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Debris Removal Firmware Guide

Parameter Values, Descriptions and Flowchart

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Revision History

Revision	Date	Author	Comments
0	Jan 22, 2002	Tony Lamprecht	Firmware flowchart is used as the basis for this document. All further changes will be made to this document. There will be no further revisions of the firmware flowchart.
A	Oct 18, 2002	Vince Beyer	Initially published on Techplanet. Add in all parameter look-up tables.
B	Feb 21, 2003	Vince Beyer	Updated Lotem 400 V2 nozzle values, add Lotem Thermoflex nozzle.
C	Sept 17, 2003	Vince Beyer / Janet Kibblewhite	Add new section on troubleshooting for the field. Add TEH1 nozzle pictures. Finalize Lotem Thermoflex nozzle parameters. Add updated Bellmouth Parameters Table. Reformat document by Janet. Update Lotem FH nozzle *flowzero* values. Added table of alternate nozzle calibration parameters with instructions. Added Lotem F/H 12mm Type II nozzle parameters and picture.
D	Nov 3, 2003	Vince Beyer	Change *set debris pnmax* parameter for Trendsetter News TH2 devices. Other minor changes.
E	Nov 26, 2003	Andrew Dobric	Add parameters for new TFX nozzle (500-01344A).
F	Mar 2, 2004	Vince Beyer	Add parameters for NEC (Fugu) Newspaper device.
G	Mar 3, 2004	Alex Kheifets	Add debris options PAEV #16 and 17 (External venting - Table 6 etc.)
H	Sept 16, 2004	Vince Beyer	Change TS News / TH2 nozzle firmware settings (table 2)
J	May 20, 2005	Alex Kheifets	Updates to Table 1 and Table 2 for ThermoFlex Mid/Narrow parameters

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1. Scope

This document is organized so that each section is more detailed than the previous. Sections 2 and 3 (tables and troubleshooting) are intended for field service use. Sections 4 and 5 and the firmware flowchart are more suited for a product development audience.

This document only applies to devices that have the new debris module built into the device control firmware or software. The first build of device firmware and software containing these changes are listed in Table 1 below.

Table 1: Firmware Versions Containing New Debris Removal Module

Output Device	Firmware Versions Supporting New Debris Module
Trendsetter Base	MPE: version 2.52b and later MCE: all versions
Trendsetter Autoloader	MPE: version 1.50 and later MCE: all versions
Trendsetter Spectrum	MPE: version 1.61 and later MCE: all versions
Lotem 800 Quantum	New debris module is unavailable*
Lotem 400 Quantum	New debris module is unavailable*
Lotem 800 (fiber head)	New debris module is unavailable*
Lotem 400 (fiber head)	1.60.x Lotem Control Software and later
Magnus 400	TBD
ThermoFlex Wide	MPE: New debris module is unavailable* MCE: all versions
ThermoFlex Mid / Narrow	New debris module is unavailable*
Trendsetter VLF	MPE: debris module is unavailable* MCE: all versions
Magnus VLF	MCE: all versions
Platesetter (VLF and 3244)	New debris module is unavailable

* as of June 1, 2003; confirmed March 3, 2004; confirmed May 10, 2005.

2. Parameter Values

Use the firmware parameter look-up table below to confirm that the firmware parameters are correct. These tables should be considered as the master source for debris firmware parameter values. Detailed descriptions of the parameters follow in Section 4.

Note: For Lotem devices with Lotem Control Software, all parameters in the tables below are located in the registry under UDRC. For MPE or MCE controlled devices, these parameters are located under >> *set debris*.

WARNING: It is very important to ensure that the media parameters *Emissions Intensity (ei)* and *Debris Options (dopt)* are set properly for the media type being imaged. Failure to do so could result in exposure to airborne emissions in excess of the applicable regulatory limits. The values for *Emissions Intensity (ei)* and *Debris Options (dopt)* are documented in the media technical note.

Table 2: Nozzle-Specific Parameters (1)

Type of Debris Nozzle	nfc	nfe	fmin (SCMH)	fmar (SCMH)	fl (SCMH)	fz (SCMH)	pnmax (kPa)	fmaxdiff (SCMH)
Thermal 1.x (50-2117B or 50-2117C) (3)	2227	2053	71	76	65	17	5.0	8.5
Thermal 2.x (50-2331A) Lotem Quantum	7280	1822	71	76	65	17	6.5	8.5
Thermal 2.x (50-2331A) Trendsetter News	7280	1822	65	68	59	17	6.5	8.5
Thermal 2.x (50-2331A) NEC (Fugu) Engine	3033	2013	65	68	59	17	6.5	8.5
Thermal 2.x (50-2331A) on any VLF engine	(3033) (2)	(2013)	71	76	65	17	(8.5) (2)	8.5
Fiber Head 12 mm Nozzle (3) Lotem 400 (P/N 500-00065A)	7622	2025	60	64	55	25	7.2	7
Fiber Head 12 mm Nozzle (3) Lotem 800 (P/N 500-00065A)	4109	2191	60	64	55	25	7.2	7
Fiber Head 20 mm Nozzle (3) Lotem 400 (P/N 500-00064A)	6750	2050	60	64	55	25	7.2	7
Fiber Head 20 mm Nozzle (3) Lotem 800 (P/N 500-00065A)	3694	2197	60	64	55	25	7.2	7
Fiber Head 12 mm Type II Nozzle(3) Lotem 400 (P/N 500-00947A)	8050	2163	(60)	(64)	(55)	(25)	12.4	7
ThermoFlex Wide (TFX Head) (P/N 50-2130C-A)	21062	2249	37	39	33	15	17.4	4.5
ThermoFlex Wide (TFX Head) (P/N 50-2130C-B)	13998	2301	37	39	33	15	17.4	4.5
ThermoFlex Wide (TFX Head) (P/N 500-01344A)	28078	2034	37	39	33	15	17.4	4.5
ThermoFlex Mid or Narrow (Lotem Fiber Head)	32800	2190	20	22	16	10	20	4.5

(1) See Section 4 for the long names of these parameters. MCE devices and Lotem Control Software use the long names.

(2) All numbers in brackets are under review, and may change in the near future.
(3) See Appendix A for identification of 12 mm, 20 mm and 12 mm Type II Lotem FH nozzles & TEH1.x version B and version C nozzles.

Table 3: Nozzle Pressure Sensor Type

Sensor Type	Sensor Range	Application	nst
Motorola MPX5100 or MPX2100 (Sensor built onto TEE and MCE Boards)	0-401 "H_2O (0-100 kPa)	POC systems only (do not use for media requiring chemical filtration)	0
Setra 2651010WD11T1C	0 – 10 "H_2O	Not Currently Used	1
Setra 2651025WD11T1C	0 – 25 "H_2O	PACC systems with TH 1.x or TH 2.x nozzles.	2
Setra 2651050WD11T1C	0 – 50 "H_2O	PACC systems with Lotem 400 or 800 Fiber Head nozzles	3
Setra 2651100WD11T1C	0 – 100 "H_2O	PACC systems with ThermoFlex Narrow, Mid or Wide Nozzles	4
Motorola MPX5100 (Satellite sensor board)	0-401 "H_2O (0-100 kPa)	POC system only. Used on TSVLF MPE driven devices	5
Motorola MPX5050 (Satellite sensor board)	0-200 "H_2O (0-50 kPa)	POC system only. Used on TSVLF MCE driven devices	6

The UDRC-L configuration cabinet used in the dual flow measurement system has a bellmouth flow sensor at the bottom of the filter compartment, below the inlet screen. The calibration parameters for the bellmouth flow sensor are shown below in Table 4. These values may vary from the firmware default values. These parameters apply to the UDRC-L type cabinets only.

Table 4: Bellmouth Parameters

bfc	bfe	pce
3559	1784	1125

In some dual flow measurement systems the flow as measured **during installation** at the debris collection nozzle does not match the flow measured at the bellmouth closely enough to allow a comfortable margin before reaching the maximum allowable difference, as set by the *flowmaxdiff* parameter. In this case the alternate nozzle parameters listed below may be used to try and get better agreement between the two flow readings.

- If the nozzle flow is low as compared to the bellmouth flow, then try the Higher Nozzle Flow Parameter set.
- If the nozzle flow is high as compared to the bellmouth flow, then try the Lower Nozzle Flow Parameter set.

These alternative nozzle parameters are for use in the dual flow measurement systems only.

Table 5: Alternate Nozzle Parameters

Type of Debris Nozzle		nfc	nfe
Thermal 1.x	Higher Nozzle Flow Parameters	1630	2100
	Lower Nozzle Flow Parameters	2980	2010
Fiber Head 12 mm on Lotem 400	Higher Nozzle Flow Parameters	5600	2075
	Lower Nozzle Flow Parameters	10400	1975
Fiber Head 12 mm on Lotem 800	Higher Nozzle Flow Parameters	3130	2230
	Lower Nozzle Flow Parameters	5450	2150
Fiber Head 20 mm on Lotem 400	Higher Nozzle Flow Parameters	5150	2090
	Lower Nozzle Flow Parameters	9250	2000
Fiber Head 20 mm on Lotem 800	Higher Nozzle Flow Parameters	2750	2240
	Lower Nozzle Flow Parameters	5050	2150
Fiber Head 12 mm Type II on Lotem 400	Higher Nozzle Flow Parameters	6700	2180
	Lower Nozzle Flow Parameters	9500	2150
Thermal 2.x	Higher Nozzle Flow Parameters	5900	1850
	Lower Nozzle Flow Parameters	9200	1790
ThermoFlex Wide (50-2130C-A Nozzle)	Higher Nozzle Flow Parameters	15000	2300
	Lower Nozzle Flow Parameters	29500	2200
ThermoFlex Wide (50-2130C-B Nozzle)	Higher Nozzle Flow Parameters	10300	2350
	Lower Nozzle Flow Parameters	19300	2250
ThermoFlex Wide (50-2130C-B Nozzle)	Higher Nozzle Flow Parameters	17500	2080
	Lower Nozzle Flow Parameters	43000	1980
ThermoFlex Narrow or Mid Nozzle	Higher Nozzle Flow Parameters	35000	2150
	Lower Nozzle Flow Parameters	60000	2090

3. Field Troubleshooting

This section describes the UDRC system in general to assist field service with troubleshooting. For detailed troubleshooting tips by error number or error message, please refer to the appropriate TechPlanet Firmware search page:

http://techplanet.creo.com/firmware/fw1ctpxml/search.htm - for MCE / Lotem Control Software (uses same error text as MCE, can search by error text if error number not given)

http://techplanet.creo.com/firmware/fw0ctpxml/search.htm - for MPE

Error messages for the debris removal system have been recently updated with problem causes and solutions for field service troubleshooting.

3.1 UDRC Naming Convention

The UDRC is available in different configurations depending on the type of media used. The UDRC configuration naming key is shown below. Not all of the combinations of cabinet type and filter type are available however. UDRC configuration information is located on the configuration label on the back of the cabinet.

UDRC-x y

- **y** — Filter Type: **P** = **P**articulate filter only; **C** = offset **C**hemical filter + particulate filter; **F** = **F**lexo chemical filter + particulate filter
- **x** — Cabinet Type: **B** = **B**ase configuration; standard flow; **L** = f**L**ow measuring configuration; standard flow; **H** = base configuration; **H**igh flow
- **UDRC** = **U**niversal **D**ebris **R**emoval **C**abinet

Figure 1: Key to UDRC Naming Convention

An External Venting option (when the exhaust airflow is vented through external piping into the atmosphere) may be added to any configuration, e.g. 'UDRC-BP with External Venting'.

3.1.1. The UDRC-L Cabinet Type

The diagram below shows the basic layout of the dual flow measurement system that uses the UDRC-L cabinet type. The nomenclature shown in this diagram is consistent with the parameter descriptions and formulas given in Section 4. The subsequent pictures show some of the important elements of this system.

