adaptiveARC

ce25 Overview

clean energy and mobile detoxification system

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adaptiveARC's patented COOL PLASMA™ Gasification Technology utilizes a combination of plasma fields, pulsed-energy technology, and UV detoxification to produce the cleanest, most cost-effective, and energy-efficient solution available.

Figure 1, Plasma Torch Demonstration

The COOL PLASMA Gasification Technology converts waste, or other carbonaceous feedstock, into operationally viable outputs using plasma field dynamics. Waste flows through a plasma arc (see Figure 1) generated by pressurizing a gas (a combination of diesel, air and electricity) and passing it through an electrical field in an oxygen-deprived chamber. This produces a high-heat environment (800-1000°C), which instantaneously breaks down the waste feedstock into its molecular components. Super heating without oxygen is not incineration and does not generate the problematic exhaust emissions produced by burning waste. Instead, the innovative COOL PLASMA Gasification technology creates a clean fuel called syngas (synthesis gas) that can be used to generate a wide range of valuable outputs including electricity, liquid fuels, and specialized chemicals. The waste feedstock material introduced into this process is detoxified and its weight reduced at a ratio of 20:1. The only solid byproducts are inert materials: dry fly ash (which is commonly used as a construction aggregate), glass, and metals.

SYSTEM OVERVIEW

The Clean Energy 25 (ce25) plasma arc processor utilizes the COOL PLASMA Gasification technology to eliminate up to 25 metric tons of waste per day (TPD); the system can also be turned down to process reduced ratios or can be run intermittently as needed. The ce25 can operate 7 days per week, 365 days per year. It is energy self-sustaining and generates excess electric power that can be used for other external needs or can be fed back into the grid. The ce25 can be used for a host of operational applications such as municipal solid waste (MSW), toxic waste, and bio-hazardous waste. The system, unlike other gasifier or pyrolysis systems, also accepts waste fuels with up to 55% moisture content and has the ability to process multiple fuel types without having to be reconfigured. The ce25 is designed to produce over 500kW of net continuous power output when processing 25tpd. A unique energy balancing feature corrects for the incidental energy fluctuations typical in waste streams when used as a fuel source. If there is a fluctuation in the waste fuel syngas production, the generator-set (gen-set — engine-generator combined into one machine) will automatically start drawing in more or less diesel to compensate for the adjusted syngas values of the waste fuel thus providing a continuous energy output level. The proprietary gen-set modifications of the ce25 system are designed to adjust for these shifts with no degradation to the system's capabilities.

