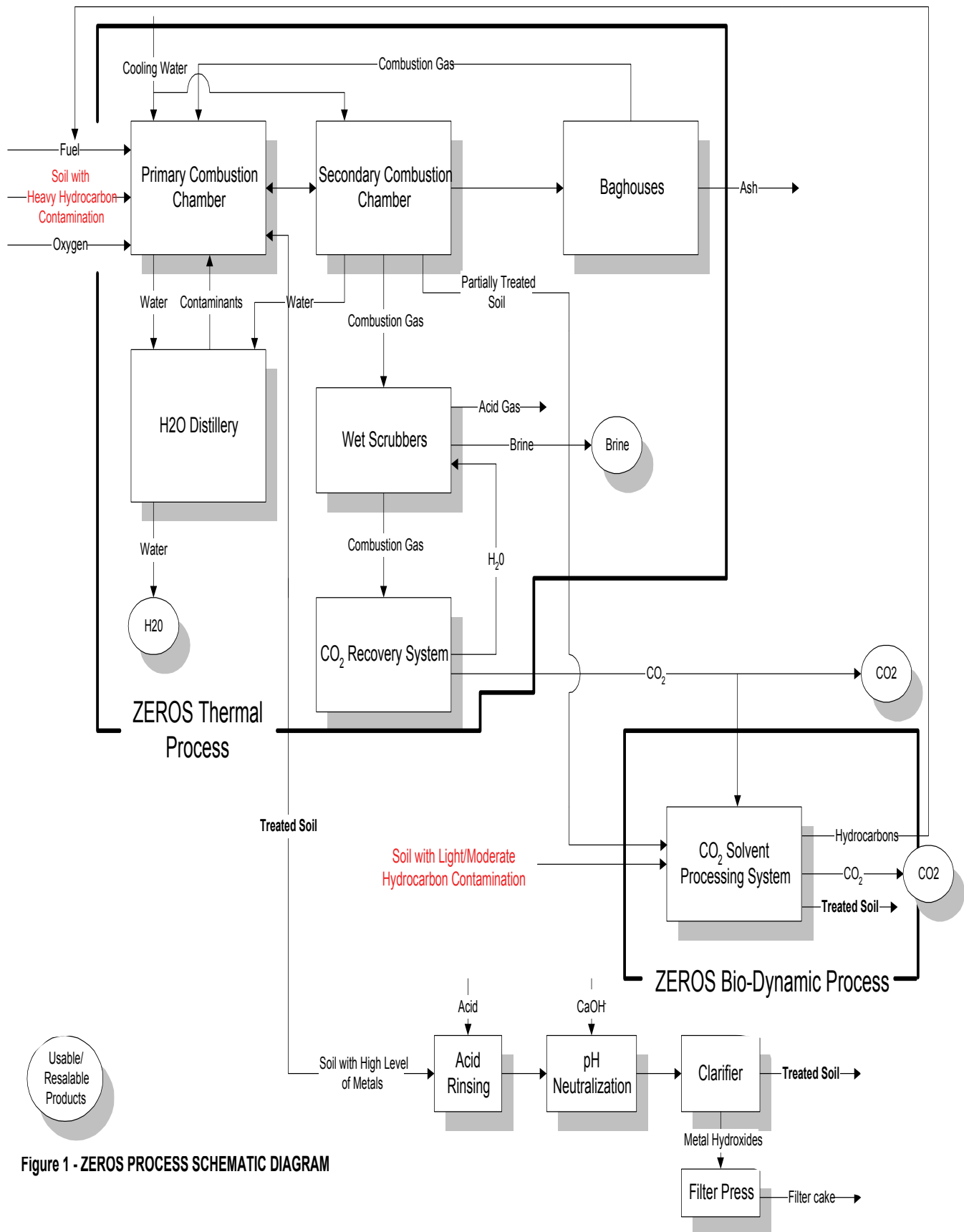


Figure 1 - ZEROS PROCESS SCHEMATIC DIAGRAM

Actual Test Results

The following provides independently analyzed trial burn data resulting from the ZEROS Thermal Process. Data is based on Hexachlorobenzene (surrogate for 2,3,7,8 TCDD (Dioxin) and PCB hazardous waste). The data indicate chlorine, hydrogen chloride gas, carbon monoxide, reformed dioxins, PCBs and total hydrocarbons were brought to below detectable limits resulting in a 100% DRE.

Thermal Stage		Oxidation		(BAF)	Project 1926	
		TABLE 1 - Summary of Test			Results	
PA Method 5 and SW-846 Method 0050						
Particulate/Chloride	Closed Stack	Run No.	TBP-1	TBP-2	TBP-3	Average
		Date (1992)	9-Oct	10-Oct	11-Oct	
		Start Time	15:38	12:13	13:01	
		Stop time	17:15	13:35	14:07	
Process Data		Hexachlorobenzene (lb/hr)	100.0	100.0	100.0	100.0
		Cl (lb/hr from hexachlorobenzene)	74.7	74.7	74.7	74.7
		Cl (lb/hr in waste feed)	539	518	425	494
		Cl (lb/hr total input)	614	592	500	569
Gas Conditions		Temperature (°F)	203	202	203	203
		Moisture (volume %)	42.1	42.7	41.5	42.1
		O2 (dry volume %)	10.9	10.7	10.9	10.8
		CO2 (dry volume %)	7.8	7.5	7.9	7.7
Volumetric Flow Rate		acfm	26,520	26,680	24,630	25,940
		dscfm	12,280	12,220	11,390	11,960
Particulate		gr/dscf	0.0030	0.0031	0.0027	0.0029
		gr/dscf @ 12% CO2	0.0046	0.0050	0.0041	0.0046
		gr/dscf @ 7% CO2	0.0042	0.0042	0.0038	0.0041
Chloride		lb/hr	0.79	0.77	1.09	0.88
		ppmv	11.6	11.5	17.3	13.5
CL Removal Efficiency	(% @ lb/hr)		99.87	99.87	99.78	99.84
SW -846 Method 0010		TABLE 2 - Summary of Test		Results		
Closed Stack		Run No.	TBP-1	TBP-2	TBP-3	Average
		Date (1992)	9-Oct	10-Oct	11-Oct	
		Start Time	14:26	10:44	15:42	
		Stop Time	18:35	15:03	20:10	
Process Data		Input Feed Rate				
		Hexachlorobenzene (lb/hr)	100	100	100	100
Heat Input		Waste Feed				
		MMBTU/hr	18.43	20.13	16.23	18.25
Hexachlorobenzene	MMBTU/hr		0.32	0.32	0.32	0.32
Total	MMBTU/hr		18.75	20.44	16.56	18.58
Carbon Monoxide	Av. ppmv @ 7% O2		5.8	1.5	3.6	3.6
Gas Conditions		Temperature (°F)	201	201	202	201
		Moisture (volume %)	42.5	43.0	42.2	42.6
		O2 (dry volume %)	10.8	11.1	11.0	11.0
		CO2 (dry volume %)	7.4	7.9	7.5	7.6
Volumetric Flow Rate		acfm	25,730	26,100	26,070	25,970
		dscfm	11,860	11,940	11,920	11,910
Hexachlorobenzene		pg/dscfm	0.95	0.93	1.10	0.99
		lb/hr	0.0000421	0.0000416	0.000049	0.0000442
Destruction Removal Efficiency(% @lb/hr)			99.999958	99.999958	99.99991	99.999956

