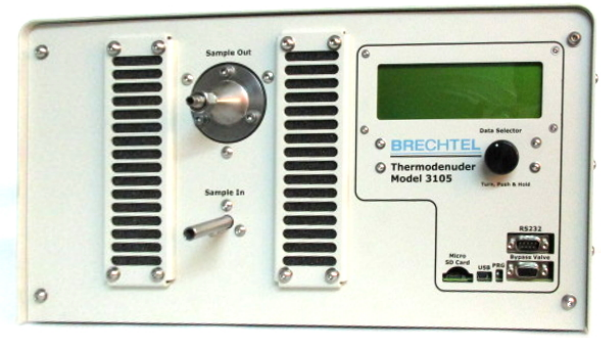
BRECHTEL

Instrument Manual

THERMODENUDER TD3105

BMI PN: 83-00025-01-B



October 24, 2018

Contents

1 Document Changes

Change Description	Page	Date	Authorized By:
Revision A	N/A	9/20/2017	CSP
Revision B	rev to v1.1 build; spec table	10/24/2018	CSP/FJB

2 Caution - READ FIRST

Read this section before running the Thermodenuder. This device operates at temperatures and electrical power levels that can be hazardous without proper care. Although fail-safes are present, user precautions are recommended to prevent fire and/or injury.

2.1 Operation

Review the items below before each operation.

- **Confirm the intake of the Thermodenuder is not exposed to high concentrations of particles or vapors that may combust at elevated temperatures.**
- **Confirm the Thermodenuder rests on a surface that can accept temperatures up to 50°C and will not deform or lose structural integrity. The surface should be rigid and flat in order to maintain an airgap under the entire Thermodenuder.**
- **The duct on the back of the device can reach temperatures over 80°C . Be sure the Thermodenuder is sufficiently clear of surrounding materials and devices.**
- **Confirm the Thermodenuder has been configured for the supplied AC input voltage. An incorrect configuration can supply 4x the rated power to the heating elements.**

2.2 Fail-Safes

A set of cooling fans, that provide a constant flow of ambient air across the heaters, help the system maintain a temperature within an accepted range. If these fans lose power, the system will overheat. The Thermodenuder has three fail-safe systems to manage any potentially destructive overheat conditions.

2.2.1 Software

The Thermodenuder's firmware monitors the temperature of the fans and will automatically increase the fan speed as the temperature approaches a maximum operating temperature. In the instance increased fan speed is not sufficient, the firmware will disconnect power to the heaters. The firmware will restore power once the system cools down.

2.2.2 Thermal Switch

If either the firmware freezes or the fan's temperature sensor outputs a faulty reading, a thermal switch located near the fans provides another level of safety to prevent fan burnout. The thermal switch opens the coil circuit on the heaters' relays, forcing the heaters into an off state.

2.2.3 Thermal Fuse

A thermal fuse is wired inline with the main power supply and has the ability to cut power to the entire system. This should only occur if the relays controlling the heaters fail in an on state. The thermal fuse needs to be manually reset. Contact Brechtel Manufacturing for reset procedures.

3 Unpacking

Each Thermodenuder is inspected and tested in-house at Brechtel Manufacturing to ensure out of the box operation upon delivery. Prior to opening, inspect the packaging container and ShockWatch impact indicators.

Open the package carefully and inspect the instrument and accessories for broken parts, scratches, dents or other signs of damage that may have incurred during shipping.

Notify BMI within 2 days of receiving your package if the shock indicator (Fig 1) has activated and/or if there is any other visible damage

Verify the contents of the shipment with the unpacking instructions, which are enclosed inside the packaging and available as a PDF file.

Retain all shipping packaging, foam inserts and cushions to ensure a safe delivery should the instrument need to be returned.

Figure 1: The black lines in the bottom image indicates the package has experiences an impact.

4 Thermodenuder Overview

The Brechtel Manufacturing Thermodenuder is a simple device designed to evaporate and capture volatile compounds coated on the surface of or inside aerosol particles. The Thermodenuder can be implemented as a component of a suite of instruments to explore how temperature affects particle volatility, size and other properties. A user typically operates the Thermodenuderby varying the set point temperature between ambient and 300°C . By stepping the set point temperature with time, insight into how particle properties change due to temperature can be observed.