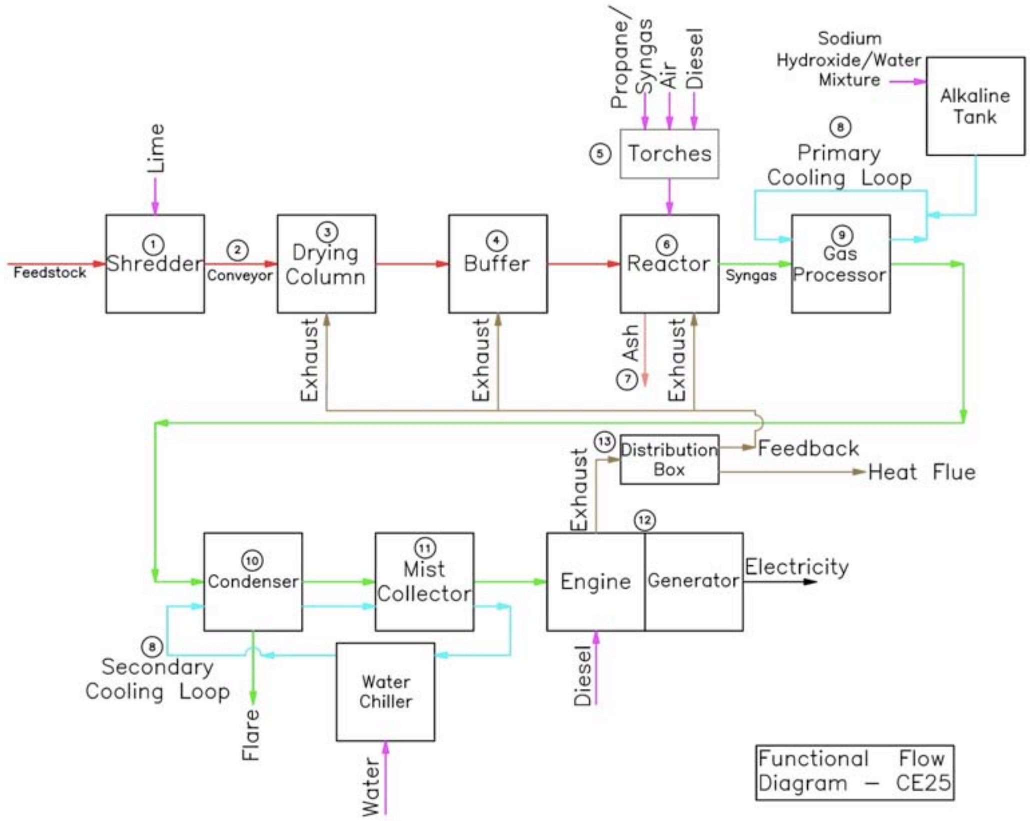

Figure 2, Functional Flow Diagram of the ce25

How the COOL PLASMA Gasification Works

1.Feedstock Preparation/Shredder

Waste (i.e. MSW, industrial residue, waste motor oil, etc.) is brought to the facility and separated by kind. Inert material or recyclable material—such as metal or glass with no caloric value (energy value) and not contributing to the heat value of the system—is diverted from the input stream. The remaining residual waste is front-loaded into the shredder where it is shredded down to roughly 3-inches in diameter, which is the optimal size fuel size for the ce25 system. Lime can be added to the shredder if the feedstock is acidic and needs to be neutralized. From the shredder the waste is conveyed to the top of the ce25 machine.

2. **Conveyor System**

The waste conveys from the shredder to the intake hopper on the drying column. The level to which the conveyor system fills the machine is controlled by level sensors in the drying column. When a sensor detects a drop in the feedstock level, the sensor sends a signal to the conveyor and the conveyor is automatically turned on until the sensor recognizes that the drying column has been refilled thus signaling to turn the conveyor off. There are multiple sensors in place to ensure the machine is filled to the correct level depending on the feedstock type.

3.Drying Column — *Acts as a holding area/pre-heater for the feedstock*

The ce25 waste input column is separated into two main areas: the drying column and the buffer/reactor. Waste is gravity fed from the point it enters the machine as feedstock to where it exits as ash/carbon. As waste enters the drying column it goes through a preliminary drying process using excess heat coming from the gen-set exhaust and heat from the reactor. The waste then proceeds down through the buffer before entering the reactor where it undergoes pyrolysis and gasification. The product of the pyrolysis and gasification is a combustible gas called syngas; the remaining material is ash/carbon.

The drying column also acts as a vapor lock to the atmosphere; this prevents ambient emissions from escaping the reaction process. This is accomplished by inputting a portion of the exhaust from the gen-set into the drying column and buffer to create a pressure differential stretching from the exhaust input to the reactor, positive to negative pressure respectively. The negative pressure is created by the vacuum that is created when the gen-set is pulling syngas from the reactor. Under normal operating conditions it does not allow syngas and ambient air to mix in the drying column.

4. Buffer — *Beginning of pyrolization*

After the feedstock has been dried and partially heated it flows into the buffer where the material is heated to its pyrolyzing temperature. This is the last step before it enters the reactor where it is converted into syngas, carbon, and ash. Pyrolization occurs in the buffer, with the majority of pyrolization occurring in the lower part of the buffer.