TABLE 3 – Summary of Discharge Test Results

Polish and Purification Stage Product
w/ Catalytic CO oxidizer, Activated carbon absorber, and HCL reaction column

<u>Product Gas Analysis</u>	POHC	HCL (as total Chlo- rides)	CO
Product Gas In (from thermal stage)			
Ug/dscm	0.93	13.5 ppmV	3.5 ppmV
lb/hr	0.0000442	0.88 lbs/hr	
<i>FINAL PRODUCT ANALYSIS</i>			
Product Gas Out (from polish stage)			
ug/dscm	<0.000099	<0.00135 ppmV	
lb/hr	<0.00000000442	<0.0088 lbs/hr	Non-detectable

Application Of ZEROS Technology For The Remediation Of Soils At A BRAC Site

As a case study, ZEROS has analyzed soil and water sampling data produced for Hunters Point Naval Shipyard. Using known contaminant levels at Hunters Point, results are calculated for the removal of hydrocarbons from soils for the system proposed. The system consists of a thermal treatment process for high level contamination, “ZEROS,”[®] and the partnering utilization of ZEROS Bio-Dynamics[®]. Soils with high levels of heavy petroleum hydrocarbons are targeted for remediation.

The analysis of this data from all IR sites of the parcel showed very high average levels of hydrocarbon contamination. The data averages indicate approximately 1 percent by volume average saturation. Note that moisture content plays a significant role in the soil processing treatment rate. These two levels have been used as the baseline to illustrate the capacity and efficiency of the ZEROS system. The data analysis yielded a production

rate of 20,000 pounds per hour through the ZEROS system. This rate is based on an average moisture content of twenty percent per volume.

The analysis indicated that at the observed concentration of hydrocarbon and moisture an endo-thermic process would be required. The introduction of contaminated constituents, fuel and oxidizer derive carbon dioxide, water and trace elements of hydrochloric gas.

When chlorine is present in the constituent being treated, hydrogen chloride gas will be produced. The hydrogen chloride will be scrubbed out of the gaseous products in the process using water. The hydrogen chloride will be converted to liquid hydrochloric acid and then neutralized outside of the thermal treatment system. The neutralization process will produce brine that will be concentrated using steam from the process and then filtered and marketed as a commercial product for sale in industry. Steam from the brine concentration process will be condensed and re-introduced into the process as make-up water for the wet scrubber. Only the filter cake will have to be discharged as a contained and managed by-product.

ZEROS Technology Treatment System HEAT & MASS BALANCE CALCULATIONS
CASE: Hunter's Point

FEED STOCK (SOIL) CHARACTERIZATION

% Water	20.00	40000.00
% Ash	79.00	158000.00
% Carbon	0.88	176.00
% Hydrogen	0.11	22.00
% Oxygen	0.00	0.00
% Nitrogen	0.00	0.00
% Chlorine	0.00	0.00
% Sulphur	0.01	2.20
Check Totals	100.00 Percent	20000.20 LBS/HR
SOIL HHV in BTU/LB	180.00	
SOIL FEED RATE	THERMAL INPUT FROM SOIL, GROSS	
20000.00 LBS/HR	3600000.00 BTU/HR	

DEFINED COMBUSTION CONDITIONS IN THE KILN

100.00	Percent Carbon to CO2 in Kiln
0.00	Percent Carbon to CO in Kiln
0.00	Percent Carbon Fixed as Soot
Required Combustion Oxygen	
648.12 LBS/HR	

COMBUSTION PRODUCTS FROM KILN FEEDSTOCK

645.92 LBS/HR CO2	
0.00 LBS/HR CO	
0.00 LBS/HR HCl	
4.40 LBS/HR SO2	
198.00 LBS/HR H2O From Combustion	
0.00 LBS/HR N2 From the Feedstock	
Defined EXCESS OXYGEN	5.00 PERCENT
Excess O2 for Feedstock	32.41 LBS/HR O2 EXCESS

4198.00 LBS/HR H2O Total from Feedstock Moisture Content & Combustion

KILN BURNER

Auxiliary Fuel (Natural Gas)

Characterization

% Water	0.00	0.00
% Ash	0.00	0.00
% Carbon	69.30	356.90
% Hydrogen	22.70	116.91
% Oxygen	0.00	0.00
% Nitrogen	8.00	41.20
% Chlorine	0.00	0.00
% Sulphur	0.00	0.00

Check Totals 100.00 Percent 515.00 Lbs/hr

FUEL HHV in BTU/LB 21830.00

FUEL FEED RATE THERMAL INPUT from Fuel

515.00 LBS/HR 11242450.00 BTU/HR

COMBUSTION PRODUCTS FROM KILN BURNER

1309.80 LBS/HR CO2 0.00 LBS/HR HCl

1052.15 LBS/HR H2O From Combustion

0.00 LBS/HR SO2 41.20 LBS/HR N2 From Fuel

Kiln Burner Stoichiometric Oxygen Demand

Burner Stoichiometric O2 Demand 1888.15 LBS/HR

Defined Excess O2 To Kiln Burner 5.00 Percent

Resultant Excess O2 From Burner 94.41 LBS/HR

Total Kiln Excess Oxygen Rate 126.81 LBS/HR

Total Kiln Moisture Rate 5250.15 LBS/HR H2O TOTAL

KILN COMBUSTION GAS CONSTITUENTS Constituent R Value

NITROGEN 41.20 LBS/HR 55.15

CO2 1955.72 LBS/HR 35.11

H2O 5250.15 LBS/HR 85.76

HCl 0.00 LBS/HR 42.38

SO2 4.40 LBS/HR 24.12

OXYGEN 126.81 LBS/HR 48.28

CO 0.00 LBS/HR 55.16

TOTAL 7378.28 LBS/HR

Water Spray 0.00 LBS/HR

Into Kiln

Total Water 5250.15 LBS/HR

Ash From Feedstock & Fuel 15800.00 LBS/HR

Soot Production Rate 0.00 LBS/HR

Total Kiln Ashing Rate 15800.00 LBS/HR

Desired Ash Temperature 1260.00 DEG.F. at 90% Gas Temp.

