

Buffered Chemical Polishing. Failure Mode Analysis

This document describes the status of the BCP system at each step of the process and provides thorough instructions to a system operator on how to safely proceed with the process (or stop the process) if an equipment failure prevents the process from completing in a normal mode. The main goal of this document is providing a guideline for the completion of the BCP process without compromising the safety of involved the personnel and the surrounding environment as well as the quality of the treated SRF cavity.

In the graphs and diagrams below a piece of equipment without color code is assumed to be in the closed (non-activated) position. It acquires a color code after it is used the first time. Valves that were blocked in the closed position are color coded from the very beginning. Tanks without color are empty. The next color code is used:

1.  Red color – a valve is closed, or a pump is idle.
2.  Light green color - a valve is opened, a pump is activated, a gauge is used to control the system.
3.  Blue color – a tank is filled with water,
4.  Dark green color – a tank is filled with acid.

The correct functioning of all valves and pumps must be tested before the procedure starts. Any suspicious situation must be analyzed so that no doubt remains that all elements are in working condition.

All valves in the system are normally closed except two bypass valves V35 and V36 that provide a way to drain the piping connected to the pumps Pmp1 and Pmp5. In order to allow a safe completion of the process in case of air pressure loss, additional features of the system are in place. If a valve is in normal position in a certain step, it can't change the status by itself unless the corresponding solenoidal valve opens. In the very unlikely situation in which a solenoidal valve fails, it can be readily accessed for repair or bypassed since it is located outside of the room where the process is performed. For reliability, there are three indicators of different type to show the liquid level in the tank T1: level meter, integrated flow monitor readings, and visual control. If one of the first two fails, the completion of the filling is controlled by the other one and verified visually.

All the steps mentioned in the document correspond to those in another document that states requirements for the BCP facility's control system development. It has been under discussion for many months, so that everybody involved in this development could familiarize himself with the control system approach and add requirements he felt were needed. This document is still open for comments, although we decided to assign a TD release number to this document for convenience (TD-04-028).

STEP 00. Initial Setting and System Activating

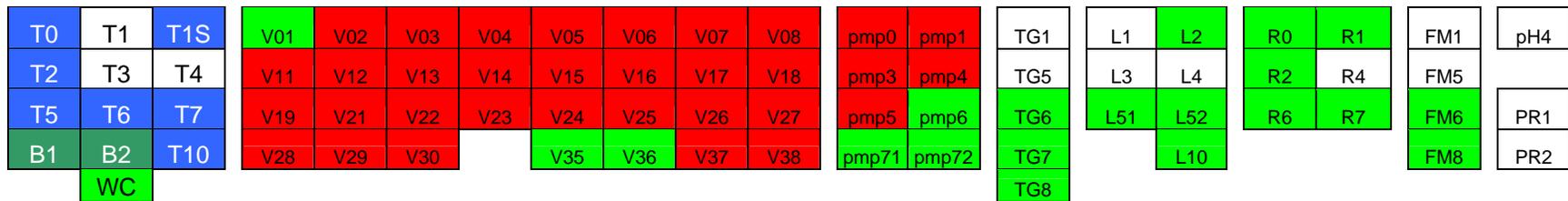
In the beginning of the procedure, the tanks T1, T3, and T4 are empty; tanks T2, T5, T6, and T10 are filled with UPW. Water Chiller (WC) is on. Pumps Pmp6, Pmp71 and Pmp72 are on, and UPW in the tank T6 (cavity jacket) is circulating through the Heat Exchanger (T7). UPW is added into the spill tray of the tank T1 (T1-S) and into the compartment’s sump pit T0. The scrubbing system is in the “**ventilation**” mode. The neutralization system is activated.

No acid is present in the room at this stage, except in the acid circuit of the heat exchanger HE and in the filter F1 (these elements are kept insulated by valves V14, V15, V21, and V22 for HE and by V17 and V18 for F1).

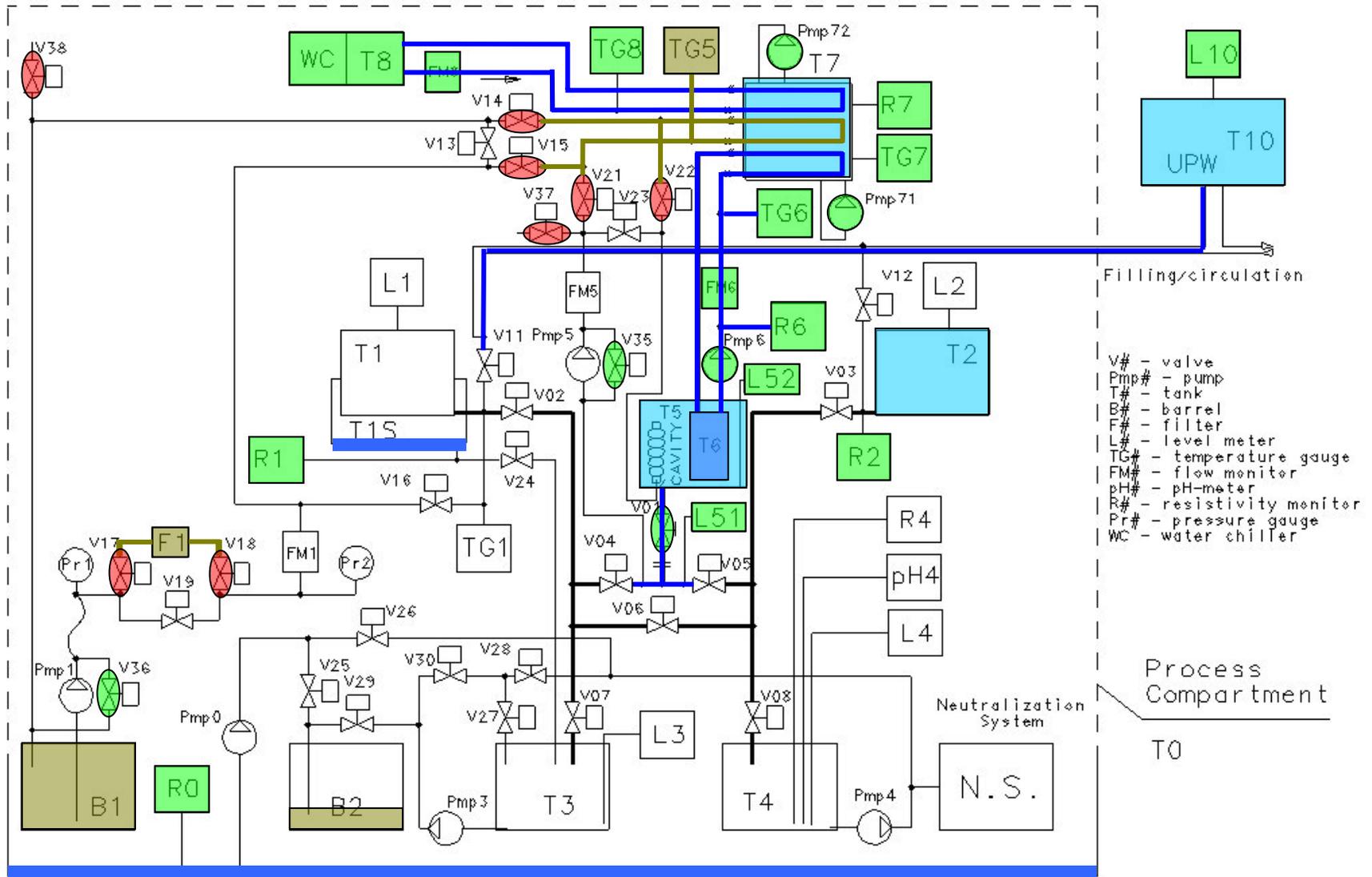
The system is being checked for leaks.

Install local hoods at the designated places in the process room. Switch the scrubber to the “**scrubbing**” mode.

Bring and connect to the hydraulic system a barrel B1 with BCP mix. Bring and connect to the hydraulic system an empty barrel B2 to contain used acid after the processing. Open V01. Leave the room and close the doors.



Failure Mode	Recommended Action
Any leak in the system’s piping or tanks	Stop the procedure, remove barrels, and repair
Any problems with connecting barrels to the system	Repair. If needed, replace a barrel or a pipe connector.
Pmp6, Pmp71 or Pmp72 fails	Stop the procedure, remove barrels, and repair
Reading of TG6, TG7, or TG8 do not agree with the expected value	Stop the process and check corresponding sensor or the chiller
Acid indicators R0, R1, R6 or R7 do not read as expected	Stop the process and check the sensors
Water quality in tank T2 is not as expected according to R2	Be sure water quality is adequate
Readings of the level meters L51 and L52 do not agree	Stop the process and check the sensors
The level meters L2 does not read as expected	Stop process and check the sensor
The scrubber does not start or switch to the “scrubbing” mode	Stop all operations and check equipment



Step 00 Initial Setting and System Activating

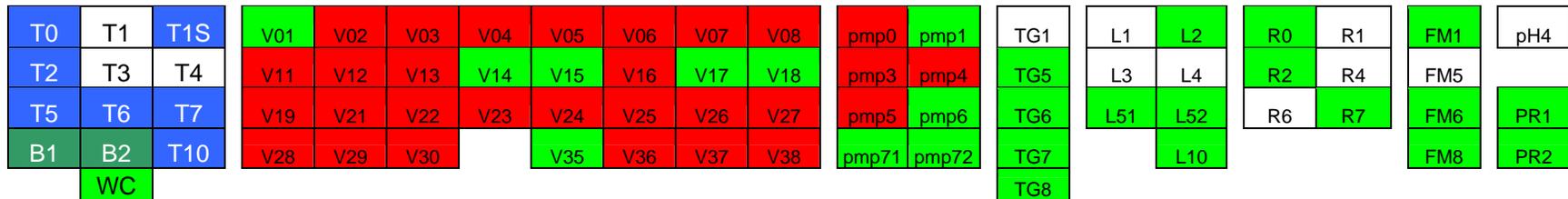
STEP 01 Cooling Acid in the Barrel B1

Open V14, V15, V17, and V18. Close V36 and start Pmp1 to circulate acid through the heat exchanger HE.

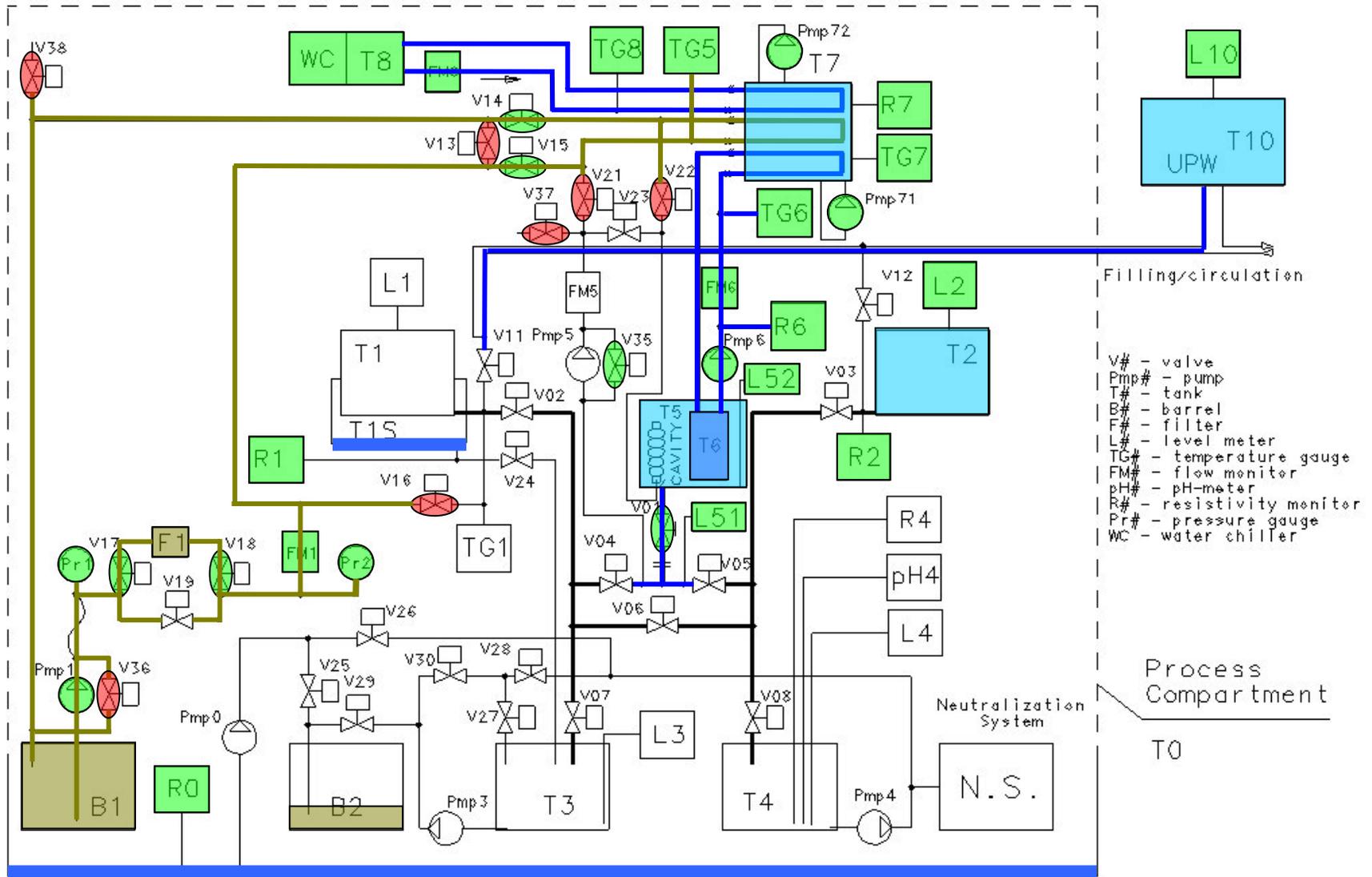
Monitor readings of FM1, FM6, FM8, TG5, TG6, TG7, TG8, R0, R7, Pr1, and Pr2.

No acid is present in Tank 5, so no damage to an RF cavity can occur. If any unpredictable situation happens, stop the process and make needed repair work.

The cooling process is over when acid temperature is about 12 C. This value can vary depending on the duration of the process.

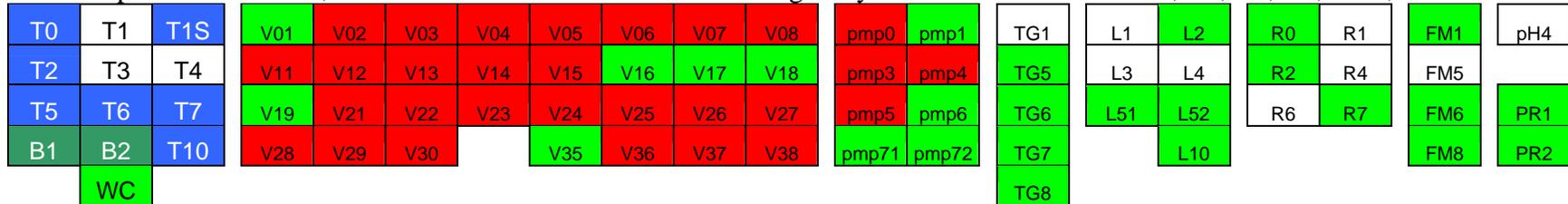


Failure Mode	Recommended Action
Any leak in the system detected by a leak detector R0 or R7 or level meters L2 , L51 , or L52	Stop the process. Enter the room to evaluate and to repair if possible
Valve V14 or V15 do not open	Check the equipment. Enter the room to evaluate and to repair
Valve V17 and V18 do not open	Use V19 instead if the acid in the barrel was filtered. If no, stop the process, and enter the room to make evaluation and repair
Pump Pmp1 does not start, does not pump acid (according to FM1), or stops	Check air pressure and the equipment. Enter the room and try to fix the problem. Stop the process and repair if needed.
Pump Pmp71 or Pmp72 stop working	If at the end of the cooling process, proceed with the process. If other, stop the system and repair.
FM1 does not read correctly	Check the cooling progress through the temperature gauges. Stop the process if cooling does not go as expected.
FM6 or FM8 do not read properly	These two components did not see any acid yet, so enter the room to check and repair.
TG5 does not agree with the expected value	Stop the system and check the sensor
TG6 or TG7 do not agree with the expected value	If short etching – proceed. If the etching time is long, stop the process and check the sensor
TG8 does not agree with the expected value	Rely on other temperature sensors, or stop the process and repair.
L2 , L51 or L52 do not read properly	Stop Pmp1 and enter the room to check the sensor
Differential pressure (PR2-PR1) is higher then 10 psi	The filter is clogged and needs to be replaced. Use bypass valve V19 if acid was filtered. Stop and replace filter if not.

