ALL Power Labs

personal scale power

Introduction to the Power Pallet

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Specifications

	10PP	20PP
Electrical output capacity	50hz: 2–11kW 60hz: 2–8kW	50hz: 4–16kW 60hz: 4–17kW
Gas output range	5-27m^2/hr	11-52m^2/hr
Gas heat at maximum output	168,993 BTU/hr	331,727 BTU/hr
Biomass consumption rate	50 hz: 2.4–13.2kg/hr 60 hz: 2.4–9.6kg/hr	50 hz: 4.8–19.2kg/hr 60 hz: 4.8–20.4kg/hr
System Footprint	49" x 49.5" (124.5 x 125.75 cm)	55” x 54” (139 x 136 cm)

(Electrical output capacity varies with feedstock quality and moisture content; drier fuel supports higher power output.)

Biomass Feedstock Requirements

Biomass feedstock must be physically compatible with the feed system and the reactor. Composition requirements such as ash content and volatiles are also taken into account for ideal gas quality. Currently, only woody biomass such as wood chips and nut shells are supported. Avoid using feedstock with high salt content due to caustic condensate that will degrade system components. Use of MSW or plastics is not recommended.

The following requirements specify the known ranges of usable biomass.

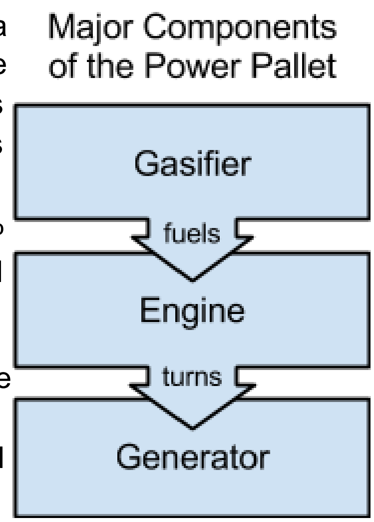
Particle size (longest dimension)	½ – 1 ½ in (1 – 4 cm) for 10PP ½ – 2 in (1 – 5 cm) for 20PP
Moisture content (% by dry weight)	25% or less during operation 15% or less during start up
Fixed carbon to volatiles ratio	20% or more
Ash content	5% or less

It is highly recommended to learn how to operate the system with ideal feedstock characteristics. When experimenting with alternate feedstocks, it is recommended to mix the alternate feedstock with the ideal feedstock in low amounts and increase the percentage of less ideal feedstock and assess the changes in system performance. If the biomass feedstock is cubic or shaped like small blocks, they may cause bridging in the hopper and reactor due to the tendency of these shapes to stack or complications with the auger system.

Overview

Conceptual overview

The Power Pallet system comprises of the ALL Power Labs' GEK TOTTI[1] series gasifier integrated with an engine coupled to a generator to produce electricity. The purpose of the gasifier is to take locally available waste biomass feedstocks and turn it into a gaseous fuel, wood gas, that is compatible for engines. The gasifier produces wood gas from cellulosic biomass feedstock by partial combustion (gasification). The wood gas is made up of about 20% H_2 and 20% CO which are both valuable gaseous fuels that the internal combustion engine consumes to generate power.



The Power Pallet has a unique advantage in providing renewable energy in markets where an abundance of local waste biomass coincides with inadequate petroleum, transportation, or electrical infrastructure.

Sequence of Processes

Each of the major processes in gasification is represented on the path from feedstock to exhaust:

- Drying— removal of moisture from the feedstock
- Pyrolysis— thermal breakdown the feedstock into tar gases and charcoal
- Combustion— burning of the tar gases to provide heat for the rest of the processes
- Reduction and tar cracking— converting the combustion products into gaseous fuel

There is a sequence of three flows through these processes:

1. the flow of solids
2. the flow of gases
3. the flow of exhaust

Extensive recovery of waste heat is one of the features that sets the Power Pallet apart, resulting in cleaner gas output as well as higher efficiency. These flow paths intersect at various points for the purpose of transferring heat from one path to another.