Ash Specific Heat 0.20 BTU/LB-Deg.F.

Heat Absorbed by Ash 3792000.00 BTU/HR

Kiln, Burner Plate, & Discharge Hood Heat Loss Estimation

Kiln Diameter 7.50 FEET

Kiln Length 42.00 FEET

Kiln Surface Area, Drum	989.60 SQ.FT.
Burner & Feed End Breech Surface Area	70.93 SQ.FT.
Kiln Structure Surface Area	1060.54 SQ.FT. Total

Ambient Temperature	60.00 DEGREES F.
Estimated Shell Temp.	400.00 DEGREES F.

Still Air Shell Heat Loss 1215425.74 BTU/HR
14842450.00 BTU/HR KILN THERMAL LOADING, GROSS
0.00 BTU/HR THERMAL REDUCTION DUE TO CO FORMATION
0.00 BTU/HR THERMAL REDUCTION DUE TO SOOT FORMATION
3792000.00 BTU/HR HEAT ABSORBED INTO ASH
11050450.00 BTU/HR KILN THERMAL LOADING, NET
5556753.47 BTU/HR LATENT HEAT OF VAPORIZATION
4278270.79 BTU/HR SENSIBLE HEAT AVAILABLE TO COMBUSTION GASES

Kiln Total Combustion Gas Mass Flow	Specific Heat, 60 to 1400 Deg.F.
NITROGEN 41.20 LBS/HR	0.262 BTU/LB-Deg.F.
CO2 1955.72 LBS/HR	0.257 BTU/LB-Deg.F.
H2O 5250.15 LBS/HR	0.494 BTU/LB-Deg.F.
HCl 0.00 LBS/HR	0.195 BTU/LB-Deg.F.
SO2 4.40 LBS/HR	0.182 BTU/LB-Deg.F.
OXYGEN 126.81 LBS/HR	0.241 BTU/LB-Deg.F.
CO 0.00 LBS/HR	0.258 BTU/LB-Deg.F.

Weighted Avg.

TOTAL MASS 7378.28 LBS/HR, GAS	0.425349645 BTU/LB-Deg.F.
KILN OUTLET COMBUSTION GAS TEMP. =	1423.22 DEGREES F.

Ash Temperature @ 0.9 Gas T.= 1280.90 Deg. F.

Heat Loss Rate to Ash 3858045.97 BTU/HR

Water Vaporized by Ash 3608.72 LBS/HR

Water Volume Vaporized 7.21 GPM

Percent of Vapor From Ash Drag Staying In The Combustion Gas Stream

10.00 Percent	0.72 GPM	360.87 LBS/HR
---------------	----------	---------------

Water Vapor Exiting The Process As Steam From The Ash Drag

6.49 GPM	3247.84 LBS/HR
----------	----------------

Thermal Energy Exiting The Process With Steam From The Ash Drag

3437518.96 BTU/HR	248810.90 BTU/HR
-------------------	------------------

Latent Heat

Sensible Heat

Volume Of Water Vapor/Steam Entering The Combustion Gas Stream

112.09 SCFM VAPOR	458.90 ACFM STEAM
-------------------	-------------------

Thermal Energy Required to Superheat Steam from The Ash Drag

Which Enters The Combustion Gas Stream

208735.01 BTU/HR

Post Ash Drag Combustion Gas Temperature	1359.66 DEGREES F.
--	--------------------

Surface Area of Discharge Hood, Cyclone, & Duct	250.00 SQUARE FT.
---	-------------------

Estimated Surface Temperature of this Structure	230.00 DEGREES F.
---	-------------------

Still Air Heat Loss Rate from this Structure 102575.16 BTU/HR

Combustion Gas Temperature at SCC Inlet 1328.50 DEGREES F.

KILN COMBUSTION GAS CHARACTERIZATION At Kiln Outlet

Volume, SCFM	Volume, ACFM			
NITROGEN 8.23	32.55	SO2 0.38		1.52

CO2	248.67	983.67	OXYGEN	22.18	87.72
H2O	1630.75	6450.89	CO	0.00	0.00
HCl	0.00	0.00			
			COMBINED	1910.21	7556.36
				SCFM/TOTAL	ACFM /TOTAL

	Enthalpy, BTU/LB - BTU/HR Ref. Ambient	
NITROGEN	341.81	14082.56
CO2	337.91	660860.39
H2O	1705.63	8954799.85 Includes Latent Heat
HCl	254.73	0.00
SO2	237.84	1046.48
OXYGEN	314.52	39884.99
CO	345.71	0.00
COMBINED		9670674.27

TOTAL MASS FLOW ENTERING THE SECONDARY COMBUSTION CHAMBER FROM THE KILN AND ASH DRAG

NITROGEN	41.20 LBS/HR	SO2	4.40 LBS/HR
CO2	1955.72 LBS/HR	OXYGEN	126.81 LBS/HR
H2O	8858.86 LBS/HR	CO	0.00 LBS/HR
HCl	0.00 LBS/HR		

	COMBINED	10987.00 LBS/HR GAS FLOW
With 10% Ash Carryover as Flyash		12567.00 LBS/HR To Cyclone Inlet
With 90% Cyclone Removal Efficiency		1422.00 LBS/HR Cyclone Discharge
TOTAL COMBUSTION GAS AND FLYASH		11145.00 LBS/HR

SCC INLET	Volume, SCFM	Volume, ACFM
NITROGEN	8.23	32.00
CO2	248.67	966.82
H2O	1742.84	6776.24
HCl	0.00	0.00
SO2	0.38	1.49
OXYGEN	22.18	86.22
CO	0.00	0.00
COMBINED	2022.30	7862.77

	Enthalpy, BTU/LB - BTU/HR Ref. Ambient	
NITROGEN	333.61	13744.92
CO2	329.81	645015.70
H2O	1690.11	8873328.81 Includes Latent Heat and Heat
HCl	248.63	0.00 Recouped From Ash Quenching
SO2	232.13	1021.39
OXYGEN	306.98	38928.71
CO	369.34	0.00
COMBINED		9572039.53

SECONDARY COMBUSTION CHAMBER CALCULATIONS

Temperature of Combustion Gases at SCC inlet	1328.50 Degrees F.
CO From Kiln	0.00 LBS/HR
Heat Release	0.00 BTU/HR From Kiln CO
Auxiliary Fuel	Feed Rate
Characterization	460.00 Lbs/Hr

