White Paper

# Making wet waste destruction a sustainable reality

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Irish environmental company SCFI was supported by the European Union's Eco-Innovation initiative in a project to build a portable unit to demonstrate its innovative AquaCritox® wet waste treatment technology. This White Paper describes the science behind hydrothermal oxidation (HTO) as a waste treatment methodology and its potential across a range of industrial applications, which is now, thanks to this project, a demonstrable reality.

# AquaCritox and Hydrothermal Oxidation

AquaCritox® is a hydrothermal oxidation process that involves the use of pressure, temperature and oxygen to effect partial or complete oxidation of the oxidisable components present in a sludge or contaminated water based waste stream. AquaCritox provides a single-step solution to the treatment of wet wastes such as sewage, drinking water, spent caustic and industrial organic aqueous waste streams. The technology delivers over 99.99% destruction of sludge – a far greater rate than other competing technologies, is also safe and odourless, and does not generate any hazardous emissions or by-products.

Typically, the process operates at minimum pressure of 165 Bar and up to 240 Bar. The use of such pressures is necessary to ensure that the water within the feedstock will remain in the near critical or super critical phase during the oxidation reaction. The use of high pressure also greatly increases the oxygen transfer rate which is often a limiting factor in lower pressure systems. This pressure is achieved and maintained by using high pressure feed pumps and a novel pressure control and let-down system. The oxidation reaction is also temperature dependent. At low temperature it is unlikely to proceed or if so, will only occur at a very slow reaction rate.

It is well known that reaction rates increase with temperature and in all chemical reactions it is necessary for the system to reach its activation energy whereby sufficient thermal energy is provided to break the bonds between atoms within molecules.

Reactions are in themselves either endothermic or exothermic and so it is necessary within the system to provide for the addition of thermal energy to initiate the oxidation process and subsequently to control the system maximum temperature to ensure that the process does not exceed the design temperature of the plant.

This temperature control is achieved by the utilisation of a combination of a heater and heat recuperative heat exchangers. Typically, the system will operate within a temperature range of 300° to 450° Celsius.

Oxygen is used as the oxidant. A dedicated pressure swing adsorption system is utilised to generate a stream of low pressure oxygen from air. This oxygen is pressurised using a high-pressure compressor before the oxygen is metered into the reactor at the required addition rate to complete the reaction.

The AquaCritox plant is based on a tubular reactor, which offers many benefits over bubble type reactors including the elimination of back mixing and the ability to operate at higher than standard industry pressures. In turn this offers the potential to use higher process temperatures leading to greatly increased reaction rates and vastly reduced reactor retention times.

The plant is fully automated and is controlled by a plc-based control system equipped with full safety interlocks.

# The Process

A liquid or slurry waste stream is transferred into the system feed tank. From here it is pumped into the system using a high-pressure feed pump which is chemically resistant to the expected feed type.

To start the system, the feed tank outlet valve is closed, and the process water valve is opened to allow water to flow to the suction side of the feed pump. The feed pump along with the choke water pumps are started and the system is allowed to reach system pressure.

Once system pressure is stabilised the process heater is started, and the system heats up to the pre-set process temperature. The feed pump forces the liquid through the primary process heat exchanger and through the heater circuit before entering the tubular reactor. Over a short time-period, the system reaches operating temperature.

Once operating temperature has been reached, a flow of oxygen into the reactor is initiated, and the water valve