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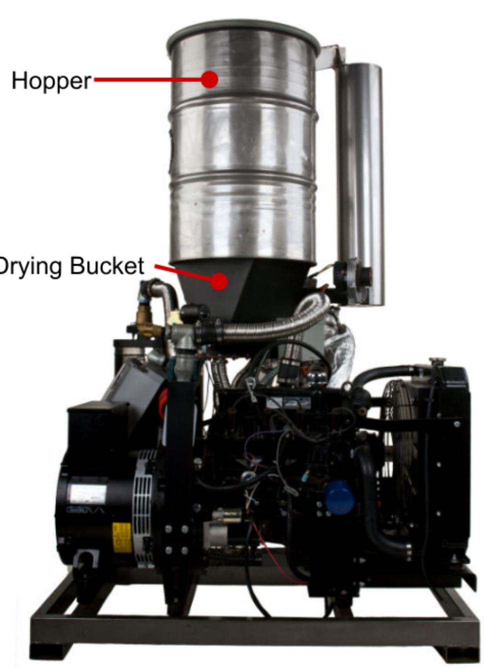
[1] GEK TOTTI is an acronym for Gasifier Experimenter's Kit, Tower of Total Thermal Integration.

Flow of Solids

The GEK TOTTI series gasifier is a radical improvement on the Imbert downdraft gasifier. The solids descend through the major zones of the gasifier by gravity, while the gases are pulled through the system by the vacuum produced by the intake strokes of the pistons in the engine. The following descriptions detail the major processes during the descent of the solid feedstock from the fuel hopper to the ash grate and how these processes convert the feedstock into wood gas[2].

Engine side of the Power Pallet



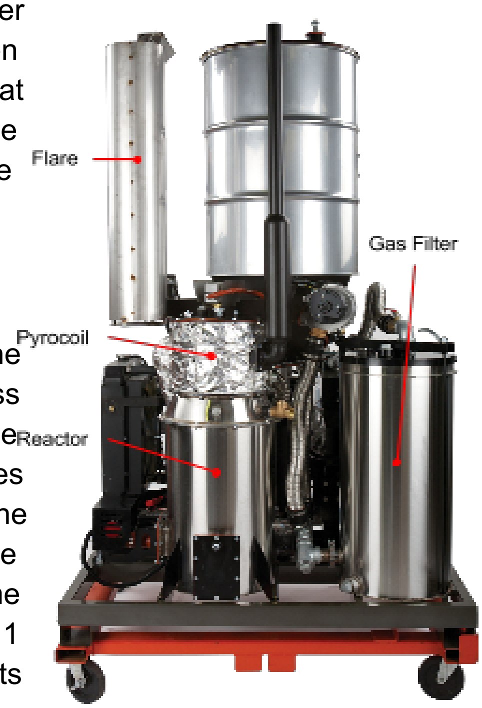
Drying

The feedstock descends by gravity from the *hopper* into the *drying bucket*. The drying bucket is a double-walled heat exchanger that assists in the drying of the feedstock at 100˚-200˚C using heat reclaimed from the wood gas. This enables the Power Pallet to gasify feedstocks with a dry basis moisture content as high as 30%.

Pyrolysis

The dry feedstock is pushed into the *Pyrocoil* by an auger. The Pyrocoil is another double-walled heat exchanger which assists pyrolysis by exposing the feedstock to even higher temperatures in the range of 300˚-600˚C using heat reclaimed from the engine's exhaust. Pyrolysis is the process by which the feedstock becomes charcoal while giving off large quantities of flammable tar gases.