The data from volatility studies are used to understand the air quality, climate and human health impacts of aerosols. The unit can also be used in a routine air-monitoring mode at urban and remote field sites to continuously measure the ambient aerosol volatility.

5 Installation

The BMI Thermodenuder is operational out of the box with no additional assembly. The sections below describe how to configure the Thermodenuder for your environment.

5.1 Power Connections

The Thermodenuder accepts a supply voltage between 100-250VAC. The back panel of the Thermodenuder has an IEC-C20 receptacle which requires a power cable with an IEC-C20 plug.

Before powering on, the Thermodenuder must be configured to the correct supply voltage. From the factory, the unit is configured for the voltage of the destination country. Confirm the sticker on the back panel matches the supply voltage to the unit.

In serial numbers 4 and above, the supply voltage configuration can be changed by toggling the voltage switch on the back panel. For serial numbers 1-3, the supply voltage configuration can be changed by connecting or removing a jumper on the circuit board inside the unit. See figure 3 for the location of the jumper. All units have a jumper included, although the configuration may vary.

- CONNECT jumper for supply voltages less than 150VAC.
- REMOVE jumper for supply voltages greater than 150VAC.

Operating the system with the voltage switch (or jumper) in wrong position will force the unite to run outside the designed range.

Figure 2: The BMI Thermodenuder requires a power cable with an IEC-C19 plug.

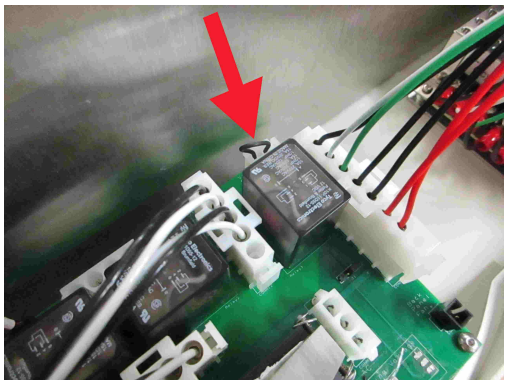


Figure 3: Install the jumper for supply voltages less than 150 VAC.

5.2 Instrument Rack Mounts

The BMI Thermodenuder is able to mount into a 19 inch instrument rack by installing ears on the side and supplying structural support to the rear of the unit. To install the rack mount bracket, remove the 6 screws (three on each side) securing the cover to the chassis. Install the bracket with provided countersink screws to ensure a flush surface. **The user must add necessary structural support for the rear of the chassis. The Thermodenuder chassis is not designed for cantilever loads.**

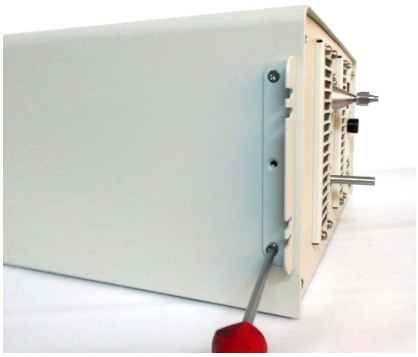


Figure 4: The rack mount bracket is installed to each side using three countersink screws.

5.3 Exhaust Duct Connection

The duct on the rear of the Thermodenuder exhausts excess heat during operation. Any temperature-capable 5in duct or duct adapter can be attached to the rear duct to divert the hot air to a desired location. Long duct runs or narrow duct may develop enough head-loss to limit Thermodenuder performance.

Warning: The exhaust duct on the rear of the Thermodenuder may reach 80° C . Be sure to confirm any materials used to divert the exhaust can withstand this temperature.

5.4 Sample Flow Connections

The sample inlet and outlet tubes are made from stainless steel. The inlet is 0.375in outside diameter and the outlet tube is 0.25in outside diameter.

5.5 Computer/Serial Communication Connection

Although not required for operation, the BMI Thermodenuder supports raw serial communication over both RS232 and USB.

