Table of Contents

1. Overview
   1.1 Notes about nomenclature and terms
      1.1.1 Feedstock, Fuel
      1.1.2 Syngas, Wood gas, Producer gas
      1.1.3 TOTTI, Pyrocoil, Pyroreactor
      1.1.4 Gasifier, Reactor
      1.1.5 Hearth, Reduction Bell
2. Feedstock Feed System
   2.1 Hopper
   2.2 Cyclone and Drying Bucket
   2.3 Auger and Fuel Level Switch
3. Annotated Figures
   Exhibit A: GEK TOTTI Gasifier with ash collection vessel
   Exhibit B: GEK TOTTI Gasifier with ash collection vessel, cont.
   Exhibit C: Gas Cowling and Pyroreactor
   Exhibit D: Gasifier cross section
   Exhibit E: Detail of Hearth and Grate Basket
4. GEK Gasifier Reactor components
   4.1 Air inlet
   4.2 Air Lines
   4.3 Air Nozzles
   4.4 Lighting Port
   4.5 Projected Hearth
   4.6 Thermocouples of the Power Pallet
   4.7 Table of Thermocouples
5. Grate Basket Shaker and Pratio
   5.1 Reading pressure values on the PCU
   5.2 Pressure Ratio Ranges and Conditions for Grate Shaker Control
6. Ash Handling
   6.1 Ash-out Auger Motor, and clearing jams
7. Gas filtration system
   7.1 Cyclone
   7.2 Packed Bed Filter
      7.2.1 Packing the gas filter
      Warning: do not operate with filter drum empty
   7.2.2 Changing the filter media
8. Flare
1. Overview

The GEK TOTTI (Gasifier Experimenter’s Kit, Tower of Total Thermal Integration) is the gasifier system at the heart of the Power Pallet. This document will introduce the major subsystems of the v5.x series GEK TOTTI gasifier in the sequence that starts from the feedstock hopper, proceeding through the drying bucket and reactor, and ends with the gas filter.

1.1 Notes about nomenclature and terms

The following are some terms you may come across in our product literature, videos, and in the course of speaking with our sales and support personnel which should be clarified to preclude confusion.

1.1.1 Feedstock, Fuel

The GEK TOTTI Gasifier onboard the Power Pallet is a refinery that takes crude biomass in the hopper and refines it into a clean-burning gaseous fuel for the engine, while producing char-ash as a waste product. In engineering parlance, material fed into a refinery to drive a chemical process would be called feedstock, and the refined product going into the engine would be called fuel. However, from the perspective of the user of the Power Pallet, the machine is fueled by biomass. Because of this, you may find the terms feedstock and fuel used interchangeably. For example, the paddle switch on top of the Pyroreactor that regulates the feeding of biomass into the Pyroreactor is called the fuel level switch (see Annotated Figure A), but in most of our literature, the biomass is referred to as feedstock.

1.1.2 Syngas, Wood gas, Producer gas

The terms syngas (short for synthesis gas), wood gas, town gas and producer gas can be found in various literature on gasification. Each term has a few implications that differentiate it from the others:

- syngas (synthesis gas) refers to a gas mixture of CO (carbon monoxide) and H\(_2\) (hydrogen) produced by reduction reactions where carbon is the reducing agent. Syngas is often used as a chemical precursor for the synthesis of other organic chemicals. Because of its use as a precursor for chemical synthesis in industry, this term usually implies a level of purity and concentration not seen in gas produced by air-aspirated biomass gasifiers.
- **wood gas** refers to gas produced by the gasification of wood. Wood gas is also rich in CO and H₂, but may also contain tar gases, and may be diluted with nitrogen gas if the gasifier was aspirated with atmospheric air. However, since the Power Pallet does not necessarily gasify wood, and can be used to gasify various other feedstocks such as palm kernel shells, nut shells, and other biomass, we do not use this term in order to avoid implying the need for wood.
- **producer gas** is a term generic enough to encompass wood gas, syngas, and other produced gasses.

We will be using the term *producer gas* throughout our documentation because it most accurately describes the product from our gasifier.