5.Plasma Torches

Since the first stage of pyrolization is endothermic, there needs to be an external heat source to start the process. The heat in the reactor comes from three plasma torches and from the gen-set exhaust. These torches use a combination of electricity, air, and diesel to start; once started, the torches can be run on syngas instead of diesel. After the feedstock has reached a sufficient reaction temperature it becomes exothermic: the feedstock gives off heat and becomes a major heat output. The torches and exhaust then aid in keeping the process stable and clean the syngas as it exits the reactor.

6.Reactor — *Converts feedstock to syngas/ash/carbon*

The environment within the reactor is oxygen deprived and under a slight negative pressure, allowing only a controlled amount of air to participate in the chemical reactions. The resultant syngas from the feedstock is pulled through the plasma field created by the torches; this pass through the plasma field rapidly breaks down organic structures and complex compounds so that the syngas only contains basic gases [hydrogen (H_2), carbon monoxide (CO), carbon dioxide (CO_2), and nitrogen (N_2)]. The plasma torches essentially polish the syngas before it exits the reactor and moves into the gas clean up phase.

7.Ash — *Inert byproduct of the ce25*

In the first step of the pyrolysis process, the feedstock is transformed into a high-carbon char; this char is then transformed into a low-carbon ash during the gas re-forming stage. The resultant ash is inert in nature and approximately 5% by weight of the incoming feedstock. This mixture settles to the bottom of the reactor; as it falls through the char grate in the reactor, a sweeper arm collects the ash into a dump tank were it will be dumped automatically into an ash collection container.

8.Gas Processor: Quenching — *Cools syngas down to 80°C after it exits the reactor*
The gas cleaning stage begins when the syngas exits the reactor. Having exited the gas processor through the plasma field, the syngas will be clean but may still carry some dust and ash. As the syngas enters the gas processor, it immediately hits a bio filter/quench, dropping its temperature to approximately 80°C.

The ce25 uses two water loops (primary and secondary) for gas processing (cooling, cleaning & pH neutralization). Water in the primary loop is circulated within the gas processor, while in the secondary loop it is circulated between the condenser, the mist collector, and the water chiller.

When water in the primary tank level drops due to hot syngas evaporating it, it will be automatically refilled from the secondary loop. As the primary loop water collects tar and ash from the incoming syngas it will become dirty; high turbidity will signal a sensor to pump the dirty water into the drying column where the water will evaporate and the tar and ash will be recirculated into the reactor.

Excess moisture from the syngas may condense in the condenser; this could lead to excess water in the secondary loop. Any excess water in the secondary loop will be diverted back into the reactor to assist in the water gas shift chemical reaction. This reaction uses the high heat of the reactor and the carbon it contains to transform water (H2O) to hydrogen (H2) and carbon dioxide (CO2). The ce25 system produces no wastewater and is instead a net consumer of water, consuming roughly 125gal/day when operated continuously. Alkaline solution can be mixed with the primary tank's water if syngas acidity causes the primary tanks water to drop below a certain pH threshold, thus raising its pH back to neutral.

9.Gas Processor — *Cleans syngas with bio filters/neutralizes pH/dries and filters syngas*
This quench process occurs in a bio filter that scrubs out any contaminants that may be in the gas. Depending on the feedstock being processed, the bio filter should last approximately four weeks. If the feedstock produces acids an alkaline solution will neutralize any gas acidity. Acidic species in the gas are absorbed into the bio-filters and combine with the alkaline components of the wash water to form minerals (essentially salts). As the gas exits the bio filter, it is centrifuged for drying purposes and then filtered through a series of particulate filters.

10.Condenser — *Condenses water out of the syngas and further cools it to 20°C*
The gas is then fed into a condenser where it is cooled from 80°C down to 20°C. This is accomplished by using sprayers that are fed from a refrigerant cooled water tank; the water from this tank is at 10°C. During this cooling, any steam that may be in the gas from the gas processing phase will be condensed. The water collected will go back to the water chiller and then back to the primary or secondary loop.

