ALL Power Labs

personal scale power

How the Power Pallet works

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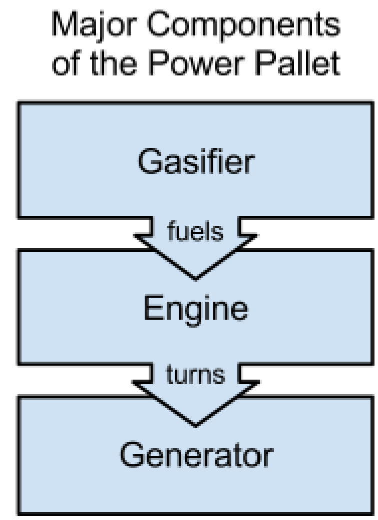
Introduction

Conceptual overview

The Power Pallet is a highly integrated gasifier generator set that gasifies cellulosic biomass using an All Power Labs' GEK TOTTI[1] series gasifier which fuels an engine that turns a generator to create electricity. This integrated system can be thought of as a generator set with a fuel refinery built onto the platform. The diesel generators the Power Pallet competes against are relatively simple only because the necessary complexity has been outsourced to large centralized petroleum refineries, with the fuel distributed over well developed infrastructure. In contrast, the Power Pallet is somewhat more complex due to the onboard gasifier, but is capable of generating power directly from locally available unrefined biomass because the gasifier serves as a refinery. Because of this, the Power Pallet has a unique advantage in providing renewable energy in markets where an abundance of local 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:

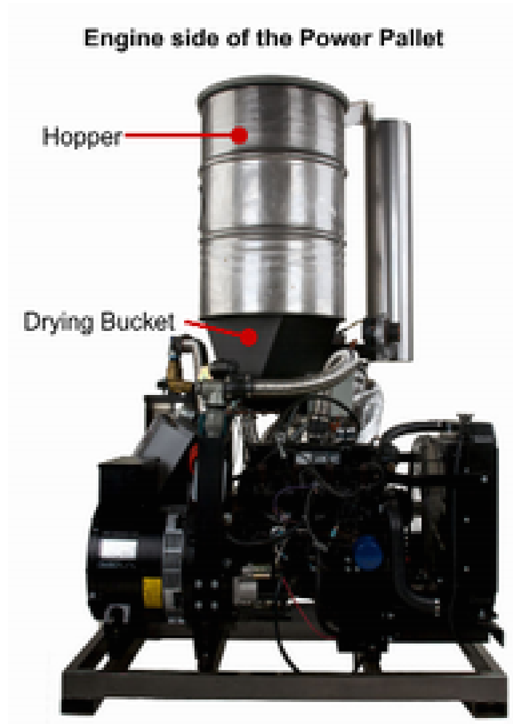
1. the flow of solids
2. the flow of gases
3. the flow of exhaust

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.

[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].

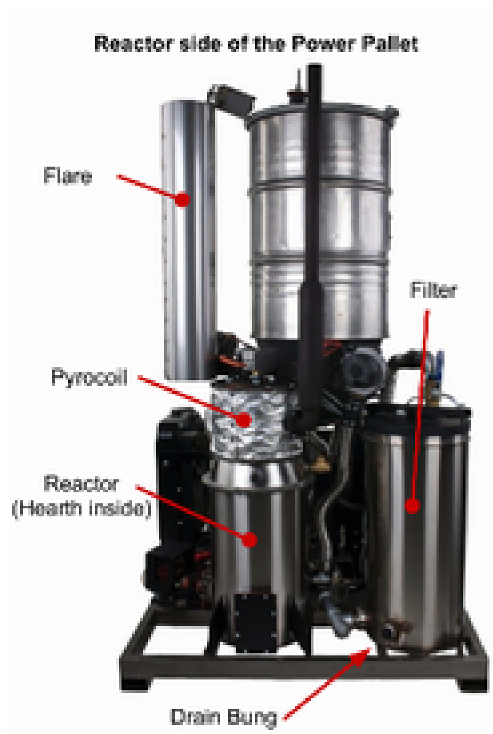


Drying

The feedstock descends by gravity from the *hopper* into the *drying bucket*. The drying bucket is a double-walled vessel that assists in the drying of the feedstock at 100˚-300˚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 a fuel auger. The pyrocoil is another double-walled vessel which initiates pyrolysis by exposing the feedstock to even higher temperatures in the range of 300˚-700˚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.