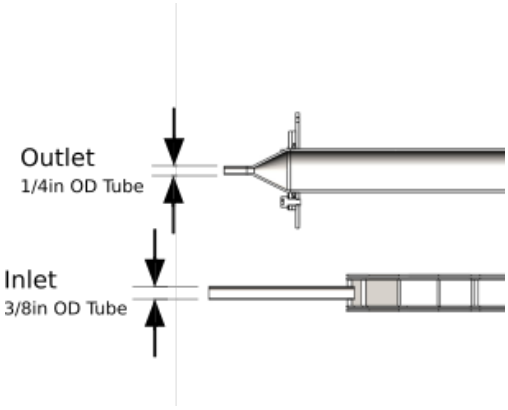


Figure 5: Inlet and Outlet tube sizes.

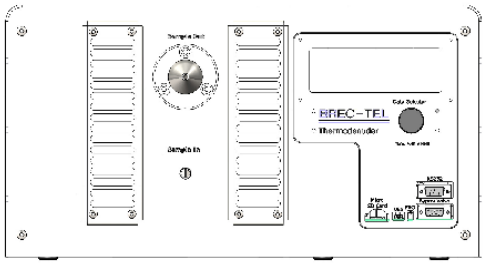


Figure 6: Thermodenuder Front Panel.

5.6 Optional: Bypass Valve Connection

An optional bypass valve is under development to allow the Thermodenuder to be bypassed but still allow sample flow through the unit to maintain desired temperatures. This feature is useful when unheated versus heated aerosol properties are to be compared over few-minute time periods. The bypass valve mounts directly to the inlet and outlet tubes of the Thermodenuder and is controlled by a dedicated electrical connection on the front panel.

6 Thermodenuder Operation

6.1 Operation Overview

The BMI Thermodenuder can be divided into three zones: 1) Heating Zone, 2) Residence Zone, and 3) Denuder and Cooling zone. Figure 7 shows a cross-section of the different zones and their locations.

When sample flow enters the device, the flow first enters the heating stage where two opposing heating elements quickly bring the sample to the set point temperature. A thermistor and control software regulate the heat flux out of the heater pair to make sure the sample flow enters the Residence Zone at the desired set point temperature. The cross-section in figure 8 shows the heater and thermistor locations within the Thermodenuder.

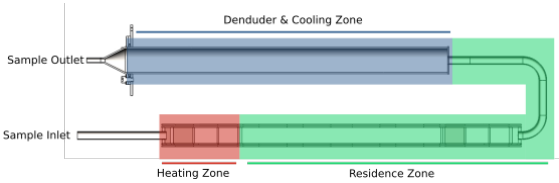


Figure 7: The BMI Thermodenuder has three distinct zones.

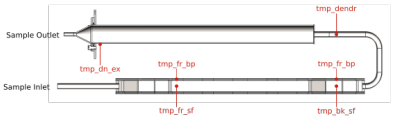


Figure 8: Location and display panel names of the temperature sensors.

In the Residence Zone, the set point temperature of the sample flow is maintained for the duration of the zone. The table below shows calculated residence times vs temperatures for three common flow rates.

Flow Rate (lpm)	Avg. Residence Time (s)	
	25°C	300°C
0.5	79.2	39.4
1	38.1	19.7
2	18.1	8.5

The residence times are calculated from the modelled maximum velocity of the flow in the heater's channel. Therefore, the residence time values are somewhat conservative. Figure 9 shows the velocity profile of the flow at several flow rates.