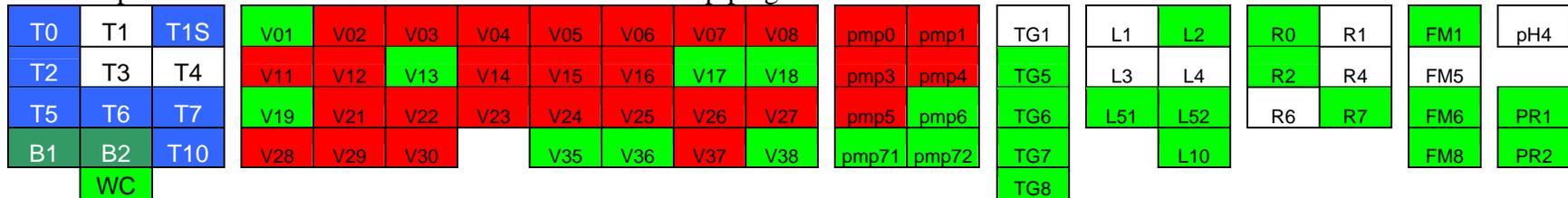


STEP 02 Filling Tank T1 with Acid

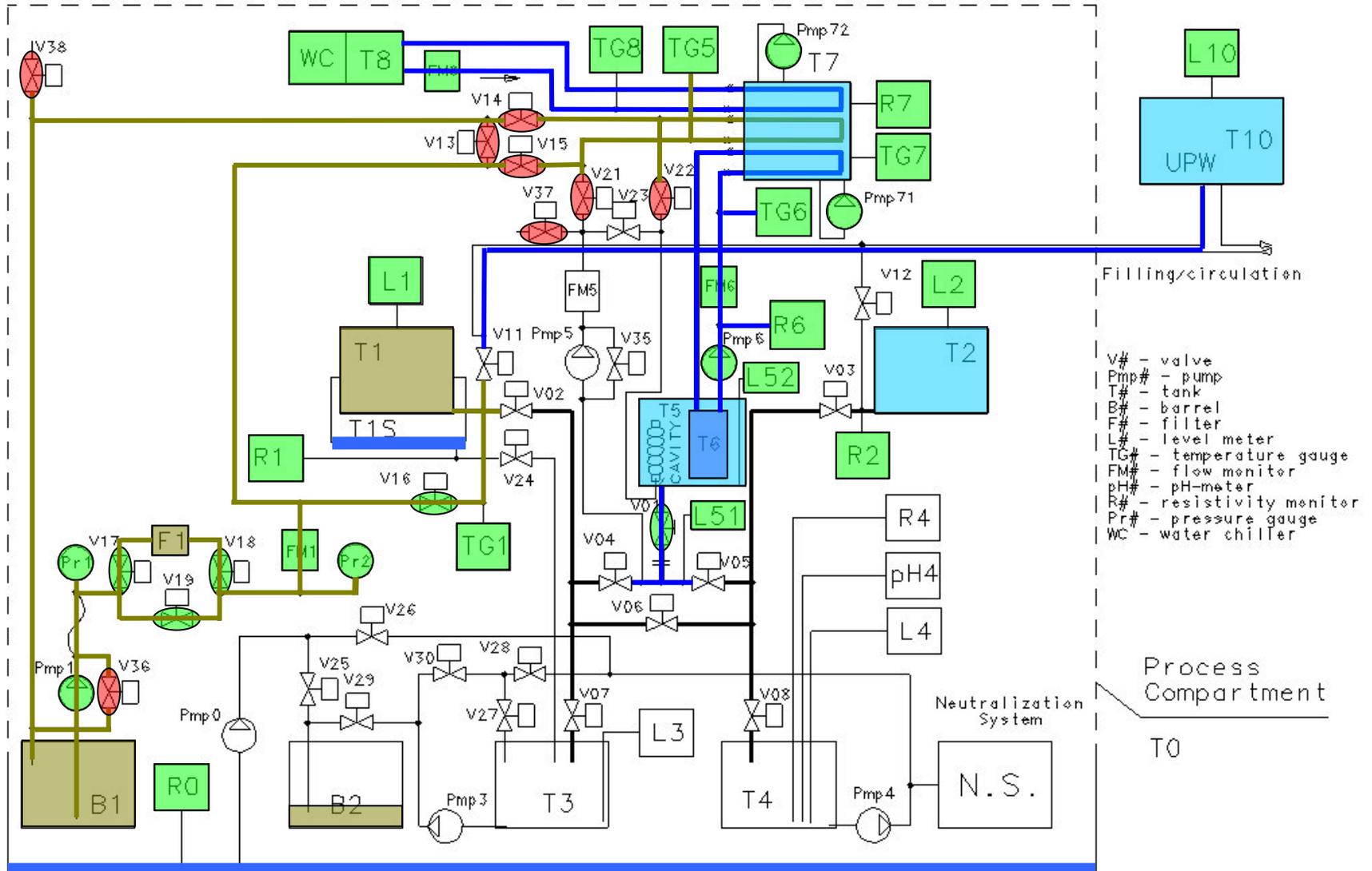
I. Open V16 and V19, then close V14 and V15 to fill the acid gravity feed tank T1. Monitor L1, R1, R6, R7, FM1, and TG1.



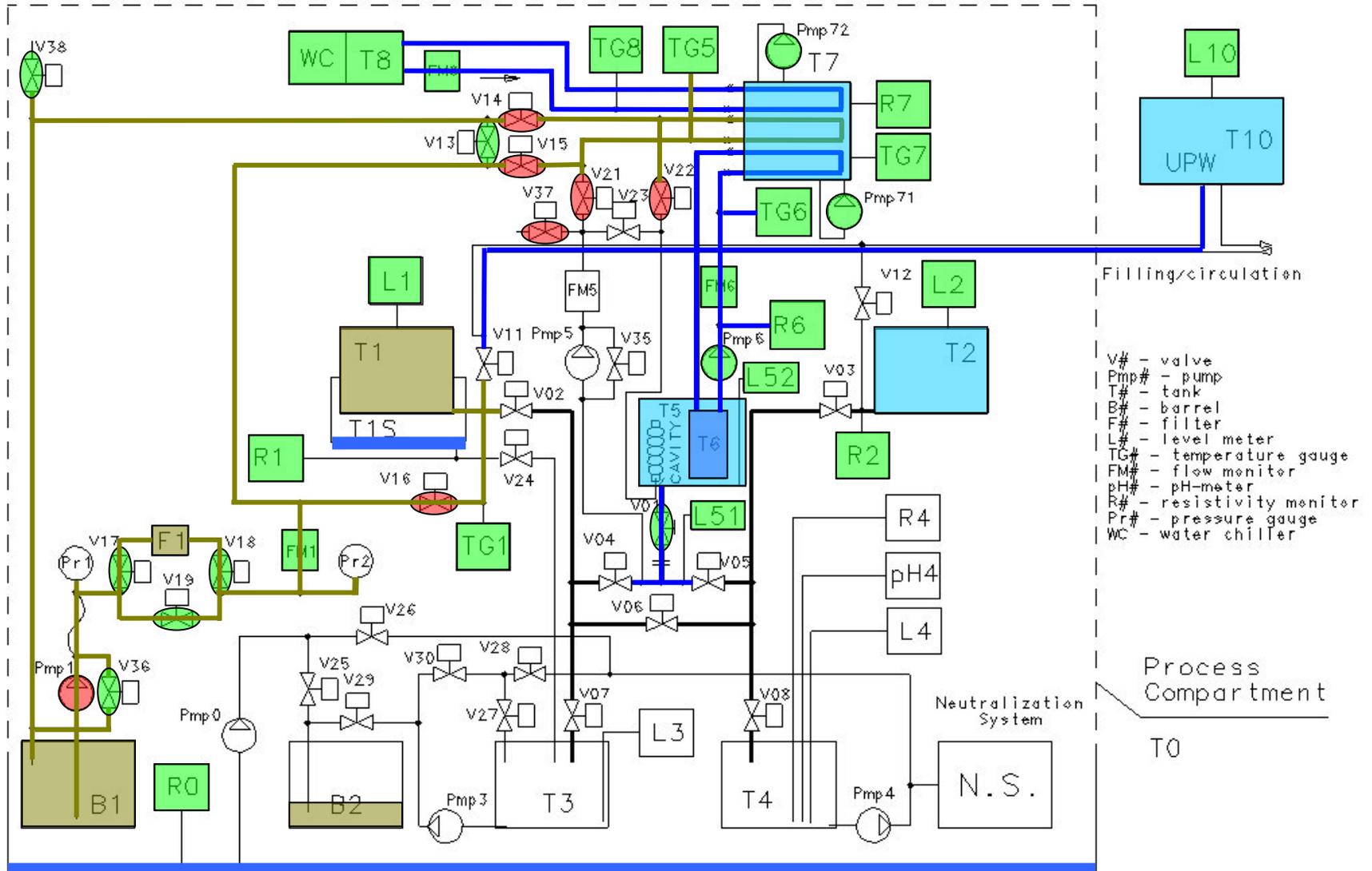
II. Pump Pmp1 is controlled both by L1 and integrated FM1; it stops when the preset acid level in T1 is reached. Close V16. Open V13 V36 and V38 to drain leftovers of acid in piping back into B1.



Failure Mode	Recommended Action
Any leak in the system detected by a leak detectors R1, R6, or R7 or level meters L1, L2, L51, or L52	Stop the process. Drain acid from tank T1 into the barrel T3 by opening V02 V07. Empty T3 to B2 by operating Pmp3 and V29 Enter the room to repair
V16 does not open	Stop Pmp1 and check equipment. Repair or stop the process.
Pump Pmp1 fails	Drain acid, if any in tank T1, back in the barrel B1 by opening V13, V16, V19, and V36. Enter the room to repair.
Both Pmp71 and Pmp72 or Pmp6 stop running	Proceed with the process adjusting the etching time. Check corresponding solenoidal valves.
Flow meter FM1 fails	Use L1
Flow meter FM5 , or FM6 , or FM8 do not read properly	Use temperature gauges to get information about the process.
TG1 does not agree with the expected value	Use TG5.
TG5 does not agree with the expected value	Stop the system and check the sensor
TG6 TG7 or TG8 do not agree with the expected value	If short etching – proceed. If the etching time is long, stop the process and check the sensor
L2, L51 or L52 do not read properly	Stop Pmp1 and enter the room to check the sensors
R1, R6 , or R7 detect a leak in the system	Evaluate conductivity rise and stop the process if it is too high



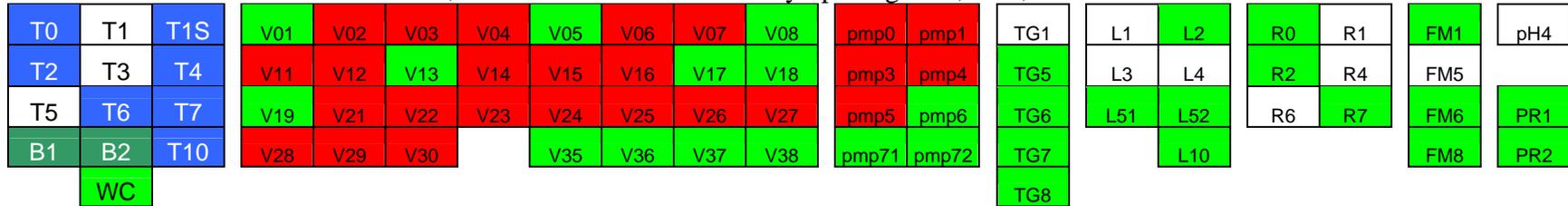
Step 02-I Filling Tank T1 with Acid



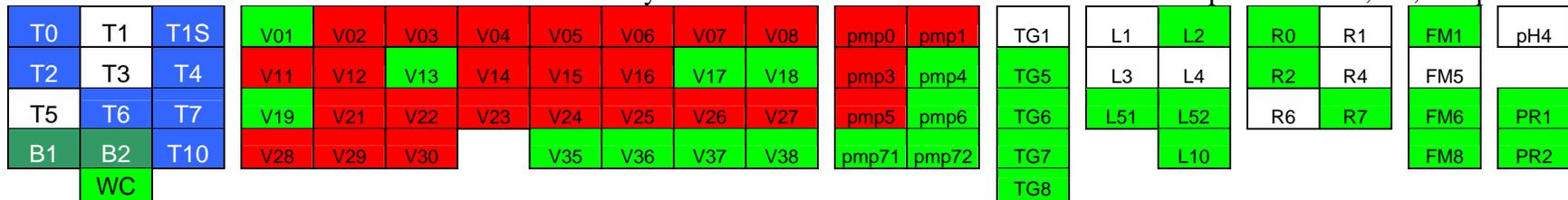
Step 02-II Completion of Filling Tank T1 with Acid

