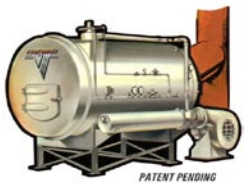
An Expert's Guide to Vortex Combustion!

Our *"Did You Know?"* Series

As part of our "Did You Know" series, we are offering this detailed description of our latest Firebird V-III™ technology, for technical folks! To learn more about vortex combustion, read our White Paper on Vortex Combustion, or other documents in this series, available online at www.AmericanEnergyGroup.org. Our ***Tech Brief*** is attached at the end of this document.



FIREBIRD™

General Description

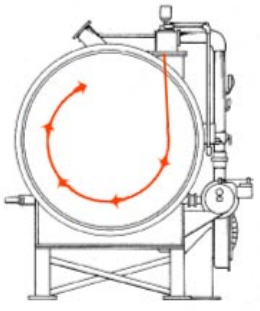
The V-III™ is a grateless combustion system (combustor) that uses high temperatures (2,000° F and above) with high speeds (a 90 mph tornado on its side) to more efficiently burn shredded waste material. This material then moves through the chamber towards the back wall, where (through a patented and proprietary method) it is re-introduced back into the vortex for continuous burning.

This overall process is known as "synergistic iteration." As the waste material burns in suspension, it becomes its own fuel, mixing with controlled amounts of air (oxygen) to achieve complete and perfect combustion. Current technology incinerators allow the waste to sit or rest on a grate while burning, which produces the harmful emissions, gases, fly ash, and smoke, because of incomplete combustion. These require expensive and complex air scrubbers to remove the contaminants prior to entering the atmosphere. The V-III™ does not produce these same harmful outputs, and therefore does not require exhaust cleaning or scrubbing.

The V-III™ handles the municipal waste needs of a population of between 40,000 and 50,000 people, which includes a typical percentage of residential, commercial, and institutional. It boasts a small footprint, which combined with the lack of offensive odors and harmful emissions, allows the system to be installed closer to populated areas.

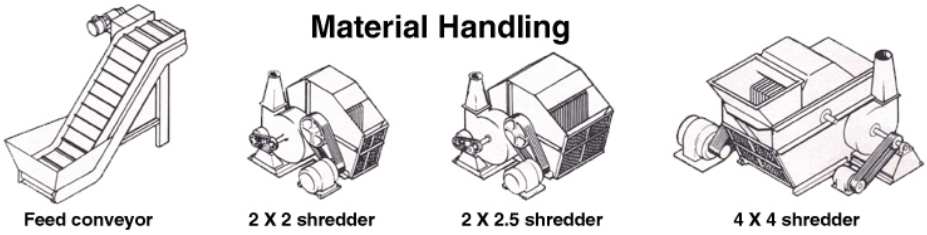
Details

The process begins with the main chamber of the combustor being primed with a long flame that is introduced tangentially into the chamber. What this means is that the flame follows the contour of the inside of the chamber so as to begin the motion and direction of the vortex, as shown in the image to the right. Once at temperature, the waste material is introduced as described below. After a short period, the primer flame can be shut off.



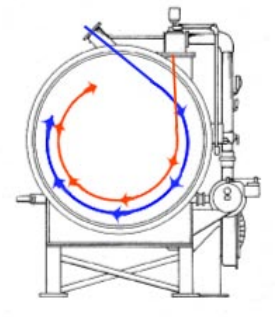
Did You Know…?
… that the three "R"s of waste management are: Reduce, Recycle, & Reuse?

This part of the process starts off with pre-sorting of the waste material, especially for municipal waste purposes. This serves two purposes; one is to have better control over the composition of the waste material to be shredded and then burned, and the second is to satisfy people's concerns for recycling. Recycling came about as a solution to the problem that certain items were not biodegradable and would survive in a landfill until the end of time. As we know, the recycling process is also very expensive and energy consuming. Since our system can handle these items properly, the need for recycling is diminished. However, to properly manage the emotional issue that is encountered with incineration, we feel that the pre-sorting will be beneficial.



Standard municipal waste shredders can be tailored to the specific needs of the community or landfill operations. Shredders are available in front-loading and top-loading models, and feed conveyors are available to facilitate easier material handling after pre-sorting operations.