11.Centrifugal Mist Collector — *Spins remaining water out of syngas*
The gas is now wet again and must be dried prior to entering the engine; to accomplish this, the gas is processed through a centrifugal mist collector. The collected water is fed back into the water chiller tank and is reused in the secondary water loop.

12.Electrical Generation — *Syngas is combusted in a diesel gen-set to produce electricity*
The clean, dry, and cool syngas enters the gen-set via the engine air intake manifold where it is mixed with ambient air to meet the stoichiometric equilibrium inside the engine combustion chamber. The stoichiometric equilibrium is the exact amount of oxygen (O2) needed for combustion to take place in the cylinder. Syngas is pulled from the reactor by the vacuum created by the engine induction system. During the 20 minute system warm-up the syngas is routed to a flare where it is combusted to determine the gas quality and determine when it should be pulled into the engine.

The intake of diesel, as well as the syngas mixture, into the engine is automatically controlled; the amount of syngas being fed into the engine is directly controlled by the gen-set output and the engine automatic governor. The amount of air being pulled into the engine is controlled by setting the valving of the engine intake manifold. Engine combustion efficiency is monitored at the engine exhaust stream. Valve position is determined by the amount of carbon monoxide (CO) and oxygen (O2) in the exhaust stream.

The engine powers a generator, which outputs electricity at 240/480V 3-phase for use behind the fence (consumed on site) or at 4,160V/12kVA (12,470V) if being fed back to the grid.

13. **Exhaust Feedback**
Exhaust coming from the gen-set is sent to a distribution box where it is fed into the drying column, buffer, and reactor; the rest exits the machine via the heat flue. This allows the ce25 to reuse the exhaust, which would otherwise be expelled as waste heat.

Demonstration

Our system has minimal fossil fuel requirements. During startup, the system's gen-set fuel consumption is 70gal//hr (100% load) of diesel. Within 20-25 minutes the system will begin to produce syngas as a result of the gasification process (see Figure 3). In COOL PLASMA Steady State mode syngas production has offset the diesel consum-ption and the same gen-set uses only 4gal/hr of diesel. One ce25 can provide 500kW net continuous clean energy.

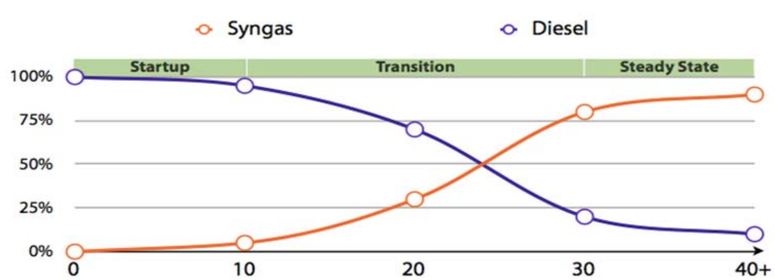

Figure 3, Diesel to Syngas Transition

The ce25 also reduces the need for water as its primary and secondary cooling loops recycle much of the water needed for the system. The water used for the system does not have to be potable and, in fact, can be recovered gray water. As it flows through the system it is continuously cleaned and only after it has become too turbid and acidic for use it is processed in the drying chamber and released as water vapor.


Figure 4, The ce25 is mobile and modular – once onsite the system can be assembled and operational within 48hrs.

TECHNOLOGY DIFFERENCE AND KEY ADVANTAGE

The engineering of the current adaptiveARC ce25 is focused on energy conservation within the process — this allows for a higher net output of energy. 90%+ of the power generated by the ce25 can be used on site or returned to the utility. adaptiveARC has developed several key innovations including: lower-power plasma torch designs; Regenerative Cleaning™ (see Figure 5) —deep integration of several gasification functions into a single elegant design system inside the gas cleanup; and the combination of adaptiveARC's unique torch and gasifier to create their proprietary COOL PLASMA Gasification technology. These key innovations drive cost and flexibility advantages into the technology, which are not available in other gasification systems. Further development of the design criteria and specifications will result in mass production at low risk.

