PF2200

PID TUNING GUIDE

DOC-001108

V2.0

CONTENTS

1 INTRODUCTION

The PF2200 Burner Management System is an automated safety controller designed to monitor and control industrial heating processes including single burner natural and forced draft appliances, as well as dual burner systems. It provides for safe burner ignition, flame detection, temperature control and peripheral input device monitoring. The user interface provides real-time system status and state information as well as detailed alert annunciation, advanced diagnostics and data logging. The system has been optimized for power consumption to be utilized in a variety of applications and can be monitored remotely.

This document provides detailed instructions for configuring the PID parameters to optimize performance over a variety of different burner applications. This document is applicable for the following PF2200 hardware and firmware versions:

PF2200 Model	Firmware Version	BMS Card Hardware Version	UI Card Hardware Version
PF2200-SB Single Burner	SB 2.1.3, SB 2.0.4	v2.3.x	v3.2.x
PF2200-FD Forced Draft	FD 2.1.2, FD 2.0.4	v2.3.x	v3.2.x
PF2200-DB Dual Burner	DB 1.0.3	v2.3.x	v3.2.x

1.1 BASIC PID CONTROL

The system is configured for Basic PID Control when **Process Control Mode** (Settings > Proc Control > Configuration) is set to one of the following:

- Bath PID Control
- Outlet PID Control
- Aux PID Control (not available for PF2200-FD Forced Draft model)

Basic PID control is effective for most applications that require monitoring of (1) a bath temperature only, (2) an outlet temperature that responds quickly to changes in the bath temperature and (3) an auxiliary process fluid temperature.

1.2 CASCADED PID CONTROL

Cascaded PID control is useful for processes that require improved outlet temperature regulation along with a controlled bath temperature. Cascaded control can improve outlet temperature stability with processes that have a longer time delay (for example the outlet temperature sensor is located a distance away from the bath).

2 BASIC PID CONTROL CONFIGURATION

The system controls fuel flow to the main burner by modulating the proportional temperature control valve (TCV) output in accordance with the configured PID parameters and the **Process Setpoint** setting of the temperature input under control. The following instructions are meant to be performed in order to ensure effective tuning of the PID control loop.

2.1 DETERMINE PROCESS CONTROL TEMPERATURE

1. Configure the controller for PID Control based on the option that best matches your application:

Application	Configuration Instructions
Only appliance bath temperature is monitored	**Settings > Proc Control > Configuration** Process Control Mode: Bath PID Control **Settings > Temps > Bath** Mode: Process Control
Process fluid outlet temperature is monitored	**Settings > Proc Control > Configuration** Process Control Mode: Outlet PID Control **Settings > Temps > Outlet** Mode: Process Control
Temperature other than Bath or Outlet requires regulation	**Settings > Proc Control > Configuration** Process Control Mode: Aux PID Control **Settings > Temps > Aux Temp** Mode: Process Control
Both appliance bath temperature and process fluid output temperature are monitored, and the outlet temperature has a long heat up/cool off delay time:	**Settings > Proc Control > Configuration** Process Control Mode: Cascaded PID Control **Settings > Temps > Bath** Mode: Process Control **Settings > Temps > Outlet** Mode: Process Control Skip to Cascaded PID Control Configuration section

2.2 CONFIGURE TEMPERATURE SETPOINTS

2.2.1 PROCESS SETPOINT AND HIGH TEMP SETPOINT

2. Record the maximum safe operating temperature and desired process temperature of the process fluid:

Max Safe Operating Temperature	Desired Process Temperature

3. Configure the temperature units, Process Setpoint and High Temp Setpoint for the process control temperature:

    Settings > Setup > Units
    Temperature: As desired
    Settings > Temps > Process Control Input
    High Temp Setpoint: Value below the maximum safe operating temperature
    Process Setpoint: As desired

2.2.2 PILOT OFF SETPOINT

The **Pilot Off Setpoint** does not affect the system while in the PID Control state but can cause configuration errors if not set up correctly.