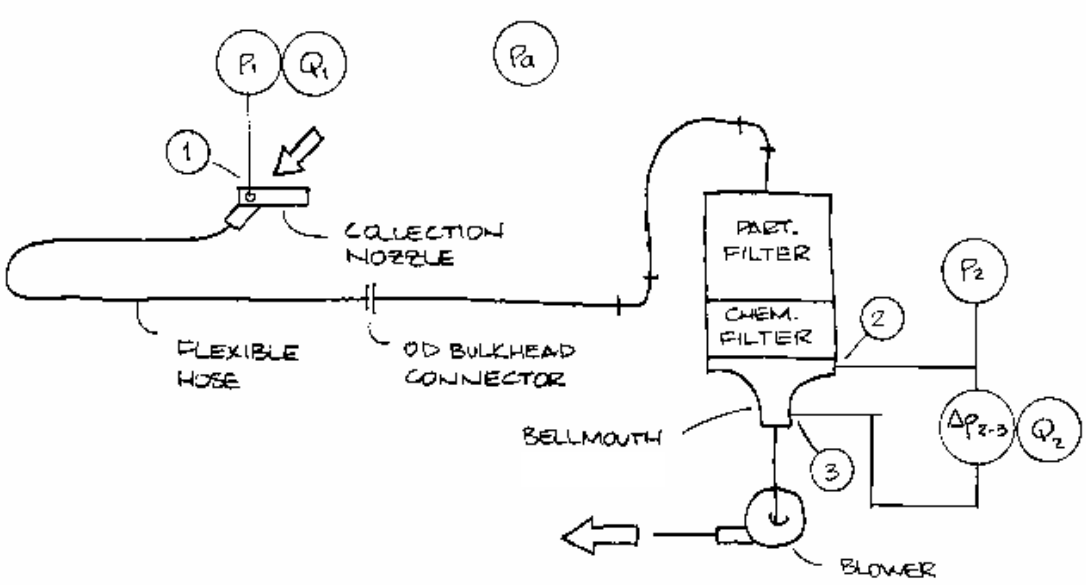


Figure 2: Dual Flow Measurement System Diagram (chemical filter will not be present in External Venting configuration)

Nomenclature:

p_a = atmospheric (or ambient) pressure
p_1 = collection nozzle vacuum pressure
p_2 = bellmouth perimeter vacuum pressure
p_3 = aspiration tube vacuum pressure
$\Delta p_{(2-3)}$ = differential pressure between p_2 and p_3
Q_1 = flow rate at collection nozzle; derived from p_1
Q_2 = flow rate at bellmouth; derived from $\Delta p_{(2-3)}$ and p_2

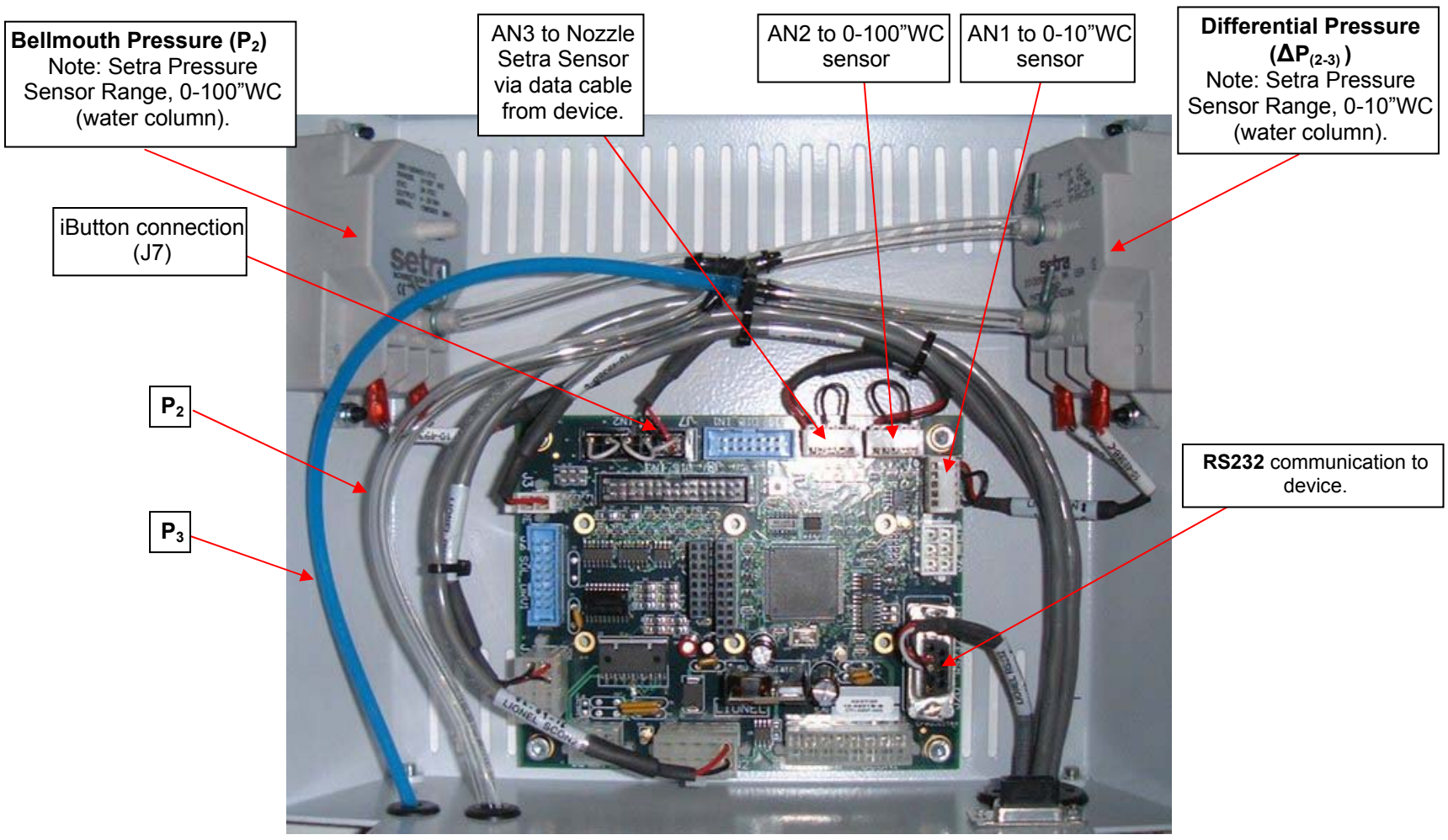


Figure 3: UDRC-L Electronics Enclosure

- Monitors flow rate at the debris nozzle via a nozzle pressure sensor.
- Second flow rate measurement location in the UDRC at the so-called *Bellmouth* at the base of the filter canister via 2 pressure sensors in the UDRC-L electronics enclosure. One sensor is called *Differential Pressure* and has a range of *0-10"H_20*. The other is called *Bellmouth Pressure* and has a range of *0-100"H_20*. (Knowing the ranges of the nozzle and UDRC sensors will help in troubleshooting).
- Checks for the presence of filters via a lid plunger switch.
- Monitors the chemical filter via an iButton embedded in the chemical filter. The programmable iButton contains information on usage of the chemical filter (current and maximum).
- All pressure sensor signals and chemical filter iButton signals are processed by the Lionel circuit board in the UDRC-L electronics enclosure. This communicates back to the output device using an RS232 communication protocol via the data cable.
- The *PACC* (*P*articulate *A*nd *C*hemical *C*ollection, see next sub-section) functionality of the debris removal firmware is used with the UDRC-L in the dual flow measurement system. Optionally, *POC* (*P*articulate *O*nly *C*ollection) functionality of the debris removal firmware can be used with the UDRC-L in the case where a second media type not requiring the use of chemical filtration is being used.
- The *PAEV* (*P*articulate collection *A*nd *E*xternal *V*enting) functionality can be optionally used with the UDRC-L if the dual flow measurement system is to be maintained, without incrementing the life of a chemical filter.

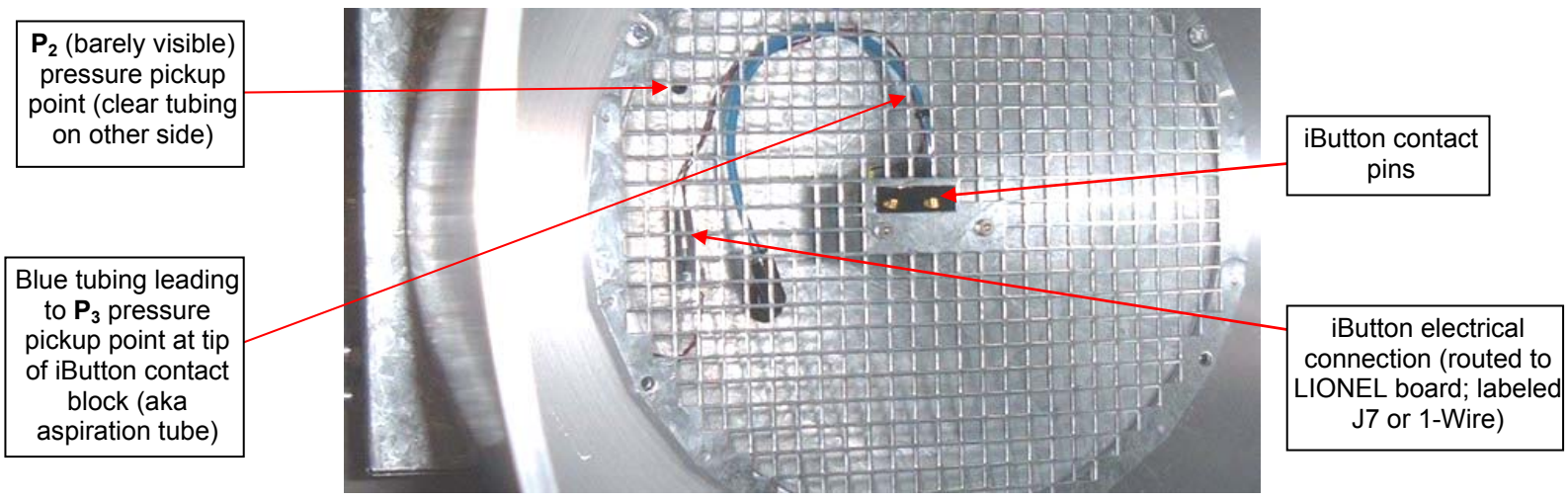


Figure 4: UDRC-L Bellmouth

3.1.2. The UDRC-B Cabinet Type

- Monitors the flow rate at the debris nozzle via a nozzle pressure sensor (typically a Motorola sensor on the TEE, MCE, or satellite board).
- Checks for the presence of a particulate filter via a lid plunger switch.
- Backwardly compatible with all Trendsetter 'Morgan' debris removal cabinets (includes a filter differential pressure switch in the UDRC lid for this purpose) [1].
- The *POC* (*P*articulate *O*nly *C*ollection) functionality of the debris removal firmware is used with the UDRC-B in the single flow measurement system.

[1] VLF MPE-based devices, ThermoFlex Wide I employ the UDRC in this mode.

3.1.3. UDRC GENERAL

- **Full Particulate Filter:** Every debris collection nozzle (the part bolted to the laser head) requires a certain *minimum flow rate* to effectively collect the debris and prevent it from accumulating on the final laser head optical element. As the particulate filter becomes full with particulate debris, the flow rate in the system decreases. The particulate filter is full when FLOW = FLOW MINIMUM.

- **Chemical Filter Expired:** Since the chemical filter does not affect the system flow rate as it filters the gases, the best way to track chemical filter life is to count the amount of media imaged. Through lab tests and a somewhat complicated analysis, we assign a chemical filter life based on throughput. This media specific value is reflected in the media specific parameter ***emissions intensity***.

- **Flow Sensors:** As shown in the schematic above, two pressure sensors give one measurement of flow in the UDRC bellmouth. However, only one pressure sensor is required to give a measurement of flow from the nozzle. The reason for this difference is beyond the scope of this document. But, be aware that a problem with either of the 2 sensors in the electronics enclosure could give an erroneous *Bellmouth Flow* reading. *Nozzle Flow* is much simpler, with only one sensor needed to give one flow reading. If interested, the formulae relating the pressure and flow readings are shown in the section on parameter descriptions.

  The flow rate values are used to determine a variety of conditions. The diagram below is a simplistic overview of how the flow rates are used to monitor the system condition. This diagram is valid for both UDRC-B and UDRC-L applications. Since the dual flow measuring system uses 2 flow measurements, generally the lower of the two flow readings is used to assess the state of the system. In the case where the two flow sensor readings differ by more than the allowable amount (set by the *flow max difference* parameter), this is an indication of a problem in the system; the nature of this problem is reflected in the text of the error message displayed.

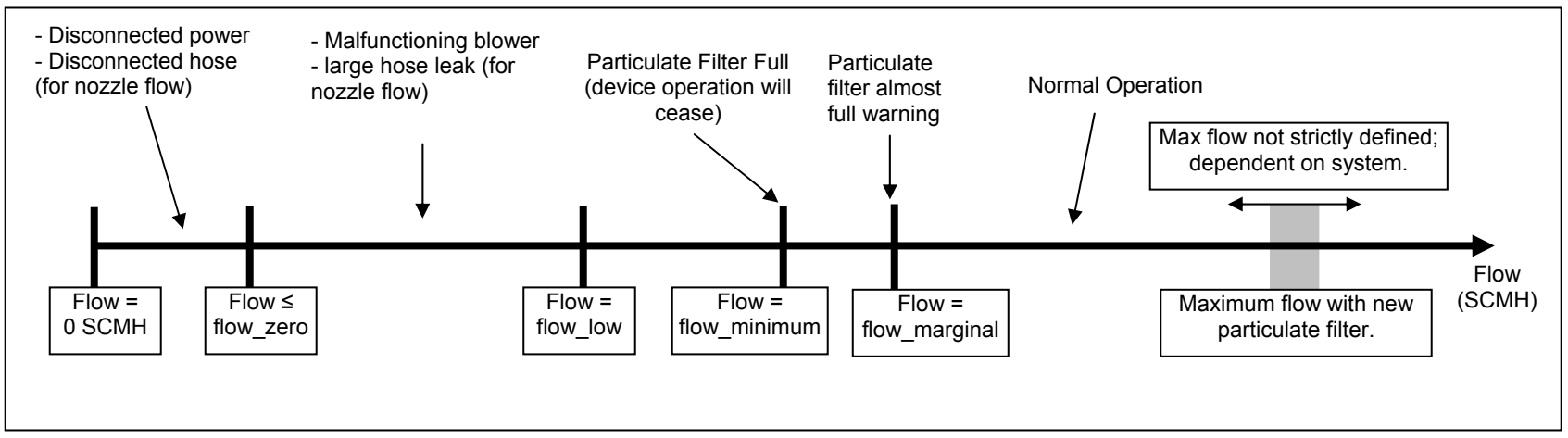


Figure 5: Diagram of Flow Thresholds

3.2 Sample Diagnostic Output (typical values and interpretation)

The best way to diagnose UDRC problems is by using the diagnostic output from the output device.

3.2.1. MCE/MPE Sample Output

See Figure 6 for sample output from an MPE Trendsetter device with a TH1.x head and a UDRC-LC (typical values could vary by 20% or more). MCE output is the same as MPE, but MCE versions may have errors in the decimal point placement of the output values similar to the Lotem 400 output (see example next section). See Figure 7 for sample output from an MPE Trendsetter with a UDRC-LC, but running under *POC* functionality (debris option 3). See Figure 8 for sample output from a **malfunctioning** MPE Trendsetter with UDRC-LC system, with troubleshooting comments.