Once the material is fed into the shredder, it moves through a material handling manifold with the help of a fan supplying the primary air for the incinerator chamber. This mixture of air and waste is introduced into the chamber tangentially, which again follows the contour of the chamber, and is blended with the motion and direction of the vortex flame, as shown with the blue curved line in the image to the left. This process now creates a super-heated vortex which burns the shredded waste material while fully in suspension. To achieve complete and perfect combustion, it is necessary to control the mixture of the waste, fuel, and oxygen. Turbulence is also a critical factor, which in this case comes about with the high-speed vortex rather than a shaker-grate as some incinerators use. Additionally, as the waste material is moving through the chamber, it is not only reducing in size, but becomes fuel for the process, which allows for a higher level of combustion and efficiency.



Did You Know…?
… that incineration has been used as a means of waste management since the 1800's?

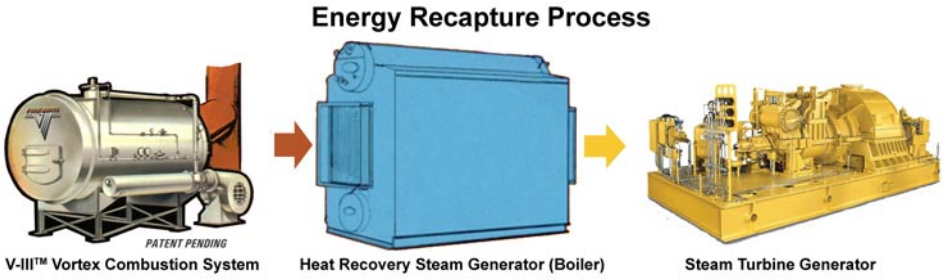
Some materials that are non-combustible are collected into a tray during this process. Because of the nature of the super-heated vortex, these materials will generally collect small amounts of ash as they are being deposited into the tray. Typical non-combustibles encountered through municipal operations are items such as ball bearings, lead, mercury, and cadmium. With the vortex combustion, these non-combustibles become sterile and neutralized, and perfectly safe for handling and proper disposal. The extremely hot air gas that exits during this process is reintroduced back upstream into the vortex to be burned off, as in the process of a manufacturing fume burner. This super-heated air acts to enhance the overall speed and temperature of the existing vortex, improving its efficiency.

The V-III™ has been designed with state-of-the-art PLCs for automation processing. It is also equipped with an array of sensors which allows complete and accurate control and monitoring of numerous factors, such as vortex temperature, vortex speed, secondary air dampers, and the air quality contained in the exhaust stack. The system is equipped with EPA-approved monitoring software, with remote access capability to provide continuous transmission of the data collected and reports directly to the state environmental protection agency, and to municipal public works managers and supervisors.

Did You Know…?
… that in addition to being part of our breathing process, CO_2 is used for adding carbonation to sodas, and in the making of wine?

With complete and perfect combustion, the only by-products are CO_2 and H_2O. No harmful emissions, gases, fly ash, odors, or even smoke, are produced through the process of this vortex incineration, therefore no scrubber systems are needed. The exhaust that is released into the atmosphere is clean and harmless, far exceeding EPA air quality specifications and standards. Because this process doesn't allow for waste to sit or to collect, as well as not having soot or other messy residue build-up, there is very little maintenance required as found with current technology systems.

This system can be used as a stand-alone waste combustor, or as part of a waste-to-energy (WtE) system, where the super-heated exhaust can be directed to a heat recovery steam generator, or boiler, and then to a steam turbine for the production of electricity. By processing the waste from a community of 40-50,000, the energy output is sufficient to supplement most if not all of the electricity requirements for that municipality. Smaller steam turbines can be used for communities or organizations that require less electricity.



Did You Know…?
… that one V-III™ system with energy recapture can generate more electricity than 4 large wind turbines?

Previous versions of this technology have been used in various applications, such as the disposal of contaminated materials from a nuclear fuel-rod facility, and infectious waste disposal. We have adapted this technology to dispose of municipal and industrial waste, enhancing the electronics and control systems. Previous versions are also installed in 14 countries around the world.

Summary

The V-III™ offers a high level of efficiency through the unique blending of extreme temperatures and high speeds, along with a patented process of reintroduction of particulate matter for continuous burning to achieve complete and perfect combustion. Because of this process, the system does not produce harmful emissions and gases, odors, fly ash, or smoke. With a small footprint, this system can be installed closer to populated areas, and offers a unique, modular design for rapid replacement or modification. The V-III™ can also be used as an eco-friendly solution for mobile needs, and can also be configured with smaller boiler/steam turbine combinations to produce electricity on a temporary basis.