Natural Gas

% Water	0.00	0.00
% Ash	0.00	0.00
% Carbon	69.30	318.78
% Hydrogen	22.70	104.42
% Oxygen	0.00	0.00
% Nitrogen	8.00	36.80
% Chlorine	0.00	0.00
% Sulphur	0.00	0.00
Check Totals	100.00 Percent	460.00 Lbs/hr
FUEL HHV in BTU/LB	Fuel Heat Release Rate	
21830.00	10041800.00 BTU/HR	

Secondary Combustion Chamber Thermal Loading, Kiln CO and Burner Fuel

10041800.00 BTU/HR, Total

COMBUSTION PRODUCTS FROM SCC BURNER & KILN CO COMBUSTION

CO2 From Kiln CO	0.00 LBS/HR
CO2 From Burner Fuel	1169.92 LBS/HR
TOTAL CO2	1169.92 LBS/HR CO2
HCl	0.00 LBS/HR HCl
SO2	0.00 LBS/HR SO2
H2O	939.78 LBS/HR H2O COMBUSTION
N2	36.80 LBS/HR N2 fuel
SCC Burner & Kiln CO Stoichiometric O2, Defined % Excess, Mass Excess	
O2 Demand	1686.50 LBS/HR
Defined Excess O2	5.00 PERCENT
Excess Oxygen	84.33 LBS/HR

SCC BURNER COMBUSTION GAS CONSTITUENTS

		Specific Heat, 60 to 1600 Deg.F.
NITROGEN	36.80 LBS/HR	0.265 BTU/LB-Deg.F.
CO2	1169.92 LBS/HR	0.263 BTU/LB-Deg.F.
H2O	939.78 LBS/HR	0.502 BTU/LB-Deg.F.
HCl	0.00 LBS/HR	0.197 BTU/LB-Deg.F.
SO2	0.00 LBS/HR	0.184 BTU/LB-Deg.F.
OXYGEN	84.33 LBS/HR	0.243 BTU/LB-Deg.F.
TOTAL	2230.83 LBS/HR	Weighted Avg.
		0.362960438 BTU/LB-Deg.F.

HEAT LOSS FROM SCC SHELL

SHELL DIAMETER IN FEET	10.00	
SHELL HEIGHT IN FEET	40.00	
SHELL AREA IN SQ. FEET	1256.64	
SCC Chamber Vol., 6" Refrac.	2544.70 Cubic Feet	
Estimated SCC Shell Temp.	450.00 Deg.F.	
Still Air Shell Heat Loss	1810342.94 BTU/HR	
Estimated SCC Outlet Temperature	1600.00 Deg.F.	
FLY ASH FROM CYCLONE GASEOUS DISCHARGE INTO SCC		158.00 LBS/HR
ENERGY REQUIRED TO ELEVATE CYCLONE FLY ASH TEMP.		8579.51 BTU/HR
FLY ASH FROM SCC BURNER INTO SCC CHAMBER		0.00 LBS/HR
ENERGY REQUIRED TO ELEVATE SCC BURNER FLY ASH TEMP.		0.00 BTU/HR

TOTAL SCC ASH LOADING	158.00 LBS/HR
DISCHARGE AS SOLID FROM BASE OF SCC	79.00 LBS/HR
CARRYOVER WITH GASES TO BAGHOUSE	79.00 LBS/HR

R Value			
NITROGEN	55.15	HCl	42.38
CO2	35.11	SO2	24.12
H2O	85.76	OXYGEN	48.28
Still Air Shell Heat Loss			1810342.94 BTU/HR
Heat Loss to Ash Discharged at Base of SCC			24332.00 BTU/HR
Water Vaporized by Discharged Ash, Mass			22.99 LBS/HR
Water Vaporized by Discharged Ash, Volume			0.05 GPM

SCC TOTAL COMBUSTION GAS CHARACTERIZATION

		Specific Heat, 60 to 1600 Deg.F.
NITROGEN	78.00 LBS/HR	0.265 BTU/LB-Deg.F.
CO2	3125.65 LBS/HR	0.263 BTU/LB-Deg.F.
H2O	9821.63 LBS/HR	0.502 BTU/LB-Deg.F.
HCl	0.00 LBS/HR	0.197 BTU/LB-Deg.F.
SO2	4.40 LBS/HR	0.184 BTU/LB-Deg.F.
OXYGEN	211.14 LBS/HR	0.243 BTU/LB-Deg.F.
TOTAL	13240.82 LBS/HR	0.439949463 BTU/LB-Deg.F.

Sensible Heat X Combustion Gas Flow Rate	7399702.95 BTU/HR
Calculated SCC Outlet Combustion Gas Temperature	1330.27 Degrees F.

SECONDARY COMBUSTION CHAMBER TOTAL GASEOUS PRODUCT DISCHARGE

	LBS/HR	ACFM	PERCENT WT.	PERCENT VOL.
NITROGEN	78.00	69.35	0.59	0.45
CO2	3125.65	1769.02	23.47	11.35
H2O	9821.63	13579.55	73.74	87.14
HCl	0.00	0.00	0.00	0.00
SO2	4.40	1.71	0.03	0.01
OXYGEN	211.14	164.35	1.59	1.05
FLY ASH	79.00	--- N/A ---	0.59	--- N/A ---
TOTALS	13319.82	15583.99	100.00	100.00

Combustion Gas Residence Time in SCC 9.80 Seconds

Estimated Cost Breakdown for Hunters Point ZEROS facility -

Estimated costs for the hypothetical Hunters Point Parcel D remediation effort by ZEROS are based on actual data from Hunters Point indicating that the highest average level of hydrocarbon contamination noted in any section is around 1 percent. Estimates are also based on a soil moisture level averaging roughly 20% by weight.

Fuel Requirements

At a projected production rate of 20,000 pounds per hour through the ZEROS process, the required fuel consumption rate is calculated to be 975 pounds per hour of natural gas. With a heating value of 21,830 BTU/LB this equates to 21,284,250 BTU/HR or approximately 21,000 standard cubic feet of natural gas per hour.

Water Requirements

Water required for chamber quench and temperature moderation is calculated to be 100,000 gallons/day. This water may be contaminated water from monitoring wells or

from a clean source. The water will be distilled during use and available for resale or reuse.

Oxygen Requirements

The oxygen consumption rate for this processing is calculated to be 4,434 pounds per hour total with a 5% excess rate. The carbon dioxide produced during this processing is calculated to be 3,126 pounds per hour.