When querying flow measurements, ensure the carriage is over the plate, and the drum is spinning. Use the appropriate debris option, or manually turn on the airjet if required for the media in question.

```
>> debris 5

Task State: Running

Currently an OFFSET filter is installed in UDRC:
  FilterUsage:  171.923
  MaxUsage:     100000.000

Whisker jet: enabled
Lid closed/filter present     : present
Blower                        : on

Nozzle Flow                   : 100.452 SCMH ( 59.123 SCFM )
Bellmouth Flow                : 95.882 SCMH ( 56.434 SCFM )

Nozzle Pressure               : 2.869 kPa ( 11.529 "H20 )
Bellmouth Pressure            : 10.274 kPa ( 41.287 "H20 )
Differential Pressure         : 1.388 kPa ( 5.577 "H20 )

Nozzle ADC sampling: Running

Bellmouth ADC sampling: Running

*** State message: DEB command (4) Complete
```

Chemical FilterUsage / MaxUsage * 100% ≈ 0.2% (filter still almost empty). This is the only way to display current chemical filter life.

These are typical flow and pressure values for a fresh particulate filter with a TEH1.x or TH2 nozzle. Note the difference in flow rates = 4.6 SCMH. This is less than flow_max_diff = 8.5 SCMH for a TEH1.x debris nozzle (ref table in Section 2).

Figure 6: Sample Diagnostic Output – MPE Trendsetter, TH1.x Head, UDRC-LC, PACC Functionality

```
>> debris 3
Task State: Running

Currently an OFFSET filter is installed in UDRC:
  FilterUsage: 0.000
  MaxUsage:    100000.000

Whisker jet: enabled
Lid closed/filter present    : present
Blower                       : on

Nozzle Flow                  : 104.886 SCMH ( 61.733 SCFM )
Nozzle Pressure              : 3.135 kPa ( 12.598 "H20 )

** Blower must be on for filter full to be valid **
Filter full (not used)       : not full

Nozzle ADC sampling: Running

*** State message: DEB command (4) Complete
```

This chemical filter output would not appear at all if a UDRC-B was installed. In debris option 3, the chemical filter usage is not incremented. Media Tech Notes indicate media specific debris option setting.

Note typical nozzle flow and pressure values fo a TH1.x nozzle, with a fresh particulate filter. As long as *Nozzle Flow* > *Minimum Flow*, the particulate filter is not full. Note absence of Bellmouth flow and 2 pressure readings since they are not used in the *POC* firmware functionality.

Ignore *Filter full (not used)* line as indicated.

Figure 7: Sample Diagnostic Output – MPE Trendsetter, TH1.x Head, UDRC-LC, POC Functionality

```
>> debris 5
Task State: Running

Currently an OFFSET filter is installed in UDRC:
  FilterUsage: 0.000
  MaxUsage:    100000.000

Whisker jet: enabled
Lid closed/filter present    : present
Blower                       : on

Nozzle Flow                  : 104.886 SCMH ( 61.733 SCFM )
Bellmouth Flow               : 145.674 SCMH ( 85.740 SCFM )

Nozzle Pressure              : 3.135 kPa ( 12.598 "H20 )
Bellmouth Pressure           : 7.903 kPa ( 31.759 "H20 )
Differential Pressure        : 2.910 kPa ( 11.694 "H20 )

Nozzle ADC sampling: Running

Bellmouth ADC sampling: Not Running

*** State message: DEB command (4) Complete
```

Error message received in this situation:

```
MPE -> Host: [ U 2 27015 14 0 Debris Removal: There may be a
partial blockage of the collection nozzle, or a leak, but
the flow rate is still above minimum ]
```

Nozzle Flow seems 'normal', but *Bellmouth Flow* greater than 'normal'. Indicates Bellmouth problem.

Note: *Differential Pressure* > 10"H_2O. Sensor is off the end of the scale! Also note *Bellmouth Pressure* < typical value with new particulate filter seen above. This points to a problem with the UDRC pressure sensor tubing, or possibly the sensor itself.*

Note: *Error number = 27015* (search for cause and resolution text on MPE Search Page in TechPlanet). This specific error will allow the machine to continue operation with a nuisance error message, since both *Nozzle Flow* and *Bellmouth Flow* > *Minimum Flow* (refer to table in Section 2).

* When troubleshooting, use the sensor flow and pressure information along with your new knowledge of the system to trace the problem. If you can't figure it out, every effort has been made to accurately document all causes and resolutions by error number on the Firmware Search Page in TechPlanet.

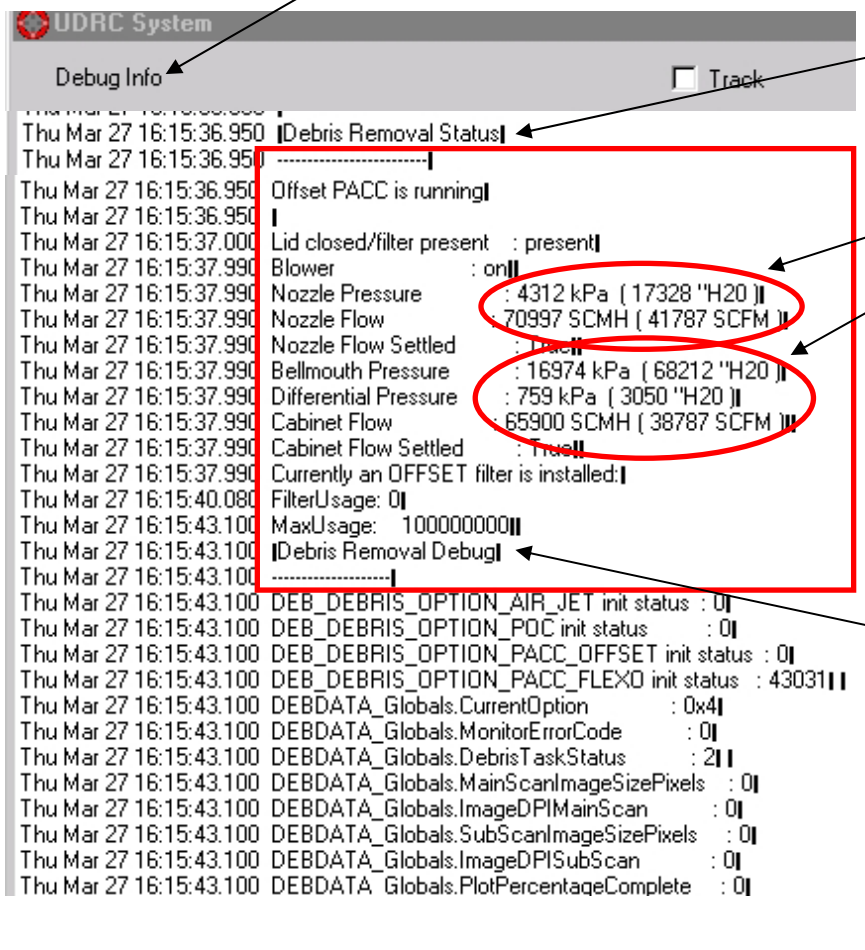
Figure 8: Sample Diagnostic Output – malfunctioning MPE Trendsetter, TEH1.x Head, UDRC-LC, PACC Functionality

3.2.2. Lotem Control Software Sample Output

The diagnostic output for Lotem Control Software is still under review, but a draft version is presented here. The same control system is used as for MCE/MPE sample output (see Section 3.2.1), but with a different display format. In other words, all analysis above applies to this system, but with different flow settings etc. Please read the notes below regarding interpretation and errors in the display.

Figure 9 shows some sample output from the Lotem Control Software debugging window. To access this window:

1. Go to the Hardware Tree and look under: *Hardware* ➔ *Expose System* ➔ *UDRC System* ➔ *UDRC System*
2. Double click on *UDRC System*.
3. Turn on the UDRC manually (via the Hardware Tree switch). Ignore the output that displays in the debugging window. Also turn on the Fufu air jet, ensure the carriage is over the plate, and drum is spinning; this is required to get a correct nozzle flow reading.
4. Wait until the flow has settled (no more messages appear in the debug window).
5. Hit the *debug info* button on the top of the diagnostic window.



The boxed info below the first dashed line under the heading *Debris Removal Status* contains all the information you really need.

Note the following missing decimal points:

- *Nozzle Pressure* = 4.312kPa (17.328"H20)
- *Nozzle Flow* = 70.997 SCMH (41.787 SCFM)
- Same problem (divide by 1000) for *Bellmouth Pressure, Differential Pressure, Cabinet Flow, Filter Usage and Max Usage*.

This example represents typical values on a Lotem 400 (or 800) with a new filter. Note the ≈ 5 SCMH difference between the *Nozzle* and *Bellmouth Flows*. Even though this is within *flowmaxdifference* registry parameter value of 7 SCMH, this is a bit too close and may cause intermittent errors. In this example, the cause of this was outdated bellmouth calibration parameters. Updated parameters are located in Table 2.

This boxed output is followed by more detailed output starting with the second dashed line under the heading *Debris Removal Debug.* All data from the *Debris Removal Status* section is repeated, but mixed with additional information which is not really useful for field troubleshooting. However, in the event of an error condition, the *Debug* section may be the only location where the flow and pressure data are displayed.

Figure 9: Sample Diagnostic Output – Lotem Control Software

You can also view this debug window while plotting to get a real time account of the UDRC activities during the plot. This output is rather long, difficult to interpret, and contains an excess amount of information for the average troubleshooting session. It is strongly recommended to debug the system by turning on the UDRC manually and hitting the *Debug Info* button. The data displayed during plotting contains the same decimal place errors noted above.

4. Parameter Descriptions

This section provides detailed information about each of the parameters used in the debris removal firmware module. This information is intended for Product Development engineers or UDRC specialists (or very brave service engineers!).

4.1 Units Conversions and Abbreviations

The following units conversions and abbreviations are used:

$ft^3/min \times 1.699011 = m^3/hr$
"$H_2O \times 0.24884 = kPa$
ft x 3.280833 = m
SCMH = Standard Cubic Meters per Hour
SCFM = Standard Cubic Feet per Minute

Note that "Standard" as used here is **not** Standard Temperature and Pressure (STP) as used in chemistry and physics (p = 1 atm and t = 0 °C), but **Standard Air** as used in the field of Heating Ventilating and Air Conditioning (HVAC). Standard Air refers to air with a density of 0.075 lb/ft^3 (1.2 kg/m^3). Density is affected by humidity, and there are two combinations of conditions normally used that both have a density of 0.075 lb/ft^3 (1.2 kg/m^3):

1) **Dry Air** with p = 29.921 "Hg ; t = 70 °F ; RH = 0% (p = 101.325 kPa ; t = 21 °C ; RH = 0%)

2) **Moist Air** with p = 29.921 "Hg ; t = 68 °F ; RH = 50% (p = 101.325 kPa ; t = 20 °C ; RH = 50%)

A convenient unit for pressure measurement in HVAC work is "inches of water column" (abbreviated as "WC, "w.c. or "H_2O). Note that there are two units for pressure measurement in "H_2O. One is "H_2O at 4°C and the other is "H_2O at 20°C. All references to "H_2O here shall be interpreted to mean "H_2O at 20°C.

4.2 NVS Parameters

The following NVS parameters are used to control how the debris removal firmware module behaves. If time and experience shows that any of these parameters do not need to be varied, then they will be hard coded. The parameter names are taken from the MPE-based device names. MCE and Lotem Control Electronics machines generally only use the long name descriptions, with possibly some subtle name differences.

debris, nfc (nozzle_flow_constant) This is the constant 'A_1' in the equation $Q_1 = \left(\frac{p_1}{A_1}\right)^{\frac{1}{x_1}}$ that is used to characterize the pressure vs. flow relationship of the debris collection nozzle. When a calibration plot of nozzle pressure (kPa) vs. flow (SCMH) is done, this constant will be a number in the form *x.xxxxxxE-4*. It must be multiplied by 10^7 before being entered as a parameter. For example. if the number is found to be 2.226510E-4, then the value to enter as the parameter is 2226.510. This parameter is used for both the single flow measurement and dual flow measurement systems. This parameter is a unit-less number that depends on the type of debris removal nozzle installed; please consult Table 2.

debris, nfe (nozzle_flow_exponent) This is the exponent 'x_1' in the equation $Q_1 = \left(\frac{p_1}{A_1}\right)^{\frac{1}{x_1}}$ that is used to characterize the pressure vs. flow relationship of the debris collection nozzle. When a calibration plot of nozzle pressure (kPa) vs. flow (SCMH) is done, this exponent will be a number in the form *x.xxxxxx*. It must be multiplied by 10^3 before being entered as a parameter. For example, if the number is found to be 2.053038, then the value to enter as the parameter is 2053.038. This parameter is used for both the single flow measurement and dual flow measurement systems. This parameter is a unit-less number that depends on the type of debris removal nozzle installed; please consult Table 2.

debris, bfc (bellmouth_flow_constant) This is the constant 'A_2' in the equation $Q_2 = \left(\frac{\Delta p_{(2-3)corrected}}{A_2} \right)^{\frac{1}{x_2}}$ that is used to characterize the pressure vs. flow relationship of the bellmouth inlet to the blower. When a calibration plot of bellmouth differential pressure (kPa) vs. flow (SCMH) is done, this constant will be a number of the form x.xxxE-4. It must be multiplied by 10^7 before being entered as a parameter. For example, if the number is found to be 3.559E-4, then the value to enter as the parameter is 3559. This parameter is used only in the dual flow measurement systems. It will not normally need to be changed in the field, unless a new style bellmouth is installed that has a different pressure vs. flow characteristic. This parameter is a unit-less number shown in Table 4: **Bellmouth Parameters**.