STEP 03 Dumping UPW from T5 to T4 and pumping out of T4

I. After T1 is filled with acid, drain water form T5 to T4 by opening V05, V08, and V37.

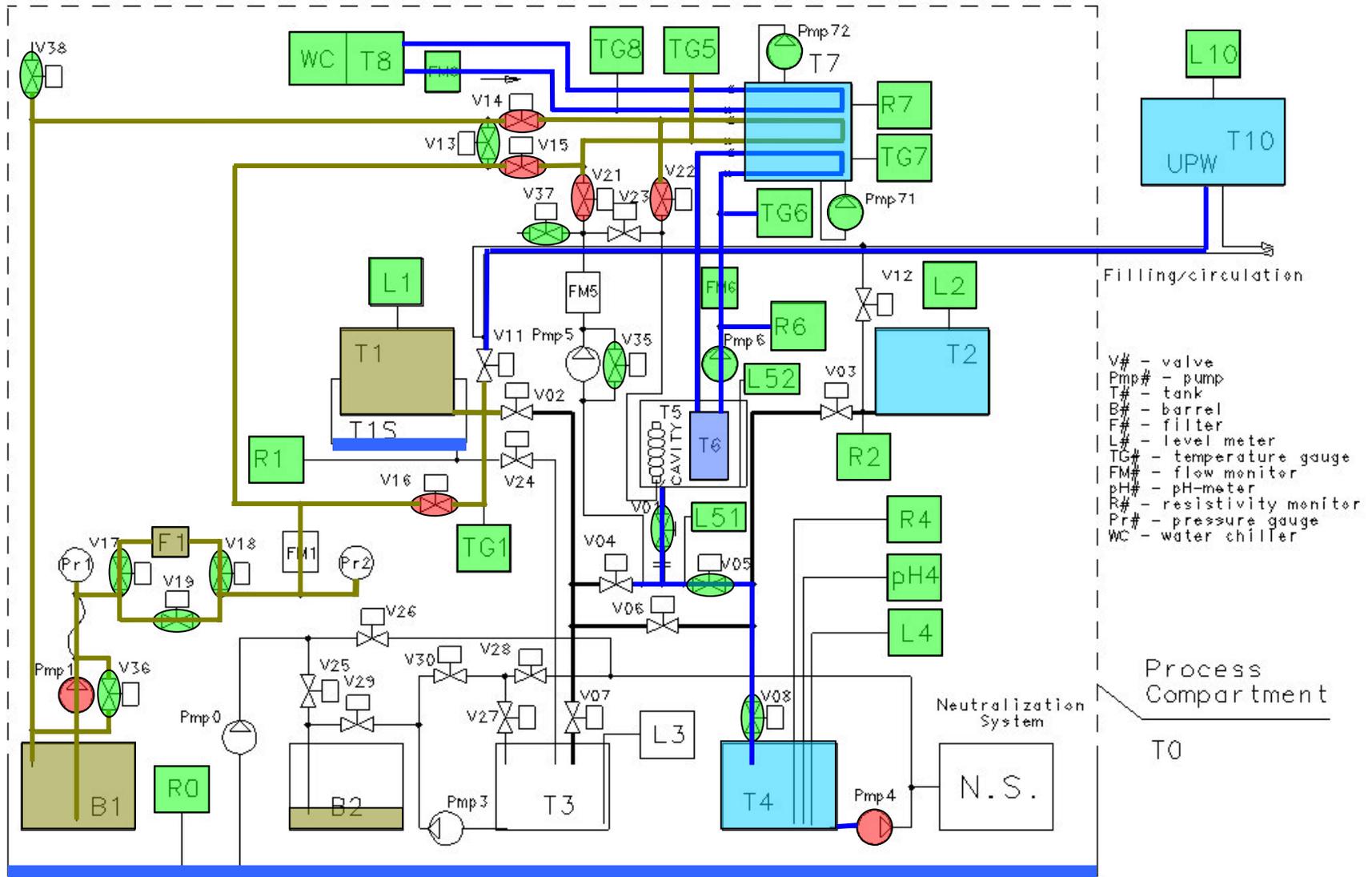


II. The valves V05 and V08 close automatically after L51 and L52 read zero level. Activate Pmp4. Check L4, R4, and pH4.



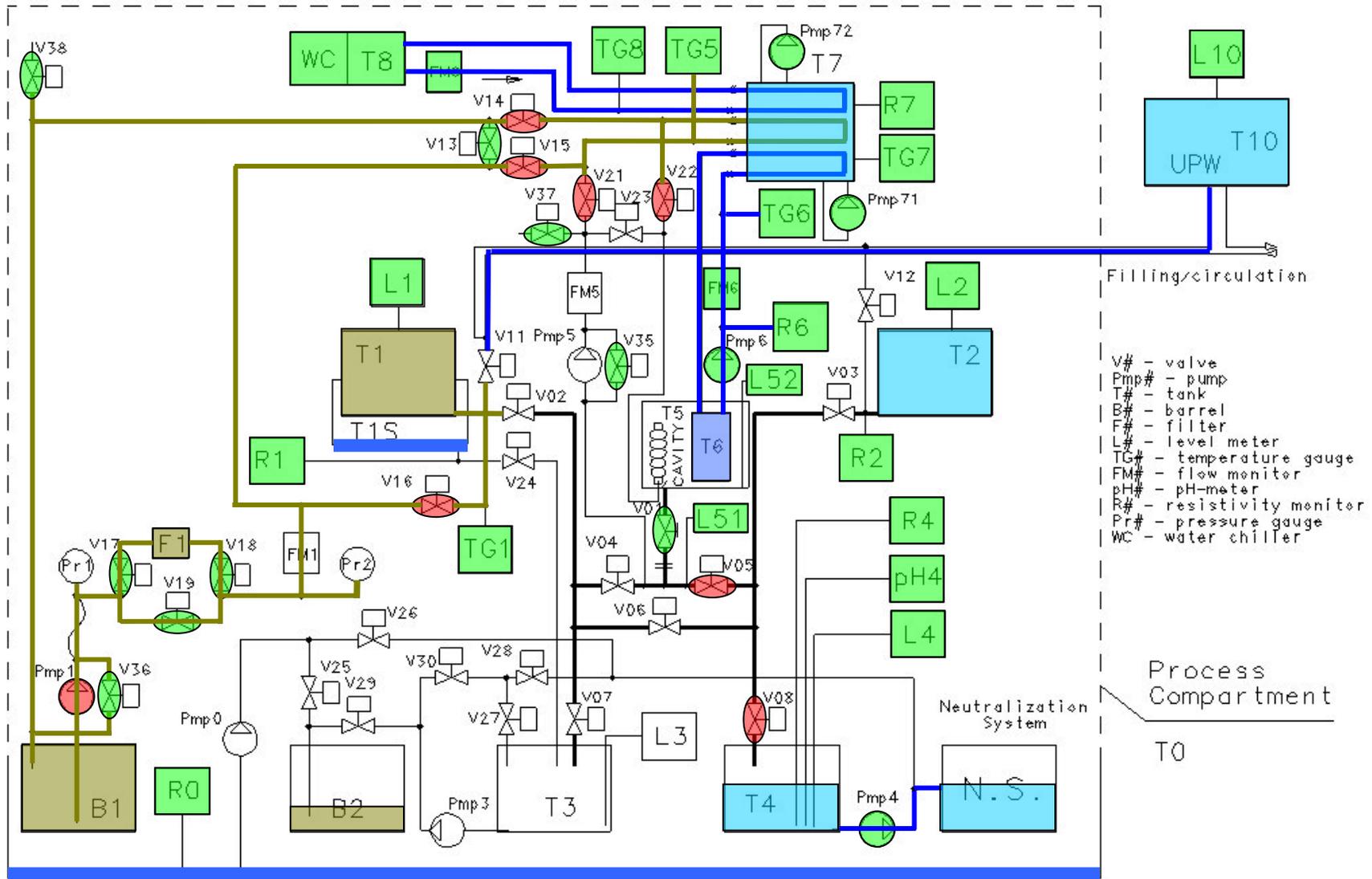
Failure Mode	Recommended Action
Any significant leak in the system detected visually, or by a leak detectors R1 , R6 , or R7 , or by level meters L1 , L2 , L51 , or L52	Dump acid, if any in tank T1, in the tank T3 by opening V02 and V07. Opening V29 and starting Pmp3, transfer the acid into B2. Enter the room to evaluate and to repair.
V05 or V08 does not open	Use V06, V04 or V07
Both Pmp71 and Pmp72 or Pmp6 stop running	Proceed with the process adjusting the etching time. Check corresponding solenoidal valves.
Flow meter FM5 , or FM6 , or FM8 do not read properly	Be sure temperature gauges are showing right readings. If not – stop the process and check equipment
TG1 does not agree with the expected value	Use TG5.
TG5 does not agree with the expected value	Stop the system and check the sensor
TG6 TG7 or TG8 do not agree with the expected value	If small etching – proceed. If the etching time is long, stop the process and check the sensor
L2 , L51 , or L52 do not read properly	Pause the system by stopping Pmp1 and enter the room to check the sensor
R1 , R6 , or R7 detect a leak in the system	Evaluate the conductivity rise and stop the process if the leak rate is not acceptable
L4 , R4 , or pH4 do not read as expected	Pause the system by stopping Pmp1 and enter the room to check

	the sensor
Pump Pmp4 does not start	Stop the process and check equipment. Enter the room if necessary. Replace the pump if needed.



Step 03-I

Dumping UPW from T5 to T4

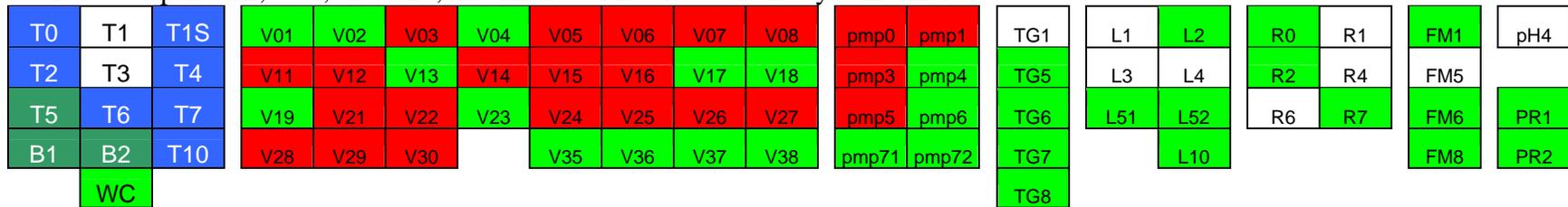


Step 03-II

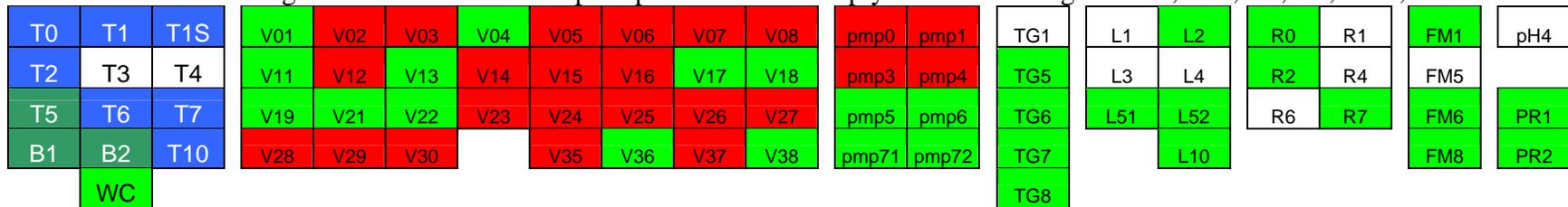
Activating Pmp4 to empty T4

STEP 04 Filling T5 with Acid, Refilling T1 with Water, Etching

I. Open V02, V04, and V23, and fill T5 with acid. Start the system timer.

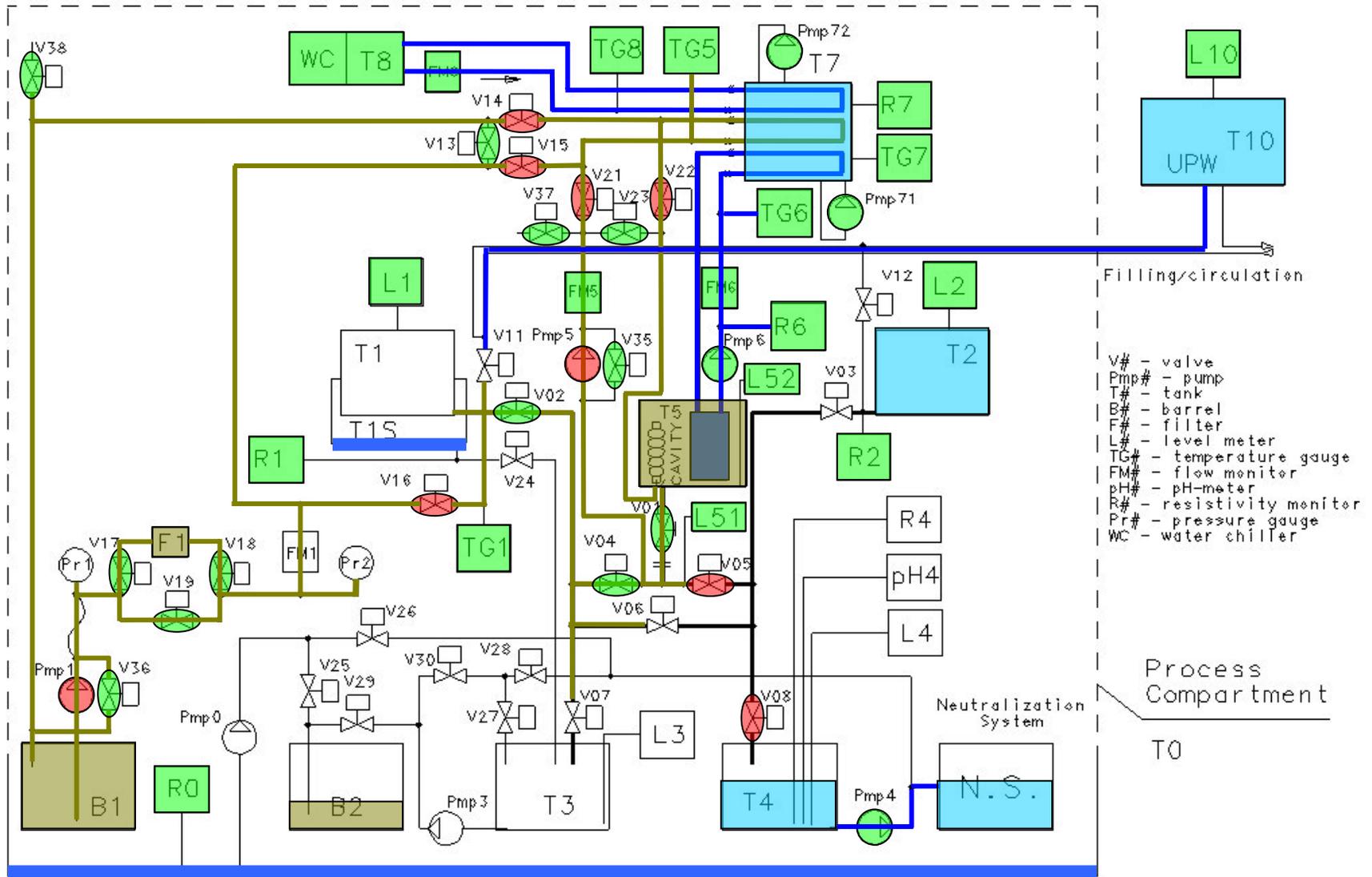


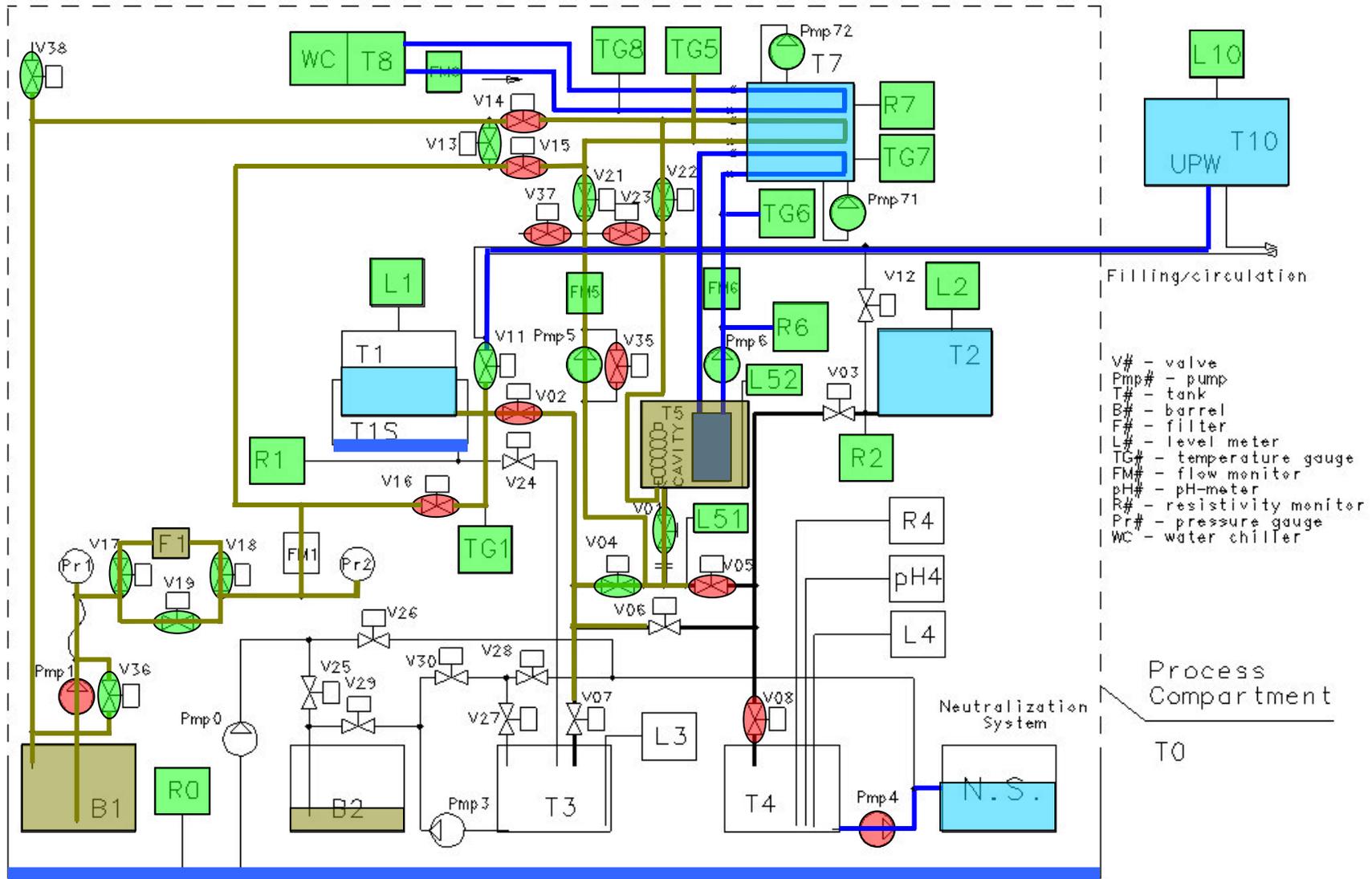
II. When L1 reads zero and T5 is filled, close V02, V35, and V37. Start Pmp5, open V21 and V22 and close V23. Open V11 to start filling tank T1 with water. Stop Pmp 4 when T4 is empty. Follow readings of L51, L52, R6, R7, FM5, and TG5.