4. Configure the **Pilot Off Setpoint** based on the following scenarios:

Scenario	Configuration Instructions
Settings > Process Control > Configuration Pilot off Mode is set to Off at Pilot Off Setpoint	**Settings > Temps > Process Control Input** Pilot Off Setpoint: Below High Temp Setpoint
Settings > Process Control > Configuration Pilot off Mode is NOT Off at Pilot Off Setpoint	**Settings > Temps > Process Control Input** Pilot Off Setpoint: Ignored

> The **Pilot Off Setpoint** is the temperature at which the system turns off all fuel flow to the burner but remains running. Once the process temperature has cooled sufficiently, the system is free to reignite and admit fuel to the burner. This can be used to avoid a high temperature shutdown and system Lockout.

2.2.3 MAIN OFF SETPOINT

The process load (heat demand) affects how quickly the process fluid heats up and cools down. Burners are typically sized for the maximum load and have a limited turn down ratio. This means that under light loads the burner may produce too much heat even at the lowest firing rate. In this case it is expected that the PID controller cannot effectively control the process temperature, which will gradually increase until it reaches the Main Off Setpoint.

> The TCV **Minimum Position** setting should be set to the lowest possible value at which the burner can remain stable. This position will be different for every appliance, so this value should be set and optimized by a burner technician. If an acceptable turndown cannot be achieved - the process temperature is continually reaching its **Main Off Setpoint** under medium to heavy loads - it is likely that (1) the burner is oversized and may need to be de-tuned to reduce its heat output, or (2) the PID parameters are configured incorrectly, and are causing an unacceptable overshoot.

5. Determine a suitable **Main Off Setpoint(s)** based on the following criteria:

Criteria	Configuration Instructions
The **Main Off Setpoint** must be below its corresponding **Pilot Off Setpoint** (if enabled)	**Settings > Temps > Process Control Input** Main Off Setpoint: Process Setpoint plus 5°C (9°F) * * Increase/decrease as required/desired after configuring all the PID parameters and observing the system behavior.
The **Main Off Setpoint** must be high enough above its corresponding **Process Setpoint** to allow for a small amount of overshoot during normal operation and system startup.	

2.3 CONFIGURE PID CONTROL PARAMETERS

2.3.1 RAMP TIME

The **Ramp Time** setting can be used to change the time that it takes to ramp the TCV output from its configured **Minimum Position** to its requested position upon a transition to the PID Control state from the Pilot state.

6. Set the **Ramp Time** to 10 seconds and increase if the change in firing rate upon entry into the PID Control state causes the pilot flame(s) to be snuffed out, or if the appliance requires a long warm-up time.

2.3.2 OUTPUT RATE LIMIT

The **Output Rate Limit** setting controls the rate at which the firing rate will increase every second and is active in all fuel states. It can be decreased to allow for mechanical linkage or alternate actuator applications that require a slower rate of change. Decreasing the **Output Rate Limit**, however, will also dampen the response time of the system thereby hindering the ability of the PID controller to effectively control process temperature in quick changing systems.

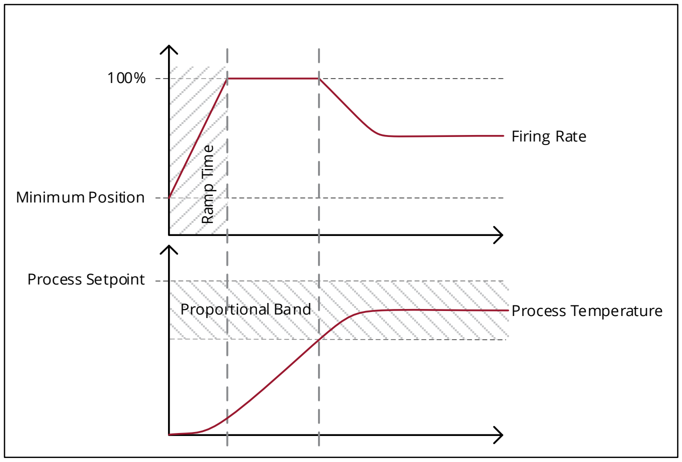
7. Set the **Output Rate Limit** to 100%/sec and decrease only if required.