debris, bfe (bellmouth_flow_exponent) This is the exponent 'x_2' in the equation $Q_2 = \left(\frac{\Delta p_{(2-3)corrected}}{A_2} \right)^{\frac{1}{x_2}}$ that is used to characterize the pressure vs. flow relationship of the bellmouth inlet to the blower. When a calibration plot of bellmouth differential pressure (kPa) vs. flow (SCMH) is done, this exponent will be a number in the form *x.xxx*. It must be multiplied by 10^3 before being entered as a parameter. For example, if the number is found to be 1.784, then the value to enter as the parameter is 1784. This parameter is used only in the dual flow measurement systems. It will not normally need to be changed in the field, unless a new style bellmouth is installed that has a different pressure vs. flow characteristic. This parameter is a unit-less number shown in Table 4: **Bellmouth Parameters**.

debris, se (site_elevation) This is the elevation at the installation site, in meters. Elevations of some 85,000 locations around the world may be found at http://www.worldclimate.com . The barometric (or atmospheric) pressure varies with elevation and weather conditions. The effect of weather conditions only introduces a small error and is neglected. The effect of elevation is, however, considerable and must be accounted for. When the site elevation is entered, the nominal atmospheric pressure is calculated as follows:

$$p_a = p_0 \left(1 - 2.2608988 x 10^{-5} h\right)^{5.2558797}$$

where $p_0 = 101.325$ kPa (the nominal atmospheric pressure at sea level), h is the site elevation in meters, and p_a is the atmospheric pressure in kPa at the site elevation h. The default is sea level or 0 m.

debris, pz (pressure_zero) This is the tolerance on a nominally zero pressure reading such that, if the actual pressure recorded or read is within *0* ± *debris pz*, then the pressure is considered to be zero. This parameter applies to all pressure sensors. The default is 0.125 kPa (0.5 "H_2O).

debris, pnmax (press_nozzle_max) This is the maximum nozzle vacuum reading expected during normal service. A reading higher than this is an indication that the debris collection nozzle is blocked. The value of this parameter depends on the type of debris removal nozzle installed; please consult Table 2.

debris, pbmax (press_bellmouth_max) This is the maximum vacuum reading expected from the bellmouth perimeter gauge pressure sensor. The parameter value will normally be the range of the sensor. If the sensor reading is greater than the range of the sensor, something is wrong with the sensor itself. The default is 24.88 kPa (100 "H_2O).

debris, pbmaxdiff (press_bellmouth_max_diff) This is the maximum vacuum reading expected from the bellmouth differential pressure sensor. The parameter value will normally be the range of the sensor. If the sensor reading is greater than the range of the sensor, something is wrong with the sensor itself. The default is 2.49 kPa (10 "H_2O).

debris, fz (flow_zero) This is the tolerance on a nominally zero flow reading such that if the actual flow rate is within *0* ± *debris fz*, then the flow rate is considered to be zero. This parameter is related to the type of debris removal nozzle installed; please consult Table 2.

debris, fl (flow_low) If the flow rate drops below this threshold, there may be something wrong with the blower. This flow rate is below minimum flow and the system cannot run in this condition. However, this threshold should also catch the situation where the blower is running, but not performing well enough to bring the flow rate above minimum. This parameter is related to the type of debris removal nozzle installed; please consult Table 2.

debris, fmin (flow_min) This is the minimum allowable flow to successfully collect debris. Under normal operating conditions, this is the flow rate at which the particulate filter is deemed to be full. The system will not run with the flow rate at, or below, minimum flow. This parameter depends on the type of debris removal nozzle installed; please consult Table 2.

debris, fmar (flow_marginal) This is the flow rate at which the operator is given a warning that the particulate filter is nearly full. This parameter depends on the type of debris removal nozzle installed; please consult Table 2.

debris, fmaxdiff (flow_max_diff) This parameter is the maximum allowable difference in flow rate between the nozzle flow and the bellmouth flow. If the actual difference exceeds the maximum allowable difference, there is a leak in the system. This parameter depends on the type of debris removal nozzle installed; please consult Table 2.

debris, nsi (nozzle_sensor_installed) This parameter is used to indicate whether or not there is a pressure sensor installed to monitor the pressure in the debris collection nozzle. If there is no sensor installed, the differential pressure switch in the cabinet will be used instead. Possible values for this parameter are: 0 = no nozzle pressure sensor installed (and the differential pressure switch will be used), or 1 = a nozzle pressure sensor is installed. The default is 1.

debris, bod (blower_off_delay) This is the delay between when the command to shut down the blower is given and the blower is actually shut down. The delay serves two purposes: 1) the blower life is extended if it does not stop and start between successive plots, and 2) a minimum delay of 20 sec is required to purge the hoses and filter canister of any debris. The default is 300 sec (5 min).

debris, nst (nozzle_sensor_type) This parameter is used to indicate the type of nozzle pressure sensor installed. In POC (Particulate Only Collection) systems, the nozzle pressure sensor is a Motorola MPX sensor installed on one of the TEE board, MCE board, or remote (aka satellite) pressure sensing board. In PACC (Particulate And Chemical Collection) systems, the nozzle pressure sensor is a Setra (brand name) sensor. whose range depends on the type of collection nozzle installed. Please consult Table 3 to determine what nst should be. The default value is 0.

debris, maxfcrs (max_flow_change_rate_setra) This parameter applies only to MPE based devices running FW0. This is the maximum allowable rate of change of flow before the flow is considered to be unstable *when a Setra sensor is installed*. It is calculated as the change in flow rate divided by SINT. The default is 3 SCMH/sec (1.75 SCFM/sec).

debris, maxfcrm (max_flow_change_rate_motorola) This parameter applies only to MPE based devices running FW0. This is the maximum allowable rate of change of flow before the flow is considered to be unstable *when a Motorola MPX sensor is installed*. It is calculated as the change in flow rate divided by SINT. The default is 14 SCMH/sec (8.24 SCFM/sec). The *maxfcr* value must be higher for the Motorola sensor because the portion of the sensor range that is being used is very small. The result is that a one bit change in the output of the ADC represents a significant change in flow rate.

debris, FlowChangeRate This parameter applies only to MCE based devices running FW1. This is the maximum allowable rate of change of flow before the flow is considered to be unstable when *any type of pressure sensor* is connected directly to the MCE board. In FW1 it is possible to filter the pressure sensor output to smooth out the quantization error introduced by the ADC. This means that it is not necessary to have different parameters for different types of pressure sensors as is the case for MPE based devices running FW0 (see *maxfcrs* and *maxfcrm* above). However, this filter is only applied when the pressure sensor is directly connected to (or mounted on) the MCE board. If the pressure sensor is connected to a satellite board (eg: Lionel or Genine), then the filter is not applied, and this parameter will have no effect.

debris, pce (pressure_correction_exponent) This is the exponent 'n' in the equation $\Delta p_{(2-3)\,corrected} = \Delta p_{(2-3)\,actual}\left(\frac{p_a - p_2}{p_a}\right)^n$ used to correct the bellmouth differential pressure to an atmospheric pressure reference. This exponent will be a number in the form *x.xxx* . It must be multiplied by 10^3 before being entered as a parameter. For example, if the exponent is 1.125, then the value to enter as the parameter is 1125.000. This parameter is used only in dual flow measurement systems. It will not normally need to be changed in the field, unless a modification to the flow measurement method is undertaken. The default is 1125 (this is a unit-less number).

sys, dbin (dblower_installed) This parameter applies only to MPE based devices running FW0. It is used to indicate what type of debris removal hardware is installed. Possible values for this parameter are: 0 = no debris removal hardware installed (i.e; air jet only), 1 = POC enabled hardware installed, 2 = PACC enabled hardware installed. The default is 1.

sys, scon This parameter applies only to MPE based devices running FW0. It is used to indicate whether SCON communication is enabled or not. Possible values for this parameter are: 0 = SCON disabled, or 1 = SCON enabled. The default is 0. SCON must be enabled for PACC operation, but is not required for POC operation.

sys, sbaud This MPE parameter is the SCON communication rate. The default is 9600.

The following table shows the correct combinations for the dbin, scon, and sbaud variables:

Debris Cabinet Type	dbin	scon	sbaud
None	0	0	9600
Morgan or UDRC-BP or -BF	1	0	9600
UDRC-LC or -LF	2	1	9600

4.3 Hard Coded Parameters

The following parameters have been hard coded, based on testing experience so far. They are listed here so that their effect on the algorithm is understood in case they need to be changed in future.

debris, sint (sampling_interval) This is the time interval between readings of the nozzle pressure from the Lionel board. The minimum this can be is 300 msec. The default is 300 msec.

debris, mrate (monitor_rate) This is the time interval between passes through the monitor function. This should not be less than 2x SINT. The default is 900 msec.

debris, swt (stability_wait_time) This is the maximum amount of time to wait for the flow to stabilize before giving an error message. The default is 35000 msec (35 sec).

4.4 Debris Removal Command Syntax

The command syntax described below applies only to MPE based devices running FW0 and MCE based devices running FW1. Devices controlled by Lotem Control Software use a GUI to control the debris removal system.

debris [option | (<#>|(whisker|poc|pacc)) [<on|off>] | all off]

Typical operations are:

debris - displays current task state
debris <**debris option**> - displays status of debris removal option selected
debris <**debris option**> <**on**|**off**> - enables/disables specified debris removal option
debris option – displays available debris options and values for those options (as shown in Table 6 below)

The <**debris option**> parameter may be a **numerical value** from Table 6 below, or one of **whisker**, **poc**, **pacc** or **paev**. Whisker jet and air jet are the same thing in this context. For example, the command **debris 5 on** will enable offset PACC debris removal and the air jet. By comparison, the command **debris pacc on** will enable PACC debris removal, but will not start the air jet. The command **debris 4 on** would accomplish the same thing as **debris pacc on** and is the preferred command structure. Debris option uses binary bit positions to enable or disable debris options. Bit position 0 (decimal 1) is for the air jet. Bit positions 1, 2 and 3 are for POC debris removal, offset PACC debris removal, and flexo PACC. Bit position 4 is for Flexo PAEV debris removal, respectively. For example to enable POC debris removal with air jet you need to turn on bits 0 (decimal 1) and 1 (decimal 2), so the debris option to use is 1+2=3.

Note: Always consult the media technical note for the appropriate *debris option* setting.

Table 6: Debris Option Values

Debris Option [1]	Binary Notation	Options Enabled
0	0	No air jet or vacuum
1	1	Air jet only
2	10	POC debris removal only (no air jet)
3	11	POC debris removal and air jet
4	100	Offset PACC debris removal only (no air jet)
5	101	Offset PACC debris removal and air jet
8	1000	Flexo PACC debris removal only (no air jet) [2]
9	1001	Flexo PACC debris removal and air jet [2]
16	10000	Flexo PAEV debris removal only (no air jet) [2]
17	10001	Flexo PAEV debris removal and air jet [2]

[1] All options not shown in this table are invalid.
[2] This option is valid for Flexo only and is not applicable to the Trendsetter or Lotem offset.

The Debris Option required for a media is listed in the media technical note.

5. Error Messages

The last three digits of debris removal error numbers are common to all systems. The first two digits indicate the type of firmware or software control. For MPE based devices running FW0, the error numbers begin with 27. For MCE based devices running FW1, or Lotem Control Software based devices, the error numbers begin with 43.

MPE (FW 0): 27xxx
MCE (FW 1) and Lotem Control Software: 43xxx

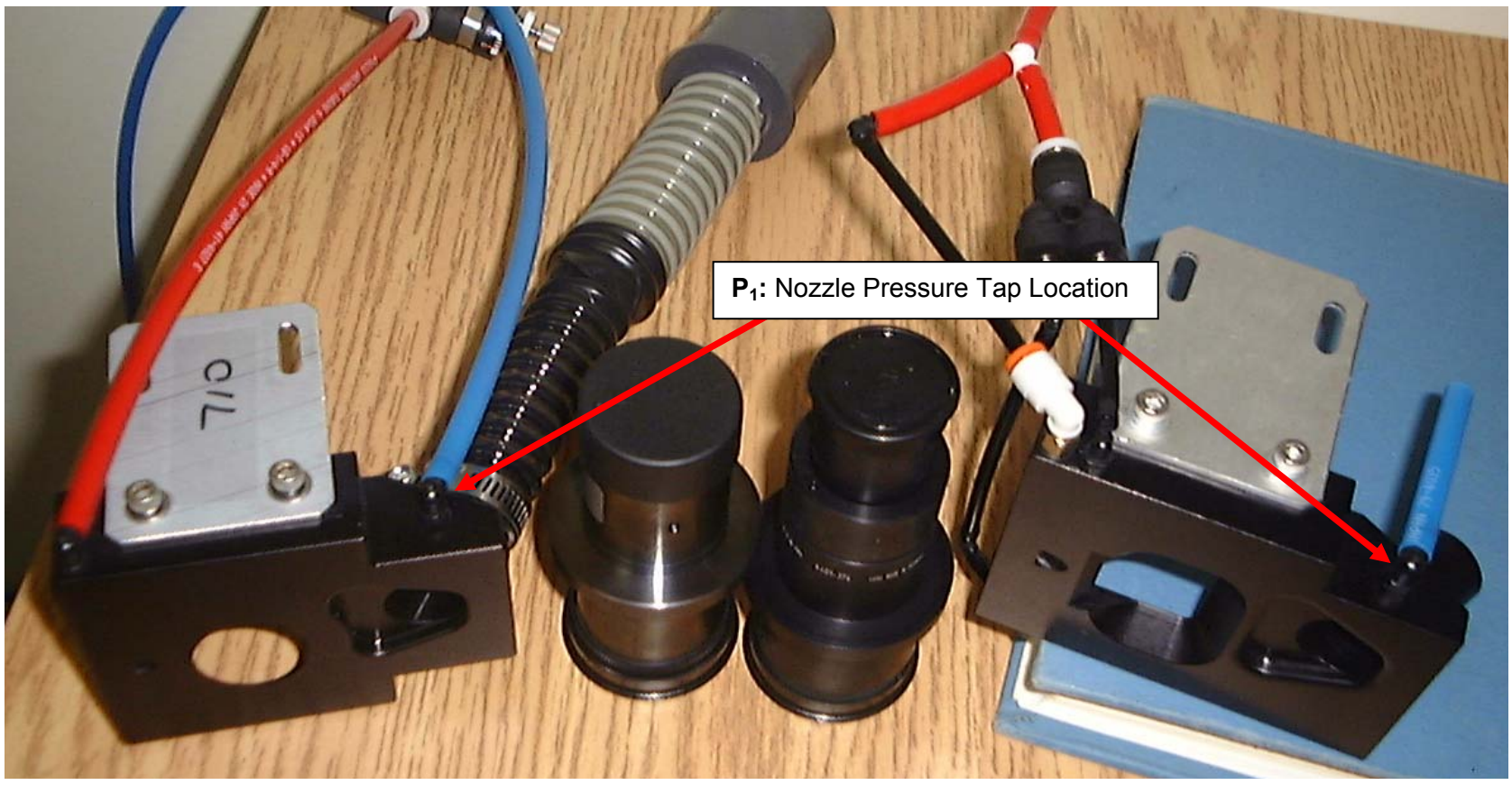
The firmware flowchart in Appendix B follows the FW0 numbering scheme (ie; 27xxx), but is valid for all systems.