### 1.1.3 TOTTI, Pyrocoil, Pyroreactor

The terms **TOTTI**, **Pyrocoil**, and **Pyroreactor** refer to parts of the engine exhaust waste heat recovery system. Some of these terms are legacy terms not relevant to the present machine, but still show up in discussions and literature, and bear clarification.

The term TOTTI in GEK TOTTI stands for “**Tower Of Total Thermal Integration**.” The original GEK gasifier only incorporated one stage of waste heat recovery—recoving heat from producer gas to preheat incoming air. Later on, an addition to the gas circuit which we deemed the “Hot TOTTI” was developed to recover the heat from engine exhaust for pyrolysis and to enhance feedstock drying with more heat recovered from the producer gas. The combined GEK gasifier with the TOTTI heat recovery system was called the GEK TOTTI.

The TOTTI structure consisted of two major components, both of which recovered waste heat: the **Pyrocoil**, and the **drying bucket**. The Pyrocoil recovered heat from engine exhaust to create conditions for lower pyrolytic temperatures (400˚-600˚) that result in primary tars, which are easier to crack. The drying bucket was a waste-heat-assisted drying vessel which enabled the gasifier to tolerate feedstock with higher moisture content. The Pyrocoil was inserted into the reactor of the GEK, and received feedstock pushed in by the auger at the bottom of the drying bucket via an inlet on its side.

In the current version of the GEK TOTTI, the Pyrocoil has been integrated into the reactor to form a new and improved structure we call the **Pyroreactor**. Because the Pyrocoil is no longer a...
distinct component, the TOTTI is no longer a distinct part of the gasifier. The name GEK TOTTI is now used as a brand.

1.1.4 Gasifier, Reactor

The reactor is the component of the gasifier that actually produces gas. When speaking of the structure circled in the image of the Power Pallet below, the terms gasifier and reactor are sometimes used interchangeably in our literature. In its entirety, the GEK TOTTI gasifier system includes the feedstock hopper, the drying bucket, the Pyroreactor, the gas cowling, the cyclone, the gas filter, and the flare system. The portion circled in the following graphic shows the Pyroreactor installed into the gas cowling; these together form the structure that is referred to as the gasifier or reactor when speaking of components of the Power Pallet.

This structure is referred to as the **gasifier** or **reactor**, since this is where the gas is actually produced.

It consists of the PyroReacter (top portion) inserted into the gas cowling (lower portion).

Behind the gasifier access panel on the PP20-GTE

1.1.5 Hearth, Reduction Bell

The term reduction bell may appear in our literature or in postings on our online forums. This term is a legacy term and does not apply to the current generation of the GEK TOTTI gasifier. In the original GEK gasifier, reduction reactions were primarily contained in a truncated cone-shaped device called the **reduction bell**. In subsequent revisions of the design, the reduction
bell became integrated with another truncated cone that contained the combustion zone. This combined combustion/reduction structure was known as the *hearth*, which was used interchangeably with the term reduction bell. The old hearth is shown below, next to the new hearth. The new hearth carries out reduction throughout the grate basket, and does not have a reduction bell; as such, the term *reduction bell* is now obsolete.

A comparison of the version 4 series hearth and the version 5 series hearth currently in use. The version 5 hearth is a projected hearth which is supported only from above, and does not have a reduction bell; reduction reactions become the dominant process starting under the combustion zone, and continue throughout the grate basket.
2. Feedstock Feed System

2.1 Hopper

The Power Pallet comes with a hopper barrel for holding feedstock. The hopper is attached to the top of the drying bucket with a silicone gasket and bolts. The hopper barrel lid is sealed at the top with a lever lock. A puff bung (a pressure relief valve) is threaded in the hopper barrel lid to release the pressure from puff events in the rare case where flame back-propagates and ignites combustible gases that may have diffused back into the hopper.