2.3.3 PROCESS PROPORTIONAL BAND

8. Configure as follows so that the system can be analyzed with the effects of the integral and derivative times removed:

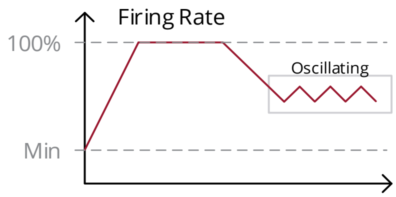
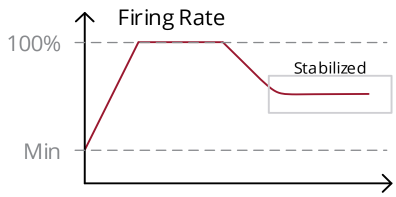
   Settings > **Proc Control** > **PID Control**
   Process Proportional Band: 10°C (18°F)
   Process Integral Time: 0°C (0°F)
   Process Derivative Time: 0°C (0°F)
   Process Integral Reset Range: 10°C (18°F)

9. Start the system and monitor the firing rate and process temperature as the appliance heats up. The goal is to maintain a steady firing rate and a temperature just below the **Process Setpoint** as shown below:

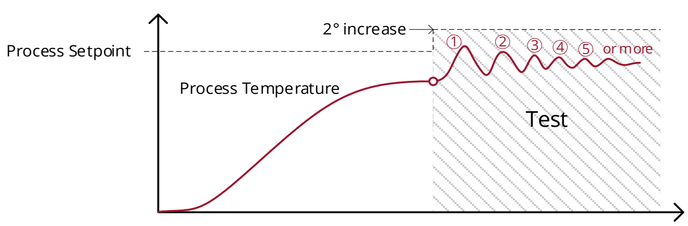
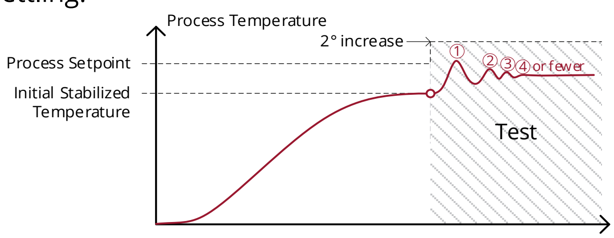


If the process is cold, the firing rate ramps up and holds at 100% until the process temperature reaches a temperature equal to the **Process Setpoint** minus the **Proportional Band**. At this point, the firing rate decreases proportionally as the temperature approaches the **Process Setpoint**. The firing rate settles between the configured TCV **Minimum Position** and 100%, and the process temperature settles below the configured **Process Setpoint.**

10. Once the heater has warmed up continue to monitor the temperature and the firing rate. Adjust the **Proportional Band** setting in accordance with the following:

Scenario	Configuration Instructions
Firing rate is continually oscillating. 	**Settings > Proc Control > PID Control** Process Proportional Band: double initial value and continue increasing slowly (if necessary) until the oscillations stop.
Firing rate has stabilized. 	**Settings > Proc Control > PID Control** Process Proportional Band: Slowly reduce until the system starts to oscillate, then increase by a few degrees.

11. Test the **Proportional Band** setting - allow the process temperature to stabilize, then increase the **Process Setpoint** by 2 degrees to test the response of the system to a **Process Setpoint** change. Adjust settings as required in accordance with the following:

Scenario	Configuration Instructions
Process temperature oscillates more than 4 times before settling. 	**Settings > Proc Control > PID Control** Process Proportional Band: Increase **Settings > Temps > Process Control Input** Process Setpoint: Return back to initial setpoint and repeat Step 11.
Process temperature oscillates 4 times or fewer before settling. 	**Settings > Temps > Process Control Input** Process Setpoint: Return back to initial value

12. Record the initial Process Setpoint configured and the initial stabilized temperature observed in the previous step.

Process Setpoint	Stabilized Temperature

2.3.4 PROCESS INTEGRAL RESET RANGE

The process temperature must be within the **Process Setpoint** plus or minus the **Integral Reset Range** for the **Integral Time** setting to have an effect on the PID control loop. If the **Integral Reset Range** is too close to the **Process Setpoint,** the process temperature may settle below the range where the **Integral Time** takes effect. If the **Integral Reset Range** is too large, the process temperature will overshoot the **Process Setpoint** on startup due to integral windup.