An American Alternative Energy Group
Tech Brief

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Vortex Combustion
The Science Behind the Technology

By Jim VanNatta

August, 2009

Contents

Science behind this technology

What is it? Basic answer:
The Firebird V-III™ is a grateless, single-chamber vortex combustor that burns shredded waste material in suspension in a 90 mph, 2,000˚ F tornado, or vortex, and forces any particulate matter to be re-introduced to the vortex for continuous combustion. Because we are able to control the atmosphere in the chamber, we achieve complete and perfect combustion. (see **Complete combustion** on the next page) This system does not require typical scrubber or filter systems, since it doesn't give off any harmful emissions.

The process starts off in a fairly standard method with the material, such as municipal solid waste (MSW) being introduced into a shredder that is configured for the makeup of the waste material collected. The single chamber of the combustor is primed with a seven-foot gas flame that is introduced to the chamber tangentially, allowing the vortex to start in the recognizable form of a tornado.

The shredded waste is conveyed through a material handler that introduces the blended waste material and primary air into the combustion chamber, also tangentially, to travel in the same path as the vortex. As the waste material burns and travels towards the back of the chamber in the vortex, secondary air is added, also tangentially, to enhance the speed and the temperature of the vortex.

The shredded material, as burning particulate matter, becomes its own fuel, which enhances the complete combustion of all particulate matter, and increases the efficiency of the system. When proper temperature and vortex velocity is reached, the gas used as a primer can be shut off similar to gas fireplaces.

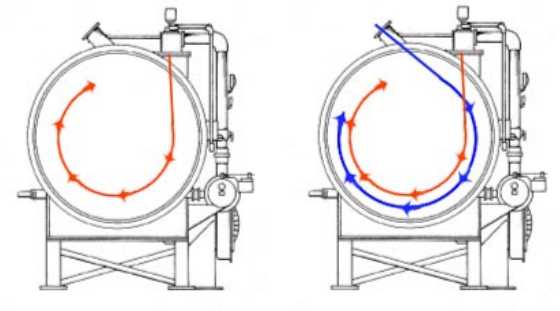
The waste material burns while in suspension, never allowing it to rest and smolder, therefore

not capable of producing harmful emissions as a by-product as standard incinerators currently operate.

Without going into any proprietary details, the vortex combustor, through a patented design process, re-introduces particulate matter that has any mass to it (even microscopic particles), back into the super-heated vortex to continue to burn until there is no mass remaining.

The re-introduction of the particulate matter into the vortex not only allows for complete combustion, but it prevents the production of harmful gases and emissions as standard incinerators do.

No other combustor on the market today uses this process. Mostly, it is because of the fact they don't have a vortex to consider. To understand this concept, the images below demonstrate how the waste or starter flame is introduced into the chamber so as to continue in the direction of the shape of the inside of the chamber, blending in with the flow of the vortex.



As the vortex containing the combustible and non-combustible materials progresses towards the back wall, the non-combustible materials and some particulate matter such as ash are pulled into a cyclone separator and collected in a tray. The heated air is then piped back into the chamber in a secondary process known as fume burning.

Most incinerators are multi-chamber devices that burn the waste in a primary chamber, and then transfer the residue to a secondary chamber for additional burning. These incinerators usually require complex scrubber systems, since the smoldering produces the harmful gases and emissions, as well as fly ash.

Complete combustion

One of the most important factors with the V-III™ system is our ability to control the atmosphere within the chamber. Through an automated process, we control the proper mixture of fuel, waste, and air. With that, we achieve what is known as complete and perfect combustion, where the only byproducts are H_2O and CO_2.

Systems using existing incineration technology operate with incomplete combustion, which is where the fly ash, fumes and odors, sparks, and smoke are produced. In complete combustion, no harmful emissions, fly ash, fumes, or even smoke is produced, and requires no special treatment such as exhaust scrubbers.

Features & Benefits

Many of the items listed below are inter-related. This is one of the overall features of the V-III™ - the blending of features to produce an even greater result. This is where the term "Synergistic Iteration" comes from.