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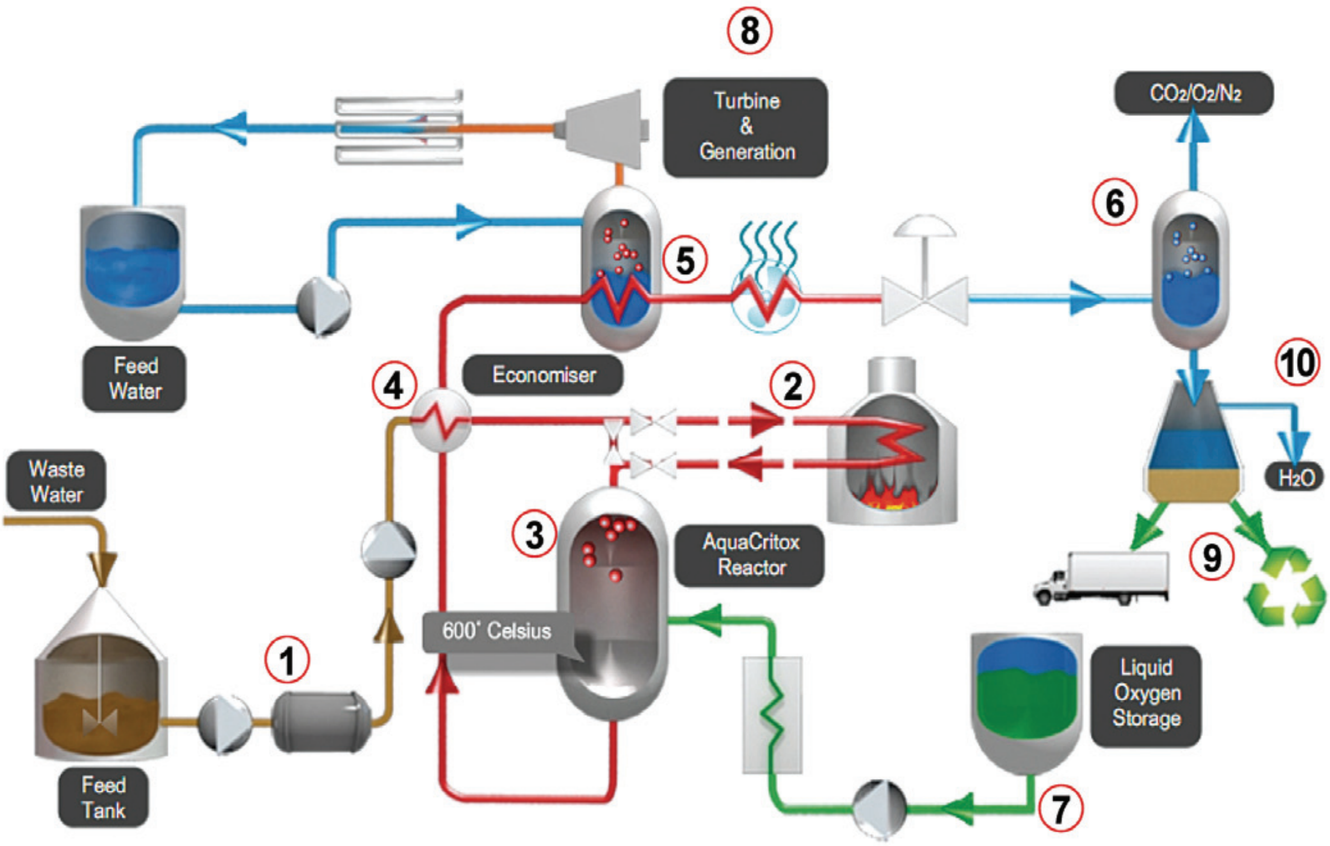


*The AquaCritox process: 1. High pressure feed pump; 2. Process heater; 3. Reactor; 4. Heat exchanger; 5. Boiler; 6. Gas / Liquid separator; 7. Liquid oxygen storage; 8. Turbine / generator set; 9. Solids capture; 10. Clean water discharge.*

slowly closes off while the feed tank valve begins to open thus allowing the material in the feed tank to be fed into the system. The off-gas and reactor temperature are monitored. The control system ensures that the required amount of oxygen is always added to the reactor to ensure full oxidation.

While the system is in operation, thermal energy is recovered from the reactor effluent using a tube-in-tube type heat exchanger. The exchanger uses pressurised water on its annulus and transfers thermal energy from the reactor effluent to the incoming feed via the primary process heat exchanger, thus heating the feed.

Oxidation reactions are exothermic and so provided that sufficient thermal energy is available in the reactor effluent, it is then possible for the system to operate in auto-thermal mode.