Reactor side of the Power Pallet



Combustion

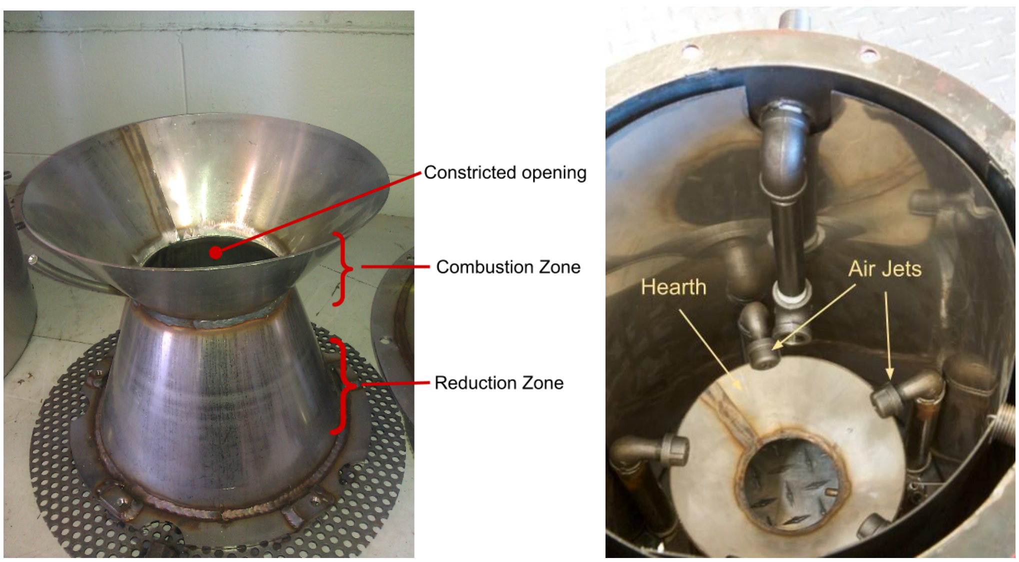
Next, the charcoal and the tar gases produced in the Pyrocoil descend into the *Reduction Bell*, an hourglass shaped passage with a constriction at the center of the gasifier. Directly above the reduction bell, five air nozzles provide a jet of preheated air to the combustion zone. In the combustion zone, the tar gases are forced through the constriction and are partially oxidized with flame temperatures ranging from 1000˚-1200˚ (See Figures 1 and 2). The heating value of the feedstock supports

[2] The term "syngas" and "wood gas" are commonly used as synonyms. In this document, we are using the term "wood gas" to avoid confusion with the additional implications of the term "syngas" as used in industry.

combustion which is the main exothermic reaction in the process. Drying, pyrolysis, reduction, and tar cracking all consume heat; and if too much heat is consumed or lost, the efficiency of the gasification process decreases. The Power Pallet's use of recovered heat from the exiting hot wood gas and engine exhaust improves the heat balance of the overall process thus increasing efficiency.

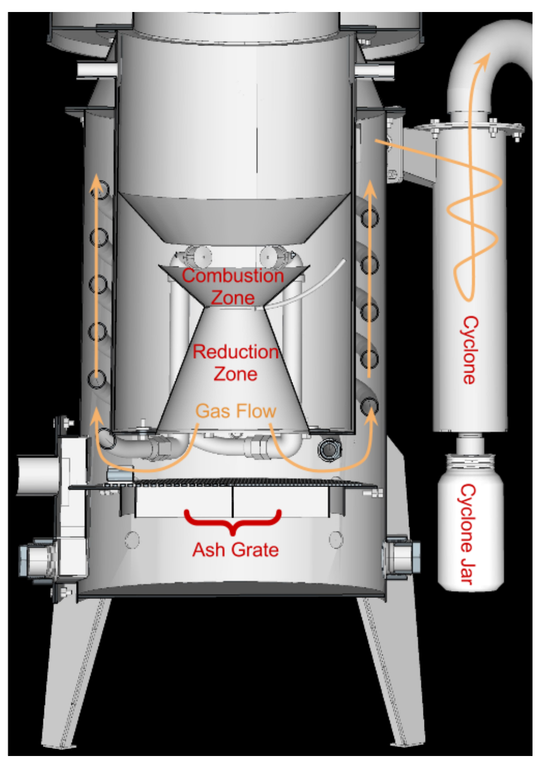
Reduction and Tar Cracking

The water vapor (H_2O) and carbon dioxide (CO_2) produced in the combustion zone pass descend through the reduction bell and pass through the hot glowing reactive charcoal in the reduction zone.