xx000 Debris Removal: not used
xx001 Debris Removal: not used
xx002 Debris Removal: Particulate Only Collection (POC) debris removal is not enabled on this device
xx003 Debris Removal: Particulate and Chemical Collection (PACC) debris removal is not enabled on this device
xx004 Debris Removal: The air jet is enabled, but not turned on
xx005 Debris Removal: The blower is not turned on
xx006 Debris Removal: The flow rate is below the minimum required
xx007 Debris Removal: The cabinet has lost power
xx008 Debris Removal: The particulate filter is not present or upside down, the lid is not closed, or the data cable is disconnected
xx009 Debris Removal: The particulate filter is almost full. Please ensure a replacement filter is on hand
xx010 Debris Removal: The particulate filter is full. You must replace the particulate filter to continue imaging
xx011 Debris Removal: The debris collection nozzle is blocked
xx012 Debris Removal: The debris hose is disconnected
xx013 Debris Removal: There is a problem with one or more of the pressure sensors in the debris removal cabinet
xx014 Debris Removal: The debris hose is disconnected, the cabinet has lost power, or the cabinet lid is not latched properly
xx015 Debris Removal: There may be a partial blockage of the collection nozzle, or a leak, but the flow rate is still above minimum
xx016 Debris Removal: There is a partial blockage of the collection nozzle, or a leak, and the flow rate is below minimum
xx017 Debris Removal: The media being imaged releases potentially harmful emissions. See the Operator Manual for more information
xx018 Debris Removal: not used
xx019 Debris Removal: The chemical filter has almost expired. Please ensure a replacement filter is on hand
xx020 Debris Removal: The chemical filter has expired. You must replace the chemical filter and reset the output device to continue imaging
xx021 Debris Removal: The chemical filter usage sensor is corrupt or the chemical filter was changed and the output device was not reset
xx022 Debris Removal: Unable to communicate with the chemical filter. See the Operator Manual for more information
xx023 Debris Removal: The chemical filter usage calculated is negative
xx024 Debris Removal: Unable to calibrate <str> pressure sensor
where <str> = *nozzle*, *bellmouth*, or *differential* as appropriate
xx025 Debris Removal: Unable to communicate with the chemical filter during initialization. See the Operator Manual for more information
xx026 Debris Removal: Timeout: the pressure sensor output failed to stabilize
xx027 Debris Removal: No debris removal options are enabled on this device
xx028 Debris Removal: There is a problem with the nozzle pressure sensor in the output device
xx029 Debris Removal: Command failed: cannot run more than one PACC option at a time
xx030 Debris Removal: Cannot start new debris option while another is in an error condition
xx031 Debris Removal: The chemical filter installed is not suitable for the selected media.
xx032 Debris Removal: The particulate filter is almost full AND the chemical filter has almost expired

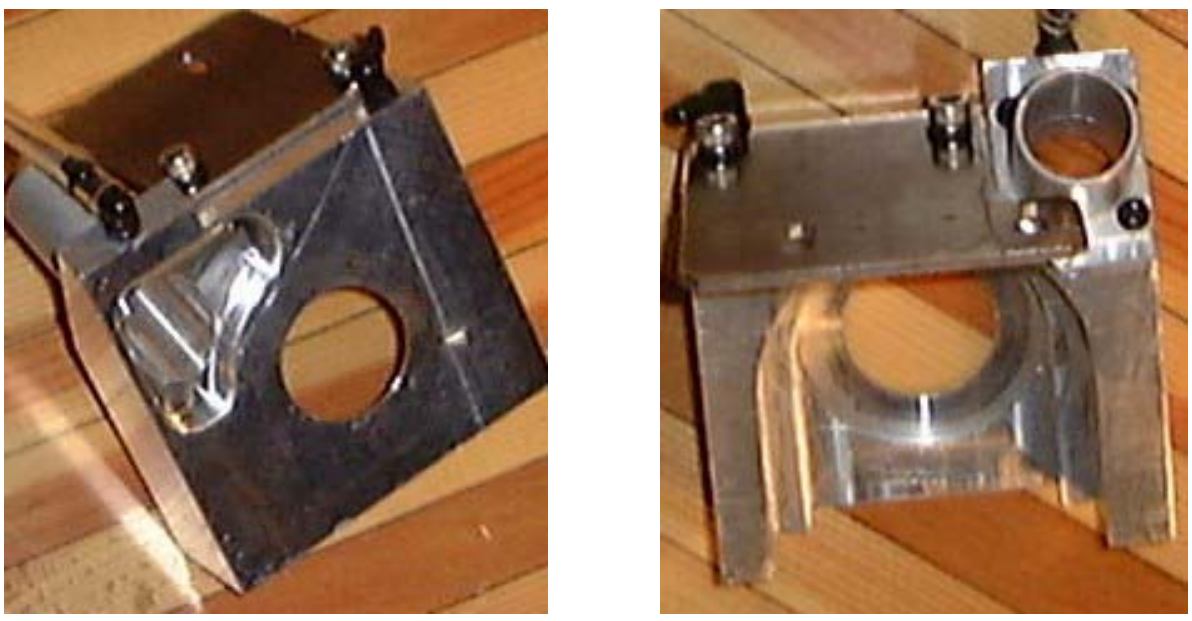
6. Appendix A - Identifying Debris Removal Nozzles



(Left) Lotem F/H 12mm Nozzle (for long lens tubes) **(Right) Lotem F/H 20mm Nozzle (for short lens tubes)**

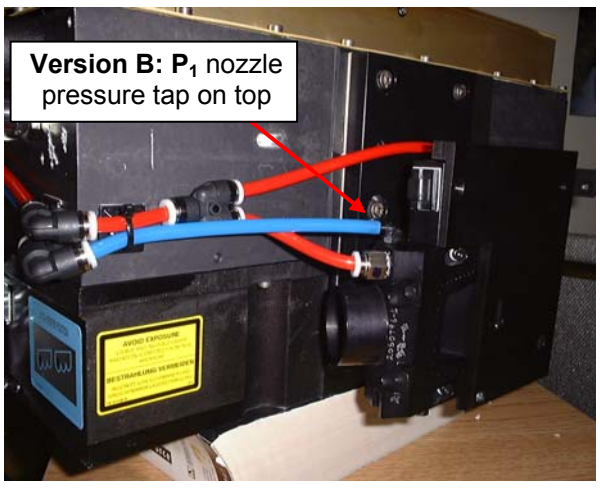


(Left) Lotem F/H 12mm Nozzle (for long lens tubes) **(Right) Lotem F/H 20mm Nozzle (for short lens tubes)**

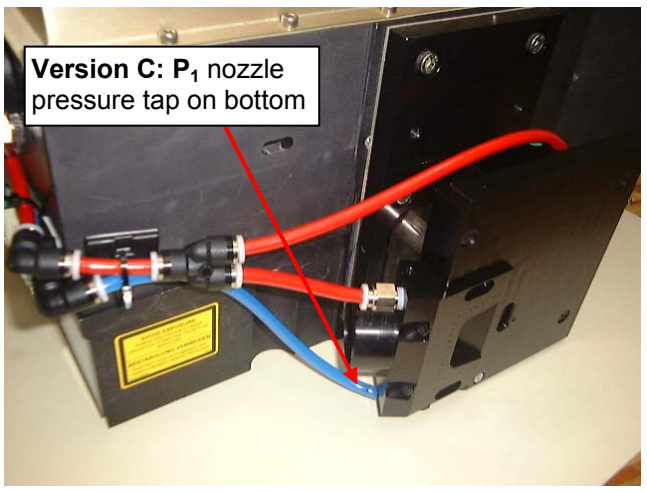


Lotem F/H 12mm Type II Nozzle (for long lens tubes). Front and back views.

Figure 10: Lotem Debris Removal Nozzles



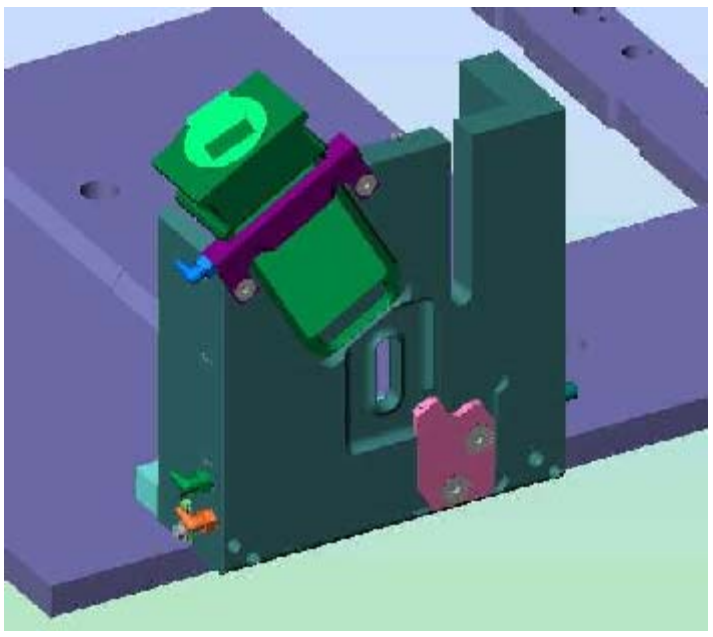
Version B nozzle (or earlier)



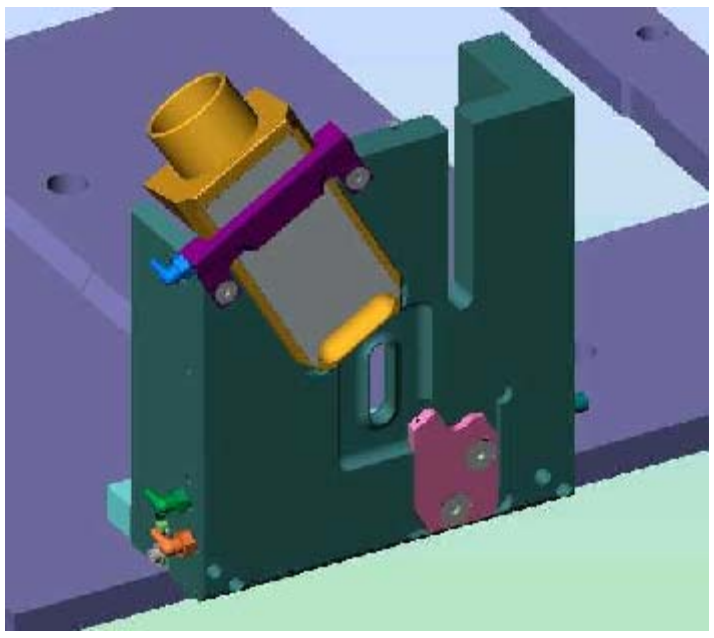
Version C Nozzle

Figure 11: TEH 1.x Debris Removal Nozzles

Note on TEH 1.x Nozzles
Most debris accumulates on the top surface of this nozzle design. Order a version C nozzle for sites with older nozzles that tend to clog with debris. Both version C and B use the same nozzle parameter values (see Table 2).