Electrical Consumption

This operation will have an average electrical consumption of approximately 280 horsepower per day or @ \$0.08 per kilowatt hour approximately \$400 per day.

Personnel Requirements

The operation will require between 32 and 40 direct operations personnel with an additional 50 to 60 indirect support persons.

Excavation and Material handling

The average cost for excavation and handling of material within this type of operation is \$10 per ton.

United States Government

Department of Energy

memorandum

DATE: March 14, 1997

REPLY TO
ATTN OF: EM-33

SUBJECT: Zero-Emission Energy Recycling Oxidation System Technology

TO: Distribution

The Office of Waste Management met with representatives for ZEROS, , inc., and received the attached technology system package. ZEROS, , inc., has been exploring opportunities for their technology system use at Department of Energy. The ZEROS System is being placed in the Federal empowerment zone in northern Mississippi and is being developed for use with the military base closures. The proposal indicates that the technology could be used to treat hazardous waste. The technology outlined uses a two stage plasma torch combustion system, energy recovery system, and combustion gas cleanup systems.

As the field operations offices responsibilities include the implementation and deployment of new technology systems, this memorandum is sent to transmit the ZEROS, , inc. Technology System for your consideration, as may be appropriate, for hazardous waste treatment and/or other site needs or uses.



James Turi

Acting Associate Deputy Assistant Secretary
for Waste Management
Office of Environmental Management

Attachment

cc:
Steve Clark, ZEROS, , inc. ✓



UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D.C. 20460

May 7, 1999

MAY 7 1999

Mr. Melvyn Riser
ZEROS Inc.
60 East 42nd Street
New York, NY 10165

Dear Mr. Riser:

Your call to EPA's Office of Solid Waste recently with a question about the effect of treating a hazardous waste. Specifically, you asked if a facility can treat a listed hazardous waste and thereby cause the waste to be delisted, such that it is no longer hazardous under the Resource Conservation and Recovery Act (RCRA).

The short answer to your question is yes. The RCRA regulations allow listed hazardous wastes to be classified as nonhazardous through a petition process, called "delisting." The specific regulations for this delisting process may be found in the Code of Federal Regulations at 40 CFR Part 260.22. I have attached a copy of the pertinent part of the regulations for you information.

From our short discussion of the plasma arc technology your company is developing, the treatment of listed hazardous waste would likely result in at least some residuals that would require delisting to be classified as nonhazardous. However, you described the process as effectively destroying organic contaminants, thus, it may not leave much in the way of residuals that need be addressed. However, you should contact the EPA staff working on delistings to further explore what a delisting entails.

The delisting program is implemented through both the EPA Regions, at the Federal level, as well as through individual State RCRA programs. You mentioned that you company operates in Texas, thus I suggest that you contact the EPA Region VI delisting coordinator, William Gallagher (214-665-6775). As I noted in our conversation, Region VI has been fairly active in processing delistings, and given the location of you operations, this may be the best place to start.

Sincerely,

Robert Kayser
Environmental Protection Specialist
Office of Solid Waste/EPA

enclosure

cc: William Gallagher, Region VI
Shen-Yi, Yang, OSW



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SECRETARÍA DE MEDIO AMBIENTE
RECURSOS NATURALES Y PESCA

**INSTITUTO NACIONAL DE ECOLOGIA
DIRECCION GENERAL DE ORDENAMIENTO ECOLOGICO
E IMPACTO AMBIENTAL**

D.O.O. DGOEIA.- 00101

Ciudad de México, a 23 ENE. 1997

**ING. ROBERTO RODRIGUEZ BAKER
GERENTE DE LA EMPRESA
BAF DE MEXICO, S.A. DE C.V.
CARRETERA A EL CASTILLO KM 11.4
C.P. 45680, MUNICIPIO EL SALTO, JALISCO
TEL: 91(3)688-0723 Y 688-0054**

Analizada y evaluada la Manifestación de Impacto Ambiental, modalidad General, y el Estudio de Riesgo, modalidad Informe Preliminar de Riesgo, relativos al proyecto "BAF de México, S.A. de C.V. Planta Procesadora de Desechos Peligrosos por Oxidación en Circuito Cerrado, El Salto, Jalisco", con pretendida ubicación en la Carretera a el Salto Km 11.4, municipio de El Salto, Jalisco, promovido por la empresa BAF de México, S.A. de C.V. y

CONSIDERANDO

- Que el 29 de marzo de 1995 se recibió en la entonces Dirección General de Normatividad Ambiental, el oficio s/n del 23 de marzo de 1995, mediante el cual la empresa BAF de México, S.A. de C.V. remitió para su evaluación en Materia de Impacto Ambiental, la Manifestación de Impacto Ambiental, modalidad General, y el Estudio de Riesgo, modalidad Informe Preliminar de Riesgo, del proyecto, "BAF de México, S.A. de C.V. Planta Procesadora de Desechos Peligrosos por Oxidación en Circuito Cerrado, El Salto Jalisco".
- II. Que el 6 de abril de 1995, la Dirección General antes señalada solicitó, a través del oficio No.D.O.O DGNA.-1501 a la Dirección General de Residuos Materiales y Actividades Riesgosas, su opinión técnica sobre el proyecto, "BAF de México, S.A. de C.V. Planta Procesadora de Desechos Peligrosos por Oxidación en Circuito Cerrado, El Salto Jalisco" promovido por BAF de México, S.A. de C.V.
- III. Que el 10 de julio de 1995 se recibió en la entonces Dirección General de Normatividad Ambiental, la atenta nota SRA.- 427/95, mediante la cual la Dirección General de Residuos Materiales y Actividades Riesgosas señaló que el proyecto "BAF de México, S.A. de C.V. Planta Procesadora de Desechos Peligrosos por Oxidación en Circuito Cerrado, El Salto Jalisco" requería de la presentación de información adicional en materia de Riesgo.

"BAF de México, S.A. de C.V. Planta Procesadora de Desechos
Peligrosos por Oxidación en Circuito Cerrado, El Salto Jalisco"
BAF de México, S.A. de C.V.