Failure Mode	Recommended Action
Any significant leak in the system detected visually, or by a leak detectors R0, R6, or R7 , or by level meters L2, L51, or L52	Stop the process. Dump acid in tank T3 by opening V04 and V07, and then into barrel B2 by opening V29 and activating pump Pmp3. Fill T5 with UPW from Tank T2 and start rinsing cycle.
V04 does not open	Use V05 and V06
V02 does not open	Pause the process and follow the troubleshooting procedure
Both pmp71 and pmp72 or pmp6 stop running	Proceed with the process adjusting the etching time
Flow meter FM5 , or FM6 , or FM8 do not read properly	Be sure temperature gauge TG5 shows temperature below 20 C.
TG5 shows temperature above 20 C	Dump acid into tank T3 by opening V04 and V07, and then into barrel B2 by opening V29 and activating pump Pmp3. Fill T5 with UPW from Tank T1 and start rinsing cycle.
TG6 or TG7 or TG8 do not agree with the expected value	Proceed with etching. Watch TG5
L51 , or L52 do not read properly	Check the level of acid in the tank T5 visually.
R0, R1, R6, or R7 detect a leak in the system	Evaluate the conductivity rise and stop the process if the leak rate is not acceptable. Dump acid into tank T3 by opening V04 and V07, and then into barrel B2 by opening V29 and activating pump Pmp3. Fill T5 with UPW from Tank T1 and start rinsing.
Pump pmp5 does not start or stops.	The process will not go normally. Stop and proceed to rinsing

V11 does not open	Use water from T2 for cavity rinsing and clean this part of the system when the process is over and it is safe to enter the room
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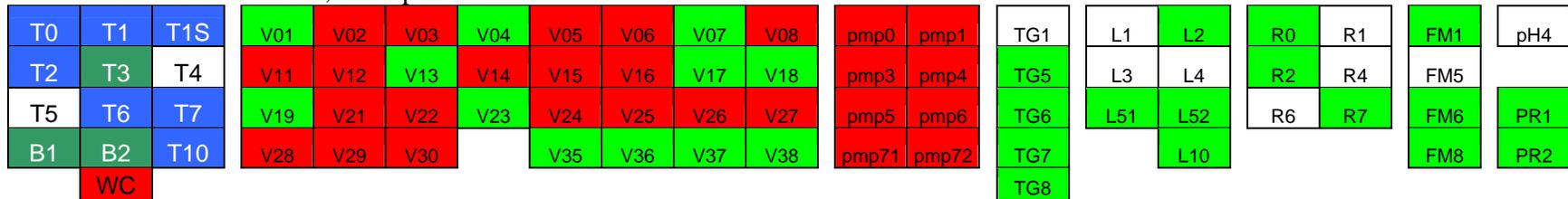


Step 04-II

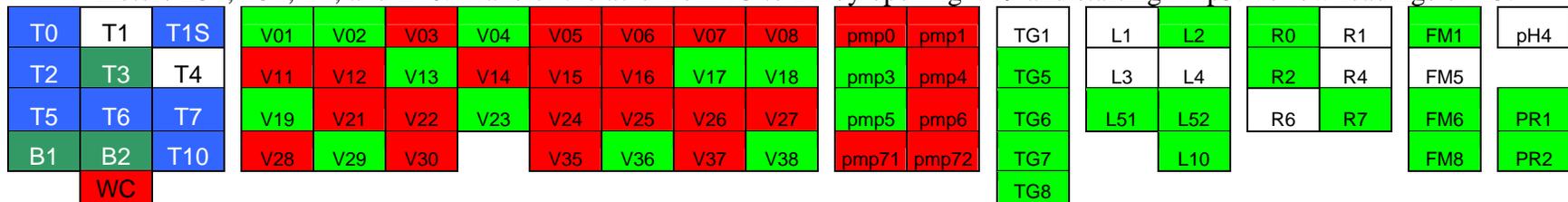
Filling T1 with Water - Etching.

STEP 05 Emptying T5, Filling T5 With Water From T1, Transferring Acid Into B2

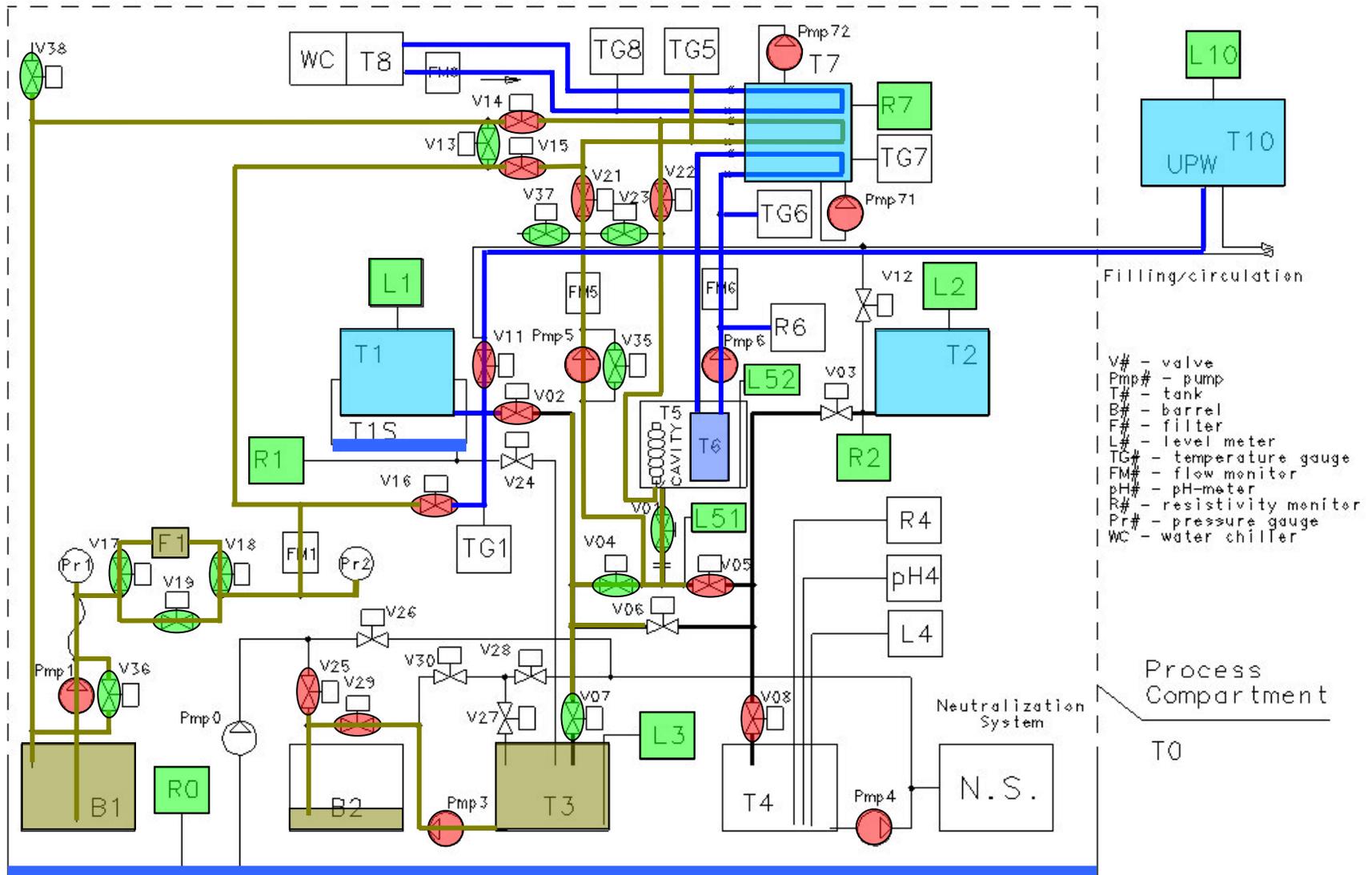
I. After the tank T1 is filled with water, close V11. When etching process is over, transfer the acid from T5 to T3 by opening V07. Stop Pmp5 and Pmp6. Open V35 and V37 to empty the cooling circuit piping. Stop the chiller. Stop Pmp71 and Pmp72. Close V21 and V22, and open V23.



II Close V07. Open V02 to fill T5 with water from T1. Close V35 and V37. Start Pmp5. Follow readings of involved level meters L51, L52, L1, and L10. Transfer the acid from T3 to B2 by opening V29 and starting Pmp3. Follow readings of L3.



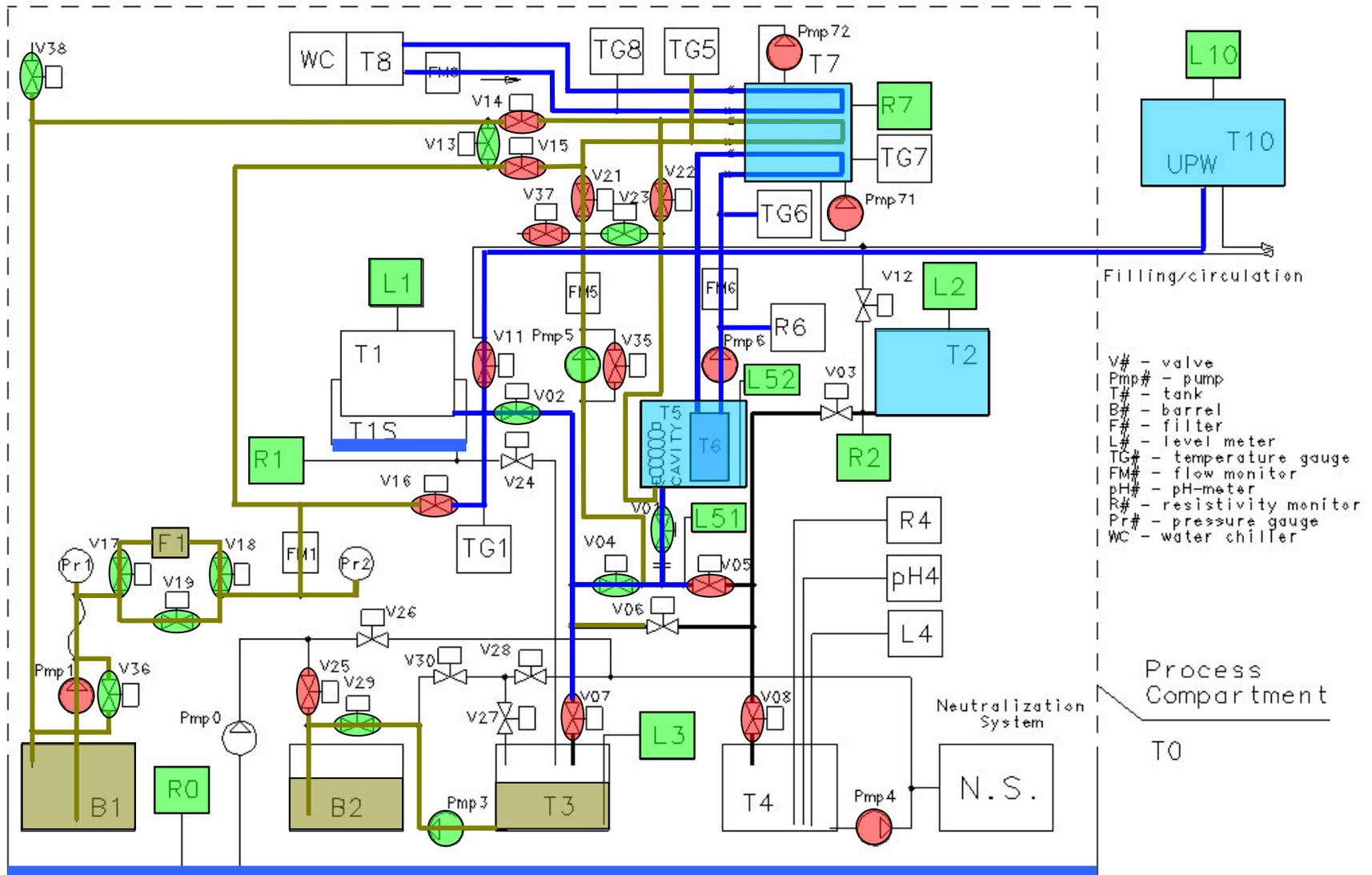
Failure Mode	Recommended Action
V07 does not open or V04 does not stay open	Use V05 and V08.
A leak develops in the tank T3 or corresponding piping	Proceed with the process by any means. Stop pump Pmp3 if a significant leak in piping.
V35 or V37 do not open	Time to empty the circulation circuit will be longer and bigger amount of acid will remain in the system. Proceed with the process
L51 or L52 do not read properly	Rely on L1, L2, L3, L4, and visual information to verify amount of acid in the tank. T5.
L3 does not read properly,	Start Pmp3 and by opening V29 transfer the acid to B2



- V# - valve
- Pmp# - pump
- T# - tank
- B# - barrel
- F# - filter
- L# - level meter
- TG# - temperature gauge
- FM# - flow monitor
- pH# - pH-meter
- R# - resistivity monitor
- Pr# - pressure gauge
- WC - water chiller

Step 05 - I

End of Etching, Emptying T5 and deactivating cooling circuits.

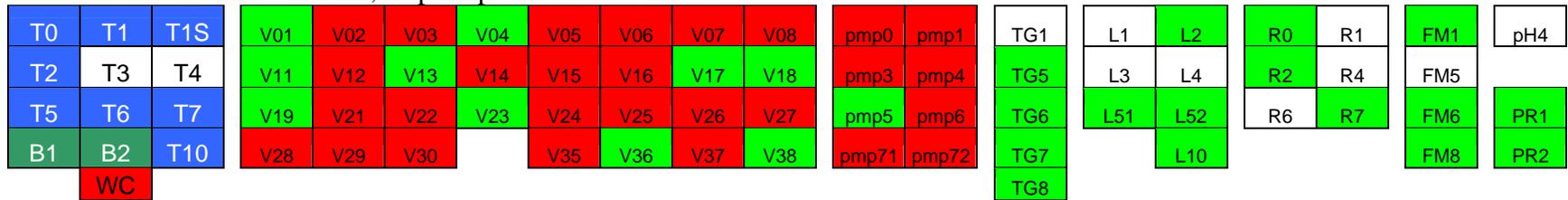


Step 05 - II

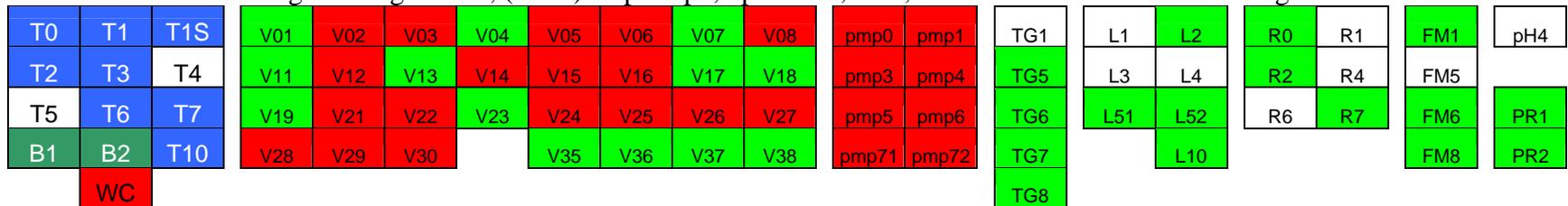
Filling T5 with UPW; Removing the Acid from T3 into B2

STEP 06 Emptying T5 and rinsing T3. Filling T5 from T2 and rinsing cavity

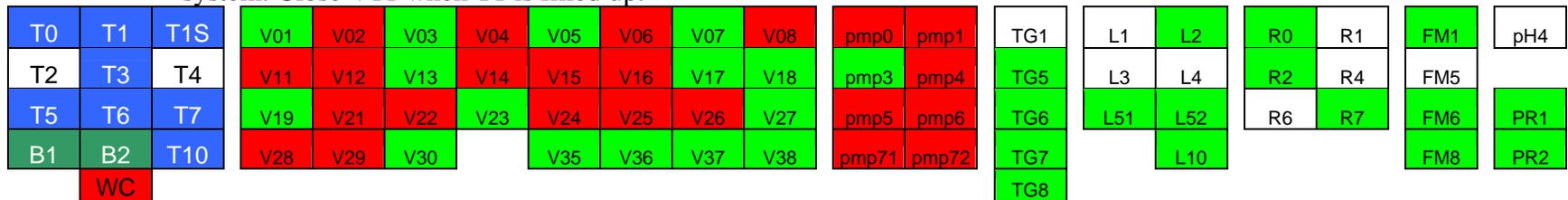
I. Close V02 when T1 is empty. Start filling T1 with UPW to preset level by using V11. After the bulk of acid is removed from T3 into B2, stop Pmp3 and close V29.