Combustion

Next, the charcoal and the tar gases produced in the pyrocoil descend into the *hearth*, an hourglass shaped passage with a constricted opening. Directly above the reactor hearth, five jets of preheated air combust a portion of the tar gases, forming the *combustion zone*, with flame temperatures ranging from 1000˚-1200˚. (See Figures 1 and 2.) Drying, pyrolysis, reduction, and tar cracking all consume heat; because gasification is so

[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.

dependent on heat, the Power Pallet's use of recovered heat to preheat the intake air increases the amount of heat available to surrounding processes.

Reduction and Tar Cracking

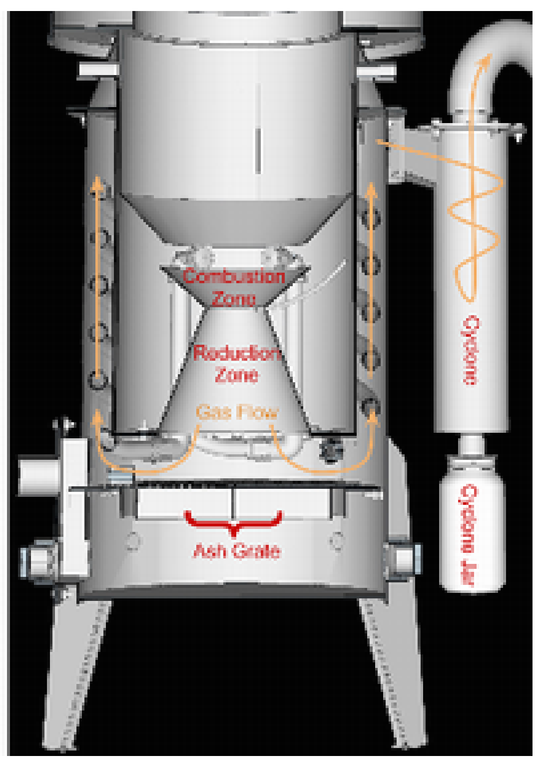
The water vapor (H_2O) and carbon dioxide (CO_2) produced during combustion pass through the hearth's constricted opening, with three effects:

1. combustion gases concentrate into a uniform zone of 800-900˚C
2. super-heated charcoal passing through the combustion zone becomes very reactive
3. the upper half of the hearth funnels unburned tar gases through the combustion zone which, when hot enough, cracks the tars all the way to H_2, CO, and some CH_4.

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

The hot charcoal (C) and the H_2O and CO_2 produced during combustion descend into the *reduction zone* of the hearth. Due to the high reactivity of carbon at these temperatures, the charcoal *reduces*–or removes an oxygen atom from–the H_2O and CO_2 as they percolate through the hot charcoal. This reaction produces hydrogen gas (H_2) and carbon monoxide (CO), both of which burn hot and clean, and do not condense into tar. 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 hearth. The Power Pallet's sensors detect this condition, and



automatically turn on 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.