Figures 1 and 2: The reduction bell, and the reduction bell installed in a partially assembled reactor.

Due to the high reactivity of carbon at temperatures of 600-900C the tars and gases are *reduced* -by removing an oxygen atom- to H_2, CO, and some CH_4 which are clean burning gaseous fuels. This conversion of the energy-rich solid feedstock into clean-burning flammable wood gas is the ultimate objective of gasification.



In the course of the reduction reactions, the charcoal chips are consumed and shrink until they pack densely and are rich in ash, inhibiting the flow of gases through the reduction bell. The Power Pallet's sensors detect this condition, and automatically actuate the *grate shaker* to shake the ash grate until the smallest pieces of char-ash fall into the *ash pit*, restoring the flow of gases. The ash grate is the end of the flow of solids in the gasifier, and the beginning of the flow of wood gas.

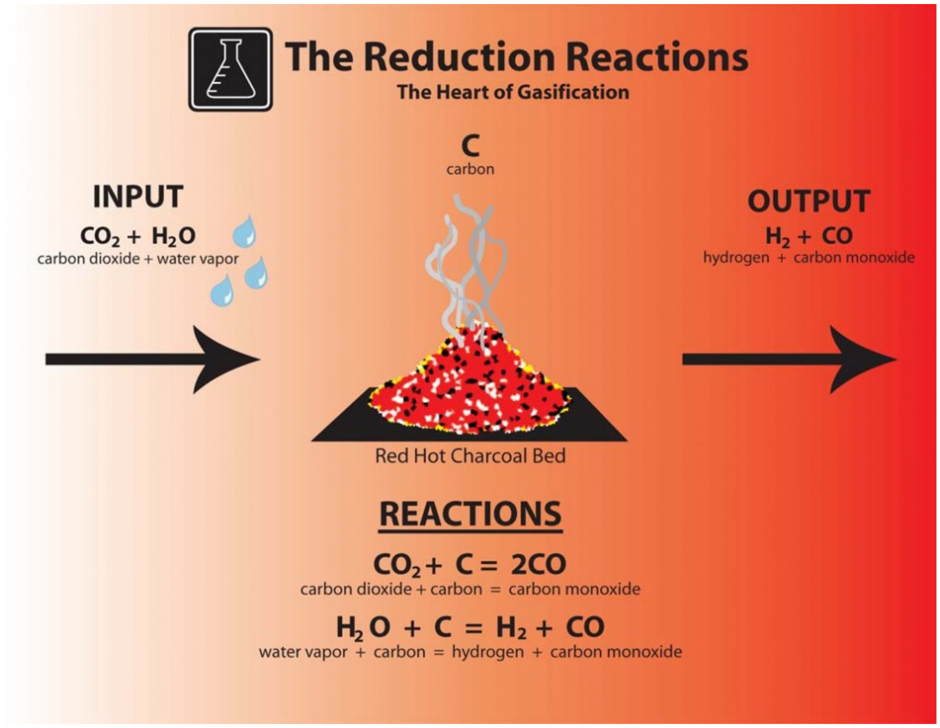


Figure 3: The reduction reactions. Charcoal is consumed converting the combustion waste gases CO_2 and H_2O into CO and H_2 gas, which burn hot and clean.