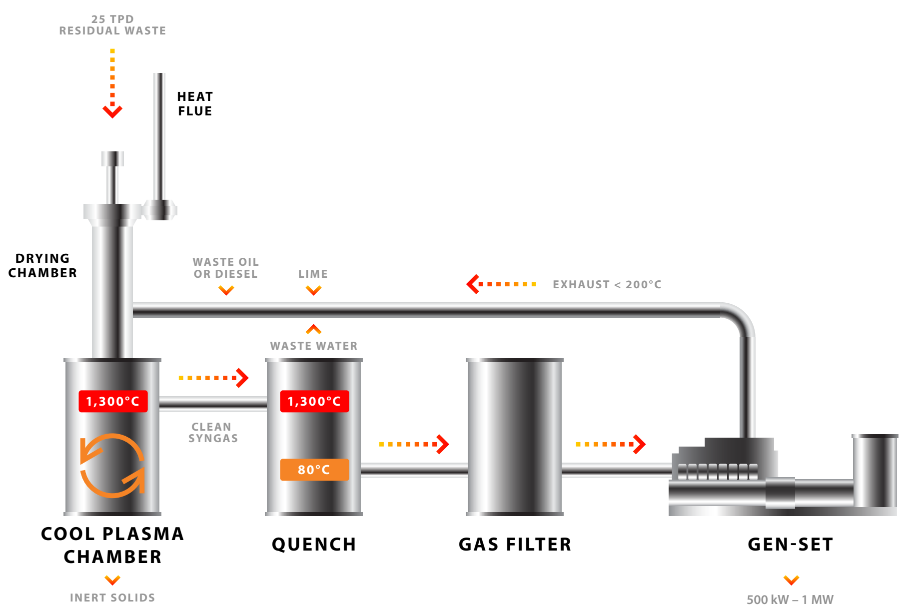

Figure 5, COOL PLASMA Gasification and Regenerative Cleaning System Diagram

COMMERCIAL OPERATIONS

In June 2010, the first commercial ce25 system was transported from Valley Tools in Hughson, California, to Bio-Sistemas Sustentables in Nicolas Romero, Mexico. 48 hours after arriving on site the system was operational and testing began. This site was provided as a temporary operating facility until it was later moved to its permanent location in September 2010. It has been in operation and processing various waste types (to include biomass, manure, MSW residuals, plastic packaging, cardboard, carpet, and construction debris) ever since.

Figure 6, The First Operational adaptiveARC Facility in Mexico City

For months this commercial unit underwent testing based on its operations using varying waste streams. Through continual operations and the data collected from testing, numerous improvements were recommended for the ce25. These recommendations resulted in improved changes in design. The 2nd Generation ce25 is currently in production in San Jose, California. As the 2nd Generation ce25 prepares to roll out, we have been able to streamline the existing operator and maintenance manual; this will make running the machine easier and safer for future operators. These manuals also help to establish a platform for future training programs to train operators and technicians.

The majority of the design upgrades/improvements resulted from hands on experience in Mexico. While great care was taken in the development and engineering of the ce25 on paper, the conditions in which a production system will operate and how the system operates in an operational environment can vary greatly from how it is designed. The majority of these improvements were simple in nature; these included such improvements as: changing plastic lines to copper; adding more sensors/gauges; adding filters; and implementing changes to keep the equipment cool and clean.

Some improvements on the 2nd Generation ce25 were made to enhance the performance of the system. These design upgrades include: adding a water cooler, condenser, and de-mister so that the gas can be cooled under a wider range of operating conditions and provide a higher quality syngas; and newly designed sight glasses so operators do not have to rely solely on gauges to operate the system and are able to see inside the machine.

Over the last 2 years, adaptiveARC has conducted dozens of demonstrations at the Mexico City facility (see Figure 6) with over 1,200 visitors attending from around the world. In November 2011, adaptiveARC concluded all tests and demonstrations at the site so that the operators and engineers in Mexico could work firsthand with the team that was constructing and building the 2nd Generation system. This has provided valuable firsthand experience in constructing a system that is easy to operate but also extremely capable.