50-2130C-B (Rear Hose Attachment)

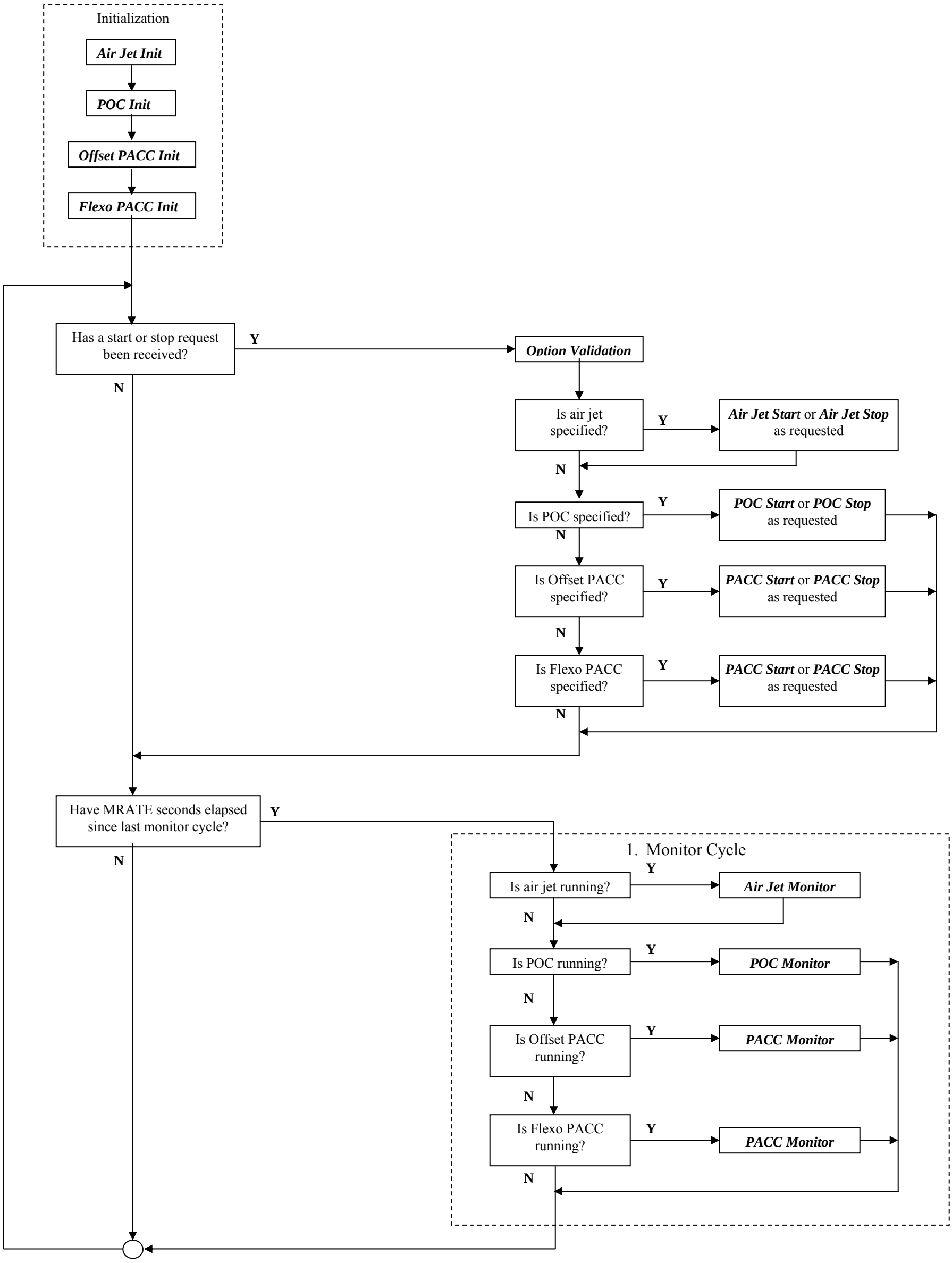


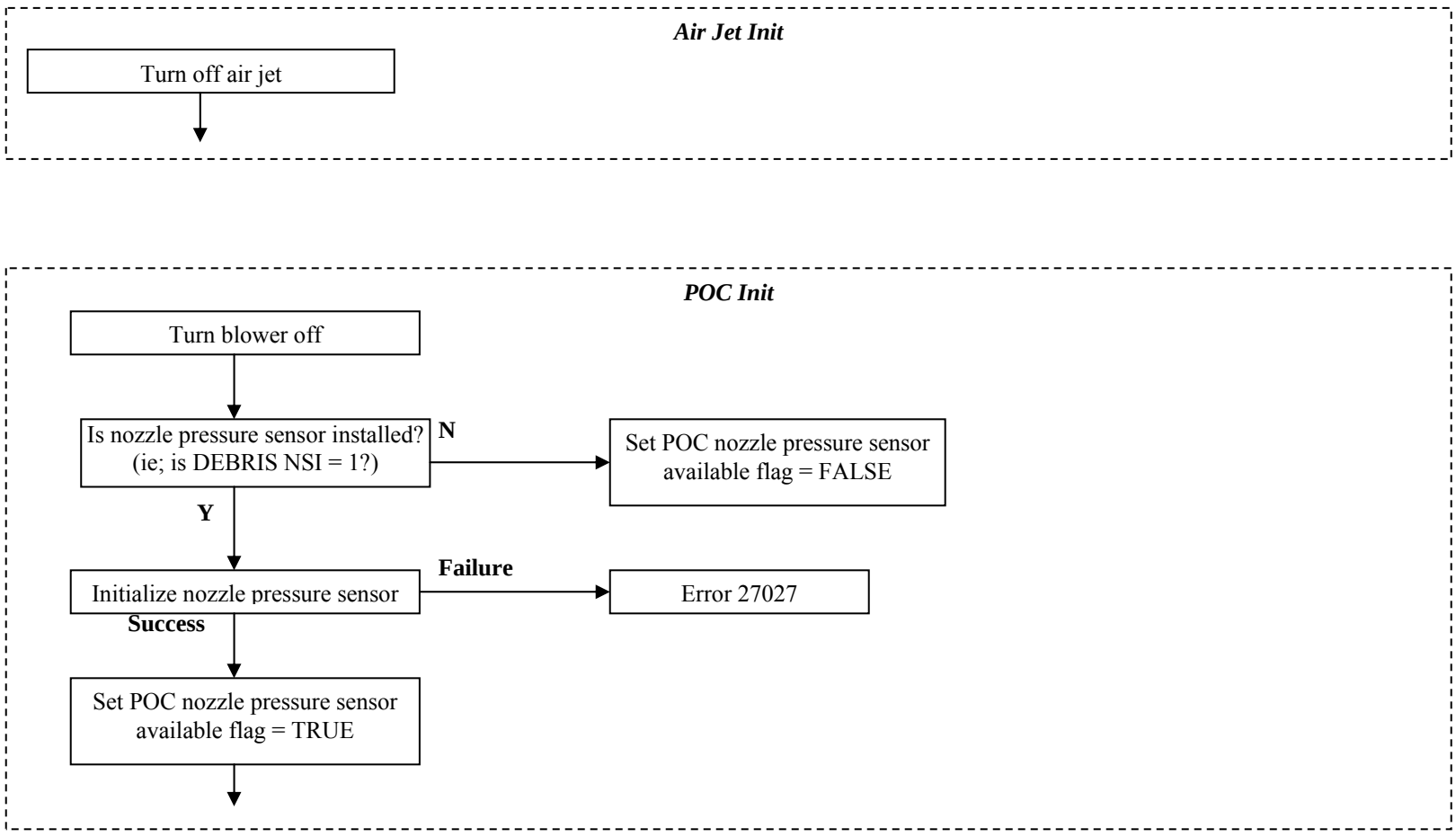
500-01344A Suction Nozzle (Top Hose Attachment)

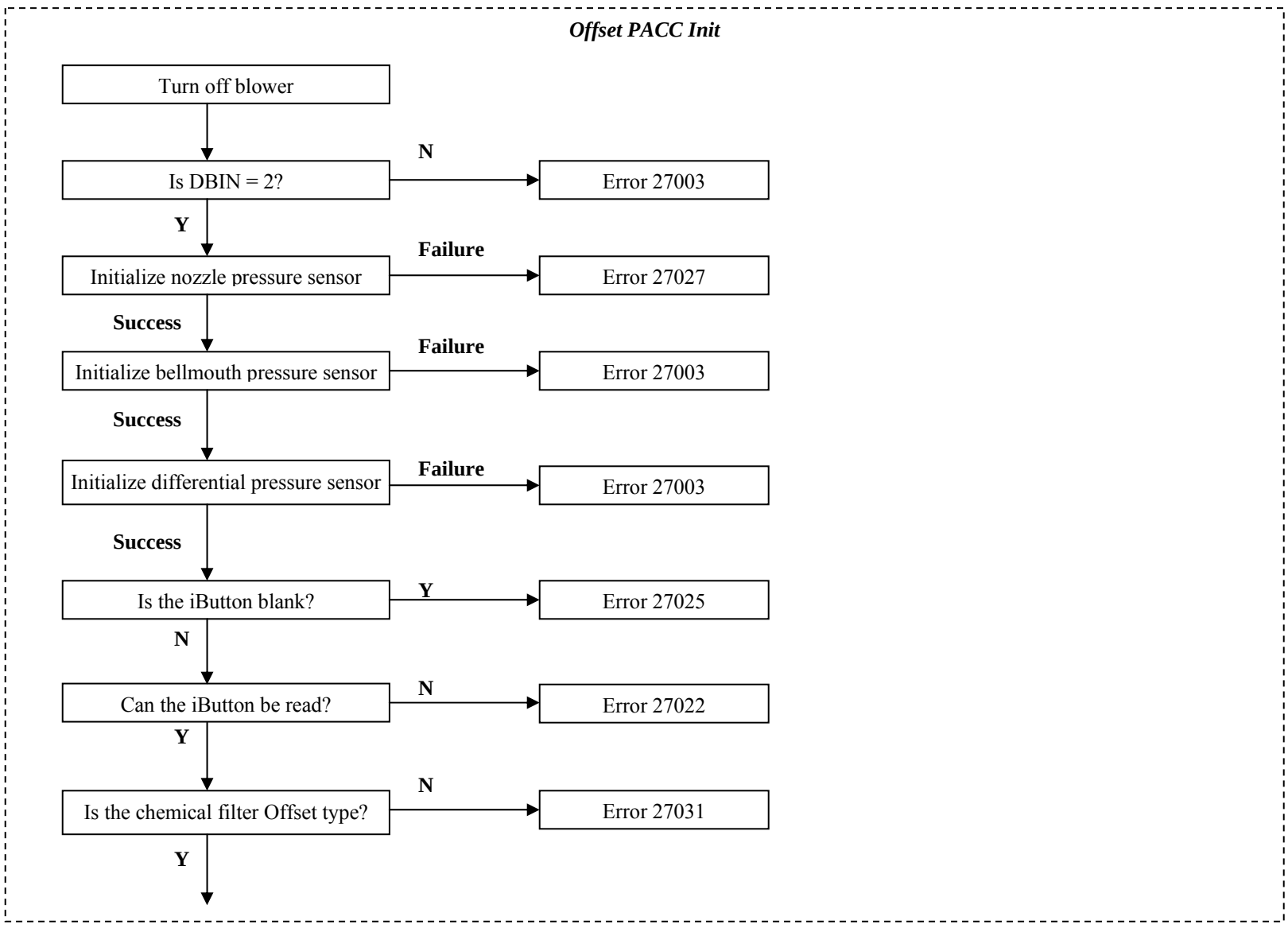
Figure 12: TFX Debris Removal Nozzles

7. Appendix B - Debris Removal Firmware Flowchart

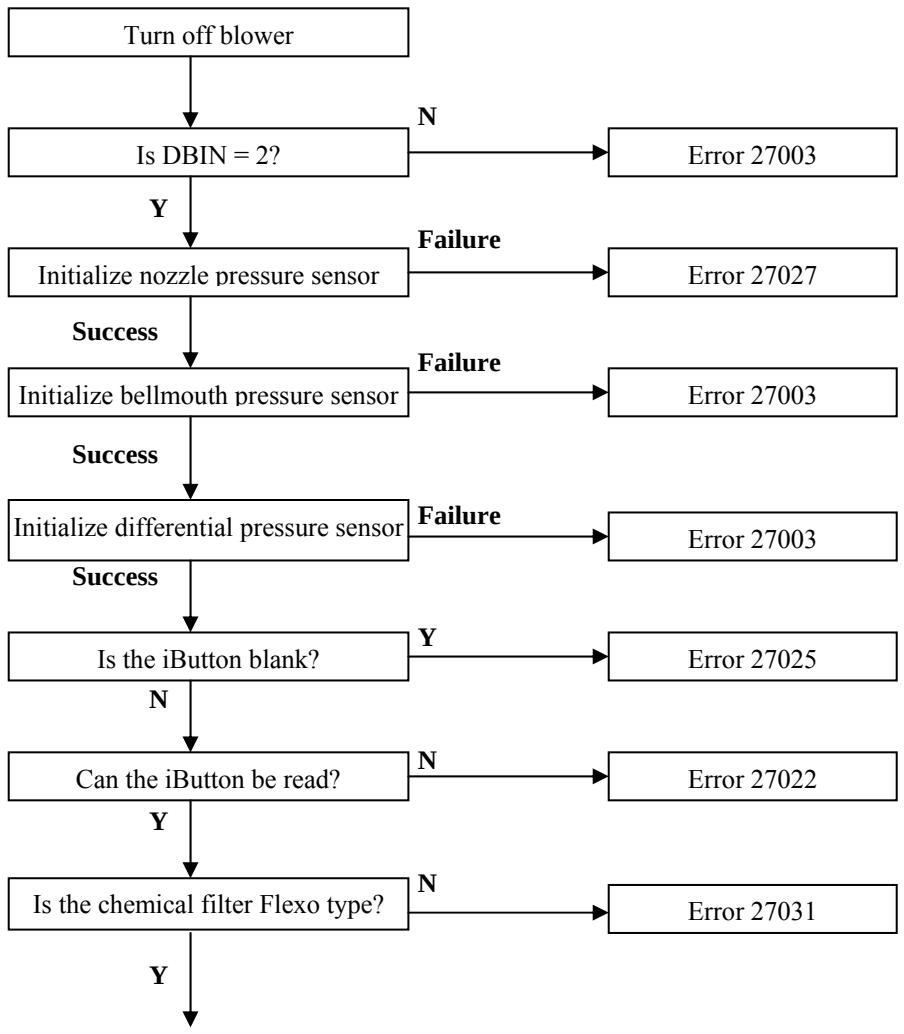
External venting PAEV configuration is not shown. (Its operation is identical to PACC, except all functions related to the iButton and chemical filter in general being disabled.)