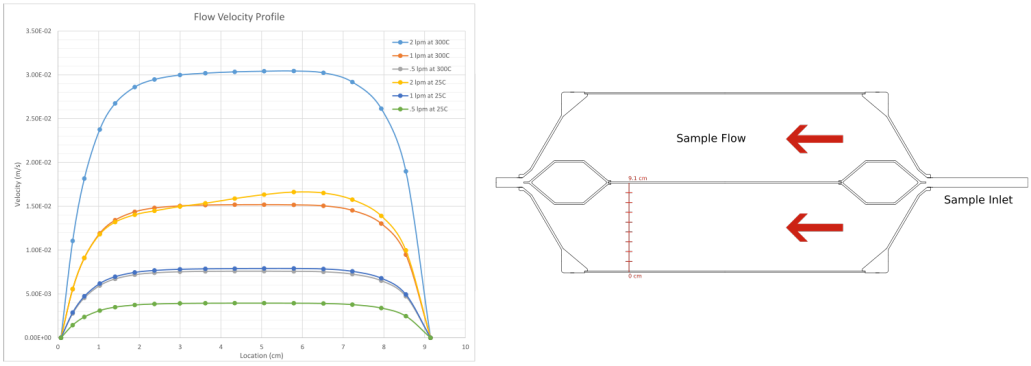


Figure 9: Velocity Profiles

Following the Residence Zone, the sample flow enters the denuder stage at the set-point temperature. As the sample flow is cooled back down to ambient in the denuder stage, volatile compounds that became gas molecules during heating will diffuse and condense on the cooler walls of the denuder which are lined with activated carbon.

The sample flow exits the device at a maximum temperature of 30°C for analysis by downstream instrumentation.

6.2 Modes of Operation

The BMI Thermodenuder has four operation modes:

- Off
- Manual Mode
- Auto Program Mode

6.2.1 Off Mode

Off mode acts as at stand-by mode for the device. In this mode the heaters remain off and the device cooling fans are powered in a low state to ensure any heat in the system is exhausted out the exhaust duct and not through the fans and into the lab environment.

6.2.2 Manual Operation

In the Manual mode, the user can adjust the set point temperature and toggle the bypass-valve. The device will operate at these fixed settings until a user makes a change.

6.2.3 Auto Program Operation

The Auto mode cycles through up to 30 programs with programmed set-point temperature, bypass-valve state and a timed duration for the program to remain at the predefined settings. A program counter is incremented by one when each program ends, and when the last program completes the counter resets

to one and the sequence of programs repeats itself. The counter also resets itself if the temperature of a program reads zero. This allows the user to reset the counter at any point.

7 Front Panel

The front panel has a four line character display with a data knob for user input. The data knob can be turned and pressed to manipulate the cursor, scroll menus and change settings.

Turning the knob in either direction will scroll through menu screens and select settings depending on the location of the cursor.

A long press will take users into the **DEFAULT SETTINGS** mode, where a new set of menus are found. Another long press of the knob will take users back to the top level menu and save any settings changed while in the **DEFAULT SETTINGS** mode. The default settings are stored so they are available when power to the unit is cycled.

There are three menus found on the top level. Below describes the available settings.

1. **SD CARD SAVE:** Toggle saving data to the SD card. *(On/Off)*

   File: Current Filename

   Files: Total number of files on SD card

   Size: SD card size in megabytes

   Used: % of the SD Card currently filled

2. **THERM DNDR:** Change Thermodenuder modes Off/Manual/Auto

   Temp: Heated sample flow temperature in heater chamber.

   Trgt: Adjust set point temperature from *0-300°C* (adjustment available in Manual mode)

   Byps: Toggle bypass valve *On/Off*

   Prg #: Displays current program number. (active in Auto mode only)

   Durat: Displays duration of program in minutes. (active in Auto mode only)

   Ctdwn: Countdown timer for program in seconds. (active in Auto mode only)

3. **TIME & DATE:**

   Time: Current time as stored in the EEPROM

   Date: Current date as stored in the EEPROM

In **DEFAULT SETTINGS** mode there are five available menus. All settings and calibration values are saved to the on-board EEPROM memory when users return to the top level menus from **DEFAULT SETTINGS** mode. If changes are made without holding the knob down and returning to top menus, e.g. powering off while in **DEFAULT SETTINGS** , the new settings will not be stored.

1. **SYS DEFAULTS** System Defaults are saved to the EEPROM initialized when the instrument power is cycled.

   td_mode: Select which mode is default. *Off/Manual/Auto*

byps_yn: Select whether a bypass valve is installed. *(On/Off)*

baud_rt: Select serial communication baud rate. *38.4k, 57.6k, 115.2k, USB*

delimit: Select data delimiter. *<CR>, TAB, SPACE*

auto_rpt: Toggle auto report. *On/Off*

rpt_lbl: Toggle report labels. *On/Off*

2. **AUTO PROGRAM**

Prog	Temp	Time	Byps
1-30	0-300°C *	0-510 mins	no=0, yes=1

* When `Temp=0` the firmware resets the program counter back to 1.

