



ALL Power Labs
personal scale power

Section 5

Software v1.3



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1. Component Control Logic

1.1 Notes about Component Control Logic

The PCU control logic monitors the reactor temperature and pressure, oxygen sensor reading, and engine state. It also controls fuel feed, char bed agitation, and ash removal. If any critical issue occurs, the control system will sound an alarm to alert the user to the state of the machine. The user has the ability to change parameter values from the defaults through the PCU menu display.

1.1.1 Filter

The pressure of the media filter is recorded as **Pfilter** and can be used to determine the pressure drop across the filter bed.

1.1.2 Igniter

The igniter is lit if the Reactor pressure (the value of the variable **Preac**) is below -100 pascals (-4 on PCU display) and the engine isn't running.

1.1.3 Feedstock Auger

Fuel is fed into the reactor with a motorized spiral auger controlled by the PCU. The PCU determines fuel level in the reactor by monitoring a mechanical paddle switch. The switch is activated by the force of fuel on the paddle once the fuel has reached a high level in the reactor. The switch is electrically closed when no fuel is present and electrically open when the paddle is depressed. When the switch is in the closed position the PCU activates the auger to feed fuel into the reactor; when the switch is open the PCU stops the feed of fuel. The PCU monitors auger motor current while feeding. The auger motor current level is used to detect mechanical or electrical faults of the fuel feed system.

1.1.4 Grate Shaker

The system attempts to keep the reactor pressure ratio within a desirable zone to optimize gas flow. The ideal zone is determined by the configurations "Pratio Low" and "Pratio High" which are the low and high set points respectively. The grate shaker does not become active until the reactor is above 40°C and under 4 inches of water vacuum (100pa).

There are three configurations used for automated control of the grate shaker:

"Grate Max Inter" for setting the maximum number of seconds the grate should go before shaking, "Grate Min Inter" for setting the minimum time between shakings, and "Grate On Interv" for setting the time which the grate shakes each time a grate shaking event occurs. The main function of the grate shaker is to cause movement in the char-ash in the reduction zone so that small ash particles that would normally restrict flow fall out into the ash tray. The grate only shakes when the reactor is deemed to be on. The system attempts to keep the Pratio within a desirable zone to optimize gas flow, where Pratio is defined as $(P_{comb} / P_{reac}) \times 100$. The ideal zone is determined by the configurations "Pratio Low" and "Pratio High" which are the low and

high set points respectively. The time until a grate shake event is like sand in an hourglass. If P_{ratio} drops below the low zone time runs out quicker (the hole in the hourglass is larger and thus sand drains faster) than if the P_{ratio} is in the proper zone. Once all of the time runs out a grate shake event occurs.

Beyond Automated control, the operator can also go to the Manual Control view on the PCU and select OFF and ON to either turn the grate off or on respectively while the operator is in this view.

The system senses the current draw of the auger motor and times the auger state to detect possible errors in feedstock transport. Fuel jams and bridging are the most common conditions.

1.1.5 Mixture Control

The system checks the lambda sensor and then uses a PID loop to adjust the servo that controls the butterfly valve that controls the air into the system. The P and I values are set in the Lambda view along with the Lambda setpoint.

| Control State | Engine | Lambda | Servo Position |
|---------------|----------|----------|--------------------|
| OFF | STOPPED | N/A | Closed |
| STARTING | STARTING | N/A | Start (30 degrees) |
| CLOSED LOOP | RUNNING | In range | PID Controlled |
| OPEN LOOP | RUNNING | Error | Last position |

If there is a loss in signal from the oxygen sensor, the logic will attempt to reset the sensor while maintaining the mixture servo at the last position until signal returns. On engine shutdown, air servo valve is opened to maximum position. After 3.5 seconds, the ignition system is de-energized and the air servo valve is closed. On grid tie systems the air servo valve is closed immediately upon receiving a shutdown signal from the DeepSea controller.

1.1.6 Reactor Conditions

The PCU monitors the temperature and pressure ratio of the reactor. The PCU sounds an alarm for reactor temperatures below the minimum threshold (default 750°C) when the engine is running because temperatures under the threshold result in inefficient tar cracking. The high levels of tar present in the gas stream at low temperatures risk fouling the engine valves and spark plugs.

The pressure ratio between the combustion pressure (P_{comb}) and the reactor pressure (P_{reac}) is indicated as P_{ratio} and the grate is shaken at the specified threshold values. A low P_{ratio} indicates fines clogging the reduction zone. A high ratio can indicate fuel burn out or bridging. If the grate shaker is unable to purge the grate basket, an error state will be in effect, and manual inspection and cleaning may be needed.