II. After rough rinsing is over, (timer) stop Pmp5, open V07, V35, and V37 and transfer the rinsing water in T3.

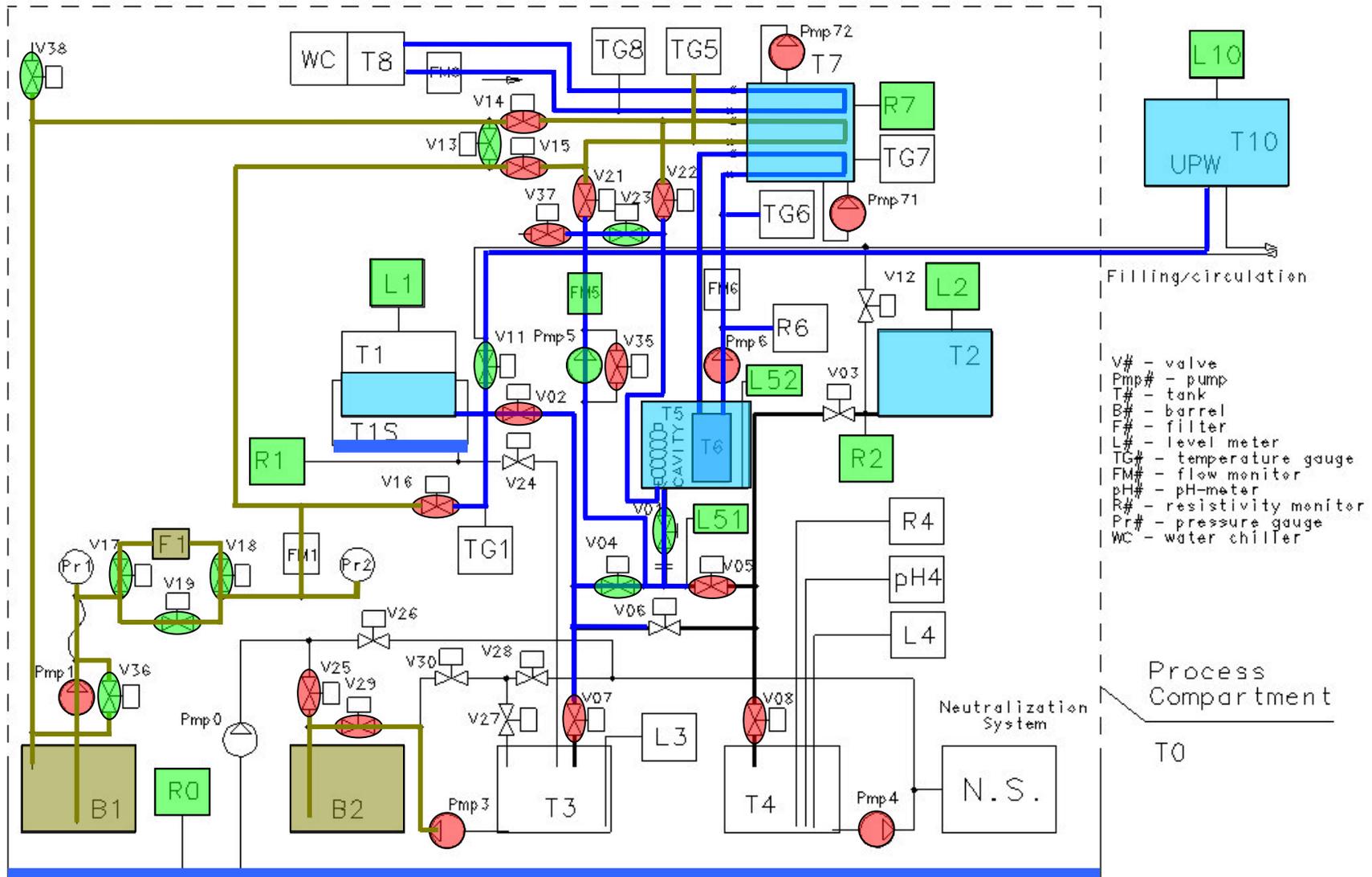


III. Close V04 and open V03 and V05 to fill T5 using UPW in T2. Open V30 and V27, and start Pmp3 to rinse piping system. Close V11 when T1 is filled up.

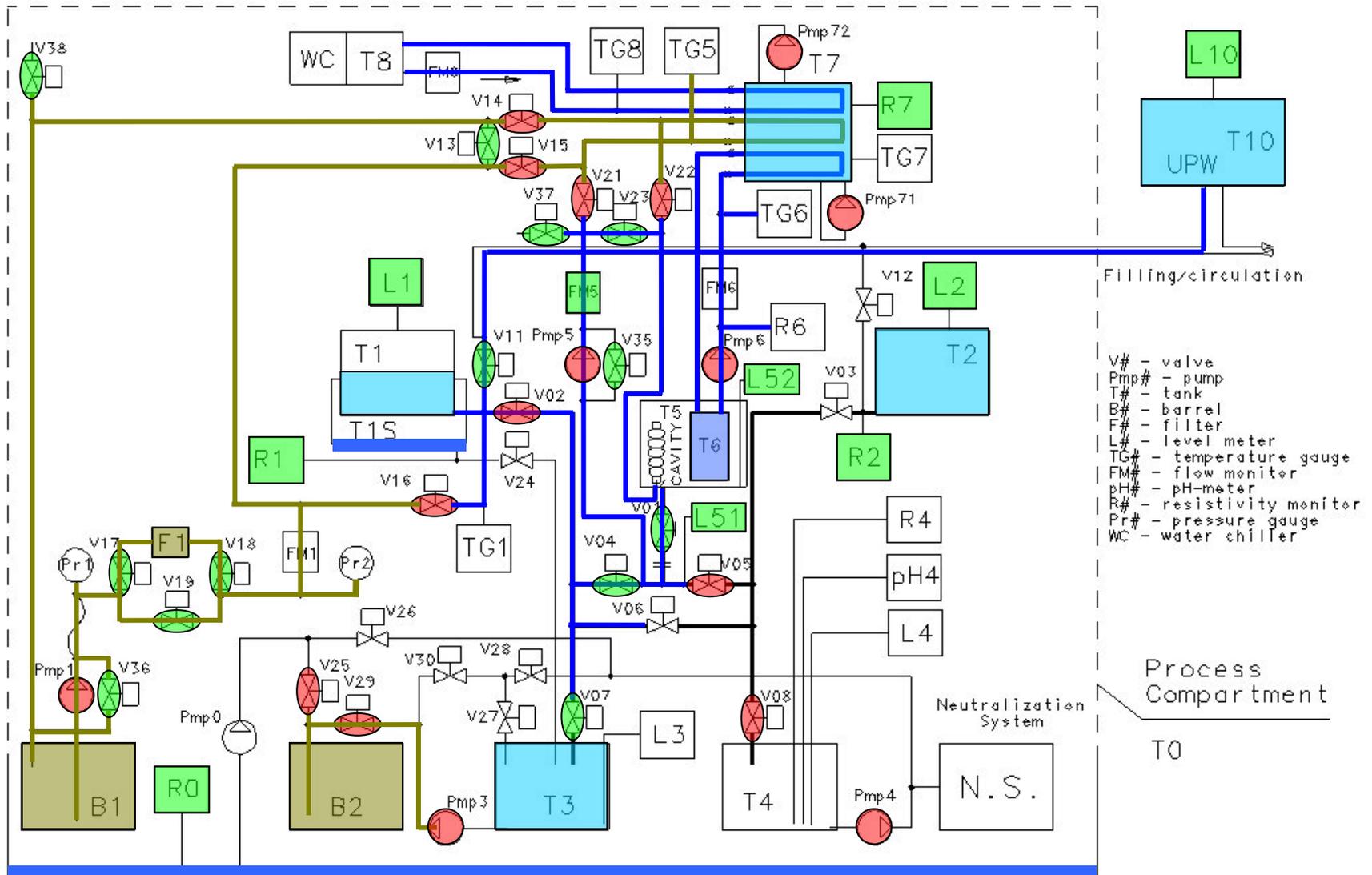


Failure Mode	Recommended Action
V07 do not close or V04 does not stay open	Use V05 and V08
V35 or V37 do not open or close	The process to empty the circulation circuit will be longer
L51 or L52 do not show expected value	Rely on readings of L1 and visual information to judge amount of water in tank T5
L2 does not read properly	Rely on visual information
V03 or V05 do not open	Go inside the room to open the valves manually
Pmp3 does not start	Leave the water in T3 and solve the problem after the process is

over. Next rinses use T4

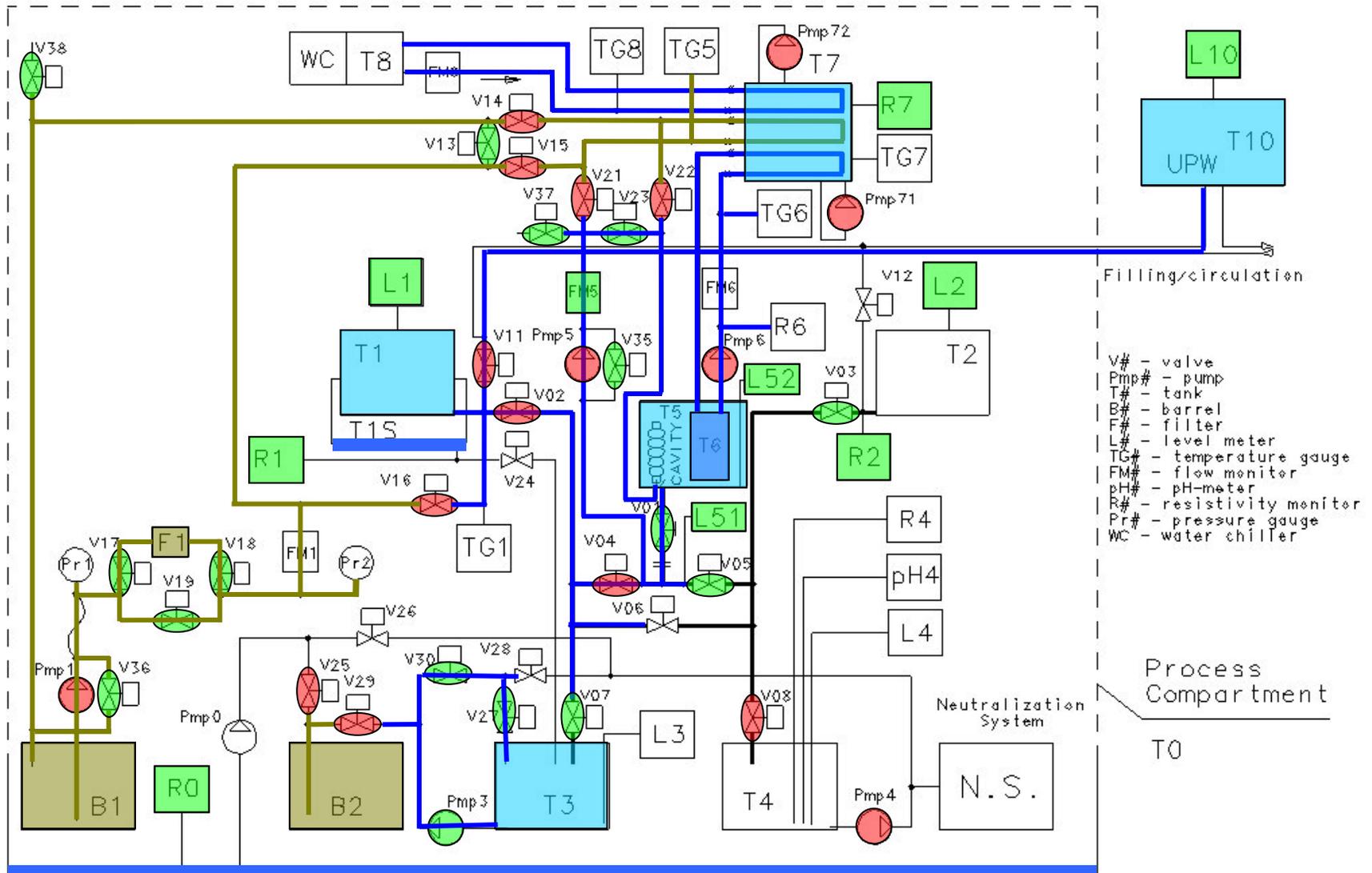


Step 06 - I Filling T1 with UPW (start); Deactivating Pmp3.



Step 06 - II

Dumping rinse water into T3

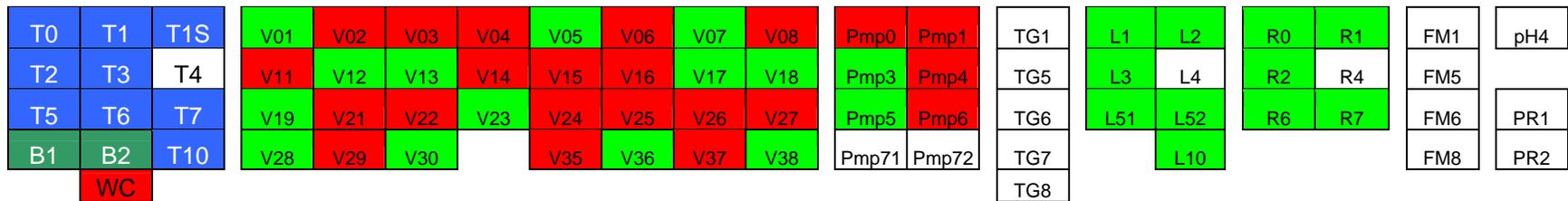


Step 06-III

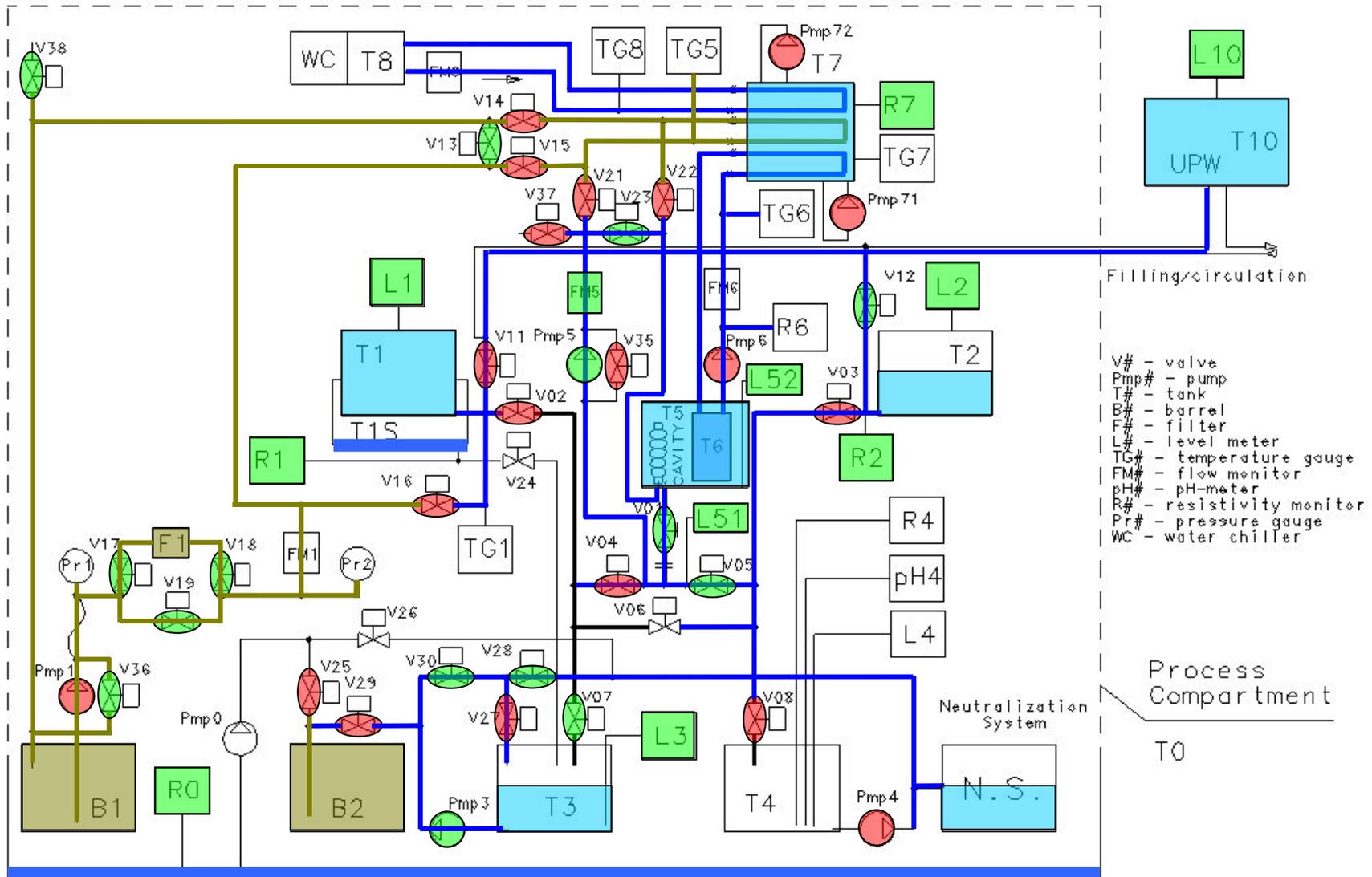
Filling T5 with UPW from T2; Rinsing T3

STEP 07 Filling T2 with UPW. Removing water from T3

Close V03 when T5 is filled. Close V35 and V37 and start Pmp5 to circulate rinsing water in the cooling circuit
 Open V12 to fill T2 from T10.
 Open V28 and close V27 to transfer the acidic water from T3 to the NS.