3. **DIAGNOSTICS – TEMP** Temperature sensor readings.

tmp_fr_sf: Front heater sample flow

tmp_bk_sf: Back heater sample flow

tmp_tb_sf: Denuder connector tube sample flow

tmp_dn_ex: Denuder exit exterior surface

tmp_cl_fn: Temperature of cooling fans

tmp_board: Temperature of PCB

4. **DIAGNOSTICS – POWER** Power levels of fans and heating elements from *0-200*

ht_pwr_fr: Front heating elements

ht_pwr_bk: Back heating elements

ht_pwr_dn: Denuder connector tube heating elements

fn_pwr_ht: Heater cooling fans

fn_pwr_dn: Denuder cooling fans

5. **MANUFACTURE INFO**

version: Firmware version number

ser_num: Instrument serial number

mfgyear: Manufacture year

mfg_mon: Manufacture month

mfg_day: Manufacture day

8 Saving Data to SD Card

The SD card file names are generated by the firmware and have the form YYMMDDA0.TXT. YY denotes the year, MM denotes the month, and DD denotes the date. The last two characters are a combination of a letter and a number and used to distinguish files saved on the same day. Filenames first increment by one to change the final number from 0 to 9. After 9, the letter increments and the number is set back to zero. For example, the first file created is A0. The file created after A9 is B0 and so on up to Z9. The number of files created in a single day is limited to 260. A new file is created when the `SD SAVE` is toggled, or when the SD Card is installed or re-installed.

To clear the SD card of old files, it is necessary to FORMAT the SD card (a quick format works) and not just delete the files. The Thermodenuder will not be able to use space freed up by simply deleting the files. When formatting an SD card be sure to choose FAT32, that is the only format that the Thermodenuder recognizes.

It is *RECOMMENDED* that SD Save be set to OFF before removing an SD card. This eliminates the possibility of corrupting the SD card.

The SD card file format consists of a header and data columns. The lines in the header start with the pound sign *#*. An example of a file header is shown on page 15. Descriptions of the parameters are inserted below and do not appear in a normal header. These parameter names are also used for serial communication.

8.1 SD Card Data File Header

```
#Thrm Dndr Serial Number:0
#firmware:1.0
#mfg_date:16/1/1                    Manufacture Date: YY/MM/DD
#
#prog=temp,time,byps                Auto program parameters
#1  = 0   ,1   ,1                    prog = program number
#2  = 0   ,2   ,0                    temp = set point temperature in °C
#3  = 0   ,3   ,1                    time = program duration in mins
#4  = 250 ,1   ,0                    byps = bypass valve state for program
#5  = 0   ,2   ,1
#6  = 150 ,3   ,0
#7  = 0   ,1   ,1
#8  = 0   ,2   ,0
#9  = 130 ,3   ,1
#10 = 0   ,1   ,0
#11 = 16  ,1   ,0
#12 = 1   ,1   ,0
#13 = 1   ,1   ,0
#14 = 0   ,1   ,0
#15 = 0   ,1   ,0
#16 = 140 ,1   ,0
#17 = 150 ,2   ,1
#18 = 160 ,3   ,0
#19 = 170 ,1   ,1
#20 = 180 ,2   ,0
#21 = 190 ,3   ,1
#22 = 200 ,1   ,0
#23 = 190 ,2   ,1
#24 = 180 ,3   ,0
#25 = 170 ,1   ,1
#26 = 0   ,1   ,0
#27 = 0   ,1   ,0
#28 = 0   ,1   ,0
#29 = 0   ,1   ,0
#30 = 0   ,1   ,0
#
#YY/MM/DD HR:MN:SC tmp_fr_sf tmp_bk_sf tmp_tb_sf tmp_dn_ex tmp_cl_fn tmp_board
ht_pwr_fr ht_pwr_bk ht_pwr_dn fn_pwr_ht fn_pwr_dn
curr_temp curr_time curr_byps prog_nmbr ctdwn_tmr err_rpt
17/08/09  15:10:38  207.2 201.1 -25.4 0   0   0   87  25  200 0 0 2048
```

