TERRAGON

Technologies de l'environnement inc.
Environmental Technologies Inc.

Technical Description Package
Micro Auto Gasification System
(MAGS^{TM} V8 or V800)

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1. TECHNOLOGY DESCRIPTION

1.1. Process Overview

Terragon has developed the Micro Auto Gasification System, or MAGS™, which is a compact, efficient and environmentally safe technology for the conversion of waste into thermal energy for use by the site where the waste is generated. MAGS can be used to eliminate all combustible waste produced by a ship, community or institution, while sterilizing the inorganic portion of the waste. Waste streams that can be easily treated by MAGS, without the need for segregation, include but are not limited to paper/cardboard, plastics, food, oily rags, oils and sludges.

MAGS uses Terragon's patented technology, *Auto Gasification*, to thermally break down waste and transform it into a solid carbon material (bio-char) and a synthesis gas (syngas). The syngas becomes the main fuel source for MAGS, which eliminates the need for external energy sources and renders the appliance virtually self-sustainable. Put simply, MAGS gasifies - or "cooks" - waste, reducing it by more than 95 percent in volume to bio-char and a hot gas (syngas). The hot gas re-circulates through the appliance to maintain the elevated temperature needed to continue the gasification process, hence *Auto* Gasification.

MAGS is an energy generating device that is fuelled by waste, and as a result produces approximately 100 kW of thermal energy for use by the site where it is located. This thermal energy can be transferred to the site for a variety of applications such as hot water or space heating, consequently enabling cost savings for the end user.

Bio-char sequesters carbon thereby reducing greenhouse gas emissions when compared to alternative methods such as landfilling and incineration. Moreover, bio-char has excellent water and nutrient retention properties when combined with soil as an additive. Because of the *Auto Gasification* process and bio-char's ability to sequester carbon, MAGS can prevent the release of up to two tonnes of CO_2 for every tonne of waste that it treats.

The MAGS technology is a simple appliance whose design incorporates many beneficial features. It is extremely compact, making it small enough to be installed in any utility room, inner-city building, or small compartments within a ship. It is fully automated, uses minimal utilities because it generates its own fuel, and can be monitored remotely by Terragon technicians, thus offering immediate assistance for troubleshooting if need be. Additionally, it is exceptionally safe and can be operated by anyone with little technical background and minimal training.

1.2. Working Principles

The proprietary *Auto Gasification* process used in MAGS has three basic elements:

(i) In the Gasifier, the organic materials are heated up to a temperature of 650°C in a low-oxygen environment, where they break down to a volatile fraction and a carbonaceous residue;

(ii) The volatile fraction is combusted at about 1,100°C in the Combustion Chamber and the hot gas is used to heat both the process air used in the Gasifier, as well as the Gasifier itself; and

(iii) The hot combustion exhaust gas leaves the heat transfer zone of the Gasifier at about 700°C and is quenched with water before being introduced to a scrubber for cleaning prior to its final release into the environment.

A schematic of the overall process is shown in Figure 1.

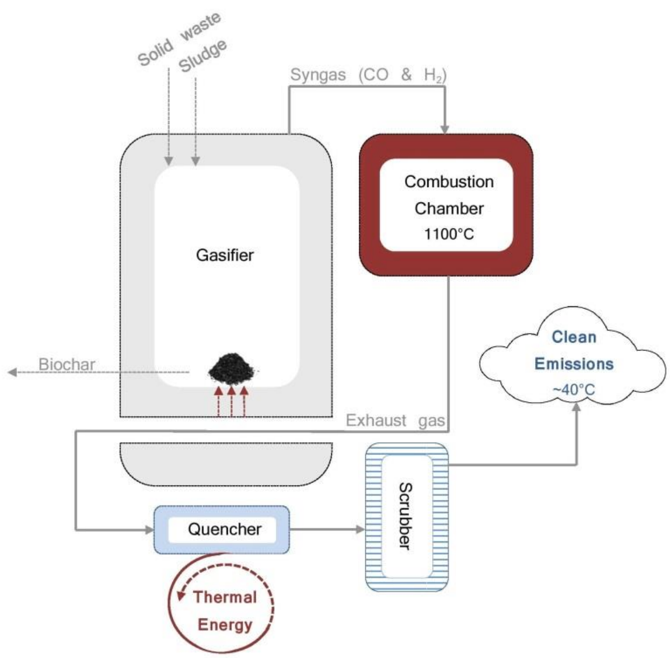

Figure 1: Simplified Schematic of the *Auto Gasification* Process

MAGS, as shown in Figure 2, consists of two Gasifiers. Each Gasifier is constructed to allow for the indirect heating of the waste inside the drum by the exhaust gases from the adjacent combustion chamber. Waste is loaded into the Gasifiers and heated up to about 650˚C (1,200 ºF). For sludge oil elimination, the sludge oil is continuously fed into the Gasifier (not shown in figure).