2.2 Cyclone and Drying Bucket

The producer gas exits the reactor between 250°-400°C and enters the cyclone for dust removal. The cyclone behaves like those used for dust separation in vacuum cleaners: gases spin in a descending vortex, then ascend through a central tube while the heavier suspended particles separate out by centrifugal force and descend into the cyclone ash can. After the cyclone, the gas flows through a passage between the double walls of the drying bucket; this
heat exchange stage recovers waste heat to dry the feedstock while simultaneously cooling the producer gas to temperatures suitable for the filter and engine. This specialized drying stage enables the Power Pallet to tolerate feedstocks with moisture contents as high as 30% when powering a high load. The gas does not come in contact with the drying feedstock; only heat is exchanged between the gas and the feedstock. In addition to improving heat exchange, the baffles between the walls of the drying bucket also help any suspended dust settle out of the gas stream.

The GEK TOTTI is intentionally designed with a structural separation between the drying zone from the pyrolysis zone. This results in more efficient tar cracking and cleaner producer gas by allowing the drying and pyrolysis to occur at different and more optimal temperatures.

2.3 Auger and Fuel Level Switch

The auger assembly, located toward the bottom of the drying bucket, includes a 12VDC motor that is powered by the 12 starter battery (not included) on the Power Pallet, and a flexible steel auger helix. The flexible auger is able to deal with some inconsistencies in feedstock and affords a greater margin of safety in the case of fuel jams. Feedstock outside of the recommended size range of ½” to 1 ½” size are difficult for the auger system to handle. The auger may not be able to handle longer slivers, easily entangled pieces, or cube-shaped feedstock. Any feedstock outside of the specified parameters may cause jams, bridging or other problems downstream of the auger regardless of how well the auger itself moves the feedstock.

The auger spiral is installed at a slight angle (about 5˚) downward so that it meets the bottom floor of the drying bucket as it enters into the reactor. Because of friction from this contact, the auger may cause a screeching noise against the drying bucket if the drying bucket is empty.

The auger motor is controlled by the fuel level switch (See Annotated Figure A); this switch leaves the auger motor on until feedstock pushes up against the stainless steel paddle of the switch, which turns the auger motor off. The sensitivity of the fuel level switch is adjusted through calibration.

The PCU detects the auger state and current to make determinations about auger performance. The logic can detect possible bridging, low fuel states, or jamming conditions. The auger circuit has two relays, one for controlling forward motion and one for reverse (used to help dislodge jams), each protected by 15A fuses located adjacent to the relays on the relay board under the PCU. (See Section 4: Automation Assembly for details.)

2.3.1 Calibrating the Fuel Switch

Calibration is done prior to assembly and installation on Power Pallet.

1. If switch rod and magnet are not concentric with switch body, bend corrugations by hand until switch rod rests at center.

2. After the switch rod is centered, drop Limiter Tube into switch body over the switch rod so that it sits inside corrugations. It should easily slide in and then slide out when the switch is inverted.
3. Bolt on Top Flange.
4. Screw in Reed Switch Assembly until the brass stud gently contacts the top of the magnet rod.
5. Unscrew the reed switch assembly 1/2 turn and tighten the stainless jam nut to prevent further movement.
6. Check the functionality of the assembled switch with a multimeter by testing continuity through the reed switch assembly leads. While connected to the multimeter, push gently on the paddle while keeping the flex switch body stationary and in the vertical upright position. The circuit should open when the paddle is pushed to about 3/4 of its total range of motion in the direction of fuel flow (90 degrees perpendicular to the face of the paddle).

2.3.2 Installing the Fuel Switch

Thread the switch into the top of the reactor fuel switch bung until hand tight. Use a pipe wrench to further tighten the switch until the indicator notch on switch bottom flange is directly opposite of the side of the drying bucket. This ensures the switch paddle face is in a normal position relative to the direction of fuel flow from the drying bucket. Be very careful not to twist Reed Switch wire while installing. Once installed, thread the wire through the third grommet from the top on the left side (gasifier side) of the central conduit, and plug it into the fuel switch terminal.