13. Copy the recorded Process Setpoint and Stabilized Temperature from above into the table below and calculate the **Integral Reset Range:**

	Process Temperature	Example
Process Setpoint	________	100°
Subtract Stabilized Temperature	- ________	- 95°
Add 5° to 10 ° Tolerance	+	+ 5°
Proposed Integral Reset Range	=	= 10°

14. Set the **Integral Reset Range** to the value calculated above; 5 to 10 degrees greater than the **Process Setpoint** minus the stabilized temperature using only the **Proportional Band**.

> It is common to adjust the **Integral Reset Range** over a few weeks as the load on the system changes to find a value that achieves an acceptable overshoot and doesn't prevent the integral from accumulating during heavy loads. If it seems like the process gets "stuck" at a temperature below the setpoint, and the firing rate does not start increasing, then increase the integral reset range.

2.3.5 PROCESS INTEGRAL TIME

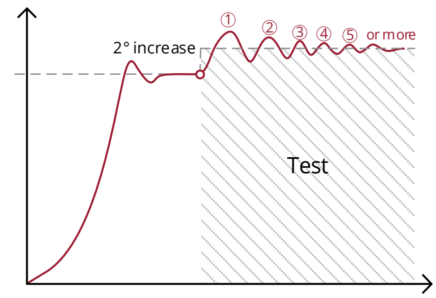
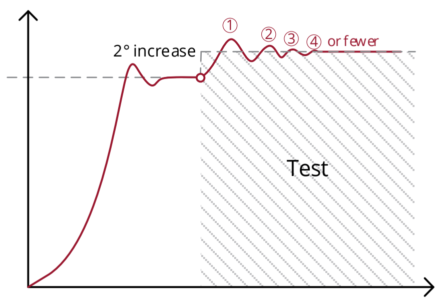
The **Integral Time** setting is used by the PID controller to pull the temperature from the stabilized temperature up to the **Process Setpoint**. Both an **Integral Time** that is too long and an **Integral Time** that is too short can cause oscillations. Priority should be put on finding a short **Integral Time** that still maintains system stability.

> The unit for **Integral Time** is minutes per repetition – this specifies the time that it will take for the PID integral term to double (e.g. An **Integral Time** of 4 mins/rep means that the PID integral term will double every 4 minutes). Increasing the **Integral Time** will slow down its effect, while decreasing the **Integral Time** will speed up its effect.

15. Set the **Integral Time** to **4 min/repeat.** Adjust settings as required in accordance with the following:

Scenario	Configuration Instructions
Process temperature begins to oscillate	**Settings > Proc Control > PID Control** Process Proportional Band: Increase by a few degrees
Process temperature continues to oscillate after **Proportional Band** adjustments	**Settings > Proc Control > PID Control** Process Integral Time: Increase
Process temperature stabilizes at the **Process Setpoint**	Proceed to next step

16. Test the **Integral Time** setting - allow the process temperature to stabilize, then increase the **Process Setpoint** by 2 degrees to test the response of the system to a **Process Setpoint** change. Adjust settings as required in accordance with the following:

Scenario	Configuration Instructions
Process temperature oscillates more than 4 times before settling. 	**Settings > Proc Control > PID Control** Process Integral Time: Increase Process Proportional Band: Increase if necessary **Settings > Temps > Process Control Input** Process Setpoint: Return back to initial setpoint and repeat Step 16.
Process temperature oscillates 4 times or fewer before settling. 	**Settings > Temps > Process Control Input** Process Setpoint: Return back to initial value

2.3.6 PROCESS DERIVATIVE TIME

The **Derivative Time** setting is rarely required for process heating applications. Most systems can achieve the required stability with **Proportional Band** and **Integral Time** alone. It is recommended to use the derivative term only if its implications are understood and the operator has experience in tuning derivative systems.