A controlled amount of pre-heated air is fed into the drum and brought into intimate contact with the waste. The heat and the oxygen in the air break down the hydrocarbons in the waste to form a syngas, composed primarily of CO and H_2, and bio-char. The syngas exiting the Gasifiers is fed into the Combustion Chamber where it is burned with excess air to form water and a hot combustion exhaust which is used to provide the thermal energy needed for the process.

Figure 2: Schematic of MAGS™

The Combustion Chamber is a thermally insulated reactor, maintained at 1,100°C through the combustion of diesel or syngas. A diesel burner system allows for the heat-up of the Combustion Chamber during start-up. The hot exhaust gases from the Combustion Chamber serve as the heat source for the Gasifiers and the process air.

At the start of each day, assuming that the unit is not being used around the clock, diesel is used to heat up the Combustion Chamber to 1,100°C. When the Combustion Chamber is adequately hot, its exhaust is directed towards a heat exchange zone located at the bottom of each Gasifier. The waste within the Gasifiers heats up, dries and begins gasifying, i.e. producing syngas. When the concentration of syngas is sufficient, the diesel burner switches off and the syngas serves as the main fuel for the Combustion Chamber.

Leaving the heat exchange zone below the Gasifiers at a temperature higher than 700°C, the exhaust gases are instantly quenched with water in a Venturi to a temperature of less than 80°C. The water quench serves to stop any recombination reactions that may form toxic compounds such as dioxins and furans. By bringing the hot exhaust in intimate contact with water, the Venturi also transfers most particles that may be in the exhaust to the water where they can be recovered in the water purification system.

The cold exhaust gas is fed into a packed column caustic scrubber to remove all remaining particulates and acid gases. A condenser is used to remove moisture from the exhaust gas prior to discharge.

The process comes to completion when all the organic waste is fully gasified and the production of synthesis gas stops. The residue, which is mostly inorganic carbon in the form of bio-char, may contain any incidental metal and glass found in the original waste. The bio-char residue is recovered as a sterilized inert material that can be stored or discharged safely. Because about half the amount of carbon contained in the waste is collected as bio-char, the MAGS technology offers significantly reduced emission of greenhouse gases, as compared to competing practices, such as landfilling and conventional incineration.

Figure 3: Photo of Bio-Char Produced by MAGS^{TM}

1.3. Types of Wastes

MAGS is designed to treat a variety of waste streams, specifically organic or combustible wastes. These waste streams include, but are not limited to:

- Paper/cardboard
- Plastic
- Food
- Fabrics
- Wood
- Oily wastes
- Sludges
- Biomedical waste
- Pharmaceutical waste

Terragon envisions MAGS to be part of a sustainable waste management solution, which includes waste reuse, recycling and composting. As such, whenever feasible, sites should recycle paper/cardboard and plastics, as well as compost food waste. Metals and glass should be recovered from the waste and not be introduced into MAGS since these materials will collect in large quantities at the bottom of the Gasifier.