1.1.7 Engine Oil Pressure

Low pressure reading for the first 3 seconds of running (startup) is ignored. For the PP20 Power Pallet, the low-pressure threshold is user configurable.

1.1.8 Automatic Shutdown

When there is an automatic shutdown, the cause remains on display and the system will not resume until reset by the user via the control panel. Shutdown causes are persistent on the display after automatic shutdown for the user to view.

1.2 Displayed Alarms and System Responses

Below is a table of the errors that are displayed and the action taken by the system.

| Alarm Message | Alarm Conditions | Time until Alarm | System Shutdown Time | Advice Displayed |
|---------------------------------|--|------------------|--|---------------------------------|
| Auger on too long | Auger on | 4 min | Auto Engine Shutdown at 6 min | Check Fuel |
| Auger off too long | Auger off | 8 min | Auto Engine Shutdown in 10 min | Bridging? |
| Bad Reactor P_ratio | if P_ratio value is <p_ratio low value and >p_ratio high value (user configurable; default = 30, 60) | Variable | No action | Reactor Fuel Issue |
| Trst low for engine | < 700°C (default; user adjustable) for trest | 3 sec | No action | Increase Load |
| Tred high for eng. | Engine on and reduction temperatures above 950°C (hystersis between 900-950°C). | Immediate | Engine shutdown at 60 sec | Low Fuel in Reactor? |
| Check Oil Pressure | Oil pressure less than user setting (default = 6psi) | No alarm | Auto engine shutdown after 0.5 sec. Note: first 3 seconds during engine start up ignored | Check Oil Pressure |
| No O ₂ Sensor Signal | Greater than .25 sec | 30 sec | Reset oxygen sensor at 0.25 sec Auto engine shutdown after 60 sec. | No O ₂ Sensor Signal |
| Auger Low Current | | 1 min | Auto engine shutdown after 3 min | Check Fuel |
| FuelSwitch/ Auger Jam | 10 auger fwd/rev cycles | Immediate | Auto engine shutdown at 20 forward/reverse cycles | Check Fuel & Switch |

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|------------------------------|---|----------|------------------------|-------------------|
| High P_{comb} | Combustion vacuum > 300 units | No alarm | Immediate | Check Air Intake |
| High Coolant Temp | Greater than 98°C default (user configurable) | 0 sec | Engine shutdown 3 sec | High Coolant Temp |
| Reduction Temp Low | Engine on and top restriction temperatures below 790°C (hysteresis between 790-800°C) | 3 sec | Engine shutdown 7 sec | Increase Load |
| Restriction Temp High | Engine on and Trst > 1050°C (user configurable) | No alarm | Engine shutdown 15 sec | Reduce Load |
| Reduction Temp High | Engine on and Tred > 975°C (user configurable) | No alarm | Engine shutdown 60 sec | Reduce Load |

The display will allow for multiple alarm conditions. If multiple alarm conditions are present, the alarm view shows the alarm count in the upper right corner. The time before shutdown is shown as a countdown on the display. Alarms that do not cause an automatic engine shutdown can be unset by resolving the alarm condition. Silencing of the alarm is allowed and turns off siren. Any new alarm conditions will turn the alarm back on.

2. Description of Operator Views

2.1 Splash Screen

```

Power Pallet
www.allpowerlabs.org
  [firmware version]
[PP S/N]           [PCU S/N]
  
```

| Variables | |
|-------------------------|--|
| <i>Firmware Version</i> | Firmware version in the format <major>.<minor>.<revision>, e.g. v1.3.0 |
| <i>PP S/N</i> | Power Pallet serial number, entered during production |
| <i>PCU S/N</i> | PCU board serial number, entered during production |

2.2 Reactor Status

```

Trst   TTT  Pcomb  PPP
Tred   TTT  Preac  PPP
Pratio RRR  Pfilt  PPP
NEXT  ALARM T:  00000
  
```

| Variables | | | |
|-------------------|--|------------------|---|
| Trst <i>TTT</i> | Temperature of restriction in °C, measured at the hearth restriction | Pcomb <i>PPP</i> | Pressure at the combustion zone* |
| Tred <i>TTT</i> | Temperature of reduction in °C, measured at top of grate basket | Preac <i>PPP</i> | Pressure of reactor, measured as gas enters the cyclone* |
| Pratio <i>RRR</i> | Pressure ratio: the quotient $P_{comb}/P_{reac} \times 100$ | Pfilt <i>PPP</i> | Pressure at the filter* |
| NEXT | Press the button below the NEXT label to advance to the next menu. | ALARM | The ALARM label will flash when there is an active alarm. Press the button below to view active alarms. |

| | | | |
|----|--|--|--|
| T: | This area displays the number of seconds the PCU has been powered on and can be used to correlate events with a timestamp in the data log. | | |
|----|--|--|--|