Be sure the notch is pointed away from the drying bucket.
3. Annotated Figures

Exhibit A: GEK TOTTI Gasifier with ash collection vessel
### Section 3 - GEK TOTTI Gasifier System

<table>
<thead>
<tr>
<th>Label</th>
<th>Description</th>
<th>Label</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Fuel Level Switch</td>
<td>5</td>
<td>Ash removal system motor</td>
</tr>
<tr>
<td>2</td>
<td>Inlet from drying bucket</td>
<td>6</td>
<td>Reactor access door</td>
</tr>
<tr>
<td>3</td>
<td>Exhaust inlet to Pyroreactor</td>
<td>7</td>
<td>Air inlet with check valve</td>
</tr>
<tr>
<td>4</td>
<td>Grate basket shaker motor</td>
<td>8</td>
<td>Ash collection vessel</td>
</tr>
</tbody>
</table>

---

770-00086 Section 3_GEK TOTTI Gasifier System (PP20) Rev B
770-00083 Power Pallet Technician's Handbook (PP20/v1.09) Rev B
Exhibit B: GEK TOTTI Gasifier with ash collection vessel, cont.

<table>
<thead>
<tr>
<th>Label</th>
<th>Description</th>
<th>Label</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Ignition port (shown with extension)</td>
<td>4</td>
<td>Pyroreactor viewport</td>
</tr>
<tr>
<td>2</td>
<td>Outlet to exhaust stack</td>
<td>5</td>
<td>Cyclone</td>
</tr>
<tr>
<td>3</td>
<td>Ash removal port</td>
<td>6</td>
<td>Cyclone ash can</td>
</tr>
</tbody>
</table>
Exhibit C: Gas Cowling and Pyroreactor

The Pyroreactor fits into the gas cowling in the assembled gasifier.

<table>
<thead>
<tr>
<th>Label</th>
<th>Description</th>
<th>Label</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Gas cowling (inner vessel)</td>
<td>5</td>
<td>Inlet from drying bucket</td>
</tr>
<tr>
<td>2</td>
<td>Gas cowling insulation shroud</td>
<td>6</td>
<td>Air lines</td>
</tr>
<tr>
<td>3</td>
<td>Ash-out auger</td>
<td>7</td>
<td>Projected hearth</td>
</tr>
<tr>
<td></td>
<td>Grate basket shaker motor</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Section 3 - GEK TOTTI Gasifier System
Exhibit D: Gasifier cross section

<table>
<thead>
<tr>
<th>Label</th>
<th>Description</th>
<th>Label</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>$P_{comb}$ pressure barb</td>
<td>6</td>
<td>Air lines</td>
</tr>
<tr>
<td>2</td>
<td>Lighting tube</td>
<td>7</td>
<td>Projected hearth</td>
</tr>
<tr>
<td>3</td>
<td>Pyrolysis column</td>
<td>8</td>
<td>Grate basket</td>
</tr>
<tr>
<td>4</td>
<td>Air nozzles</td>
<td>9</td>
<td>Ash scroll</td>
</tr>
</tbody>
</table>
Exhibit E: Detail of Hearth and Grate Basket

Cross-section detailed view of grate basket and ash handling system

Transparent top view of ash handling system

<table>
<thead>
<tr>
<th>Label</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Label</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td></td>
</tr>
</tbody>
</table>
4. GEK Gasifier Reactor components

Please refer to the annotated figures on the prior pages for images of the parts described below.

4.1 Air inlet
(See Annotated Figure A)
The air inlet is a check valve allows air to enter the system when the gasifier is operating and under suction, but does not allow expanding hot producer gas to escape out through the inlet during shutdown.

4.2 Air Lines
(See Annotated Figures C and D)
After entering the air inlet, the air is divided among the five corrugated air lines that spiral around the outside of the reactor. The air lines are the first stage of waste heat recovery; they preheat the incoming air while cooling the producer gas. The recovered heat increases the temperature of incoming air to about 600˚C, which contributes to hotter combustion and improved tar cracking.

4.3 Air Nozzles
(See Annotated Figure D)
The air nozzles experience the hottest temperatures in the reactor as they introduce the air into the combustion zone; temperatures in the range of 1200˚C are often found directly in front of the nozzles. The air nozzles are oriented directly at the center of the column, right above the projected hearth.