Features

- High speed vortex – 90 mph
- High temperature – 2,000°
- Shredded waste material burns fully in suspension
- Single chamber, grateless combustion
- Patented method for re-introducing particulate matter into super-heated vortex
- Eliminates usual odors, fumes, smoke, and harmful emissions
- No costly scrubbers needed
- Virtually non-existent amount of ash residue produced
- Extremely low maintenance
- Small footprint - unit is 8 feet by 11 feet
- Unit can handle the waste needs of a population of 40,000 (residential, commercial, & institutional)

- Modular design – components such as shredders, boilers, & steam turbines, can be easily integrated
- Economic operation – 7 people minimum to operate for a 24 hour shift
- Energy recapture – using decades-old method of combustors as combustion source
- Offers a wide array of applications

Benefits

- Unique combination of high speed and temperature produces an extremely efficient combustion process
- By forcing the particulate matter to be re-introduced into the vortex, material that still has any matter to it will burn until fully combusted, never being allowed to smolder and produce harmful emissions, odors, or smoke
- Since waste material burns in suspension, never resting on a grate or on the floor of the chamber, and the unit does not require expensive and complex scrubber systems, there is very little maintenance needed
- Since there is no fly ash produced, and very little if any ash residue produced, there are no secondary disposal concerns. There are non-combustible items, such as hard metals like ball bearings that are collected in a small trap that can be easily emptied.
- Small size allows the system to be installed in existing facilities, or keeps costs of site construction down
- Small communities will now have a chance to control their waste management issues, with a unit that can be installed closer to populated areas than current technologies
- With possibility of adding peripherals, design allows for easy integration of peripheral items such as shredders, without complicated redesign
- Modular configuration allows for easy retrofitting, or for replacement of any or all components for any reason
- One unit without the energy recapture option, can be operated on a 24 hour basis with 3 people on the busiest day shift, and 2 each on the remaining shifts
- With stack temperatures of around 2,000°, the V-III™ in combination with a boiler and steam turbine, can produce an efficient and high-powered steam output, to generate electricity. Waste to energy (WtE) has been used as a clean source of energy for more than 50 years.
- System is adaptable for a variety of applications, from municipal, industrial, hospital/medical/infectious waste, to landfill reclamation, to any process that requires clean, efficient combustion.

Energy recovery system

The V-III™ is available in two primary configurations. The first one is integrated with only a shredder, and used only for waste combustion. The second version is similar to the first, but will have a boiler and steam turbine, or a customized boiler / steam turbine combination. This will be used for waste combustion and energy recovery in what is known as waste-to-energy, or WtE. This complete system is called VorCinErgy™. These systems can also be mounted on truck beds or railroad cars for mobility.

Peripheral components

Expanding on the turnkey configuration information, below are brief descriptions of the components of those set-ups. These peripheral components have been commercially available for many decades, and are considered to be somewhat “off the shelf.”

Shredders

Shredders have been in use since early in the 20th Century, and have played an important role in reducing waste volume for various applications.

Heat recovery steam generator

HRSG, or boiler, is the system that takes the exhaust from the combustor (or any combustion source) and converts it to steam that will be used by the steam turbine to produce the electricity. These systems are also designed to fit a variety of conditions, including temperature, BTU output, and thermal flow coming from the combustion source.

Steam turbine

The steam turbine uses the steam produced with the boiler, and produces clean electricity. With the extremely high stack temperatures that come from the V-III™'s exhaust, the system is able to produce impressive amounts of power from such a small footprint. There are smaller turbines if the V-III™ is used for mobile applications such as FEMA first response for disaster areas.

Nearly 80% of the electricity generated around the world uses a steam turbine, no matter what is used for the combustion source. In some form, steam turbines have been around for hundreds of years, and those that produce electricity have been around nearly as long as electricity itself!

Glossary of Terms

BTU – British Thermal Unit. In North America, , the term "BTU" is used to describe the heat value (energy content) of fuels, and also to describe the power of heating and cooling systems, such as furnaces, stoves, barbecue grills, and air conditioners. When used as a unit of power, BTU 'per hour' (BTU/h) is understood, though this is often confusingly abbreviated to just "BTU".

Baghouse – Fabric collectors that use filtration to separate dust particulates from dusty gases. They are used as a dust collector in conjunction with other scrubber devices.

Bottom ash – Ash residue that comes to rest on the bottom of the combustor. This is also referred to as sterile ash.

Combustion - Combustion or burning is a complex sequence of exothermic chemical reactions between a fuel (usually a hydrocarbon) and an oxidant accompanied by the production of heat or both heat and light in the form of either a glow or flames, appearance of light flickering.

In a complete combustion reaction, a compound reacts with an oxidizing element, such as oxygen, and the products are compounds of each element in the fuel with the oxidizing element. (In the V-III™ process, this fuel is used up in the continuous combustion produced as the particulate matter is forced to re-circulate back into the super-heated vortex.)

Dioxin - Dioxins occur as by-products in the manufacture of organochlorides, in the combustion of chlorine-containing substances such as PVC (polyvinyl chloride), in the bleaching of paper, and from natural sources such as volcanoes and forest fires.