* Pressure in units of 0.1 inches of water column (e.g. a reading of 10 means 1 inch of water column)

2.3 Lambda

| | | | |
|--------|-----|--------|-----|
| LamSet | SSS | Lambda | LLL |
| P | PPP | I | III |
| NEXT | ADV | + | - |

Lambda is the quotient of actual air:fuel ratio divided by the stoichiometric air:fuel ratio. It gives you an idea of how the actual ratio compares to the theoretical stoichiometric mixture. Lambda = 1 is an stoichiometric; Lambda > 1 indicates a leaner mixture, Lambda < 1 is a richer mixture.

| Values | |
|--|--|
| SSS | Lambda setpoint (lambda × 100) Default: 1.05 |
| LLL | Current lambda reading (lambda × 100) |
| PPP | Lambda PID P value (P × 100) Default: 0.13 |
| III | Lambda PID I value (I × 100) (PID D value is 0, so control loop is actually PI) Default: 1.00 |
| <i>Note: Running the system at different set points can greatly impact emissions and or cause the system to become unstable. Do not adjust from default values without review from a technician.</i> | |

| Keypad | | | |
|-----------------|----------------------|---------------------|---------------------|
| NEXT | ADV | + | - |
| Go to next menu | Go to next menu item | Increase item value | Decrease item value |

2.4 Manual Control

| |
|----------------|
| Manual Control |
|----------------|


```

<Component>: <MODE>
NEXT  ADV           MODE
    
```

| Values | |
|---------------------|---|
| <i>Component</i> | Grate Shaker, Fuel Auger, or Ash Auger |
| <i><Mode></i> | Grate Shaker <ul style="list-style-type: none"> • Auto: Grate shaker will turn on at intervals according to parameters. • ON: Grate shaker on continuously • OFF: Grate shaker disabled. Fuel Auger <ul style="list-style-type: none"> • AUTO: Fuel auger will turn on when fuel level is low • OFF: Fuel auger disabled Ash Auger <ul style="list-style-type: none"> • AUTO: Ash auger will turn on at intervals according to parameters. • ON: • OFF: Ash auger disabled. |

2.5 System Information

```

[PP S/N]           [PCU S/N]
                Time:      SSSS
                [SD Card Status]
NEXT  ADV
    
```

| Values | |
|-------------|---------------|
| <i>S/N</i> | Serial Number |
| <i>SSSS</i> | Time reading |

2.6 Testing

```

Test Relay: X
FETX Name
State: [state]
NEXT  ADV  ON   OFF
    
```

| Tests | |
|--|---|
| 0. Fuel Auger Fwd | Turns on/off auger forward relay (FET0) |
| 1. Grate | Turns on/off grate shaker relay (FET1) |
| 2. Engine/Governor | Turns on/off engine ignition relay (FET2) |
| 3. Starter | Turns on/off engine starter relay (FET3) |
| 4. Flare | Turns on/off flare igniter relay (FET4). |
| 5. Ash Auger | Turns on/off Lambda meter reset relay (FET5). |
| 6. Alarm | Turns on/off flare igniter relay (FET6). |
| 7. Fuel Auger Rev | Turns on/off flare igniter relay (FET7). |
| <i>Note: Menu is not available while engine is running</i> | |

| Keypad | |
|-----------------|-----------------------|
| NEXT | TEST |
| Go to next menu | Advance through tests |

2.7 Analog Inputs

```

Analog Input: ANAX
FET Name
State: /state/
NEXT  ADV  ON   OFF
    
```

| Analog Input | FET Name |
|--------------|---|
| ANA0 | ANA_Lambda |
| ANA1 | ANA_Fuel_Switch |
| ANA2 | ANA_Eng_Switch |
| ANA3 | ANA_Oil |
| ANA4 | ANA_Auger_current |
| ANA5 | ANA_Throttle_Pos |
| ANA6 | ANA_Coolant_Temp |
| ANA7 | Unused (<i>Currently shows ash auger current</i>) |

2.8 Air Servo

```
ServoMin LLL Max HHH
Careful of Sides!

NEXT ADV + -
```

| Values | |
|------------|---|
| <i>LLL</i> | Servo Minimum (Closed)— minimum servo mixer angle (degrees) |
| <i>HHH</i> | Servo Maximum (Open)— maximum servo mixer angle (degrees) |

| Keypad | | | |
|-----------------|----------------------|---------------------|---------------------|
| NEXT | ADV | + | - |
| Go to next menu | Go to next menu item | Increase item value | Decrease item value |