4.4 Lighting Port
(See Annotated Figure B)
This port allows the operator to light the feedstock in the reactor with a small propane torch during start-up. This port is to be closed when the temperature indicated for the display variable Trst (Temperature at the restriction) on the PCU display is 100˚C or above.

4.5 Projected Hearth
(See Annotated Figure D)
The projected hearth is the heart of the version 5 of the GEK TOTTI gasifier, which is used on the Power Pallet version 1.08. This structure begins at the bottom of the pyrolysis column and projects into the grate basket. Its shape regulates the flow of solids and gasses for the key chemical processes of gasification—combustion, tar cracking and reduction.
Combustion occurs in the area above the restriction in the projected hearth; a portion of the tar gases and charcoal are combusted by the introduction of preheated air. The restriction in the hearth funnels all of the combustion gases and unburned tar gases together to homogenize the temperature while causing the tar gases to flow through a concentrated hot spot of about 800°-900°C, resulting in efficient tar cracking—the thermal decomposition of these tars into CO and H₂ gas. Tar cracking is necessary for reducing the tar content of the gas and to make the gas compatible with internal combustion engines; even though tar gases are combustible, they can badly foul an engine by condensing into a thick sticky substance, and must either be burned, cracked, or filtered out to protect the engine from fouling.

Reduction is an endothermic process that converts the CO₂ and H₂O, produced during the combustion of tar gasses and charcoal produced during pyrolysis, into clean burning gases that are suitable for use in the engine. The carbon from the hot charcoal in the reduction zone has a very high oxygen affinity, and will react with CO₂ and H₂O according to the following reactions:

\[
\text{CO}_2 + \text{C} + \text{heat} \rightarrow 2\text{CO}
\]

\[
\text{H}_2\text{O} + \text{C} + \text{heat} \rightarrow \text{CO} + \text{H}_2
\]

The CO and H₂ (and some methane, CH₄) are the combustible gases that make up approximately 40-50% of the volume of the producer gas; the rest of the volume consists of non-flammable N₂ from the air aspirating the gasifier, and any unreduced CO₂ and H₂O.

4.6 Thermocouples of the Power Pallet
The Power Pallet comes with three ungrounded type K thermocouples to monitor the reactor and engine coolant temperature. The following table indicates the location, temperature ranges during normal operation, and other technical specifications.

### 4.7 Table of Thermocouples

<table>
<thead>
<tr>
<th>Display Variable</th>
<th>Trst</th>
<th>Tred</th>
<th>Tcoolant</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abbreviation of:</td>
<td>Temperature at the restriction</td>
<td>Temperature of reduction</td>
<td>Temperature of coolant</td>
</tr>
<tr>
<td>Specific Location</td>
<td>Inside a steel sleeve; measures under the restriction of the hearth</td>
<td>Inside a steel sleeve; measures at the top of the grate basket</td>
<td>Top of engine coolant circuit, before coolant enters radiator.</td>
</tr>
<tr>
<td>Steady-state operating temp.</td>
<td>800˚–1000˚C</td>
<td>700˚–800˚C</td>
<td>&lt;100˚C</td>
</tr>
<tr>
<td>PCU Port</td>
<td>T0</td>
<td>T1</td>
<td>T2</td>
</tr>
<tr>
<td>Thermocouple Specs</td>
<td>K-type, 1/16&quot; dia. x 24&quot; L</td>
<td>K-type, 1/16&quot; dia. x 24&quot; L</td>
<td>K-type Pipe Plug Probe</td>
</tr>
</tbody>
</table>
See the troubleshooting guide at the end of the Section for instructions on how to test the thermocouples.

5. Grate Basket Shaker and $P_{\text{ratio}}$

Onboard the Power Pallet, the only direct influence the PCU exerts on the gasifier is the timing and triggering of the grate basket shaker. A reciprocating mechanism driven by the grate basket shaker motor causes the basket to rapidly rotate back and forth about 15° on its vertical axis, and is programmed to shake the grate for a period of three seconds once every five minutes. The shaking of the grate basket serves two purposes:

1. the periodic shaking cause the column of char bearing down on the activator cone (see Figure E, item 4) to settle and descend down and radially outwards into the grate basket as the char is consumed by reduction reactions. The settling of char into the basket moves char through the combustion zone, preventing any char from residing in the hottest zone for too long. The agitation of the char pieces and the shorter residence time in the hot zone reduces the risk of ash fusion and clinker formation.
2. the reciprocating motion causes ash and small particles of char to migrate down toward the bottom of the basket, where the smallest pieces fall through the holes to be removed as char-ash.