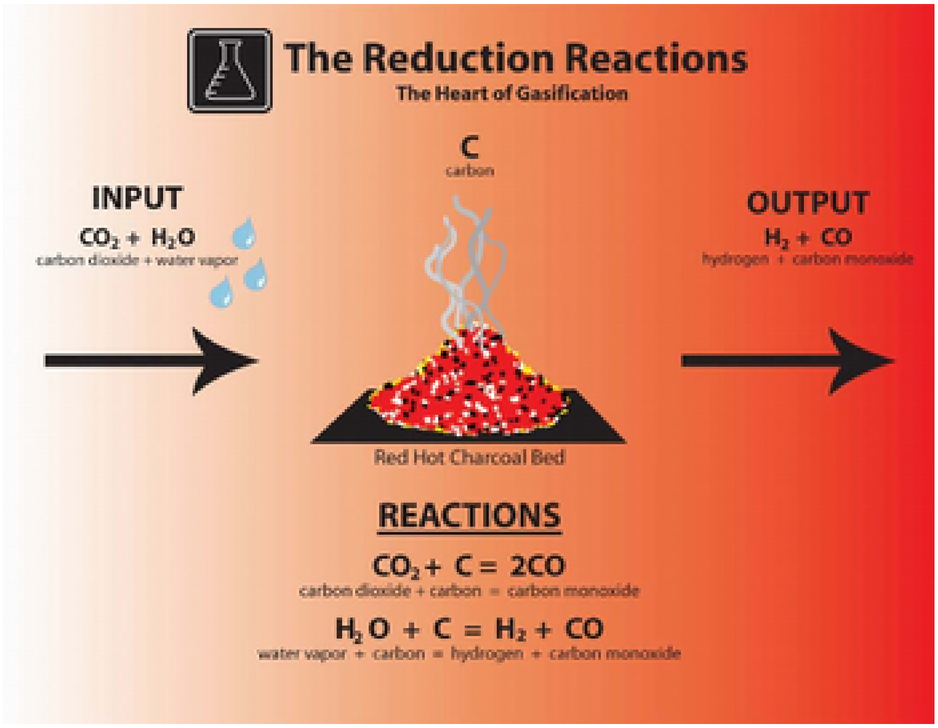


Figure 3: the reduction reactions. Charcoal is consumed converting the combustion waste gases CO_2 and H_2O into CO and H_2 gas, which burn hot and clean.

Flow of Gases

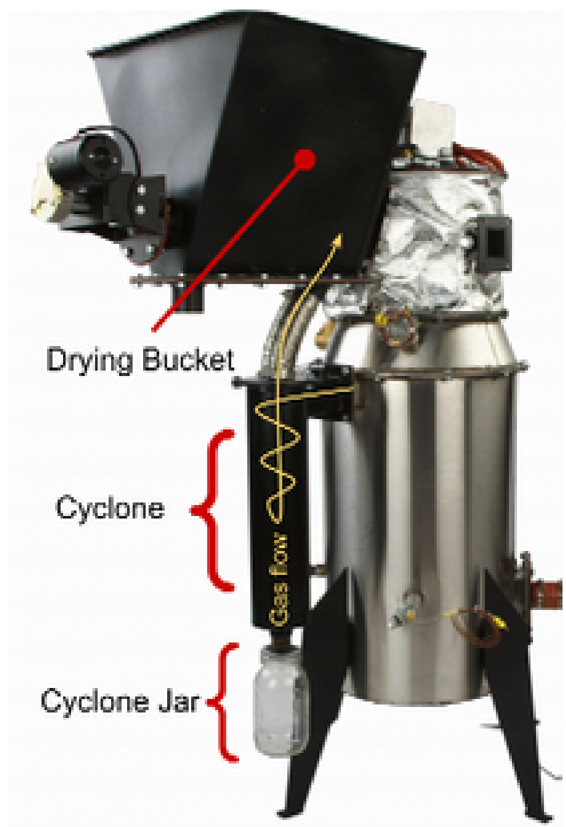
First stage of waste heat recovery: Preheating intake air

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 jets 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, which achieves two objectives:

1. Tar removal: Residual tar gases condense on the filter media, protecting the engine from tar build-up
2. Wood gas drying: residual water vapor that was not reduced also condenses out of the wood gas

The filter uses wood chips as its media, gradually progressing to sawdust towards the top of the filter. A pair of foam discs prevent sawdust from being sucked into the engine itself.

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

One of the most outstanding features of the Power Pallet is the electronic automation, which enables it to be a turn-key energy-producing system without the need for an operator standing by at all times. A series of pressure, temperature, current, and oxygen sensors, among others, send signals to the *Process Control Unit* (PCU), run on an open-source Arduino software platform, which in turn automatically controls the various physical functions required to keep the system running smoothly. These functions include:

- grate shaking, to maintain the stability of the reduction reactions
- augering the feedstock into the system as needed
- adjusting the air-fuel mixture to ensure complete combustion of the wood gas, resulting in high efficiencies and clean emissions
- triggering an alarm if any events of concern arise, such as a low-fuel state

The automation also allows for such value-adds as data-logging and spare input/output capability, permitting end users to increase the automation's functionality, along with the ability to edit the open-source code. The complexity of the electronics system is what makes the Power Pallet so simple to operate, and distinguishes it from other gasification systems.

Conclusion

The Power Pallet compactly integrates biomass gasification with a generator set, 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-neutral renewable energy. With access to affordable biomass feedstocks, the Power Pallet is a powerful and cost-effective tool for achieving environmentally-sound energy independence.