After the reactor effluent has passed through the heat exchanger it is still under pressure. The flow passes through a cooler to bring the stream to ambient temperature and is then directed into the pressure control and let-down system where pressure is reduced from 240 bar to ambient. The pressure control and let down system is unique to SCFI and utilises a patented system of pressure reduction coils together with a choke arrangement. This system is particularly robust and capable of handling three phase flow which will always be encountered when processing waste streams such as sludges, slurries and contaminated waste waters and caustics.

# Engineering challenges

A number of engineering solutions were needed to overcome process and safety challenges encountered in the development of this Eco-innovation supported demonstration plant.

While the process at overview level is simply described as pressurise, heat, add oxygen, cool down and depressurise, the detailed operation of the system is in fact much more complex.

As temperatures change within the system, the viscosity and density of water changes significantly. These process fluctuations can present problems in ensuring that solids will be transported through the system and so particular attention was paid to system velocities at each stage of the process. Modelling ensured that effective solids transport was achieved by ensuring a minimum velocity based on density at each stage of the process.

An increase in fluid temperature that results from heat exchanger or exothermic reaction can lead to rapid pressure increases and decreases within the system. To overcome this phenomenon, SCFI designed a unique pressure control system. The system utilises banks of capillary coils together with a choke water addition pump. The system is valve-free and appropriate for three phase flows.

Changes in temperature across the system can lead to metal expansion, therefore attention was focused during design to ensure that stresses within the system are always relieved.

Because the demonstrator is designed to be transportable to customer sites and may be deployed in any region around the world, it has been housed in three insulated shipping containers that are fitted with refrigeration units. The presence of refrigeration offers the possibility of operating this equipment in hot locations such as the Middle East. Additionally, because the system is within insulated containers, all equipment has to have exceptional levels of thermal insulation, not only to ensure process efficiency but also to minimise the load on refrigeration units.

Special attention was paid to system pressure relief. Because the process is based on a long tubular reactor arrangement it was necessary to carry out detailed calculations regarding size and location of pressure relief valves to ensure overall integrity of the system. These calculations were particularly difficult because in the event of a pressure relief event three phases would be experienced at the relief valve outlet.

Once all P&ID drawings were finalised the entire plant was modelled in three dimensions using CAD software. This allowed layouts to be finalised and isometric drawings for fabrication issued. Safe operation of the system at all time is of paramount concern. The final design was subjected to a full HAZOP study and incorporates many safety features including emergency shut-down, safety interlocks, pressure relief systems, fire detection, carbon monoxide detection, excess oxygen detection, nitrogen blanketing and motion sensors.

Procurement of all components required the development of a data sheet for each item specifying each instrument and piece of equipment in detail. Once all equipment was delivered to site, mechanical and electrical engineers undertook the assembly. Because the demonstrator would ultimately be housed within shipping containers and space would be at a premium, the build team pre-assembled components where possible before then moving them into the containers. This minimised the number of mechanical and electrical personnel required within the container space at any one time during construction.

# Outcomes

With the support of the Eco-innovation initiative, SCFI has been able to build a fully operational demonstrator unit which can be used to showcase the effectiveness of AquaCritox HTO in actual working environments around the world. The company believes that this will facilitate quicker commercialisation of this environmentally-friendly technology as an appropriate solution for a variety of hitherto difficult wet waste treatment challenges.

**WHAT IS ECO-INNOVATION?**

The European Union's Eco-innovation initiative helps SMEs with innovative, environmentally beneficial products which have been proven through piloting, overcome obstacles to commercial success. It's part of the EU's commitment to not only boost economic growth, but ensure Europe leads the way in helping meet the world's sustainability challenges.

**PROJECT PARTNERS**

Besides SCFI, other partners involved in this project included: Air Products (to meet oxygen supply and equipment needs); Eras Eco/Ormonde Organics (for demonstrator testing support); Ecuity Consulting (to address regulatory and certification activity) and Richmond & Towers (to coordinate marketing and dissemination).

For more information on SCFI, AquaCritox and the Eco-innovation project, visit www.scfi.eu

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