Besides the periodic shaking, which is timed, the PCU also determines whether small char pieces are choking the flow of gas through the char basket by calculating $P_{\text{ratio}}$ (Pressure ratio, displayed as $Pratio$ on the PCU screen), which is a parameter that indicates how much of flow restriction is being imparted on the gas by the char bed.

$P_{\text{ratio}}$ is calculated as the following:

$$P_{\text{ratio}} = \frac{P_{\text{comb}}}{P_{\text{react}}} \times 100$$

where $P_{\text{comb}}$ stands for the pressure above the combustion zone, and $P_{\text{react}}$ stands for the pressure in the reactor after the gas has passed through the grate basket. They are displayed as $P_{\text{comb}}$ and $P_{\text{react}}$ on the PCU screen. The following graphic indicates where these two pressure readings are taken from.
When $P_{\text{ratio}}$ is too low, it indicates flow restriction due to small char pieces; to correct for this flow restriction, the programming accelerates the countdown timer to trigger grate shaking sooner in order to purge the small pieces of char. When $P_{\text{ratio}}$ is too high, it indicates that bridging is occurring inside the reactor, and is preventing char from filling the grate basket.

The variables from which regulate the countdown timer for the grate shaker and how to adjust them are explained in Section 5: Software.

The pressure readings on the Power Pallet are as follows:

<table>
<thead>
<tr>
<th>Display variable</th>
<th>$P_{\text{comb}}$</th>
<th>$P_{\text{react}}$</th>
<th>$P_{\text{filt}}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abbreviation of:</td>
<td>Pressure at the combustion zone</td>
<td>Pressure of the reactor</td>
<td>Pressure at the filter</td>
</tr>
<tr>
<td>Specific Location</td>
<td>Reading taken at the top of ignition tube, which leads to the top of the</td>
<td>Reading taken at the gas outlet from the reactor right before it enters the</td>
<td>Reading taken at the top of the filter.</td>
</tr>
</tbody>
</table>
Section 3 - GEK TOTTI Gasifier System

<table>
<thead>
<tr>
<th>PCU barb</th>
<th>P2</th>
<th>P0</th>
<th>P1</th>
</tr>
</thead>
</table>

5.1 Reading pressure values on the PCU

The numbers the PCU uses to represent the magnitude of vacuum for its pressure readings stand for measurements in a rather unusual unit: tenths of an inch of water column. The use of this unit of vacuum pressure comes from the legacy of the manually operated GEK gasifiers, which had water filled manometer tubes indicating the level of vacuum, as measured off of a scale marked off in inches. These units happen to be very conveniently scaled for the purpose of operating our gasifiers, since most of the pressures encountered in our gasifier fall between 1 and 12 inches of water column.

The following table shows the various ranges that the pressure measurements can fall under, and the interpretation of what these various values of $P_{\text{ratio}}$.
5.2 Pressure Ratio Ranges and Conditions for Grate Shaker Control

<table>
<thead>
<tr>
<th>Pressure Ratio (Pratio)</th>
<th>Condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;30</td>
<td>Lower boundary: gas flow when Pratio is &lt;30 is likely to be restricted due to fine char accumulating in the grate basket. This condition may also be caused by clinkers.</td>
</tr>
<tr>
<td>30-60</td>
<td>good: ideal operating conditions</td>
</tr>
<tr>
<td>&gt;60</td>
<td>Upper boundary: reduction bell is empty, or feedstock is too coarse; possibly out of feedstock, or feedstock is bridging in reactor</td>
</tr>
</tbody>
</table>

The design of the version 5 GEK TOTTI reactor has largely eliminated low Pratio problems. However, if you encounter bad Pratios while operating your Power Pallet, please see the troubleshooting section at the end of this Section for how to address problems indicated by Pratio. Low Pratios usually indicate that small char pieces are accumulating in the grate basket, whereas high Pratios usually indicate that bridging somewhere in the column is preventing char from descending into the grate basket.