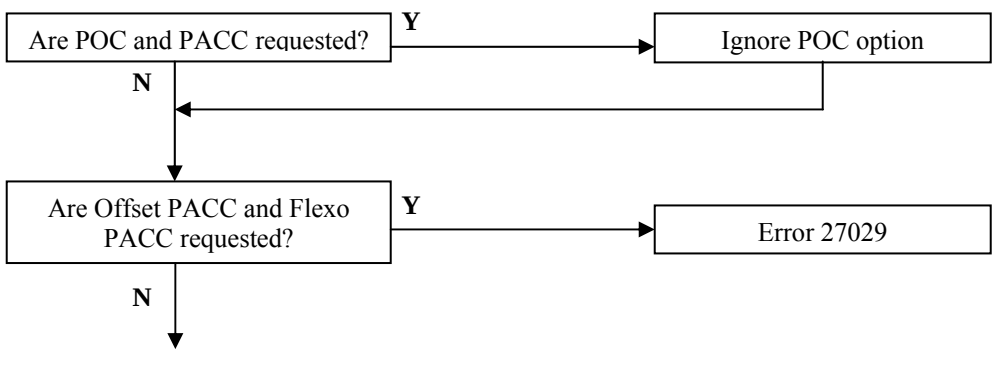

Air Jet Init
Turn off air jet
POC Init
Turn blower off
Is nozzle pressure sensor installed? (ie; is DEBRIS NSI = 1?)
N
Set POC nozzle pressure sensor available flag = FALSE
Y
Initialize nozzle pressure sensor
Failure
Error 27027
Success
Set POC nozzle pressure sensor available flag = TRUE

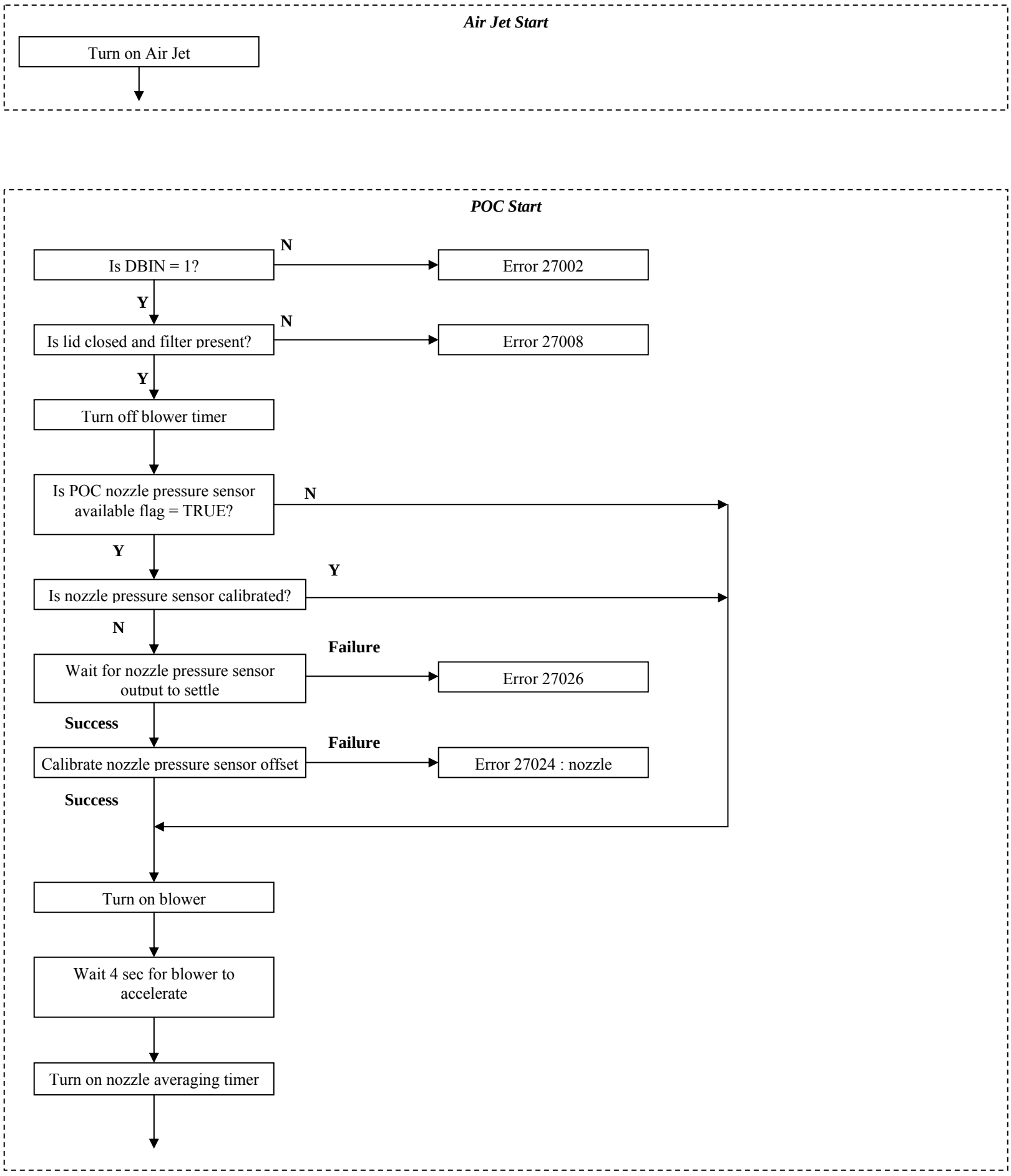

Offset PACC Init
Turn off blower
Is DBIN = 2?
N
Error 27003
Y
Initialize nozzle pressure sensor
Failure
Error 27027
Success
Initialize bellmouth pressure sensor
Failure
Error 27003
Success
Initialize differential pressure sensor
Failure
Error 27003
Success
Is the iButton blank?
Y
Error 27025
N
Can the iButton be read?
N
Error 27022
Y
Is the chemical filter Offset type?
N
Error 27031
Y

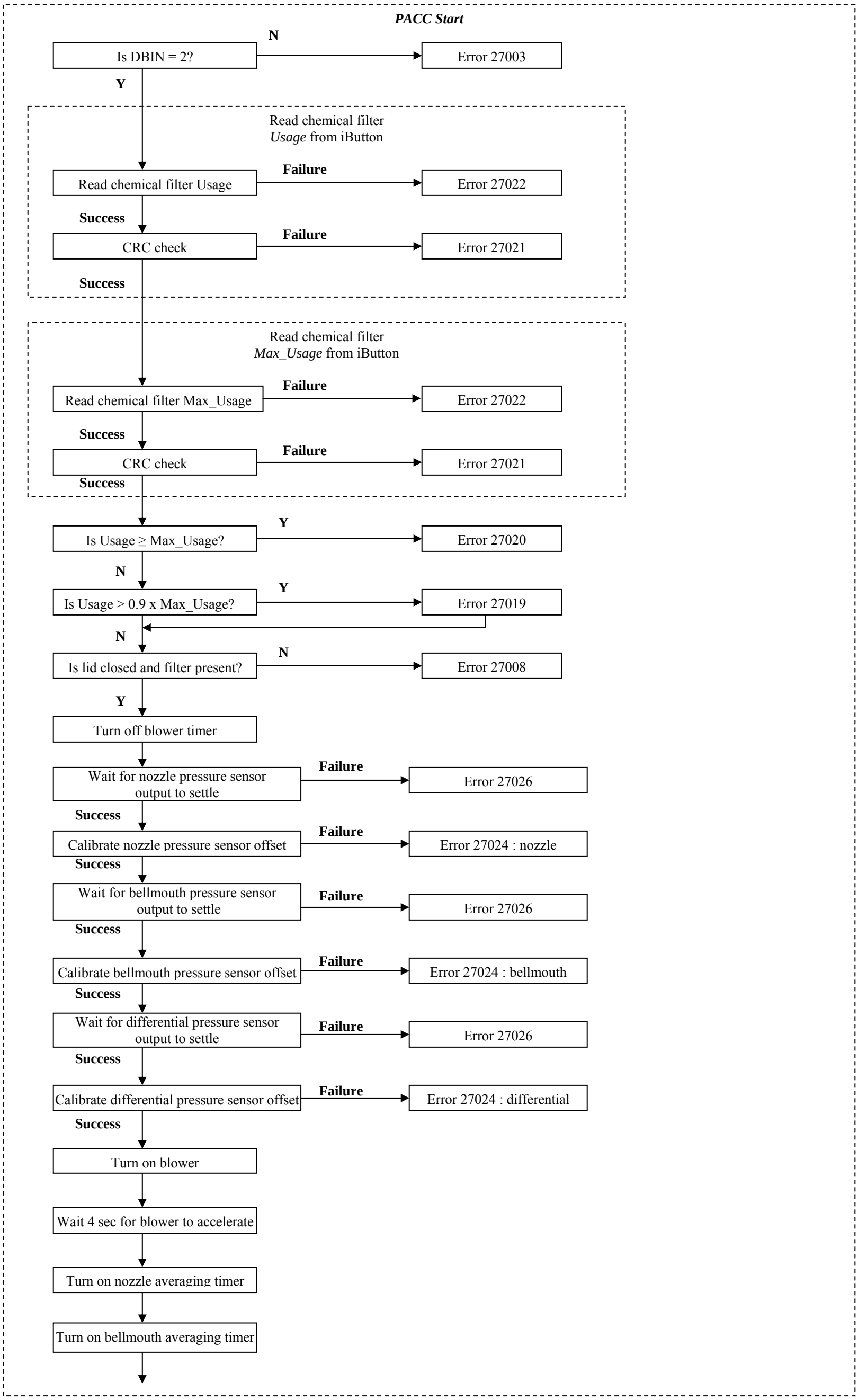
Flexo PACC Init



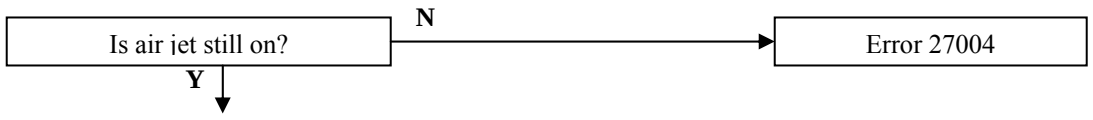
Option Validation



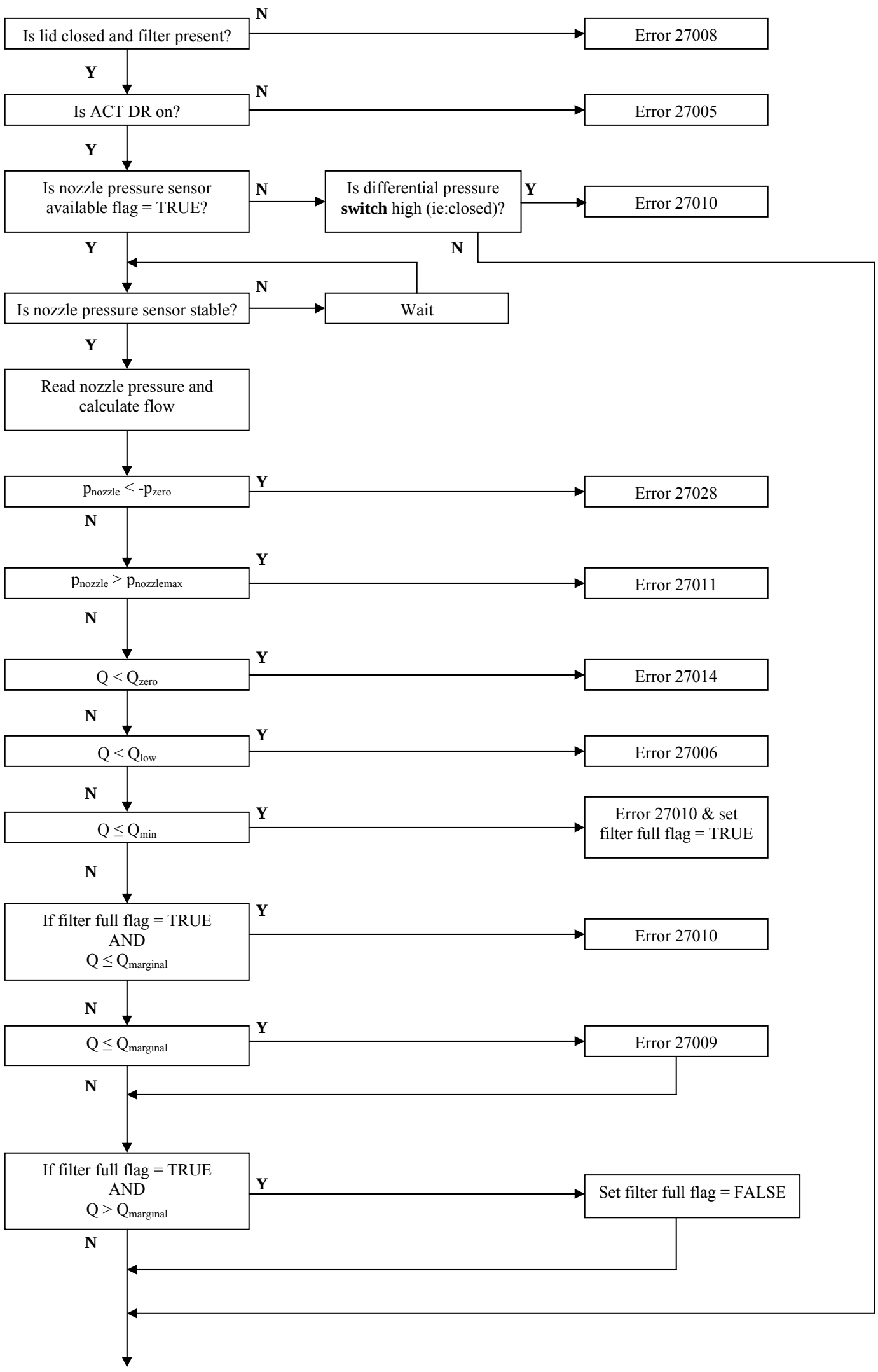

Air Jet Start
Turn on Air Jet
POC Start
Is DBIN = 1?
N
Error 27002
Y
Is lid closed and filter present?
N
Error 27008
Y
Turn off blower timer
Is POC nozzle pressure sensor available flag = TRUE?
N
Y
Is nozzle pressure sensor calibrated?
Y
N
Wait for nozzle pressure sensor output to settle
Failure
Error 27026
Success
Calibrate nozzle pressure sensor offset
Failure
Error 27024 : nozzle
Success
Turn on blower
Wait 4 sec for blower to accelerate
Turn on nozzle averaging timer