Failure Mode	Recommended Action
V12 does not open	Open the valve manually to fill the tank.
V28 does not open or V30 closes	Open/close the valve manually
L51 or L52 do not read properly	Rely on L2, L3 and on visual information
L3 does not read correctly	Use the expected flow rate of pmp3 to decide how long the transferring process should last

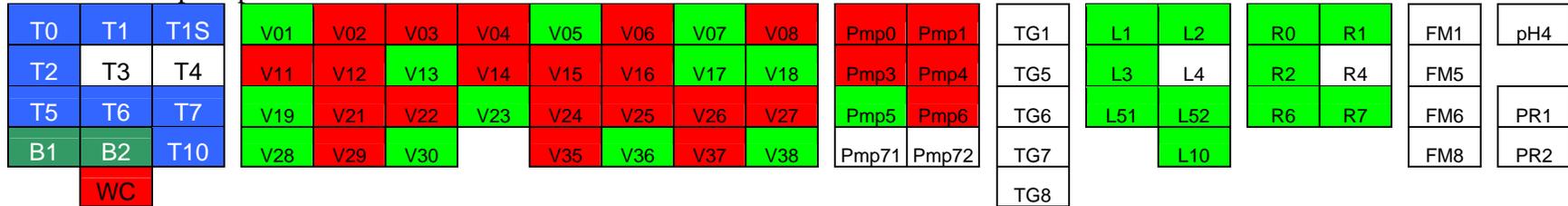


Step 07

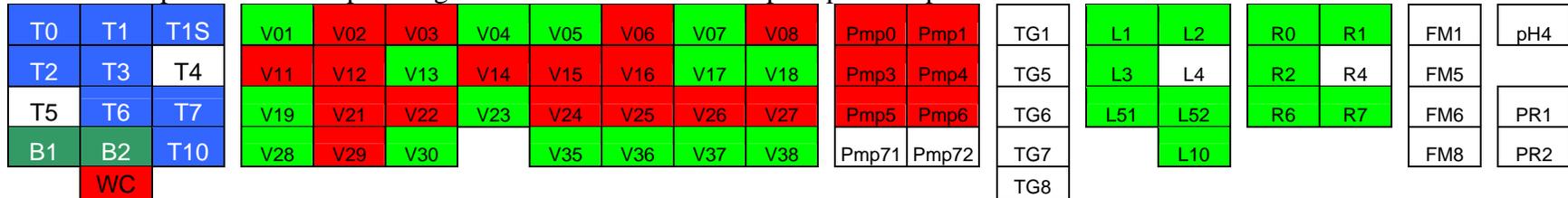
Filling T2 with UPW. Removing water from T3

STEP 08 Emptying T5 into T3. Start Final Rinse by Filling T5 from T2. Filling T2

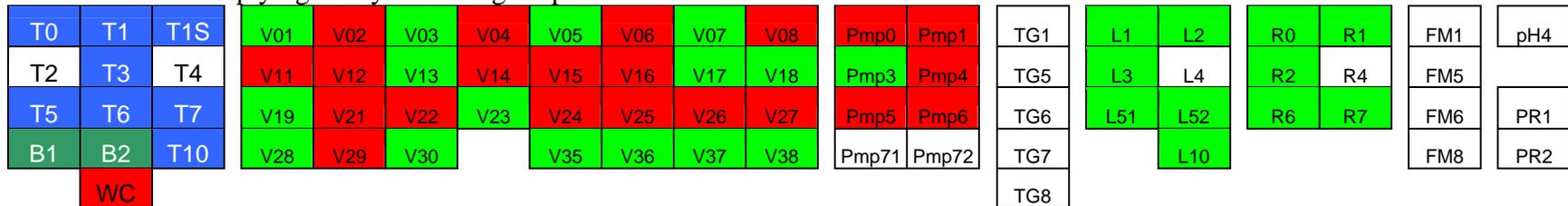
I. Stop Pmp3 when the level of T3 reaches zero. Close the valve V12 when T2 is full.



II Open V04 to dump rinsing water from T5 into T3. Stop Pmp5 and open V35 and V37.

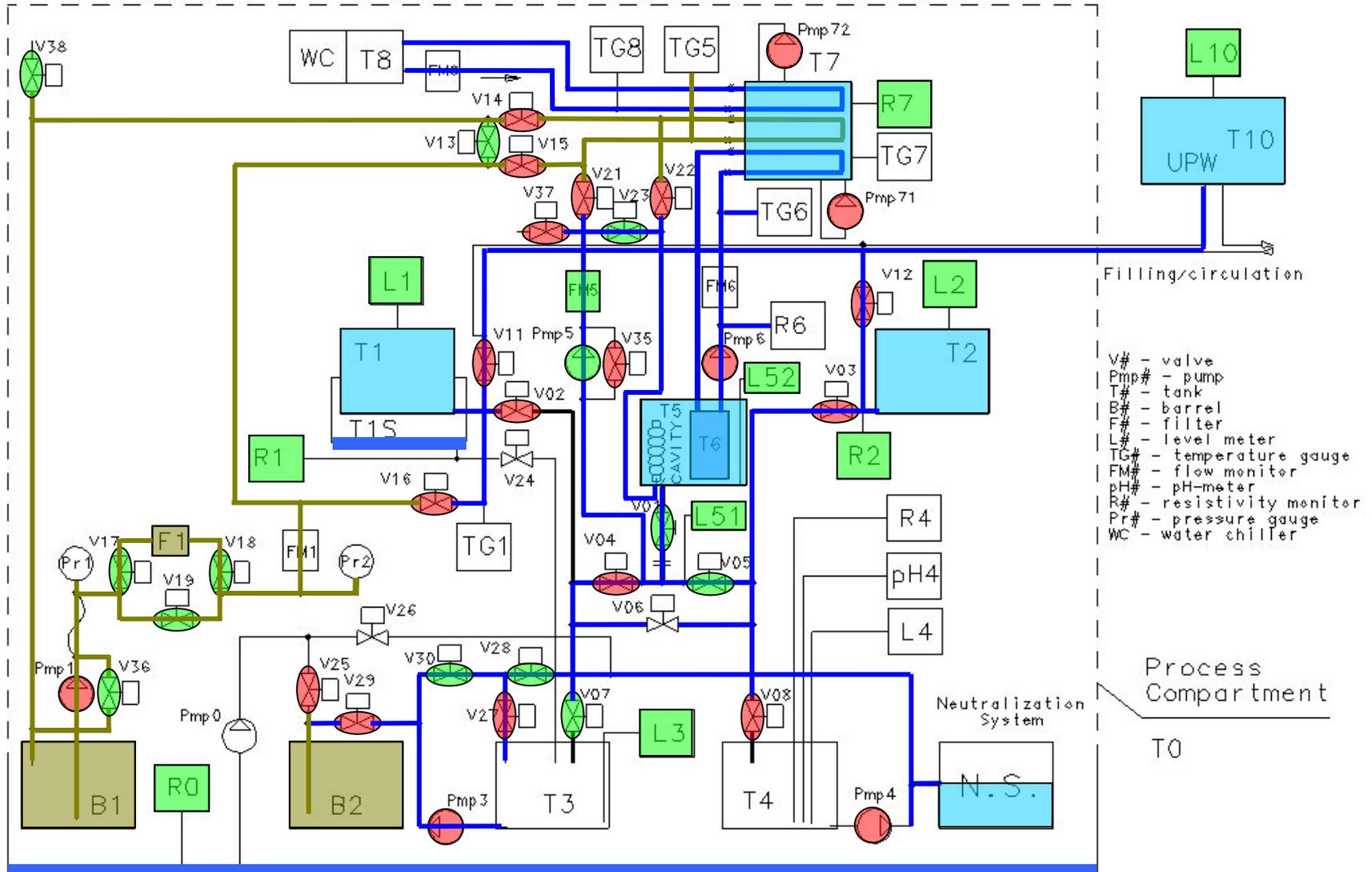


III After T5 is emptied, close V04, open V03 and fill the tank T5 with UPW from T2 for the first cycle of the final rinsing. Start emptying T3 by activating Pmp3.

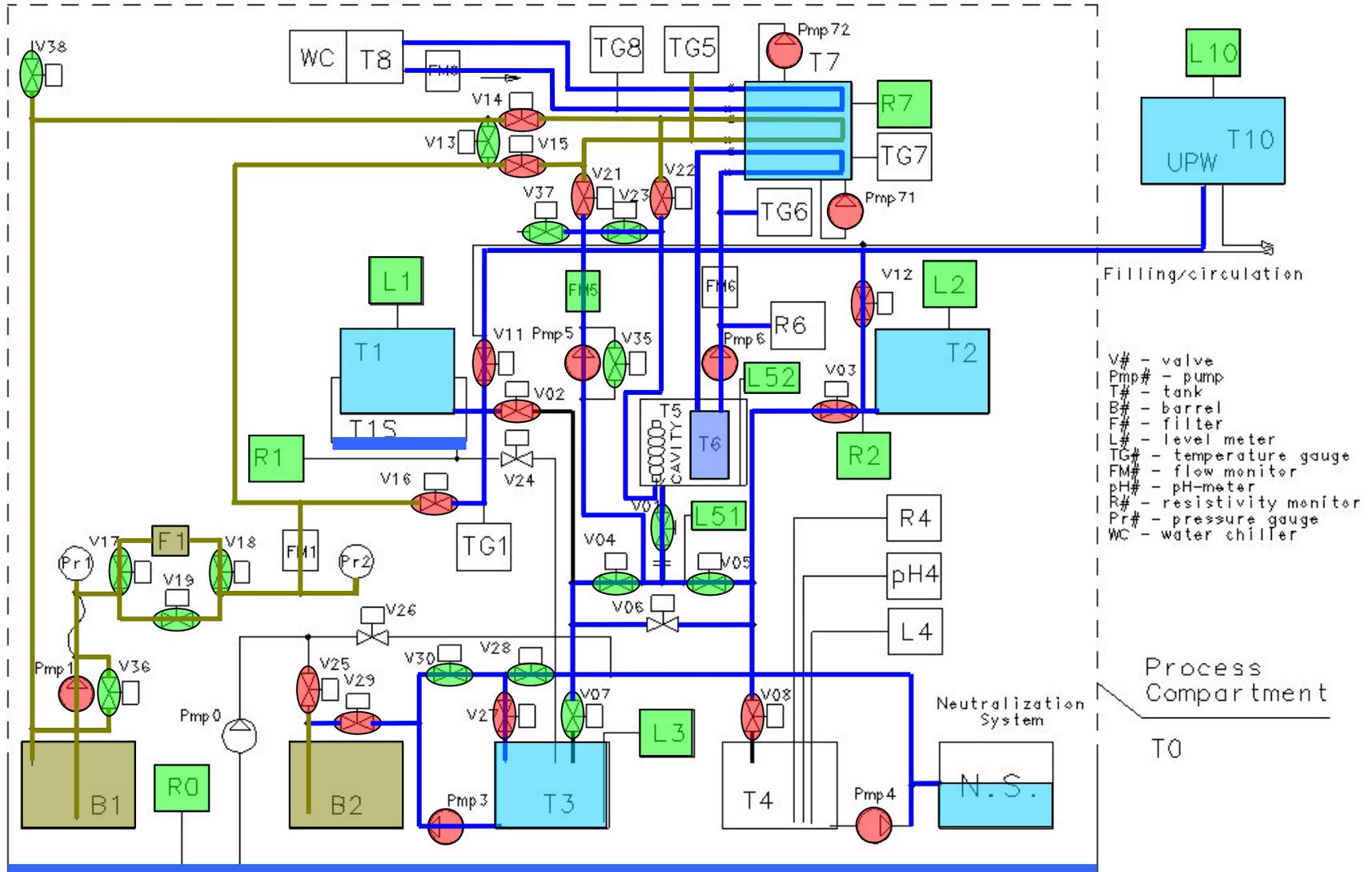


No acid is present is the active part of the circuit at the moment. If any failure, try to keep cavity under water, not to expose it to air.

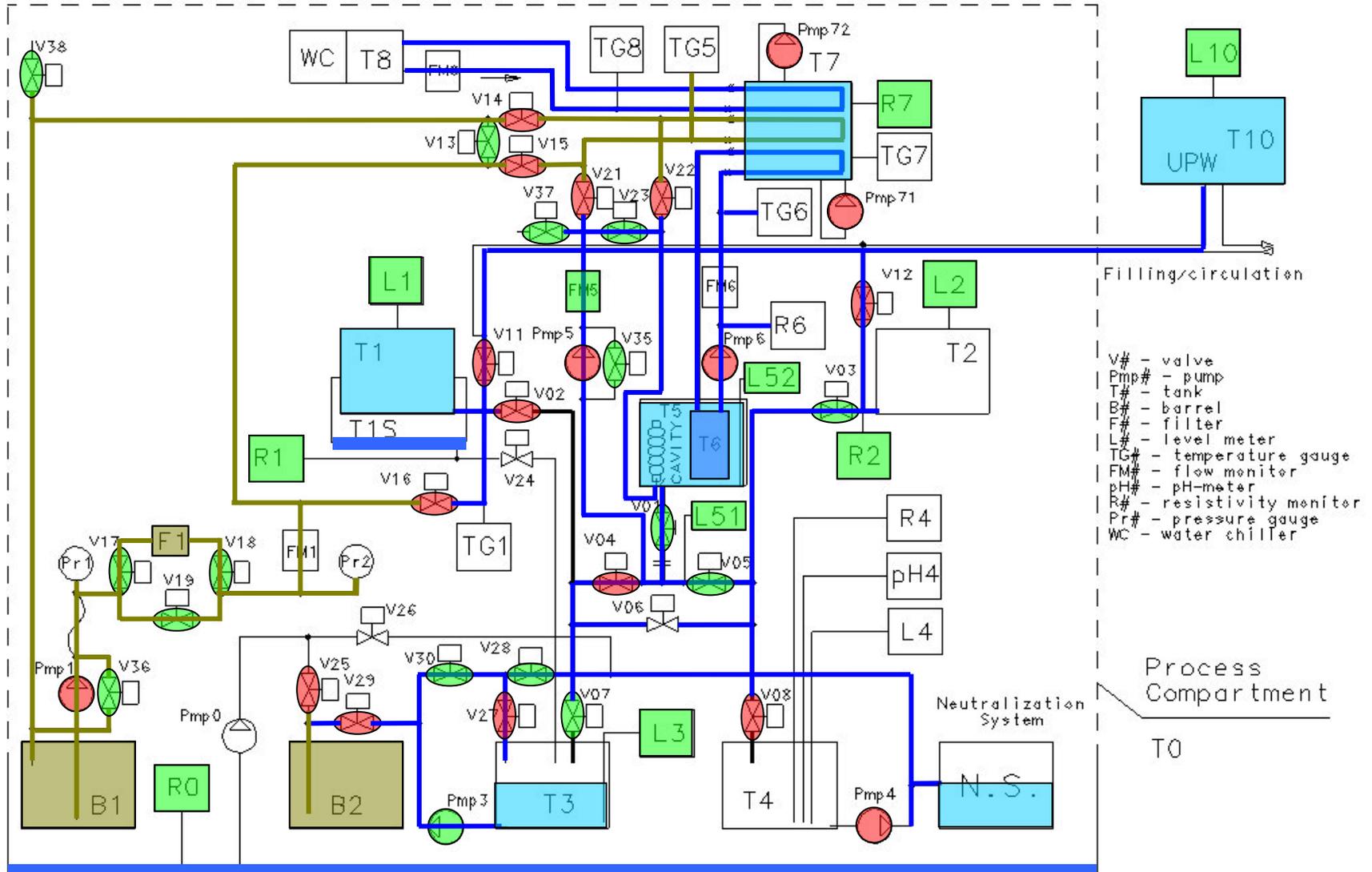
Failure Mode	Recommended Action
V12 does not open	Open the valve manually to fill the tank.
Major leak in T5	Try to seal or remove the cavity out of the tank keeping it wet by using an auxiliary source of UPW.
A leak develops in the tank T1 or corresponding part of the system	Dump water from T1 into T3 if it is empty or in T4 if it is full. Empty T3 and T4 and proceed with cavity rinsing
A level gauge does not read properly	Use visual control to proceed with the rinsing



Step 08 - I End of Rough Rinse.



Step 08 - II Dumping T5 into T3.