Flow of Gases

First stage of waste heat recovery: Preheating intake air

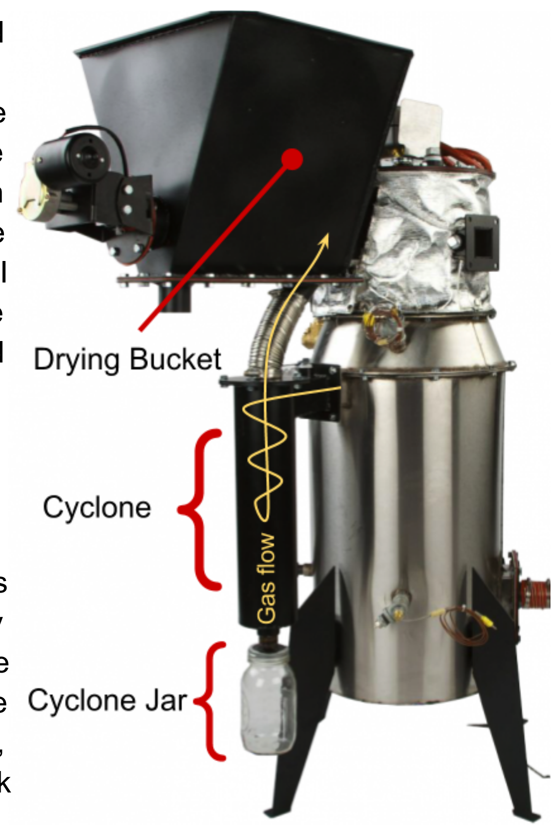
At the end of the reduction reaction, the wood gas is too hot to be used in an engine. Traditional gasifiers pass the hot wood gas through a radiator to dissipate residual heat, but the Power Pallet recovers this heat to increase its operating efficiency and the quality of the wood gas.

The flow of solids descends through the core of the reactor, ending at the ash grate. The hot wood gas then ascends through a space outside the reactor's core, exchanging heat with the *air lines*—corrugated tubes through which air flows from its intake to the air nozzles in the combustion zone. (These tubes can be seen in the cross section on the prior page. Also, see Figure 4 below.) This process not only preheats the intake air flowing towards the combustion zone, but also cools the wood gas significantly.

Figure 4: A view of the internal parts of the reactor. The air lines that pre-heat intake air using heat recovered from fresh wood gas.

Removing particulates: Cyclonic dust separation

As wood gas passes through the reduction zone and ash grate, it accumulates ash and charcoal dust, which must be separated so that they do not foul the parts of the Power Pallet downstream. Particulate removal is achieved by use of the *cyclone*, in which the gas spins in a descending vortex, causing the suspended dust and ash to separate due to centrifugal force. The wood gas then ascends out of the cyclone through a central passage as the particulates descend into the *cyclone jar*.



Second stage of waste heat recovery: Drying the feedstock

Despite the heat transfer to the air lines, the wood gas retains some residual heat, which is recovered by routing the gas into the space between the double walls of the drying bucket. This heat exchange process cools the gas sufficiently to be safely filtered, while also enabling the gasifier to tolerate feedstock with a higher moisture content.

Gas filtration

The last stage of the flow of wood gas before it is combusted in the engine is filtration. Residual tar gases condense on the filter media, protecting the engine from tar build-up. The filter uses wood chips or charcoal as the filter media. A pair of oiled foam filter discs filter the fine particulates and prevent the filter media from entraining in the gas stream. The char-ash that is cleaned from the bottom of the gasifier can be saved to use as filter media. When the filter media is spent, it can be dried and added back into the feedstock at less than 10% to recycle back into the system which eliminates tarry waste streams that are seen in other gasification systems.

Combustion of wood gas in the engine

After filtration, the clean and cooled wood gas is mixed with air, which cools it down even further. A condensate jar captures any additional condensation, and then the air-fuel mixture is drawn into the engine to be combusted for the production of power. The entry of the wood gas into the engine is the end of the flow of gases, and the beginning of the flow of exhaust.