2. INSTALLATION SPECIFICATIONS

2.1. Technical Specifications and Performance

TECHNICAL SPECIFICATIONS	
Total Weight:	**5,400 kg** (11,800 lbs)
Overall Dimensions: **(multiple configurations available)**	**2.5 m (L) x 3.5 m (W) x 2.1 m (H)** (8.2 ft x 11.4 ft x 6.9 ft)
PERFORMANCE DATA	
OPERATING CONDITIONS	
Nominal Solid Waste Throughput:	The throughput depends on the bulk density of the waste being treated. A typical waste loading containing 50% food (MARPOL recipe) would result in the treatment of approximately **50 kg/hr** (110 lb/hr).
Sludge Oil Throughput:	**15-20 L/hr** (3.9-5.3 gal/hr)
Gasifier Operating Temperature:	**up to 600 °C** (1,200 °F)
Combustion Chamber Operating Temperature:	**1,100 °C** (2,012 °F)
Types of Waste Streams:	Although MAGS can accept a variety of waste mixtures, it is ideally suited for the treatment of organic wastes, including but not limited to: paper/cardboard, plastics, food, wood, rags, oils, solvents, sludge, etc.
UTILITIES/CONSUMABLES	
Electrical Consumption:	22 kW (440VAC/60Hz or 400VAC/50Hz)
Type of Fuel:	Light oil #1 or #2 (diesel), NATO F76 fuel, natural gas, other fuels also possible.
Fuel Consumption:	**11.5 l/hr** (3 gal/hr) for heat-up, which takes a maximum of 1.5 hours. Some additional fuel may be required, depending on waste composition and waste loading frequency.
Caustic (NaOH 10 wt %):	**60 mL/kg solid waste** (0.9 fl.oz/lb) NaOH. This varies according to waste composition.
EMISSIONS	
Gaseous	Total flow approximately **200 SCFM** (5.6m3/min) at less than **65°C** (149°F). MAGS will comply with all applicable air emission regulations.
Condensed Water	About **3-8.5 l/hr** (0.8-2.2 gal/hr), depending on application and waste composition.
Bio-char	< **5%** waste volume reduction
Audible	Less than **75** dBA within 5 feet
System's Surface Temperatures	Less than **45 °C** (113°F)
ENERGY RECOVERY	
Energy Recovery Output	Between **100 kW – 130 kW** depending on application and waste composition

2.2. Utility Requirements

MAGS requires a small amount of diesel fuel and electricity during the process. At the start of every day, assuming that the MAGS stopped working for a few hours and cooled down, diesel fuel is required to heat the combustion chamber to 1,100°C before the waste treatment process begins. Up to 15 liters of diesel fuel may be required to heat up the Combustion Chamber. During normal operation, no additional diesel fuel is required, as the waste produces syngas which acts as the fuel for the process. However, if the waste has a very high moisture content (>50%), or if the operator fails to feed waste to the system, the diesel burner will automatically turn on to keep the temperature of the Combustion Chamber at its operating temperature.

Electrical energy is required for the liquid ring pump which is used to maintain the overall system at negative pressure, the cooling water circulation pump, the valves and instrumentation and the waste water discharge pump. The electrical energy requirement for the system is approximately 22 kW.

2.3. Thermal Energy

The operation of MAGS results in a significant amount of energy generation due to the exothermic combustion reactions occurring in the combustion chamber. Most of the excess energy is transferred to the cooling water during the quench of the exhaust combustion gas. Approximately 100-130 kWh per hour of thermal of energy can be recovered from the process in the form of hot water (50°C). In many applications, the hot water generated by MAGS can be used as the feed to a boiler (i.e. in a hotel, apartment building) thereby reducing the energy demands of the boiler. Terragon works closely with clients to help determine the best strategy for recovering the thermal energy from MAGS. If the energy cannot be used by the site, an air-cooler (cooling fan) can be provided to dissipate the energy and allow for closed-loop water cooling.

3. EMISSIONS

3.1. Gaseous and Liquid Effluents

The final exhaust from MAGS is neither odorous nor visible and the technology can be operated anywhere in the world, including within major cities. The final exhaust composition, as measured on the MAGS by an independent laboratory, using simulated biomedical waste, is clean and meets all regulations as shown in Table 1, below.

Table 1: Emissions from Auto Gasification Technology

Contaminants	*Emissions from MAGS*	Units
Particulates	0.77	mg/m^3
Carbon Monoxide (CO)	34	mg/m^3
Hydrochloric acid (HCl)	<0.6	mg/m^3
Sulphur dioxide (SO2)	< 2.6	mg/m^3
Hydrofluoric acid (HF)	<0.028	mg/m^3
Nitrogen oxides (NOx)	112	mg/m^3
Opacity	< 5	%
Total organic gases (CH_3H_8 equivalent)	0.6	µg/m^3
Dioxins/Furans	0.001	ng/m^3
Cadmium	0.16	µg/m^3
Mercury	0.56	µg/m^3
Lead	3.7	µg/m^3

MAGS also generates some water, on average about 5-20 L/hour, both from the water contained in the waste and from the combustion of the H_2 contained in the synthesis gas. The water generated is reasonably clean, as it is passed through a 2 µm filter before being discharged. The inorganic and organic compositions, as well as other parametric concentrations of the water after filtration, based on the operation of MAGS, are shown in Tables 2,3, and 4, respectively. The water effluent will meet all applicable, municipal water discharge standards.