Effluent – the flue gases or exhaust present in the exhaust stack or flue sections.

Emissions - Exhaust gas or flue gas is emitted as a result of the combustion of fuels such as natural gas, gasoline, diesel fuel, fuel oil, coal, or in our case, an combustor. It is discharged into the atmosphere through an exhaust pipe, flue gas stack or propelling nozzle.

Fly ash – Fly ash is similar to bottom ash in composition, but is typically lighter and tends to be lifted upward with the thermal air flow caused by combustion. Fly ash is considered a pollutant since it often gets discharged into the atmosphere if proper air scrubbing methods aren't in place.

Furan **-** Also known as furane and furfuran, it is a heterocyclic organic compound. It is typically derived by the thermal decomposition of pentose-containing materials, cellulosic solids especially pine-wood. Furan is a colorless, flammable, highly volatile liquid with a boiling point close to room temperature. It is toxic and may be carcinogenic.

Gas or gases - a gas is a state of matter (solid, gas, liquid), consisting of `particles (molecules, atoms, ions, electrons, etc.) without a definite shape or volume that are in more or less random motion. Plasma is a highly ionized gas that occurs at high temperatures. The term gas or gases is often associated with harmful emissions, but actually is a description of collection of particles.

Grate **-** A grate is a frame of iron bars to hold fuel for a fire, or some form of combustion.

Incineration - a waste treatment technology that involves the combustion of organic materials and/or substances. Incineration and other high temperature waste treatment systems are described as "thermal treatment." Current methods of incineration of waste materials convert the waste into bottom ash, flue gases, particulates, and heat, which can in turn be used to generate electric power. The flue gases are cleaned of pollutants before they are dispersed in the atmosphere.

Leachate - The liquid that drains or 'leaches' from a landfill; it varies widely in composition regarding the age of the landfill and the type of waste that it contains. It can usually contain both dissolved and suspended material.

Particulate matter - Also referred to as particulates or fine particles, particulate matter (PM) are tiny particles of solid or liquid suspended in a gas or liquid. They are described by their size. For instance, $PM_{2.5}$ represents particles less than 2.5 micrometers in aerodynamic diameter.

Plasma arc gasification - A waste treatment technology that uses electrical energy and the high temperatures created by an electrical arc gasifier. This arc breaks down waste primarily into elemental gas and solid waste (slag), in a device called a plasma converter. The process has been intended to be a net generator of electricity, depending upon the composition of input wastes, and to reduce the volumes of waste being sent to landfill sites. To date, this is an extremely expensive process that is still not ready for mass usage.

Scrubber systems are a diverse group of air pollution control devices that can be used to remove some particulates and/or gases from industrial exhaust streams. Traditionally, the term "scrubber" has referred to pollution control devices that use liquid to wash unwanted pollutants from a gas stream. Recently, the term is also used to describe systems that inject a dry reagent or slurry into a dirty exhaust stream to "wash out" acid gases. Scrubbers are one of the primary devices that control gaseous emissions, especially acid gases. Terms used in relation to scrubbers:

- Partial quench, dry acid gas scrubber with dry lime injection
- Dry scrubber
- Rotary atomizing wet scrubber
- Lime injection system
- Powdered activated carbon injection system
- Vertical upflow two-stage multi-microventuri scrubber system
- Secondary/tertiary chamber
- Water quench followed by sodium bicarbonate injection system with dry reaction chamber and pulse-jet baghouse
- Passive absorber
- Caustic soda injection
- Venture scrubber with packed bed absorption unit using dilute NaOH (sodium hydroxide)
- Packed column gas scrubber
- Wet ESP

- Flux force/condensation collision scrubber system
- Rapid gas quench system
- Demister
- Carbon bed absorber
- Electrostatic precipitators

Secondary chamber - A grateless incinerator having a pair of combustion chambers including a primary chamber and a secondary chamber separated by a movable closure means. Incineration is started in the primary combustion chamber, and then ash including unburned residual matter is dropped from the primary chamber through the movable closure means to the secondary chamber which is located below. Smoke and gas generated by continuing combustion of the incompletely burned residual matter is returned through a controlled passageway to the incinerator downstream where it is again subjected to incinerating temperatures before it is directed through an exhaust duct to the atmosphere.

Tangential – A tangent is a line or a plane that touches a curve or a surface at a point so that it is closer to the curve in the vicinity of the point than any other line or plane drawn through the point. See diagram on page 7 for further clarification.