Flow of Exhaust

Third stage of waste heat recovery: Exhaust-heat assisted pyrolysis

The engine emits exhaust at temperatures high enough to cause pyrolysis. Rather than let this energy go to waste, the Power Pallet routes the exhaust between the double walls of the Pyrocoil for heat exchange so the exhaust can bring the feedstock up to the temperatures where pyrolysis begins. When woody biomass is exposed to lower pyrolytic temperatures for an extended period of time, the result is more thorough pyrolysis and cleaner wood gas, because the tars produced in the lower pyrolytic temperature range are easier to crack.

It is important to note that the exhaust does not mix with the feedstock; it simply exchanges heat through the inside walls of the Pyrocoil. After the exhaust has deposited its useful heat into the Pyrocoil, it exits out the tailpipe.

Automation

he Power Pallet is a turn-key system with a series of pressure, temperature, current, and oxygen sensors, among others that is monitored by the *Process Control Unit* (PCU). The PCU run on an open-source Arduino software platform, which automatically controls the various physical functions required to keep the system running smoothly. These functions include:

- grate shaking, to maintain the flow of feedstock and to purge small char particles from the gasifier bed
- augering the feedstock into the system as needed

- adjusting the air-fuel mixture for the engine to ensure complete combustion of the wood gas, resulting in high efficiencies and clean emissions
- triggering an alarm if any events of concern arise

The PCU also allows for data-logging, additional input/output capability as well as the ability to modify the code for research, development and customizations. The automation system allows simple operation of the Power Pallet, and distinguishes it from other gasification systems of its class.