Increasing the **Derivative Time** will reduce its effect on the system, while decreasing the **Derivative Time** will increase its effect. This means that changes in process temperature will result in smaller counter-responses as the **Derivative Time** is increased.

3 CASCADED PID CONTROL CONFIGURATION

Cascaded PID Control allows two separate control loops to act quickly on elements they can control. The Bath temperature is directly and immediately affected by the TCV firing rate, and the outlet temperature is directly affected by the bath temperature. The smaller the time delay between action and response of the PID input, and output, the more stable the system can be. For example, by changing the bath temperature via its setpoint, the outlet temperature will also change in quick response. By combining these two control loops, the overall time delay of the system can be reduced, thereby creating a more stable process.

When in Cascaded PID Control mode, the PID parameters (Settings > Proc Control > PID Control) that are prefixed with “Process” pertain to the bath temperature PID control loop, while the parameters prefixed with “Cascade” pertain to the outlet temperature PID control loop. The output of the outlet PID control loop determines the **Process Setpoint** of the bath temperature, and the output of the bath PID control loop determines the firing rate for the TCV output.

The following instructions are meant to be used in conjunction with the Basic PID Control Configuration instructions above. Familiarize yourself with all above instructions and procedures before configuring the system for Cascaded PID Control.

3.1 CONFIGURE TEMPERATURE SETPOINTS

3.1.1 PROCESS SETPOINT AND HIGH TEMP SETPOINT

A. Record the maximum safe operating temperature and desired process temperature for each process fluid. Select the Bath **Process Setpoint** to be near the minimum expected bath temperature during operation. This will be the bath temperature during light loads or near the minimum flow rate of the process. The bath temperature will usually settle just a few degrees above the outlet temperature during normal operation:

When in Cascaded PID Control mode, the cascaded output (Bath setpoint) can only be decreased by the outlet PID control loop down to the configured bath **Process Setpoint.** Ensure that the bath **Process Setpoint** is low enough to prevent overheating of the outlet temperature. The bath **Process Setpoint** should be set to a value that will allow the outlet to cool off during minimum load conditions.

	Max Safe Operating Temperature	Desired Process Temperature
Bath		
Outlet		

B. Configure the temperature units, Process Setpoint and High Temp Setpoint for each process control temperature:

   Settings > Setup > Units
   Temperature: As desired
   Settings > Temps > Bath
   High Temp Setpoint: Value below the maximum safe bath operating temperature
   Process Setpoint: As desired
   Settings > Temps > Outlet
   High Temp Setpoint: Value below the maximum safe outlet operating temperature
   Process Setpoint: As desired

3.1.2 PILOT OFF SETPOINT

C. Configure the **Pilot Off Setpoint** for both the bath and outlet inputs per step 4 of the Basic PID Control Configuration instructions above.

3.1.3 MAIN OFF SETPOINT

D. Configure the **Main Off Setpoint** for both the bath and outlet inputs per step 5 of the Basic PID Control Configuration instructions above.

> When in Cascaded PID Control mode, the Bath **Process Setpoint** can only be increased by the outlet PID control loop up to the **Main Off Setpoint** minus 1 degree

3.2 CONFIGURE BATH PID CONTROL PARAMETERS

In most cascaded PID applications, the Bath PID control loop will only use a **Proportional Band**, as it is the quickest and most stable control loop for the bath temperature.

E. Change **Process Control Mode** (Settings > Proc Control > Configuration) to **Bath PID Control**
F. Follow steps 6, 7, 8, 9, 10 and 11 of the Basic PID Control Configuration instructions above to configure the **Process Proportional Band** setting. Do not configure any of the other PID parameters prefixed by "Process"

3.3 CONFIGURE CASCADED PID CONTROL PARAMETERS

G. Change **Process Control Mode** (Settings > Proc Control > Configuration) to **Cascaded PID Control**

3.3.1 CASCADE PROPORTIONAL BAND

H. Configure as follows:

   Settings > Proc Control > PID Control
   Cascade Proportional Band: 10°C (18°F)
   Cascade Integral Time: 0°C (0°F)
   Cascade Derivative Time: 0°C (0°F)
   Cascade Integral Reset Range: 10°C (18°F)

I. Start the system and monitor the outlet temperature and the cascaded setpoint (displayed as the Bath setpoint on the UI Status Screen). The goal is to determine a stable proportional band for the outlet temperature. The outlet temperature should stabilize a few degrees below it **Process Setpoint** with the caveat that the cascaded setpoint must also remain stable.