8.2 SD Card Data Column Headings

Parameter	Description
YYMMDD	current date: YY/MM/DD
HR MN SC	time format: hours:minutes:seconds, 24 hour clock
tmp_fr_sf	temperature: front heating elements, sample flow (in °C)
tmp_bk_sf	temperature: back heating elements, sample flow (in °C)
tmp_tb_sf	temperature: denuder entrance tube, sample flow (in °C)
tmp_dn_ex	temperature: denuder exit, exterior surface (in °C)
tmp_cl_fn	temperature: heater cooling fans (in °C)
tmp_board	temperature: circuit board (in °C)
ht_pwr_fr	power level: front heating elements (min=0 max=200)
ht_pwr_bk	power level: back heating elements (min=0 max=200)
ht_pwr_dn	power level: denuder connector (min=0 max=200)
fn_pwr_ht	power level: heater cooling fans (min=0 max=200)
fn_pwr_dn	power level: denuder cooling fans (min=0 max=200)
stpt_temp	set point: temperature (°C)
stpt_time	set point: time (min)
stpt_byps	set point: bypass valve state (off=0, on=1)
prog_nmbr	auto program: program number
ctdwn_tmr	auto program: countdown timer of current program (sec)
err_rpt	error bits

See figure 8 for temperature sensor locations.

9 Serial Communication

9.1 Serial Receive Commands

Serial Command	Label: Description
`settings`	`td_mode:` Thermodenuder Mode *Off/Manual/Auto* `byps_yn:` Bypass Valve *Yes/No* `auto_rpt:` Auto Report *On/Off* `rpt_lbl:` Report Labels *On/Off*
`auto`	Current auto program settings: *Prog*, *Temp*, *Time*, *Byps*
`setpoints`	`stpt_temp:` Current setpoint temperature. `stpt_time:` Duration as programmed in auto mode. *(min)* `stpt_byps:` Bypass valve state. `prog_nmbr:` Current auto program number. `ctdwn_tmr:` Time left in current auto program. *(sec)* `err_rpt:` Error report code.
`temp`	`tmp_fr_sf:` Front heater sample flow `tmp_bk_sf:` Back heater sample flow `tmp_tb_sf:` Denuder entrance tube sample flow `tmp_dn_ex:` Denuder exit exterior surface `tmp_cl_fn:` Temperature of cooling fans `tmp_board:` Temperature of PCB
`power`	`ht_pwr_fr:` Front heating elements `ht_pwr_bk:` Back heating elements `ht_pwr_dn:` Denuder connector tube heating elements `fn_pwr_ht:` Heater cooling fans `fn_pwr_dn:` Denuder cooling fans
`read`	Combines serial requests of **`setpoint, temp, power`** as single request.
`time`	HH:MM:SS
`date`	MM/DD/YY
`usbid`	Unique USB identification name
`mfginfo`	Unique device information

Serial Command	Label: Description
rtclck	clk_sec Stored RTC (real-time clock) seconds clk_min Stored RTC minute clkhour Stored RTC hour clk_day Stored RTC day clk_mon Stored RTC month clkyear Stored RTC year
store	Saves current defaults to the EEPROM.

9.2 Serial Send Commands

Many settings and parameters can be changed on the Thermodenuder through serial commands.

Serial Command	Description
td_mode	**0** = Off **1** = Manual Mode **2** = Auto Program Mode
byps_yn	**0** = No Bypass Valve Installed **1** = Bypass Valved Installed
delimit	**0** = Return **1** = Tab **2** = Space
rpt_lbl	**0** = Display values only in terminal. **1** = Display values and labels.
stpt_temp	Write new set point temperature.
stpt_byps	Toggle bypass valve state. **0** = Bypass not enabled **1** = Bypass enabled

Note: Serial command values sent in hex decimal format.

9.3 Send Auto Program Parameters

To write the set point temperature, duration, and bypass valve state for a new program, send the following serial command for each program:

<program number> = <temperature>,<duration>,<bypass valve>

Below is an example input:

Serial Input	Auto Program Parameters
1e=c8,14,1	Program: *29* Temperature: *200° C* Duration: *20 min* Bypass Valve: *On*

Note: Serial command values sent in hexadecimal format.