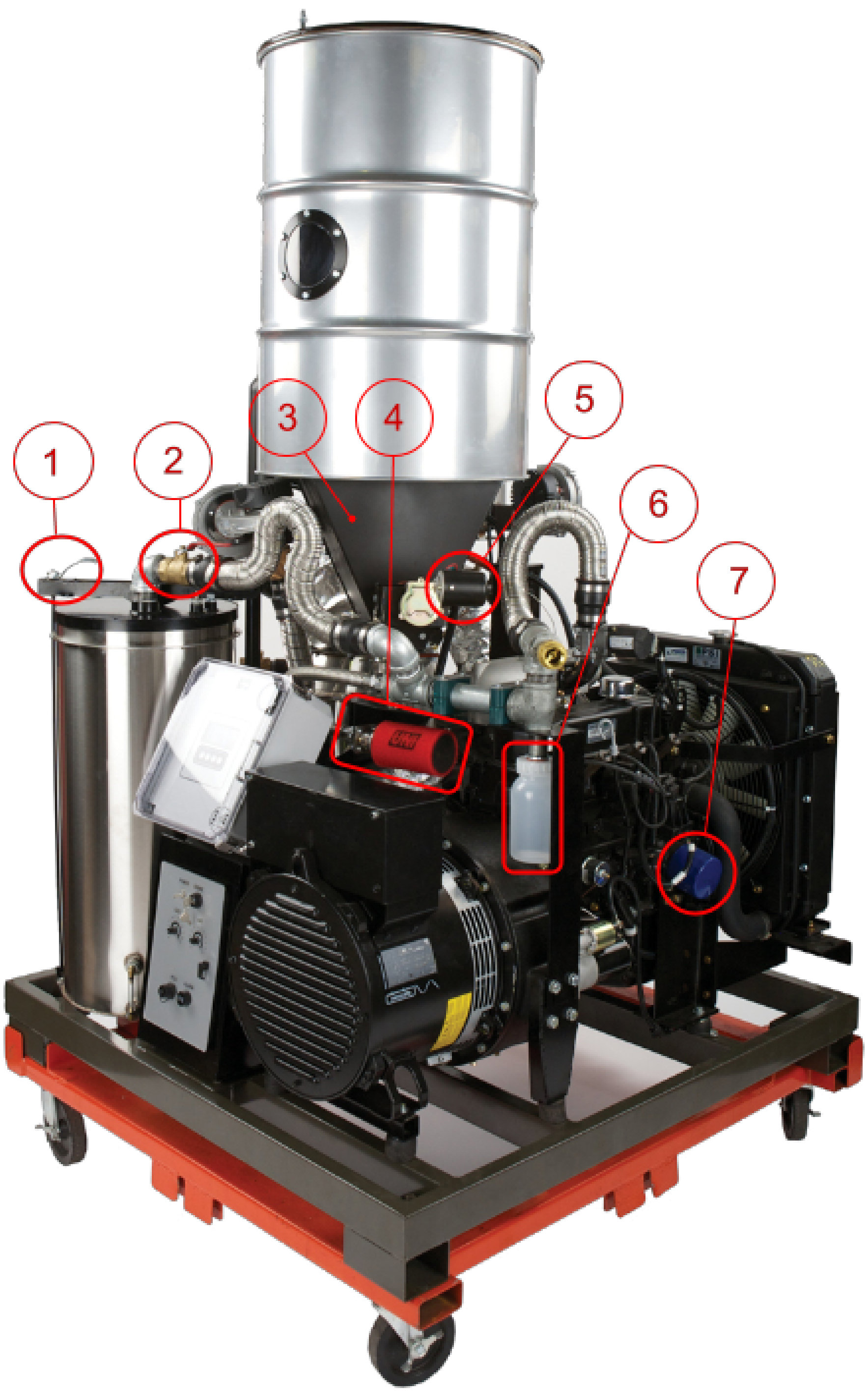
The GEK Power Pallet

The Power Pallet compactly integrates biomass gasification with a generator, using multiple levels of waste heat recovery to boost efficiency and quality of wood gas. This technology represents a significant advancement in the field of small-scale carbon-negative renewable energy. With access to affordable and waste biomass feedstocks, the Power Pallet is a powerful and cost-effective tool for achieving environmentally-sound energy independence.

Identifying Power Pallet components (Front view)

1. Feedstock Hopper
2. Gas filter (packed bed filter)
3. PCU (Process Control Unit)
4. Main Operation Panel
5. Generator
6. Electrical Connection Box
7. Exhaust Pipe
8. Dual Gas Blowers (part of flare assembly)
9. Safety Relief Valve

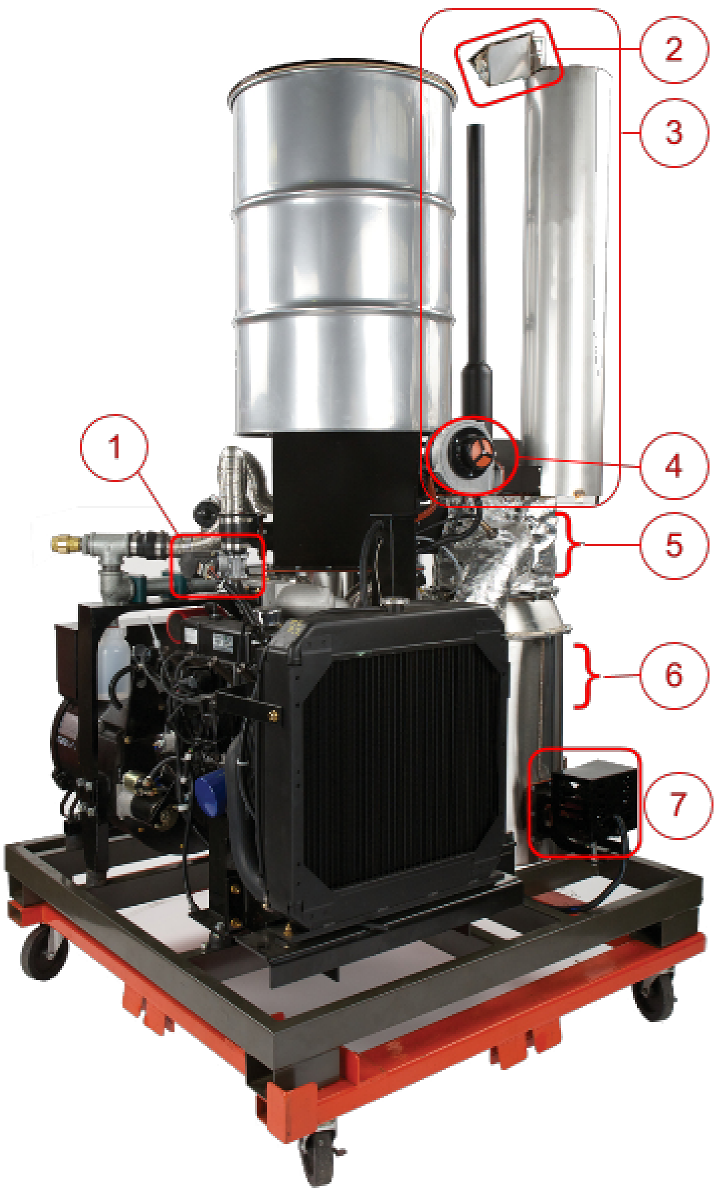
Identifying Power Pallet components (Front-side view)