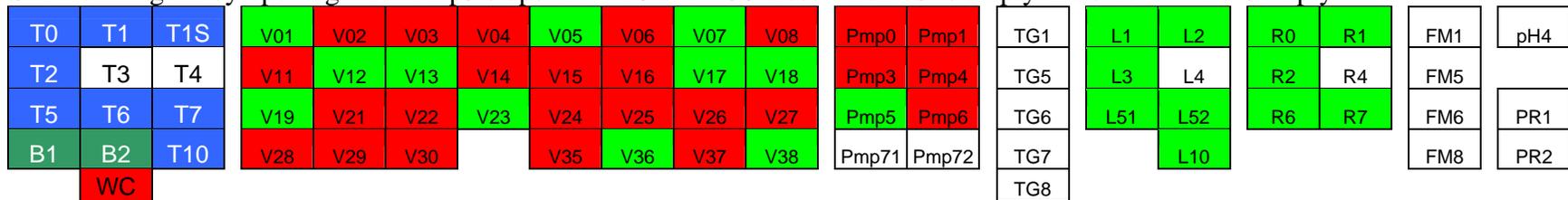


Step 08 - III Filling T5 with UPW; Emptying T3.

STEP 09 Start Final Rinsing Cycle; Filling T2, Dumping Rinsing Water Into T4, Emptying T4

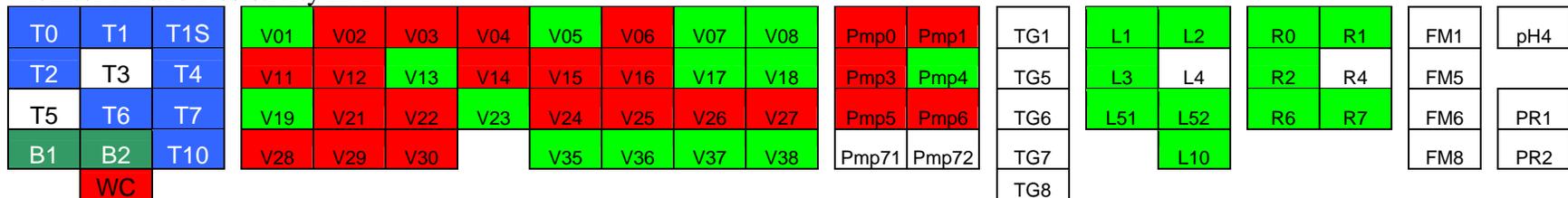
I. Close V03 when T5 is full. Close V35 and V37 and start Pmp5.

Start refilling T2 by opening V12. Pmp3 stops and V28 and V30 close when T3 is empty. Be sure that T4 is empty.



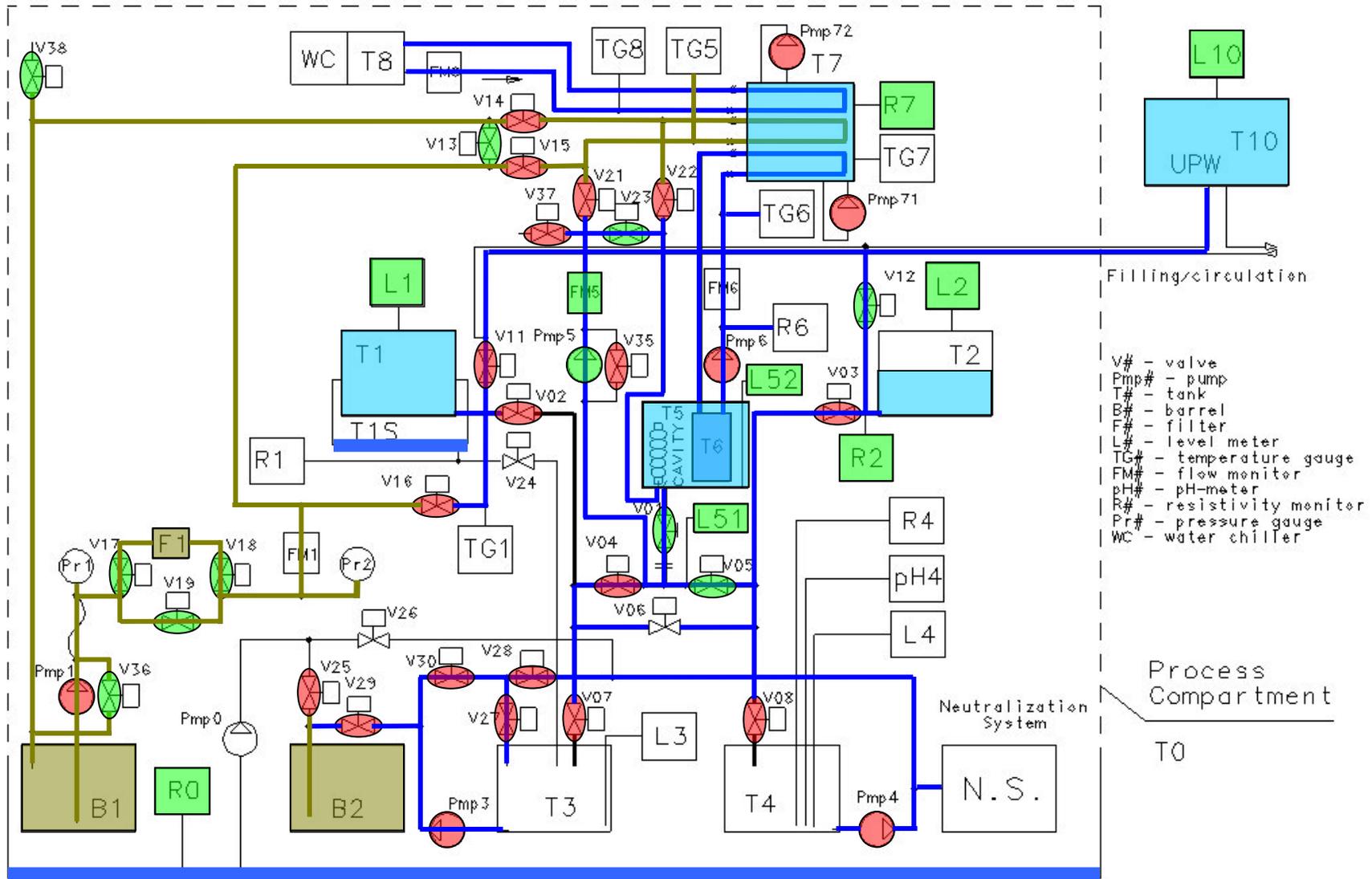
II When T2 is full, close V12. When rinsing is completed, stop Pmp5, open V08, V35, and V37 and dump the water from T5 into T4. Start Pmp4 to remove water from T4 into the neutralization system NS.

Monitor Ph and Resistivity in T4



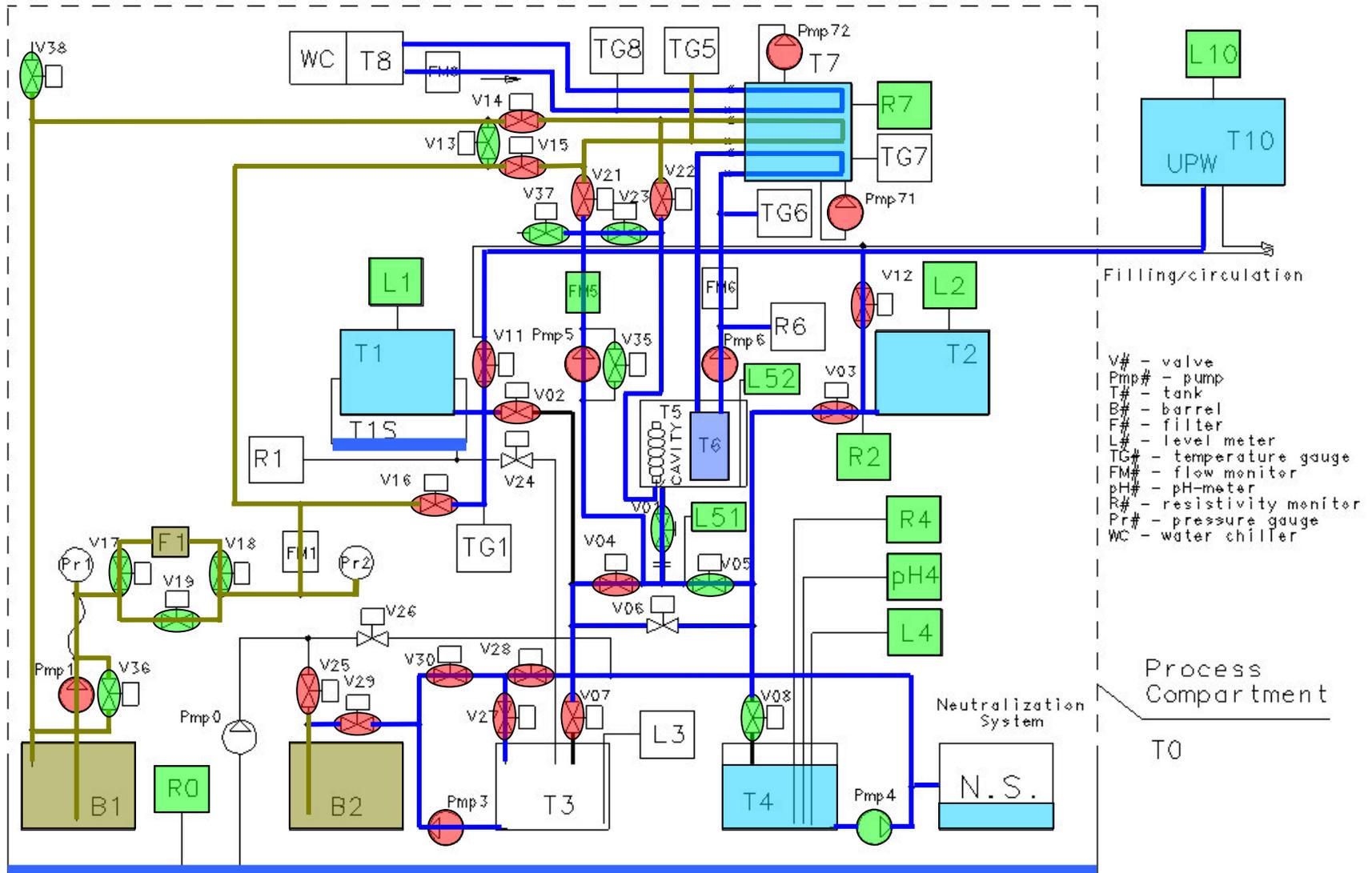
No acid is present in the active part of the circuit at the moment. If any failure, try to keep cavity under water, do not expose it to air for too long.

Failure Mode	Recommended Action
V08 do not open	Enter the room and open manually.
Major leak in T5	Try to seal or remove the cavity out of the tank keeping it wet by using an auxiliary source of UPW.
A leak develops in the tank T1 or corresponding part of the system	Dump water from T1 into T3 or T4 if T3 is full. Empty T4 and proceed with cavity rinsing
A level gauge does not read properly	Use visual control to proceed with the rinsing



Step 09 -I

Filling T2 with UPW



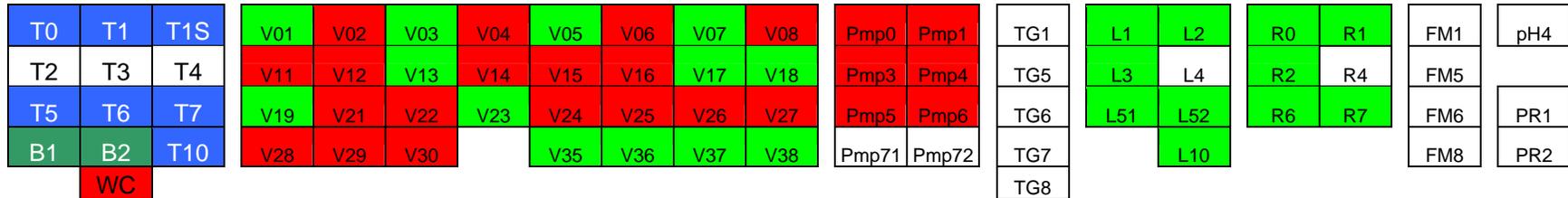
Step 09 -II

Dumping UPW from T5 into T4; Removing water from T4 into NS

STEP 10 Final Rinse.

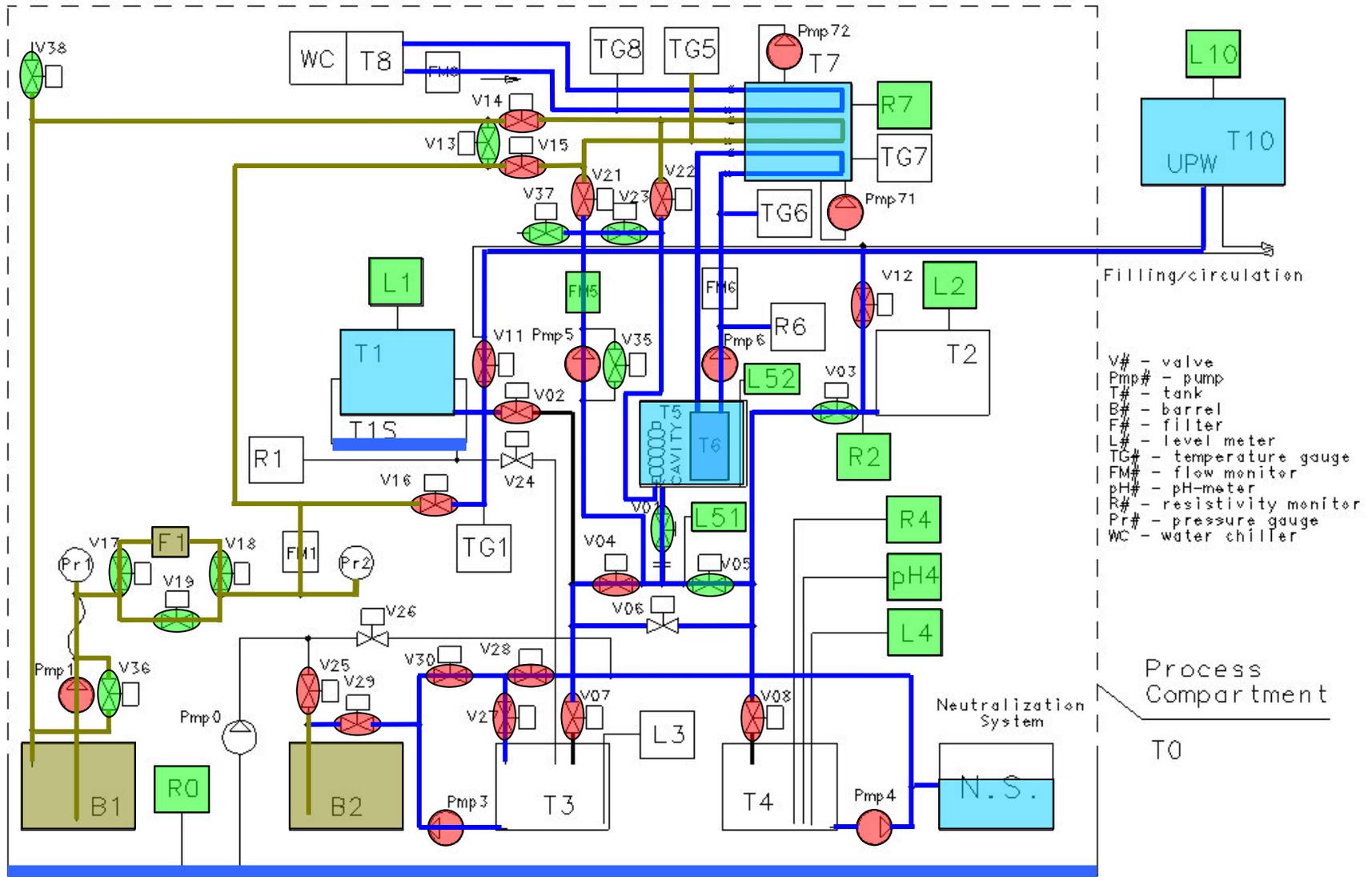
Close V08 when T5 is empty. Open V03 to fill tank T5 with UPW. Stop Pmp4 when T4 is empty.

Repeat the rinsing cycle steps 9 and 10 until the desired values of pH and resistivity of the rinse water in T4 are reached. When the rinsing goal is achieved, proceed to step 11.