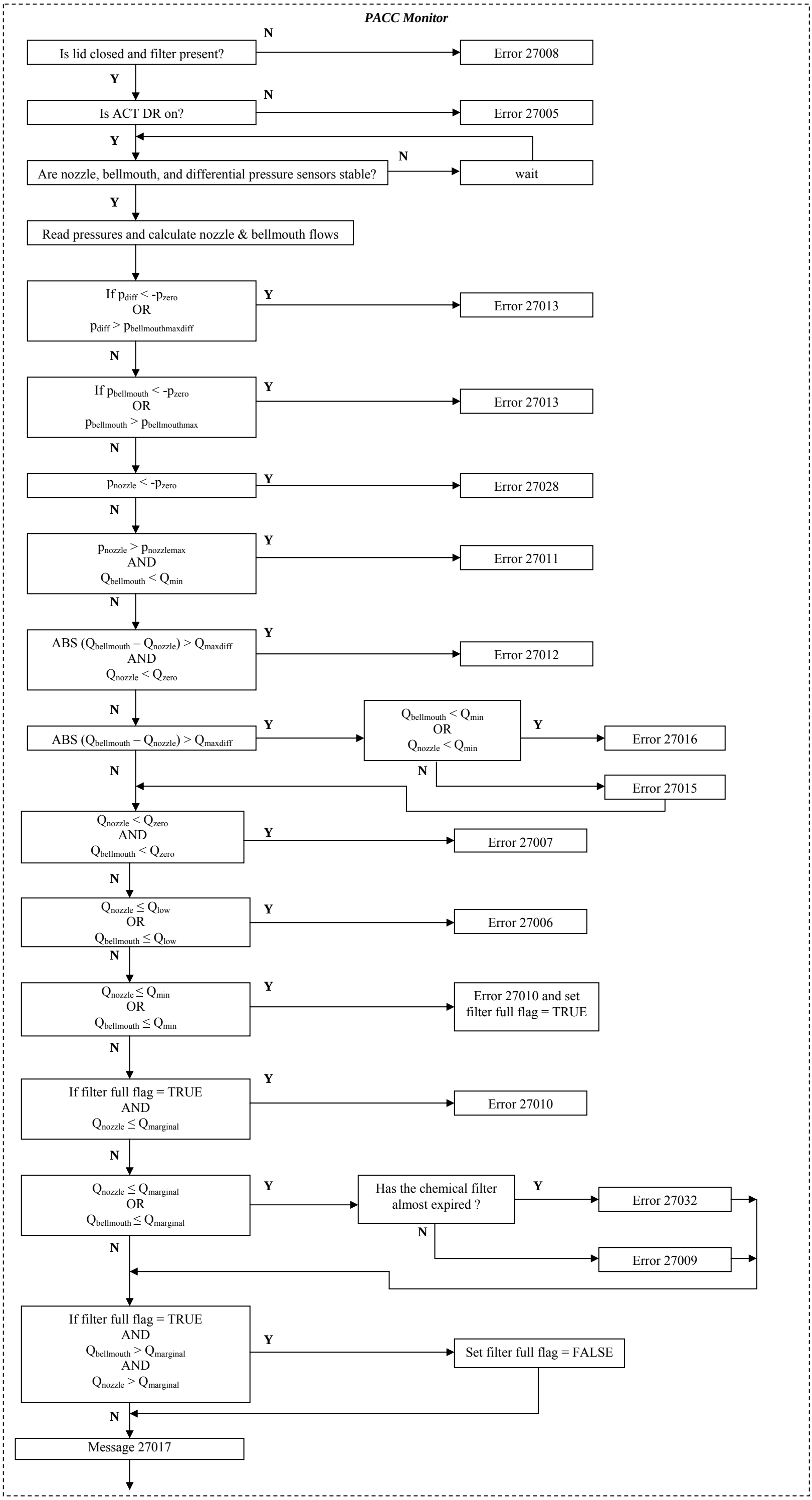

PACC Start
Is DBIN = 2?
N
Error 27003
Y
Read chemical filter Usage from iButton
Read chemical filter Usage
Failure
Error 27022
Success
CRC check
Failure
Error 27021
Success
Read chemical filter Max_Usage from iButton
Read chemical filter Max_Usage
Failure
Error 27022
Success
CRC check
Failure
Error 27021
Success
Is Usage ≥ Max_Usage?
Y
Error 27020
N
Is Usage > 0.9 x Max_Usage?
Y
Error 27019
N
Is lid closed and filter present?
N
Error 27008
Y
Turn off blower timer
Wait for nozzle pressure sensor output to settle
Failure
Error 27026
Success
Calibrate nozzle pressure sensor offset
Failure
Error 27024 : nozzle
Success
Wait for bellmouth pressure sensor output to settle
Failure
Error 27026
Success
Calibrate bellmouth pressure sensor offset
Failure
Error 27024 : bellmouth
Success
Wait for differential pressure sensor output to settle
Failure
Error 27026
Success
Calibrate differential pressure sensor offset
Failure
Error 27024 : differential
Success
Turn on blower
Wait 4 sec for blower to accelerate
Turn on nozzle averaging timer
Turn on bellmouth averaging timer

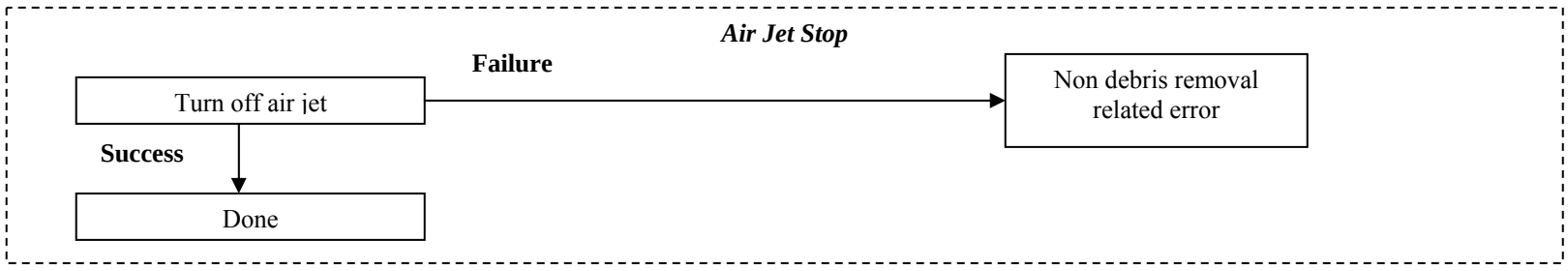
Air Jet Monitor



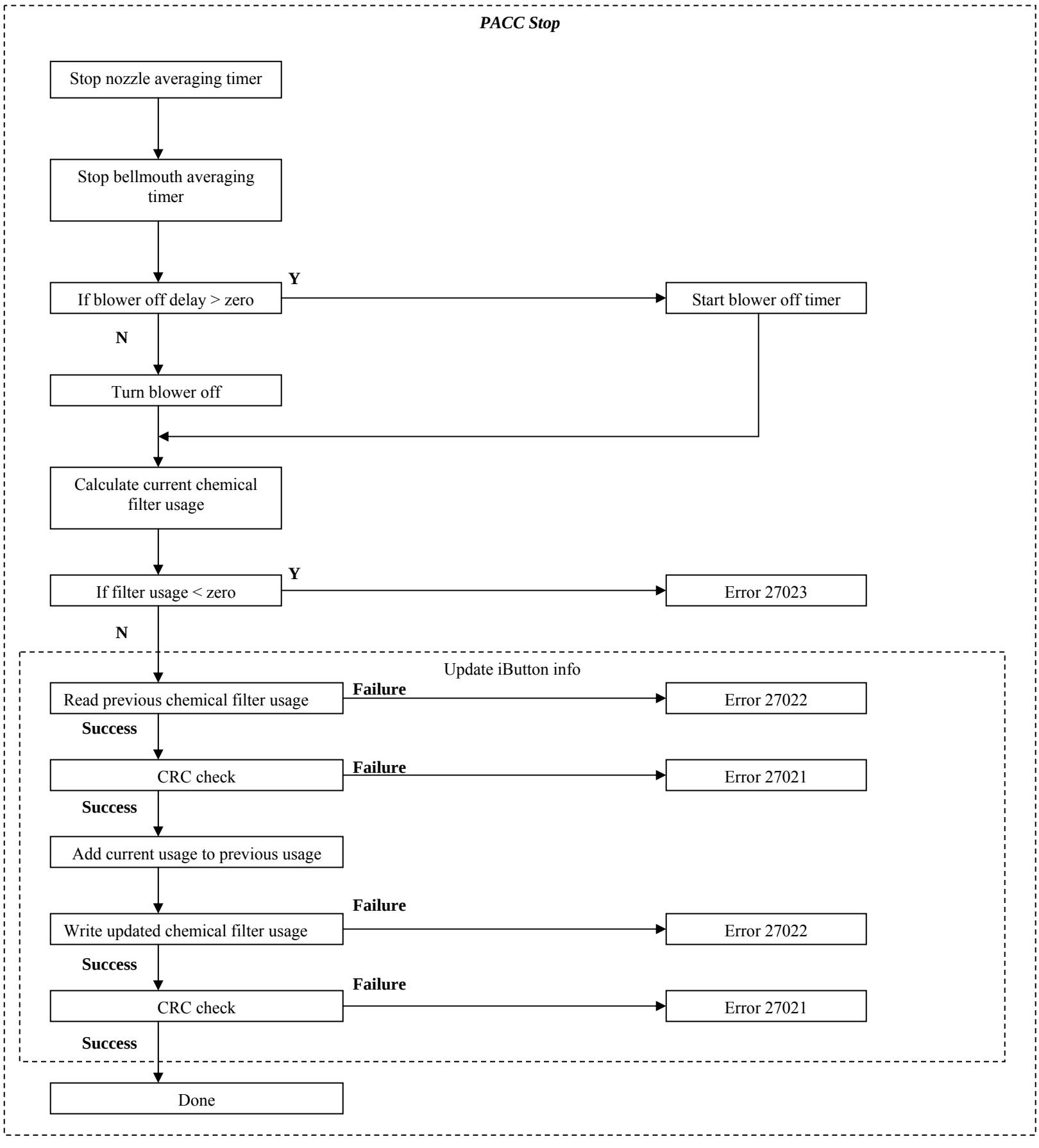
POC Monitor




PACC Monitor
Is lid closed and filter present?
N
Error 27008
Y
Is ACT DR on?
N
Error 27005
Y
Are nozzle, bellmouth, and differential pressure sensors stable?
N
wait
Y
Read pressures and calculate nozzle & bellmouth flows
If $p_{diff} < -p_{zero}$ OR $p_{diff} > p_{bellmouthmaxdiff}$
Y
Error 27013
N
If $p_{bellmouth} < -p_{zero}$ OR $p_{bellmouth} > p_{bellmouthmax}$
Y
Error 27013
N
$p_{nozzle} < -p_{zero}$
Y
Error 27028
N
$p_{nozzle} > p_{nozzlemax}$ AND $Q_{bellmouth} < Q_{min}$
Y
Error 27011
N
ABS ($Q_{bellmouth} - Q_{nozzle}$) > $Q_{maxdiff}$ AND $Q_{nozzle} < Q_{zero}$
Y
Error 27012
N
ABS ($Q_{bellmouth} - Q_{nozzle}$) > $Q_{maxdiff}$
Y
$Q_{bellmouth} < Q_{min}$ OR $Q_{nozzle} < Q_{min}$
Y
Error 27016
N
Error 27015
N
$Q_{nozzle} < Q_{zero}$ AND $Q_{bellmouth} < Q_{zero}$
Y
Error 27007
N
$Q_{nozzle} \leq Q_{low}$ OR $Q_{bellmouth} \leq Q_{low}$
Y
Error 27006
N
$Q_{nozzle} \leq Q_{min}$ OR $Q_{bellmouth} \leq Q_{min}$
Y
Error 27010 and set filter full flag = TRUE
N
If filter full flag = TRUE AND $Q_{nozzle} \leq Q_{marginal}$
Y
Error 27010
N
$Q_{nozzle} \leq Q_{marginal}$ OR $Q_{bellmouth} \leq Q_{marginal}$
Y
Has the chemical filter almost expired ?
Y
Error 27032
N
Error 27009
N
If filter full flag = TRUE AND $Q_{bellmouth} > Q_{marginal}$ AND $Q_{nozzle} > Q_{marginal}$
Y
Set filter full flag = FALSE
N
Message 27017


Air Jet Stop
Turn off air jet
Failure
Non debris removal related error
Success
Done

POC Stop
Stop nozzle averaging timer
If blower off delay > zero
Y
Start blower off timer
N
Turn blower off
Done


PACC Stop
Stop nozzle averaging timer
Stop bellmouth averaging timer
If blower off delay > zero
Y
Start blower off timer
N
Turn blower off
Calculate current chemical filter usage
If filter usage < zero
Y
Error 27023
N
Update iButton info
Read previous chemical filter usage
Failure
Error 27022
Success
CRC check
Failure
Error 27021
Success
Add current usage to previous usage
Write updated chemical filter usage
Failure
Error 27022
Success
CRC check
Failure
Error 27021
Success
Done