10 Thermodenuder Specifications

Temperature

Description	MIN	MAX	UNIT
Setpoint	0	300	°C
Chassis (bottom)		50	°C
Exhaust		80	°C

Power

Description	MIN	MAX	UNIT
Voltage Input	100	240	VAC
Power Input		1500	Watts

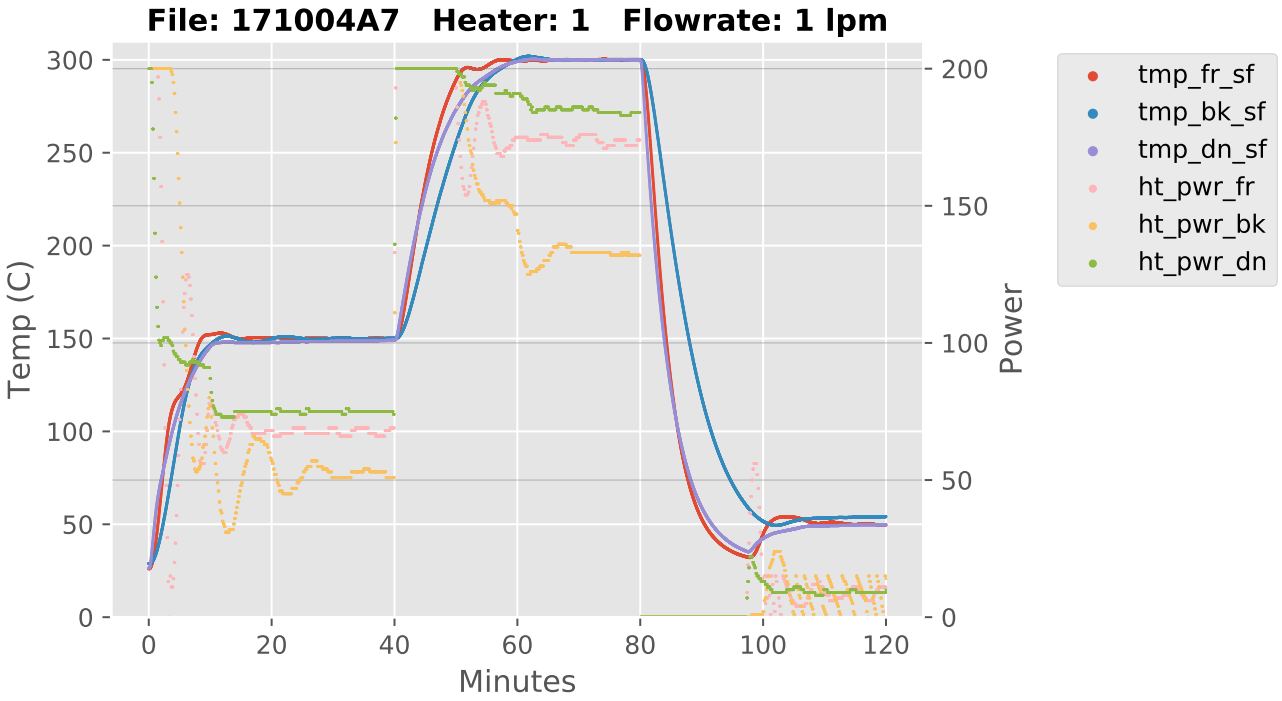
Physical Dimensions

Description	CHASSIS	MAX	UNIT
Width	17.3	21.2	in
Depth	21.2	25.0	in
Height	9.2		in
Weight	43		lbs

11 Appendix

11.1 Time Response of Temperature vs Setpoint

Expected temperature profile for three setpoint temperatures.


File: 171004A7 Heater: 1 Flowrate: 1 lpm
Temp (C)
Power
Minutes
0
20
40
60
80
100
120
0
50
100
150
200
250
300
0
50
100
150
200
tmp_fr_sf
tmp_bk_sf
tmp_dn_sf
ht_pwr_fr
ht_pwr_bk
ht_pwr_dn