1. Gas filter lid clamp
2. Gas-to-engine valve
3. Drying bucket
4. Air mixing servo valve and intake air filter
5. Feedstock auger motor
6. Condensate jar
7. Engine oil filter

Generator corner view of the 20PP

Identifying Power Pallet components (Rear-side view)

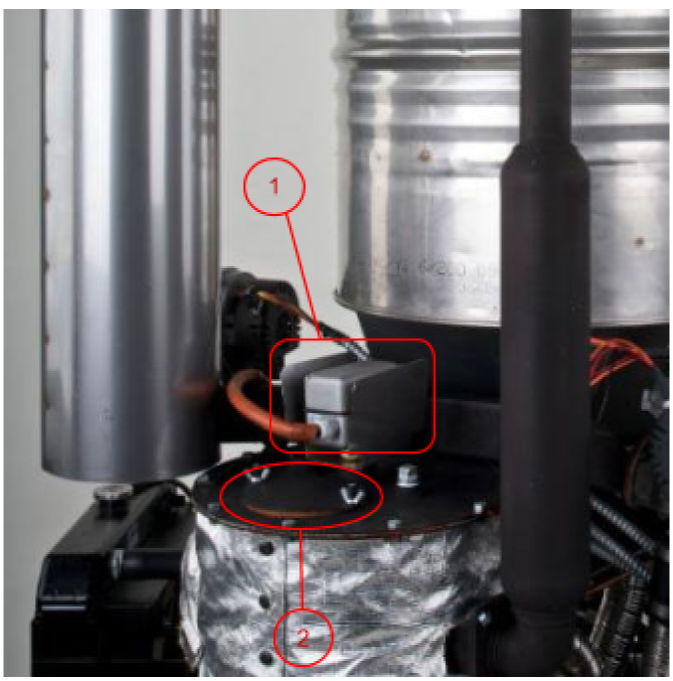


Radiator corner view of the 20PP

1. Engine governor and throttle servo valve
2. Flare igniter
3. Flare assembly
4. Air blower (part of Flare assembly)
5. Pyrocoil
6. Reactor
7. Grate shaker assembly

Identifying Power Pallet Components (Detailed Views)

- Oxygen sensor
  (Located on the exhaust conduit leading to the pyrocoil.)



1. Fuel switch
2. Reactor access port

Identifying Power Pallet components (continued)

- Lighting port, with cap
  (Located on pyrocoil, facing the gas filter.)

Identifying Power Pallet components (Control Panel)

1. Engine Hour meter
2. Air / Fuel ratio dial for oxygen sensor
3. PCU display and input buttons
4. Main power switch
5. Engine key switch
6. Gas suction adjustment knob (controls dual gas blowers on flare assembly)
7. Air blower adjustment knob (controls air blower on flare assembly)
8. USB connection port for the PCU
9. Warning alarm