> When in Cascade PID mode, the outlet temperature is often more stable when tuned to be over damped. This means that the proportional band is larger than what may be tuned for a normal PID loop. The reason for this is to allow more time for the bath temperature to heat up and reach its requested setpoint before the outlet requests a setpoint change.

J. Continue to monitor the outlet temperature and the cascaded setpoint. Adjust the **Cascade Proportional Band** setting in accordance with the following:

Scenario	Configuration Instructions
Outlet temperature or cascaded setpoint is oscillating.	**Settings > Proc Control > PID Control** Cascade Proportional Band: Increase and reassess.
Outlet temperature and cascaded setpoint are both stable.	No action required. Move on to next step.

K. Allow the process temperature to stabilize, then increase the Outlet **Process Setpoint** by 2 degrees to test the response of the system to a **Process Setpoint** change. Confirm that the bath temperature and outlet temperature both stabilize within 4 decaying oscillations.

> The **Cascade Proportional Band** can be decreased, if desired, to speed up the response of the bath temperature change. However, the key point here is to not allow the cascaded setpoint to change to a different setpoint before the bath has had time to react to the initially requested value. The outlet PID should be just slow enough to request a bath setpoint and for the bath to achieve that temperature before the outlet requests a different bath temperature.

L. Record the initial Outlet **Process Setpoint** configured and the initial stabilized temperature observed in the previous step.

Process Setpoint	Stabilized Temperature

3.3.2 CASCADE INTEGRAL RESET RANGE

M. Copy the recorded Process Setpoint and Stabilized Temperature from above into the table below and calculate the **Integral Reset Range:**

		Process Temperature		Example
Outlet Process Setpoint				100°
Subtract Stabilized Temperature	-		-	95°
Add 5° to 10 ° Tolerance	+		+	5°
Proposed Integral Reset Range	=		=	10°

N. Set the **Cascade Integral Reset Range** to the value calculated above; 5 to 10 degrees greater than the Outlet **Process Setpoint** minus the stabilized temperature recorded.

3.3.3 CASCADE INTEGRAL TIME

O. Set the **Cascade Integral Time** to **4 min/repeat.** Adjust settings as required in accordance with the following:

Scenario	Configuration Instructions
System becomes unstable/ begins to oscillate.	**Settings > Proc Control > PID Control** Cascade Integral Time: Increase
System continues to oscillate after **Integral Time** adjustments	**Settings > Proc Control > PID Control** Cascade Proportional Band: Increase
System is stable	Proceed to next step

P. Allow the process temperature to stabilize, then increase the **Process Setpoint** by 2 degrees to test the response of the system to a **Process Setpoint** change. Confirm that system stabilizes within 4 decaying oscillations. Adjust settings as required in accordance with the following:

Scenario	Configuration Instructions
System takes too long to achieve stability	**Settings > Proc Control > PID Control** Cascade Integral Time: Decrease **Settings > Temps > Outlet** Process Setpoint: Return back to initial setpoint and repeat Step P.
Process temperature oscillates 4 times or fewer before settling.	**Settings > Temps > Outlet** Process Setpoint: Return back to initial value

4 DOCUMENT REVISION HISTORY

Document Version	Release Date	Applicable BMS Hardware	Applicable UI Hardware	Applicable Firmware
v2.0	22 MAR 2021	v2.3.x	v3.2.x	SB 2.0.4, SB 2.1.3 FD 2.0.4, FD 2.1.2 DB 1.0.3
v1.0	01 APR 2020	v2.3.x	v3.2.x	SB 1.3.1

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