*A New, Minimal Emission Oxidation System (MEOS) Concept
for Power Generation in Battlefield Environments*

VOLUME I: TECHNICAL

BROAD AGENCY ANNOUNCEMENT

BAA Number: BAA03-02, Addendum 6

Technical Area: Mobile Integrated Sustainable Energy Recovery (MISER)

Lead Organization: ZEROS, Inc., P.O. Box 888, Highlands, TX 77562
EMAIL: sc@zerosinc.com
PHONE: 281-424-2700
FAX: 281-424-2512

Technical POC: Mr. Steve Clark, President, ZEROS, Inc., P.O. Box 888, Highlands, TX, 77562

Administrative POC: Mr. Steve Clark, President, ZEROS, Inc., P.O. Box 888, Highlands, TX, 77562

Category: Small Business

Collaborating Research Partners: ZEROS, Inc., Box 888, Highlands, TX, 7762
Oak Ridge National Laboratory, Box 2008, Oak Ridge, TN, 37831
Stirling Technology Co., 4208 W Clearwater Ave., Kennewick, WA 99336

Total Funding Requested **Funds (Details in Volume 2)**

RESEARCH TEAM MEMBERS

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EXECUTIVE SUMMARY

The U.S. military land-based operations of the future are intended to be self-sustaining and must minimize long logistics tails. Stationary military units typically generate large quantities of solid waste in the form of packaging material, including significant amounts of plastics. We propose to develop a novel concept for recycling this plastic waste to generate power. Our concept uses oxidation, rather than the typical gasification or pyrolysis techniques, to burn the fuel at high temperatures, and uses the heat to drive a Stirling engine. Fuel in the form of pre-shredded plastic waste (assumed to be 1/3 each of polypropylene, polyethylene, and polystyrene) is burned in a fluidized bed combustion system in an oxidative environment for several seconds, providing for ample opportunity for extremely high process oxidation efficiency and high temperature. The combustion gases (mostly carbon dioxide and steam) are then passed through a secondary combustion chamber and additional oxygen is added to assure complete combustion. A portion of the combustion gasses are recirculated through the primary and secondary combustion chambers as a synthetic air model to moderate temperatures and enhance combustion (O₂ extraction). Water is injected with the recirculated gas stream into the primary combustion chamber where sub-stoichiometric combustion allows the waste fuel stream to mix with water causing OH free radicals to release forming oxygen and hydrocarbons. This oxygen extraction in the primary chamber will provide approximately 25% of the oxygen load requirements. The process combustion gasses are then passed through the secondary combustion chamber and water is captured as a system effluent where electrolysis can assist in separating the oxygen from water to provide another 25% of the oxygen requirement. The system would utilize a small oxygen generator to provide the balance of the 26.7 pounds of oxygen for complete combustion of the waste product.

The oxidation process is unique in that the system utilizes no ambient air; therefore no nitrous oxides are formed in the combustion process. Since nitrogen is approximately 80% of air, the total mass through the system is 75% less than a system using ambient air. The result is a system that can be 50% smaller than a system with similar capacity using standard technology. Also, because of the absence of nitrogen to retard the combustion process, much higher temperatures can be achieved more quickly with less fuel energy.

In addition, the oxidation process recovers a much higher percentage of recoverable heat energy by nature of its process than do other systems that utilize ambient air in the combustion process. As a side benefit in this military application, the oxidation process eliminates or considerably reduces the need to control significant amounts of pollutants. Unlike gasification and pyrolysis systems which tend to capture only a small part of the energy content of waste, the proposed concept should be able to capture 90% of the packaging energy content for use in electricity generation. For example, in an unrelated application using the oxidation system concept, our industry partner achieved 87% energy capture. We believe that, when optimized for the proposed application, at least 90% energy capture can be achieved. We will develop a proof of concept in phase I of the proposed project. In particular, we plan to achieve the following process parameters:

1. The mass of fuel out per mass of waste in will be 32 kg/hr combustion gas/3.7 kg waste
2. The fuel lower heating lower value will be 0.675 MJ/kg
3. Parasitic energy requirements (electrical and thermal) per mass of waste will be 2400KJ/Kg
4. The residence time for waste in the reaction zone will be 13 seconds.

In phase I, the system will be capable of burning fuel at a rate of 8.2lb/h (with at least 70% energy capture) to produce 24h of continuous power generation. Our calculations show that for our system, a fuel mass flow rate of 8.2lb/h corresponds to a fuel product that is at least 70% as efficient as JP-8 in a generator. Also, the system will be designed to ensure that the generation of solid residue is minimized to less than 10% of the input. The system will require a spark ignition from a battery only for startup, but will be self-sustaining after that.

We have identified a path for scaling the Phase I proof of concept into a portable unit, transportable on a standard, three-fourths of a ton, two-axel trailer. Upon successful results from phase I, improvements/optimizations will be made, based on the knowledge gained, to enable continuous generation of 5 kW of electric power, by converting 6.5 lb/h plastic waste with 90% energy capture. Scaling of the system to meet phase I and phase II can be accomplished utilizing standard design concepts and reducing the size of the

apparatus to diameters that correspond with the mass flow projections. Higher temperatures can be achieved by the use of new refractory material which can lead to increase energy efficiency. The system size can be scaled by utilization of new, innovative design concepts. For components that are typically large items the reduction of weight by use of new materials will be a goal of this project.

1. PROBLEM AND TECHNICAL APPROACH

1. 1 Significance of Problem

There is a need for the development of portable power generating units that will make use of the considerable amount of plastic packaging material generated by U.S. stationary military land-based operations. Such units will make such land based operations self-sustaining as well as increase the availability of power-when-needed in the field, while simultaneously minimizing the logistics footprint.

1. 2 Technical Approach

1.2.1 Basic System Design Approach and Options to be Considered in Phase I

A team of ZEROS, Oak Ridge National Laboratory, and Stirling Technologies has formed to deliver a system that will meet or exceed all of the system requirements. ZEROS is committing almost 3:1 of in-kind funding to this effort (\$3.5M to the requested \$1.5M). Figure 1 depicts the proposed Minimal Emission Oxidation System Concept for Power Generation in Battlefield Environments. Fuel, in the form of shredded plastic packaging waste (assumed to be 1/3 each of polypropylene, polyethylene, and polystyrene), is thoroughly burned in a fluidized bed combustion (FBC) system. The FBC system is oxygen fired. No air, with its 80% nitrogen burden, is introduced into the FBC. The hot combustion gas from the fluidized bed is passed to a secondary combustion chamber (SCC) before going through a heat exchanger. Some of the cooled return gas from the heat exchanger output is fed back into the process along with the pure oxygen, providing for thermal oxidation of fuel. The SCC will enable higher temperature heat delivery to the heat exchanger and to the Stirling engine, thus ensuring higher efficiency. The use of an induction draft fan in the system should be able to maintain the

system at approximately 12 PSI. Since in this model the accidental release of combustion gas is not a critical factor, a pressure vent to the atmosphere, such as a pin diaphragm, may be used in case of system upset. This would minimize weight and size of the apparatus. The actual working fluid temperature available for power production is estimated to be 2000 °F for primary temperatures and 4400 to 4500 °F for secondary temperatures as needed. Generated effluents are primarily carbon dioxide and water. Carbon dioxide is a non-regulated compound and the water can be captured for beneficial use.