Table 2: Inorganic chemical typical concentration measured in scrubber water effluent

Parameters	Concentration after filtration (mg/L)
Aluminum	1.0
Antimony	0.03
Arsenic	0.00
Barium	<0.01
Beryllium	<0.01
Bismuth	<0.1
Cadmium	<0.01
Chromium	0.02
Cobalt	0.01
Copper	0.08
Cyanide	<0.02
Fluoride	0.4
Iron	2.88
Lead	0.07
Manganese	<0.005
Mercury	0.000
Molybdenum	0.70
Nickel	0.02
Nitrate	<0.98
Nitrate and Nitrite	<0.07
Selenium	0.00
Silver	<0.02
Thallium	<0.05
Tin	<0.01
Titanium	<0.01
Vanadium	<0.03
Zinc	<0.01

Table 3: Organic chemicals typical concentration measured in scrubber water effluent

Parameters	Concentration after filtration (mg/L)
Benzene	0.00005
Benzo (a) pyrene	0.00011
Carbon Tetrachloride	<0.0005
1,2-Dichloroethane	<0.0005
1,1-Dichloroethylene	<0.0005
Cis-1,2-dichloroethylene	<0.0005
Trans-1,2-dichloroethylene	<0.0005
1,2-Dichloropropane	<0.0005
Dichloromethane	<0.005
Tetrachloroethylene	<0.0005
1,1,1-Trichloroethane	<0.0005
1,1,2-Trichloroethane	<0.0005
Trichloroethylene	<0.0005
Vinyl Chloride	<0.0023
Phenols	0.7
Mineral Oil & Grease	0.4
Total Oil & Grease	1.5
PAH	0.012
TKN	<0.3
$SO4^{2-}$	<57
Ethylbenzene	0.000
Toluene	0.000
Xylene	0.000
Cl-	39
Styrene	0.0222
Trihalomethane	<0.0005

Table 4: Other parameters and their typical concentrations of MAGS' scrubber water

Parameters	Concentration after filtration (mg/L)
TSS	4
COD	86
BOD_5	13

3.2. Solid Residue

Bio-char is produced during the thermal decomposition process that occurs in the MAGS waste processing chamber. As the waste decomposes, approximately 50% of the carbon in the waste remains in the chamber as a solid residue that is referred to as bio-char. Bio-char is a stable solid rich in carbon content, and therefore can be used to sequester carbon in soil, since the carbon in bio-char is not accessible to normal microbial decay.

Bio-char is suitable for amendment of weathered and deprived soils (low pH, absent potassium, low or no humus). Bio-char can prevent the leaching of nutrients out of the soil, partly because it absorbs and immobilizes certain amounts of nutrients, thus reducing the amount of fertilizer required. Bio-char has also been shown to increase the water retention ability of soil.

Leachability testing on the Bio-Char produced from MAGS was carried out by an independent laboratory (ConsulAir, Montreal, Canada). The typical composition of the bio-char produced from MAGS can be found in the results from the TCLP (Toxicity Characteristic Leaching Procedure) analysis, which are presented in Table 5. The measured values for each element are compared to the limit values taken from the Québec (Règlement sur les matières dangereuses- c. Q-2, r.32.3) for solids to be landfilled.

All measurements taken showed that the bio-char produced from MAGS is not hazardous and can be either landfilled without causing environmental concerns or used for soil enrichment. Of course, the quality of the bio-char depends to a great degree on the quality of the waste being treated. If hazardous waste, such as batteries and paints, are found within the waste being, they may contaminate the bio-char with heavy metals, making it unsuitable for soil enrichment.

All waste generation sites must have a plan to avoid the disposal of hazardous materials with ordinary waste and to test the bio-char produced by the MAGS regularly to ensure that it is suitable for the intended use.

Table 5: Characterization of Bio-Char

Species	MAGS (TCLP)	Limits[1]	Units
Arsenic	<0.01	5	mg/L
Barium	1.5	100	mg/L
Boron	<0.7	500	mg/L
Cadmium	<0.01	0.5	mg/L
Chromium	0.06	5	mg/L
Fluoride	1	150	mg/L
Lead	1.1	5	mg/L

[1] Québec-Loi sur la qualité de l'environnement c. Q-2, r.32.3

Species	MAGS (TCLP)	Limits[1]	Units
Mercury	<0.0004	0.1	mg/L
Nitrite	<0.07	100	mg/L
NO_2-NO_3	<0.07	1000	mg/L
Selenium	<0.01	1	mg/L
Uranium	<0.005	2	mg/L