TECHNICAL PERFORMANCE

Waste Reduction vs. Energy Generation: The Fuel Blend Composition table (see Table 1) and Energy Balance Worksheet (see Table 2) are analytical tools to measure waste elimination, diesel fuel reduction and energy generation.

Fuel Blend Composition

Waste composition varies from day-to-day. The Fuel Blend Composition table illustrates types of waste, waste input percentages, and average BTU based on solid waste fuel blend from an average landfill, transfer station or manufacturers recycling facility (MRF).

Table 2 illustrates that on average, the waste fuel available at a municipal solid waste (MSW) facility or MRF is sufficient to optimize the operation of a ce25 system. With optimized waste fuel moisture content (20-35%) and fuel blend BTU value (4,000—6,000BTU), diesel fuel requirement will be minimized and energy generation maximized. The ce25 system processes approximately 1 ton of waste per hour and generates up to 500kW.

Feedstock	BTU's	kj/kg	% Input	TPD	kg per day	kj per day	avg. kj/kg	avg. btu/lb.
Fuel Blend Characteristics								
RDF residual from MRF	7,000	16,282	15%	4	3,750	61,057,500		
Processed MSW	4,500	10,467	85%	21	21,250	222,423,750		
Total			100%	25	25,000	283,481,250	11,339	4,875
Conversion Factors								
	2.326	btu/lb to kj/kg						
	1000	ton to kg						
Metric Ton	2204	ton to lbs.						
	25	tons per day						

Table 1, Fuel Blend Composition and Average BTU

Energy Balance Worksheet

The engineering of the ce25 is focused on energy conservation within the process — this allows for a higher net output of energy. A fuel blend composition with 4,875 BTU will have a net generation of up to 500kW. Actual net generation, waste reduction and fossil fuel consumption results will be based on feedstock BTU blend and determined through site commissioning and demonstrating.

Syngas Volume Production & BTU's for Feedstock				
Feedstock Type:	**85% MSW and 15% RDF**			
Feedstock Calculations				
***Tons of feedstock per hour**	1.14			
BTU's *per* SCF of Syngas	148			
BTU value per ton of feedstock	10,744,500			
****Useable BTU's after losses**	8,058,375			
BTU per hour	9,157,244			
SCF of Syngas per ton	54,449			
SCF of Syngas per hour	61,874			
Therms per hour	95.67			
Bio-Fuel (Diesel Calculations)				
Caloric Value Range Bio-Fuel	5000-5900	kJ/m3		
BTU value per gallon of Bio-Fuel	128,000			
Bio-Fuel Gal/hr	40.00			
Bio-Fuel BTU's per hour	5,120,000			
Bio-Fuel BTU's per hour at 12:1 ratio	409,600			
Bio-Fuel BTU's per ton of feedstock	360,448			
Total BTU per ton Syngas : Bio-Fuel	8,418,823			
Total BTU's per hour Syngas : Bio-Fuel	9,566,845			
Input Variables (KCal/kg or BTU/lb. only) in Green				
KCal/kg	**2,708**			
BTU/lb.	**4,875**	B27 * Assumptions: B11		
Energy Balance (BTU/hour)	**Loss**	**Remaining**	**Efficiency**	
Reactor Thermal & Chemical Conversion	2,296,043	7,270,802	76%	
Latent Heat Loss in Gas	727,080	6,543,722	90%	
Diesel Engine and Generator Efficiency	4,057,108	2,486,614	38%	
Transformer and Transmission Efficiency	74,598	2,412,016	97%	
System Efficiency			24%	
Parasitic Energy Need	68,240	2,343,776	24.50%	
Totals				
Net Generator Output (BTU/h)	**2,343,776**			
Net Generator Output (MWe)	**0.69**			
MW/h in a 22 hour operation	**15.18**			

Table 2, Energy Balance Worksheet