2.9 Calibrate Pressure Sensors

```
Calibrate Pressure
Sensors to zero?

NEXT YES
```

| Keypad | |
|-----------------|----------------------------|
| NEXT | YES |
| Go to next menu | Calibrate pressure sensors |

Note: This will zero pressure sensors to handle any sensor zero-offset. Only calibrate when the system is fully off and under no vacuum or pressure. This menu is not available while engine is running

2.10 Configuration

Configurations
[Configuration name:Value]
ADV to save choice
NEXT ADV *HHH* *LLL*

| Keypad | | | |
|-----------------|----------------------------------|---|---|
| NEXT | ADV | <i>HHH</i> | <i>LLL</i> |
| Go to next menu | Go to next configuration submenu | Text depends on configuration submenu. See Configuration Menu and Options below. | Text depends on configuration submenu. See Configuration Menu and Options below. |

Note: Menu is not available while engine is running

2.11 Configuration Menu and Options

| Configuration Setting | Options | Default |
|-----------------------|---|---|
| Reset Defaults? | NO: does not reset defaults YES: resets factory defaults for all values. | NO |
| Engine Type | 10k 20k | Factory default matches original Power Pallet size. |
| Relay Board | NO : system DOES NOT have relay board installed YES : system DOES have relay board installed | YES |
| Auger Rev(.1s) | + : increase value - : decrease value (Units: 0.1 seconds) | 1.0 sec |
| Auger Low(.1A) | + : increase value - : decrease value (Units: 0.1 Amps) | 3.5 Amps |
| Auger High(.1A) | + : increase value - : decrease value | 10.0 Amps |

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|-----------------|--|------|
| | (Units: 0.1 Amps) | |
| Low Oil(PSI) | + : increase value - : decrease value (Units: 1 PSI) | 6 |
| Datalog SD card | YES: command to datalog to SD card (if present). NO:command to not datalog to SD card | YES |
| Pratio Accum# | +5 : increase value - 5: decrease value (Units: 5) | 50 |
| High Coolant T | + : increase value - : decrease value (Units: 1°C) | 98 |
| Display Per .1s | Not Used | N/A |
| Trst low temp? | +5 : increase value -5 : decrease value (Units: 5°C) | 650 |
| Trst High Temp | +5 : increase value -5 : decrease value (Units: 5°C) | 1050 |
| Tred High Temp | +5 : increase value -5 : decrease value (Units: 5°C) | 975 |
| Pfilter Accum# | + : increase value - : decrease value (Units: 1) | 50 |
| Grate Max Inter | +5 : increase value -5 : decrease value (Units: 5) | 30 |
| Grate Min Inter | +5 : increase value -5 : decrease value (Units: 5) | 60 |
| Grate On Interv | + : increase value - : decrease value (Units: .1second) | 30 |
| Servo Start Pos | + : increase value - : decrease value (Units: 1) | 30 |
| Lambda Rich | + : increase value - : decrease value (Units: 1) | 140 |
| Modbus Enabled? | NO: Disables modbus YES: Enables modbus if in use | NO |

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|------------------------|--|--|
| Modbus Baud | + : increase value - : decrease value (Units: 1) | 3 |
| Modbus Parity | + : increase value - : decrease value (Units: 1) | 0 |
| Modbus Address | + : increase value - : decrease value (Units: 1) | 1 |
| Grid Tie? | YES: Grid tie configuration (with Deep Sea) NO: Off-Grid configuration. | Factory default matches original Power Pallet configuration. |
| Praio Low | + : increase value - : decrease value (Units: 1) | 30 |
| Trst Warn Temp | 5+ : increase value 5- : decrease value (Units: 5°C) | 750 |
| Pratio High | + : increase value - : decrease value (Units: 1) | 60 |
| Ash Aug Lim (A) | + : increase value - : decrease value (Units: 1) | 10 |
| Ash Aug Hyst(A) | + : increase value - : decrease value (Units: 1) | 1 |
| Ash Aug Period | 5+ : increase value 5- : decrease value (Units: 5) | 900 |

2.12 Alarm

```
ALARM [current]/[total]
[Alarm Name]
[Alarm Advice]
NEXT ADV QUIET RESET
```

| Keypad | | | |
|-----------------|-----------------|---|------------------------------------|
| NEXT | ADV | QUIET | RESET |
| Go to next menu | Show next alarm | Silence alarm (will be turn on again if a new alarm occurs) | Reset conditions causing the alarm |