Our basic concept is to use the heated working fluid as input to a Stirling engine. However, other methods of utilizing the heat are also possible and these will be thoroughly examined during Phase 1 of this work. For the purposes of this proposal, the other methods that will be examined are briefly reviewed below:

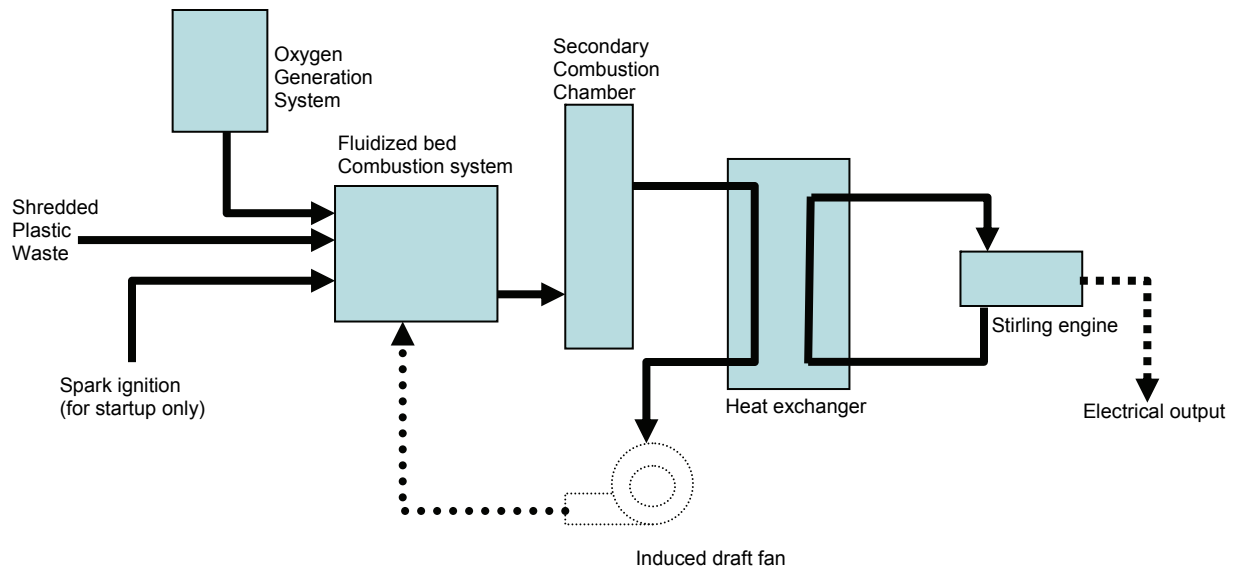


Fig. 1. Proposed Minimal Emission Oxidation System Concept for Power Generation in Battlefield Environments. While the fuel combustion will remain the same, we will also examine other options for power generation (e.g., use of microturbine) in phase I. See text.

Option 1: Stirling Engines

Stirling engines are classified as external combustion engines. They are sealed systems with an inert working fluid, usually either helium or hydrogen. This working fluid is used over and over. Rather than burning fuel inside the cylinder, the engine uses external heat to expand the gas contained inside the cylinder and push against its pistons. The engine then recycles the same captive working fluid by cooling and compressing it, then reheating it again to expand and drive the pistons, which in turn drives a generator. These units absorb heat from a wide range of sources and convert it to electricity with minimal emissions and low maintenance requirements. Typical heat sources include standard gaseous and liquid fuels with options to accept low Btu landfill and digester gas, petroleum flare gas and other low-grade gaseous, liquid and solid waste fuels. Raw heat from solar concentrators or flue gas stacks can also be converted to electricity, with no fuel costs and no incremental emissions. Similarly, the proposed process will convert raw heat from combustion of plastics directly to electricity. These engines are generally found in small sizes (1-52 kW). Overall, the electrical efficiency of current Stirling engines is in the range of 12 to 30%.

The primary challenges faced by Stirling engines over the last two decades have been their long-term durability/reliability and their high capital cost relative to reciprocating engines. While these challenges have delayed the penetration of Stirling engine technology, manufacturers are now beginning to approach run-times that could be acceptable in some distributed power applications such as the proposed process configuration. Our industry partner, Stirling Co., has considerable expertise in developing reliable Stirling engines, and this expertise will be utilized in developing the electricity generating end of the MEOS system.

Option 2: Microturbines

Combustion gas turbines, although originally used for aircraft propulsion, have been developed for stationary use as prime movers. Turbines are available in sizes from 28 kW to 480 MW (38 hp to 644,000 hp) and can burn a wide range of liquid and gaseous fuels.

Combustion turbines consist of an air compressor section to boost combustion air pressure, a combination fuel-air mixing and combustion chamber (combustor), and an expansion power turbine section that extracts energy from the combustion gases. ORNL developed a method to convert raw heat from combustion processes directly to electricity using a microturbine. In this process, which has a patent pending, ambient air is compressed and passed through a heat exchanger (recuperator) to provide the motive force for the microturbine. Use of a microturbine to generate electricity in the proposed process will be evaluated. Preliminary investigations show that the smallest microturbine currently manufactured is 30kW. Most microturbine units are currently designed for continuous-duty operation and are recuperated to obtain higher electric efficiencies (20 to 30% levels for sizes 100 kW and below). A more thorough survey of the market for availability of smaller microturbines to meet the MISER requirements will be performed under this proposal.

Option 3: Thermo-Electric (TE) Generators

A thermo-electric (TE) generator performs the same functions as an engine-powered electric generator. Both produce electricity and are reliable. The main difference is that the TE unit is virtually silent, with no engine noise. The thermo-electric generator produces electricity without any moving parts except a small cooling fan. Heat from the burner's flame flows through a number of thermo electric devices, in the direction of cooler, air-cooled fins. Heat is then expelled from the air-cooled fins to the surrounding air by a fan - the one moving part. The flow of thermal energy through thermo-electric elements creates thermal gradients in the TE materials, which in turn cause voltages to occur across the TE material.

TEG uses thermocouples made of high performance crystalline semiconductor material. Passing heat through this material generates a voltage across the thermocouples, causing a very high current to circulate in a closed primary ring.

Thermo electric material, with impressed thermal gradients, operate as if they were a number of individual batteries connected in series, The key solution to TE power

generation lies in the way the TE elements are connected, and especially how they are operated.