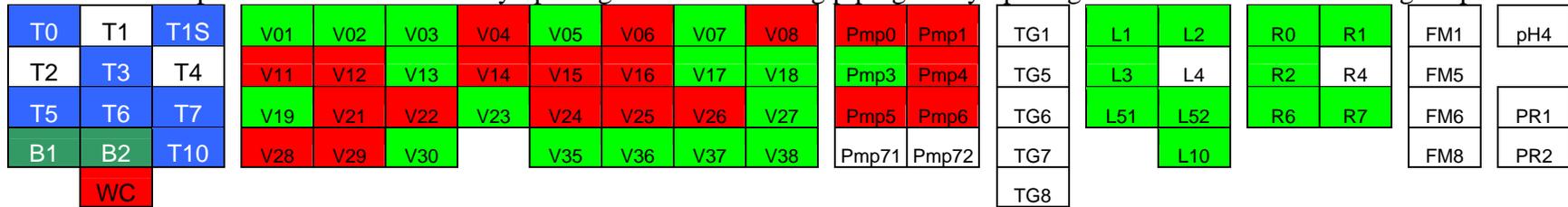
No acid is present in the active part of the circuit at the moment. If any failure, try to keep cavity under water, do not expose it to air for too long.

Failure Mode	Recommended Action
V08 does not open	Enter the room and open manually.
Major leak in T5	Try to seal or remove the cavity out of the tank keeping it wet by using an auxiliary source of UPW.
A leak develops in the tank T1 or corresponding part of the system	Dump water from T1 into T3 or T4 if T3 is full. Empty T4 and proceed with cavity rinsing
A level gauge does not read properly	Use visual control to proceed with the rinsing
Pmp4 or Pmp3 do not start	Bring in an auxiliary pump and remove water from the tanks

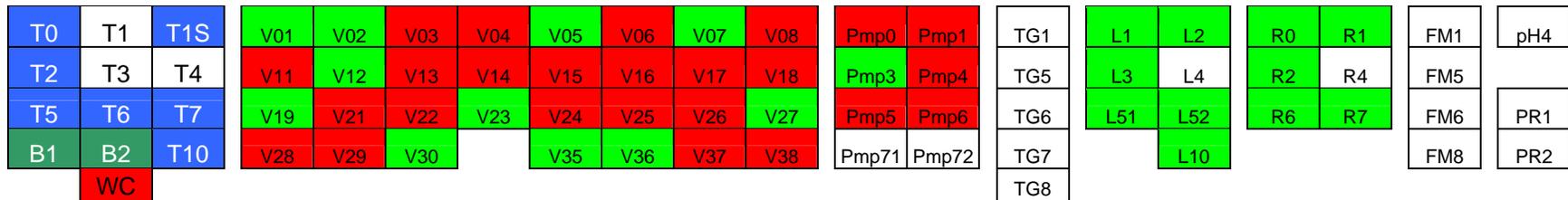


STEP 11 **Completing the process**

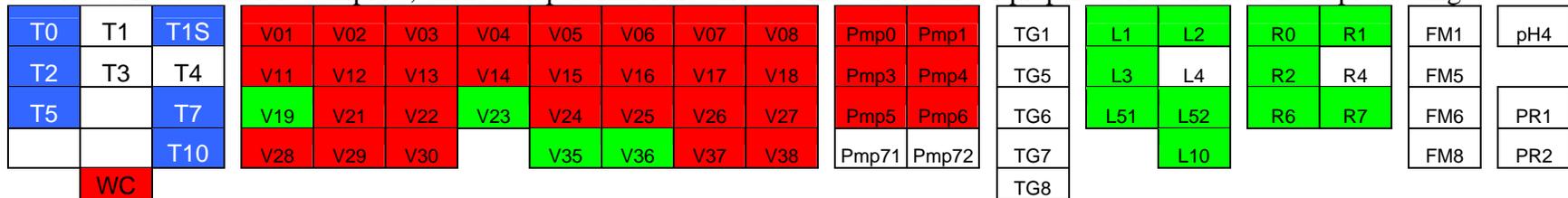
I. Dump water from T1 into T3 by opening V02. Start rinsing piping T3 by opening V30 and V27 and activating Pmp3.



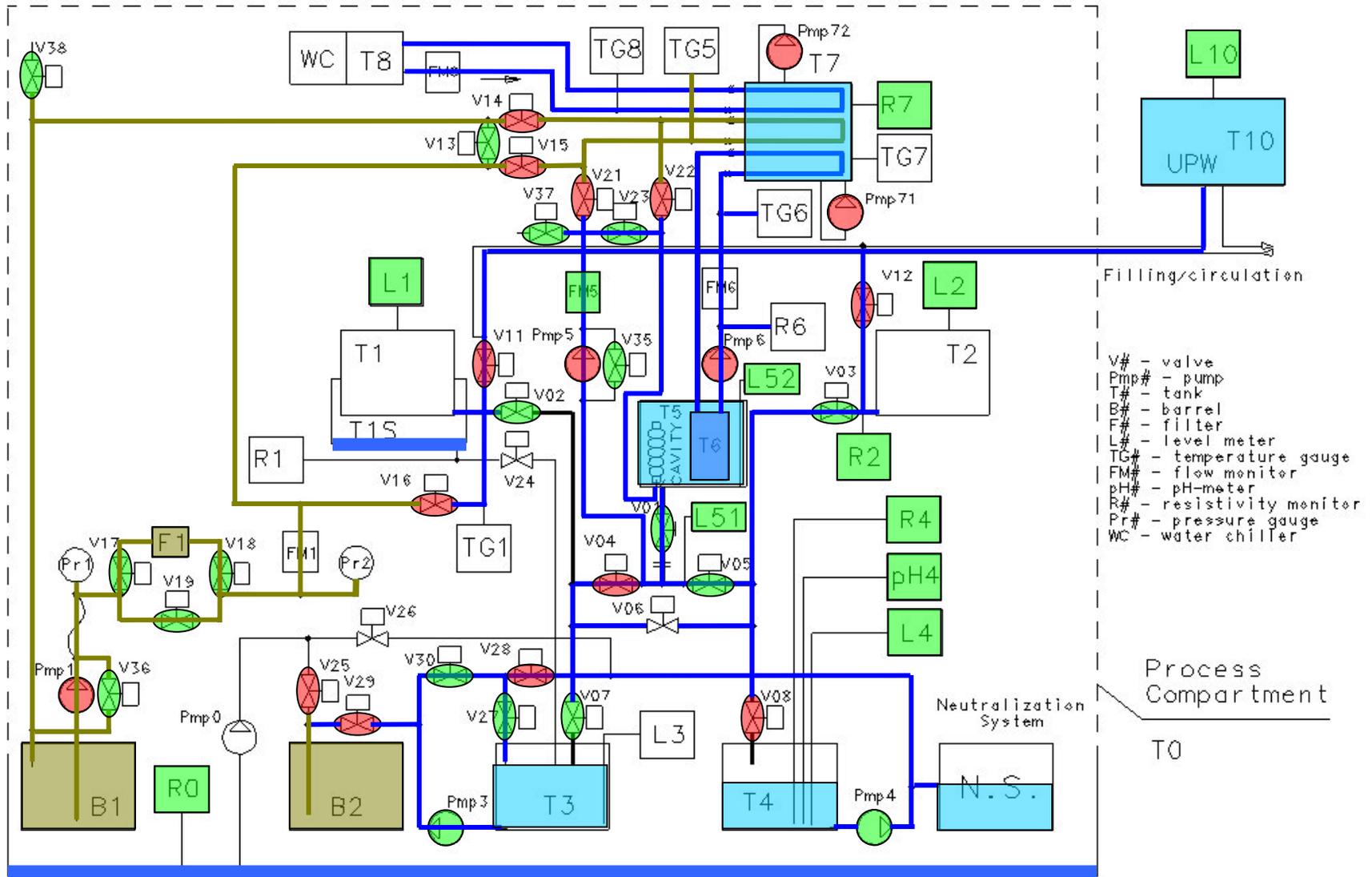
II. Close V03. Fill T2 with UPW by opening V12. Empty T3 into the neutralization system NS when it is convenient. Close and block V17 and V18. Close V13 V37 and V38.

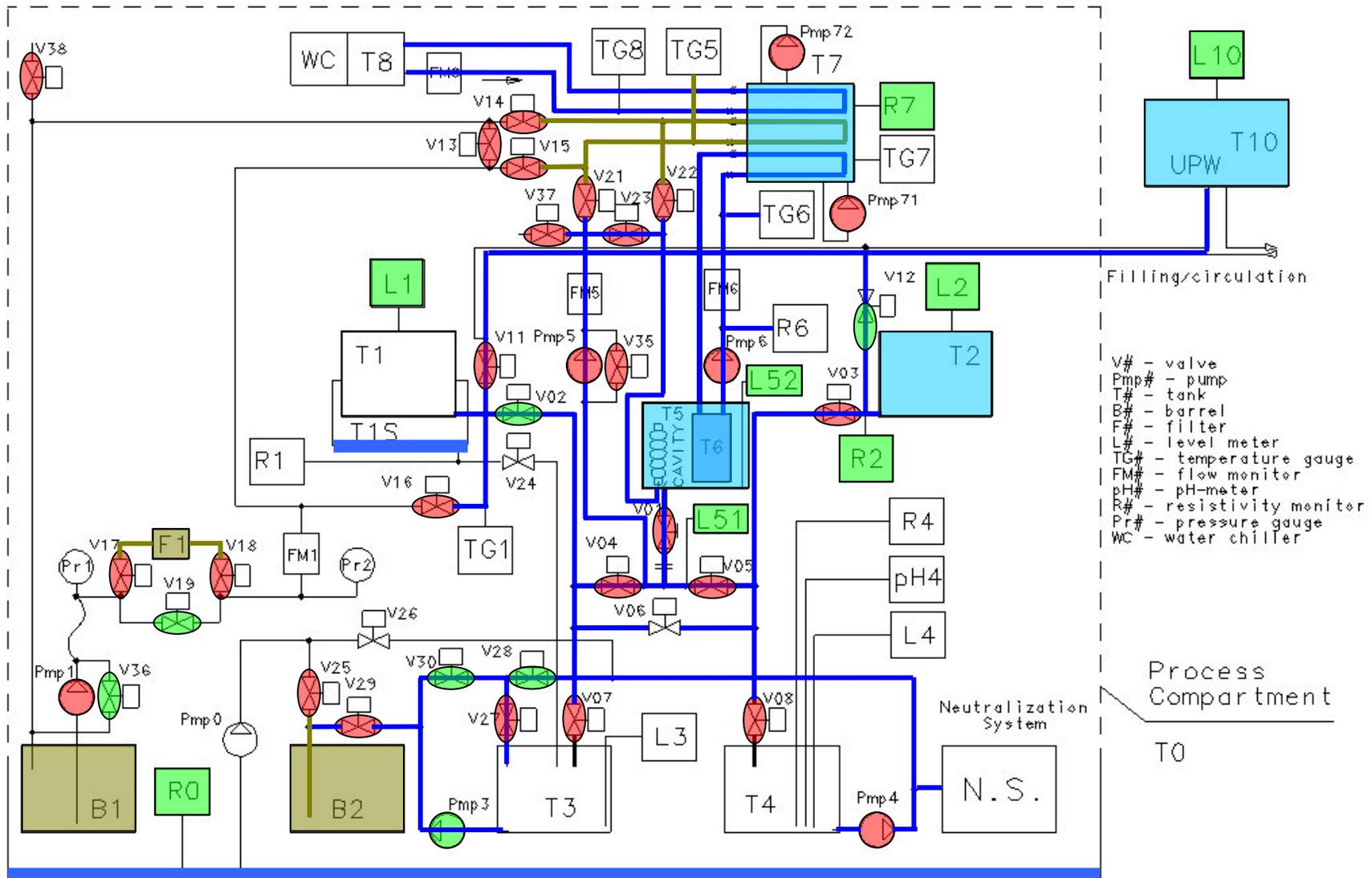


III. When the rinsing goal is reached, cavity rinsing circuit are disconnected and cavity is removed from the room for resistivity rinsing and High Pressure rinsing. Barrel circuits are disconnected and B2 and B1 are moved to the storage area. Thorough investigation is done to the room and equipment with the goal to decontaminate all suspicious spots that could be residuals of acid. During these steps, personnel must be properly dressed, and gas analyzer reading must be used to avoid exposure to high acid fume concentration. Disconnection of barrel circuits must be done with the use of local hoods for additional protection. Filling piping can be rinsed by UPW circulated by Pmp1 through open V13 if a break in polishing activities is expected. After decontamination is complete, undressed personnel are allowed into the room for preparation to the next BCP processing.

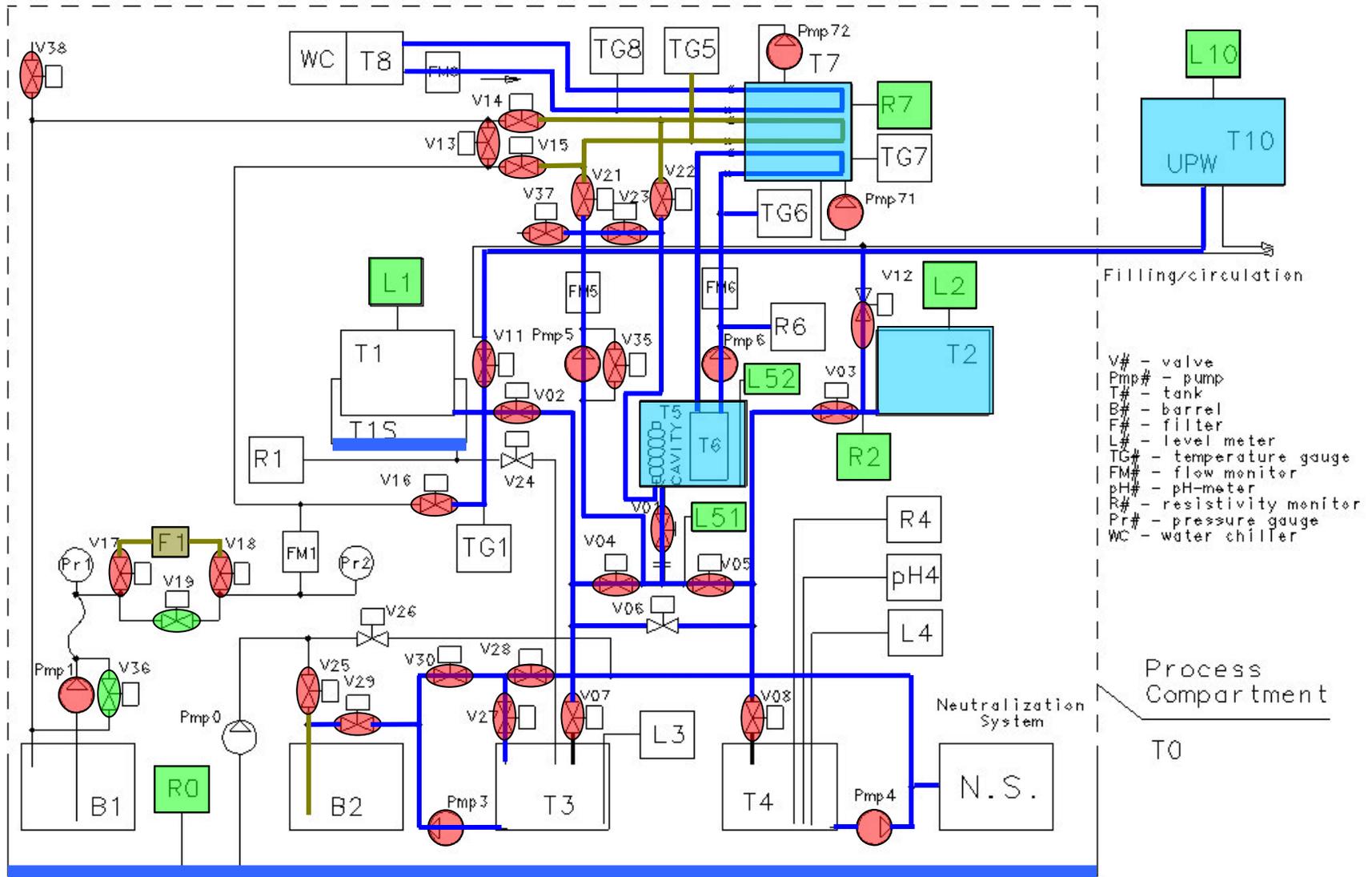


In the end of the process, all the valves are closed, T2 and T5 are still filled with water that can be used for rinsing T3 and piping if needed. Acid is still present in the filter and in the acid heat exchanger. Those circuits are insulated by pairs of valves: V14 - V15 and V17 - V18. The valves must be blocked to prevent from accidental opening. Level meters L2 and L52 and resistivity gauge R2 are active while there is water in the tanks T2 and T5. Resistivity gauge R0 is active until it is safe for undressed personnel to enter the room. The room cleaning procedure is described elsewhere.





Step 11-II Filling T1 with UPW. Removing water from T3 into NS



Step 11-III

Completing the Process