Note: If the alarm caused a shutdown of the engine or auger, the alarm MUST be reset or acknowledged for the system to operate correctly

4. Data Logging Outputs

When data logging with the PCU, a table of values is output with the following variable headings and information.

| Variable | Value | Units |
|-------------------|---|---------|
| Time | Time since PCU is powered on | Seconds |
| T_tred | Temperature at the restriction of the reduction bell (0°-1250°C) | °C |
| T_bred | Temperature at the bottom of the reduction bell (0°-1250°C) | °C |
| T_eng_coolant | Temperature of engine coolant | °C |
| T_reactor_gas_out | <i>Temperature of gas coming out of reactor (Not implemented)</i> | °C |
| P_reactor | Pressure of reactor (vacuum pressure) | Pascals |
| P_filter | Pressure at the top of the gas filter (vacuum pressure) | Pascals |
| P_comb | Pressure at the combustion zone (vacuum pressure) | Pascals |
| P_Q_air_rct | <i>Not implemented</i> | Pascals |
| P_Q_gas_eng | <i>Not implemented</i> | Pascals |
| ANA0 | Oxygen sensor signal | °C |
| ANA1 | Fuel switch state | mV |
| ANA2 | Key switch voltage | mV |

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|-----------------------|--|---------------------|
| ANA3 | Engine oil pressure | mV |
| ANA4 | Feedstock auger current | mA |
| ANA5 | Throttle position (enabled since 11/2013) 0.75v-4.25v DC, quantized into integer between 0-1023 | enumerated |
| ANA6 | <i>Coolant Temperature, same as T_Eng_coolant (not used)</i> | °C |
| ANA7 | <i>governor auxiliary signal (not used)</i> | |
| Grate | Grate shaking state, enumerated (1=ON, 2=OFF) | enumerated |
| P_ratio_reactor | Pressure ratio ($P_{comb}/P_{react} \times 100$) | 0-100 |
| P_ratio_state_reactor | State of P_ratio_reactor (GOOD, BAD) 30 < Pratio < 70 is good | enumerated |
| Grate_Val | Grate state accumulator value (0 - 320000 for shaking period) | enumerated state |
| P_ratio_filter | Filter flow ratio ($P_{react}/P_{filter} \times 100$) | 0-100 |
| P_ratio_filter_state | State of filter (good, bad) | enumerated |
| Lambda_In | Air/fuel ratio reading from O ₂ sensor | |
| Lambda_Out | Air/fuel ratio target for air premix | |
| Lambda_Setpoint | Air/fuel ratio set point | |
| Lambda_P | Engine air premix/oxygen sensor P value for PID loop | |
| Lambda_I | Engine air premix/oxygen sensor I value for PID loop | |

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|----------------|--|------------|
| Lambda_D | Engine air premix/oxygen sensor D value for PID loop | |
| P_reactorLevel | Reactor State (0= OFF, 1= LOW, 2= MEDIUM, 3= HIGH) | enumerated |
| T_tredLevel | Temperature state (0=COLD, 1= COOL, 2=WARM, 3=HOT) | enumerated |
| T_bredLevel | Temperature state (0=COLD, 1= COOL, 2=WARM, 3=HOT) | enumerated |
| Engine | Engine state (1=ON, 2=OFF) | enumerated |
| AugerCurrent | Biomass auger current in 0.1 of an amp | |
| AugerLevel | Auger state: 0= off, 1= starting, 2= forward, 3= forward, high current, 4= reverse, 5= reverse, high current | enumerated |

5. Serial Commands

The following commands are available over a serial connection made at 115600 baud:

| Symbol | Action |
|---------------|--|
| ? | Device info |
| ! | Rewrite specified EEPROM space (give number followed by ';') |
| p | Add 0.02 to p |
| P | Subtract 0.02 from p |
| i | Add 0.02 to i |
| I | Subtract 0.02 from i |
| <i>d or D</i> | <i>Reserved for d in PID (not implemented)</i> |
| c | Calibrate Pressure Sensors |
| s | Add 10 to Servo1 calibration |
| S | Subtract 10 from Servo1 position |
| l | Add 0.01 to lambda_setpoint |
| L | Subtract 0.01 from lambda_setpoint |
| t | Subtract 100 ms from Sample Period (loopPeriod1) |
| T | Add 100 ms from Sample Period (loopPeriod1) |
| g | Shake grate |
| G | Switch Grate Shaker mode (Off/On/Pressure Ratio) |
| m | Add 5ms to grate shake interval |
| M | Subtract 5 ms from grate shake interval |
| e | Engine Governor Tuning mode |
| h or H | Print Help Text |