Thermo electric devices are highly reliable due to their solid state construction. Thermo electric modules in various types of assemblies have been used for years in different military / aerospace applications, such as satellites. The challenge has been to concentrate this power into a compact package and maintain sufficient output for practical consumer use.

The efficiency of these devices is around 12%, generally smaller than either Stirling engines or microturbines. However, the overall advantages of using such a system for electricity production will be thoroughly examined in phase I of the proposal.

Thermionic Generators

An elementary thermionic generator, or thermionic converter, consists of a hot metal surface (emitter) separated from a cooler electrode (collector) by an insulator seal. The interelectrode gap is usually a fraction of a millimeter in width. Electrons evaporated from the emitter cross the interelectrode gap, condense on the collector, and are returned to the emitter via the external electrical load circuit. The thermionic generator is essentially a heat engine utilizing an electron gas as the working fluid. The temperature difference between the emitter and the collector drives the electron current.

Thermionic generators are characterized by (1) high operating temperatures, typically emitter temperatures between 2420 and 4040°F and collector temperatures ranging from 980 to 1520°F; (2) high current density (around 5-10 A/cm²); and (3) relatively good conversion efficiency (about 10-15%). Such generators are of specific interest in deep space exploration systems using a nuclear decay heat source. Although the temperature of the gas stream expected in this proposed arrangement of plastic combustion is appropriate for achieving the needed emitter temperature, we are not aware of any manufacturers of such devices for this specific application. The possibility of a commercially available system will be thoroughly examined during phase I of this work.

1.2.1 Technical Challenges Addressed

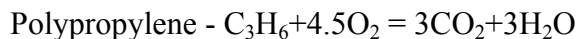
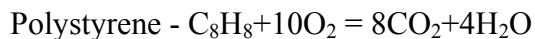
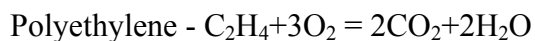
Several technical challenges will be addressed during the development of the MEOS concept. These are the following:

(a) Utilization of the Energy Content of the Waste as the Sole Means of Fueling the Process

Our method of achieving this is to (1) use the oxidation method to ensure an efficient combustion and maximize energy output, and (2) use only the heat energy to produce power.

The proposed MISER concept, as described earlier, is an oxidation process that achieves high efficiency combustion through the use of excess oxygen. A fluidized bed will be used as the combustion chamber. The shredded plastic with oxygen will be initially ignited with a spark ignition source. Once the ignition occurs, the spark source will not be needed during the continuous operation. The oxidation process exposes the combustion gases to a high temperature, high turbulence, and an oxidative environment for a few seconds, resulting in high process oxidation efficiency. Prototype demonstration units in a rotary kiln combustor achieved 87% efficiency without process optimization. A portion of the cooled combustion gas will be returned to the fluidized bed to provide temperature control for the combustion process.

The input fuel is a combination of Polyethylene (C₂H₄), Polystyrene (C₈H₈), and Polypropylene (C₃H₆), each 33.33% by weight. The equations for oxidation combustion for the three plastics are:



With a fuel input stream of 1/3 each of the three plastics, the chemical and mass balances yield the following:

For each pound of combined plastic fuel burned, stoichiometric combustion requires 3.22 lbs of oxygen and this produces 3.29 lbs of carbon dioxide and 0.93 lbs of water. For a 5% excess oxygen, to help ensure high efficiency combustion (at least 90+ %), the input oxygen per pound of fuel becomes 3.38 lbs. For a minimum of 8.2 lbs of fuel/hour, the oxygen required is 27.7 lbs/hr with 27 lbs of CO₂, 7.6 lbs of H₂O, and 1.32 lbs of O₂ in the output stream.

With the heating value of the plastic ranging from 26-43 MJ/hr, the heat energy (using an average heating value of 34.5 MJ/hr and converting to English units) available is approximately 130,000 BTUs/hr. The goal of Phase I is to capture at least 70% of this energy. For our MEOS system, the capture mechanism is a heat exchanger/recuperator that will transfer the heat energy of the combustion gases to working fluid in the Stirling Engine cycle. By using a primary and secondary combustion chamber concept we can elevate the SCC temperature as high as we need to maximize efficiency. Additionally, we might use the Sterling engine concept to drive the O₂ generator since we should have sufficient raw heat available under this concept. The power draw for system operation is minimal. If we use the two combustion chamber concept we should have on one draft fan internal and a small motor to fuel feed and ash drag.

The processing of 8.2 lb/hr of fuel will yield 131,200 Btu/hr and require 26.7 lb/hr oxygen and yield 0.0 lb/hr of solid residue or ash. The oxygen will be acquired from the primary combustion chamber through polymerization at the rate of 6.6 lb/hr and from oxygen extraction via heat at the secondary combustion chamber outlet at the rate of 6.6 lb/hr. The balance of the oxygen (14 lb/hr) will be provided from a small oxygen generator having approximately 2kW parasitic requirements of electricity.

The detailed energy and mass balances (attached in the Appendix as an Excel spreadsheet) show that ~90,000 BTU/hr are available leaving the SCC which is ~70% of the input energy from the waste (130,000 Btu/hr). The output of the SCC is 71 lbs/hr of combustion gases at 4400 °F with a mixture specific heat of 0.317 BTU/ (lb-°F).

(b) Minimization of Solid Residue

The unique approach to the MEOS system design ensures that the generation of solid residue is minimized to less than 10% of the input. The fuel used is pure hydrocarbon, which will oxidize to CO₂ and H₂O. The only residual remaining will be the inert/inorganic matter contaminating the waste plastic, which will be much less than 10% of the total mass.

(c) Fuel Quality for Continuous Generation of Power

In the MEOS concept, the actual energy source for electricity production is the heat content of the working fluid from the heat exchanger. The working fluid will be helium. The use of a heat exchanger ensures a clean working fluid, and the system the design ensures continuous generation of power as long as plastic waste is available. Although the start up of the MEOS system will require external power, such as a glow plug, the system should be self sustaining for continuous operation. Plastic hydrocarbons have sufficient exothermic heat value to sustain combustion with fuel and oxygen feed. The use of a devise such as a glow plug will develop heat in the range to volatize plastic, which has a relatively low melting point. The off gas from this process with oxygen or a small amount of standard fuel will create combustion that will sustain itself.

(d) Scaling for Portability

Scaling of the system to meet phase II objectives can be accomplished utilizing standard design concepts and reducing the size of the apparatus to diameters that correspond with the mass flow projections. Higher temperatures can be achieved by the use of new refractory material and size can be scaled by utilization of new, innovative design concepts. For components that are typically large items the reduction of weight by use of new materials will be a goal of this project