It is possible to manually turn the grate shaker on and off via the buttons and user interface of the PCU. See the Section on Automation for this procedure.

6. Ash Handling

The ash handling system of the v5 GEK TOTTI consists of the scroll plate, the ash-out auger and its motor, and the ash collection vessel. (See Annotated Figure E for the top/ghosted view of what the ash handling system looks like. All of the items in this section refer to this annotated figure.) As the grate basket is shaken, char ash accumulates on the floor of the reactor under the basket. Once there, the following sequence removes the char-ash:

- the scroll plate periodically rotates and pushes the char-ash out towards the walls of the gas cowling
- the scroll plate also pushes char-ash that is already against the walls of the gas cowling along the walls until it falls into the opening on the side of the auger tube. (This opening resides behind the reactor access door facing the inside of the reactor.)
the auger pushes the char up the tube toward the ash collection vessel, where it accumulates.

The ash collection vessel has enough capacity to store the char ash from approximately 24 hours of Power Pallet operation, with variation due to load and feedstock qualities.

6.1 Ash-out Auger Motor, and clearing jams

Both the ash-out auger and the scroll plate are driven by the ash-out auger motor. The motor turns the auger, and the auger turns the scroll plate by pushing against the teeth along the edge of the scroll plate. In the case of an obstruction jamming the moving parts, a current sensing circuitry detects the resistance against the motor and the PCU cycles the motor back and forth to clear the blockage. If the blockage cannot be cleared by cycling, the machine will sound an alarm and indicate this blockage on the PCU. Such blockages may need to be cleared manually.

Before manually clearing an obstruction in the ash handling system, the operator should ensure good ventilation in the work area; clearing jams in the ash handling system involves opening the reactor, which may expose the operator to carbon monoxide if there is insufficient ventilation. First turn off the Power Pallet and let it fully cool down, then open the reactor access door. Let any gases in the reactor vent out and away, then scoop out any char near the access door. The operator should be able to find any obstructions by reaching around the auger tube and feeling along the edge of the opening, where hard material may have become pinched between the auger and the edge of the opening in the tube. Visual inspection may reveal obstructions preventing the scroll plate from turning. Ensure an air-tight seal when replacing reactor access door; air leaks are hazardous to the machine.

7. Gas filtration system

The gas that emerges from the reactor will contain fine particulates, some uncracked tar gases, and water vapor. To mitigate these contaminants, the v5.x GEK TOTTI gasifier has a much improved reactor design that optimizes tar cracking and offers maximal area for gas percolation through the char, lessening high speed flow near the char bed that is more likely to entrain fine particles. However, on the occasions where the gasifier may not be operating in its ideal temperature range for tar cracking, and to capture any residual dust that does become entrained in the gas stream, the system must still protect the engine from these contaminants. It does so by removing dust using the cyclone, filtering out tar with the packed-bed filter, and collecting condensation from the cooling producer gas using a condensate vessel.

7.1 Cyclone
After the producer gas leaves the gasifier, it is directed into the cyclone, where it cools and spins to separate out particles of charcoal dust and condensation from the temperature drop. The condensate and particulates descend and accumulate in the cyclone ash can at the bottom. (See Annotated Figure B) The can, which has enough capacity to support 24 hours of operation, should be emptied each time before starting the Power Pallet. When reattaching the cyclone ash can, it is important to establish an airtight seal, since air leaks are hazardous to the gasifier.

7.2 Packed Bed Filter

The packed bed filter is a 25 gal (94 liters) canister that is to be filled with sifted biomass or charcoal as its filter media. The filter separates out any particulates, tar that survived tar cracking, or condensate that failed to be captured through the cyclone; as the producer gas ascends through the filter, it cools further and condenses residual tars onto the sifted biomass.

The filter comes with two perforated disc screens; one to hold the filter media off the bottom of the filter canister, and one to hold down the two oiled foam discs that come with the filter, which rest on top of the filter media to trap dust particles. The top perf disc is especially important because it holds the foam discs down against the suction of the engine. Without this disc, the vacuum from the engine will pull the foam into the gas outlet, causing a serious bottleneck for the gas to travel through that will ultimately choke the engine.

Note: The images shown below are for the PP20 and PP25. The PP25 has a square filter, but the instructions are the same.

![Perforated discs and foam filters that come with the gas filter.](image)

7.2.1 Packing the gas filter

1. Set one of the screens on the tabs that are about 5 inches (13 cm) above the bottom. This 5 inch space below the filter media bottom grate is reserved for collecting condensate in the filter. The level of condensate can be checked through the condensate level indicator tube.
Condensate may be drained through the gas inlet at the bottom of the filter.

2. Add the layers of sifted biomass as shown in the image above.
3. Insert the black (coarse, 45 dpi) foam disc, then the green (fine, 65 dpi) foam disc, and then gently insert the perforated steel screen on top. Be careful to not damage the gasket around the upper lip of the filter drum when inserting and removing the screen.

4. Be sure not to overfill the filter. There should be a 2 inch (5cm) space at the top of the filter.

The filter is only designed for filtering gas produced from cellulosic biomass. The filter is not sufficient for filtering the gas products of coal, peat, plastics, or municipal solid waste (MSW); none of these feedstocks are suitable for use in the GEK TOTTI.
Warning: do not operate with filter drum empty

*Do not* attempt to operate the Power Pallet with an empty gas filter drum. Running the system with an empty gas filter could be hazardous to the user and the machine; air inside the empty filter drum will mix with gas entering the drum, and any stray spark or static could violently ignite the mixture.

7.2.2 Changing the filter media

The filter media gradually accumulates tar and needs to be checked and changed as necessary. The filter media should be checked weekly; since most of the fouling of the filter occurs during startup, check your filter media more often if you start your machine often. Long operating sessions foul the filter much less than frequent starts.

When changing the filter media, the spent filter media should be dried and blended into fresh feedstock to no more than 10% of the total mixture. The tar that condenses on the filter media is energy dense, and is not problematic for the gasifier as long as it is blended with plenty of fresh feedstock.
8. Flare

The gases produced during the startup process are too rich in tar to be burned in an engine, so they are cleanly burned off in the flare until the reactor is hot enough to produce clean gas. The flare is designed to burn the tar gases with sufficient heat and oxygen such that the flare exhaust is clean and smoke-free.

8.1 Blowers

The reactions in the gasifier are driven by suction; during normal operation, the engine provides the suction, but during startup, the suction is provided by a pair of blowers connected in a series. This pair of blowers are identified as the gas blowers, and can be seen mounted on the flare assembly. The rate of suction of the gas blowers is controlled by the knob on the control panel labeled ‘GAS’. The gas blowers are connected in a series in order to achieve enough suction and high enough a flow rate to bring the reactor up to operating temperatures while being powered solely by the 12V DC car battery onboard the Power Pallet. A third blower, also mounted to the flare assembly, provides air to the flare so that the tar-rich gases produced during the startup process can be burned cleanly. This blower is identified as the air blower, and is controlled by the knob on the control panel labeled ‘AIR’.
During startup, water vapor and some smoke will initially emit from the top of the flare until the igniter lights it. Once the smoke starts burning, the user should adjust the **AIR** setting so that the combustion descends into the flare. The combustion has descended into the flare if the flare makes a deep-toned roaring sound. If flame is visible above the flare, this indicates that the flame is starved of oxygen. Adjusting the air blower knob such that the air setting is somewhat higher than the gas setting provides enough oxygen to pull the flame it into the flare stack for more efficient combustion.

### 8.2 Igniter

At the top of the flare, there is a triangular device that has a peg-shaped hot surface that glows orange during the startup process. This structure is the igniter:

The igniter automatically turns on when **Preact** is greater than 5 and the engine is not running. When these conditions are true, the igniter relay turns on the igniter at the top of the flare stack, which glows orange with heat, igniting any gases that emit from the top of the flare, including smoke and carbon monoxide.