# TAC L5 SERIES: OPERATION PHILOSOPHY

The operation of the Vapour Absorption Machine (VAM) is totally controlled by the PLC. The operational philosophy of VAM can be classified as:

A. Start-up sequence
B. Control actions
C. Safety measures
D. Shut down sequences

## A. START-UP SEQUENCE

- When the VAM is powered on, the status of the VAM as displayed on the operator panel will be “VAM READY TO START”, provided the VAM has completed the ‘DILUTION’ cycle before control panel was powered off.
- This status indicates that the VAM can be started now.
- Else the VAM will first undergo ‘DILUTION’ as described in the Power Failure resumption described below.
- When the VAM is started, the PLC sends signal to start the Chilled Water Pump immediately.
- The PLC then waits for activation of Flow switch, DP switch and Chilled Water Pump feedback Signal for 10 minutes time.
- During this time, whenever these safeties become healthy, PLC will initiate start sequence, it will send signal to start the Hot water pump and the Hot water Control Valve will start its slow opening simultaneously.
- Both HP and LP Absorbent Pumps switch ON.
- After a span of 15 seconds from start, the PLC first sends signal to start the Cooling Water Pump / to open the cooling water automatic shut off valve.
- After a span of 15 seconds from start, the Refrigerant Pump switches ON based on Evaporator level.
- After a delay of 2 seconds, PLC sends signal to start Cooling Tower Fan.
- If after completion of 10 minutes from chilled water pump start, chilled water Flow switch, DP switch and Chilled Water Pump feedback Signal safeties are not healthy, then chilled water pump will be stopped, the VAM status will return to “VAM READY TO START”, the start command would have to be given again on the panel/by remote for the VAM to start again.

## B. CONTROL ACTIONS

The control actions performed by the PLC are as given below.

1. Fixed ramp rate of loading for Thermal shock prevention
2. Capacity Control
3. Chilled Water L-Cut control
4. Crystallisation prevention
5. Cavitation protection of Refrigerant Pump
6. Hot water Control Valve control on Generator Temperature
7. Chilled Water low / no flow interlock with Cooling Water Flow
8. Cooling Tower Fan control on Cooling Water Inlet Temperature
9. HP Absorbent Pump AC Drive Modulation
10. LP Absorbent Pump AC Drive Modulation

### 1. FIXED RAMP RATE OF LOADING FOR THERMAL SHOCK PREVENTION:

- This control is to prevent the sudden rush of Hot water to the Generator during cold start and to protect the VAM from thermal shock.
- For this, the Hot water Control Valve is opened gradually over a span of 7 minutes from the VAM start up or whenever the Generator temperature is less than 70°C.
- After the slow opening duration is over, the control is switched over to Chilled Water outlet temperature PID control loop automatically.
- In case, the Chilled Water Outlet Temperature is already below the set point, then the slow opening is bypassed and the control is through the PID.

### 2. CAPACITY CONTROL:

- The cooling capacity of the VAM is the total heat extracted from the Chilled Water. If the Chilled Water flow rate to the VAM is kept constant, the cooling capacity is proportional to the difference in the temperatures of the inlet and outlet Chilled Water.
- Load changes are reflected in the rise or fall of the temperature of the inlet Chilled Water.
- As the Chilled Water inlet temperature rises or falls, the Chilled Water outlet temperature tends to follow the same pattern.
- A temperature sensor in the outlet Chilled Water senses this change in temperature. This signal is fed to the PLC.
- An inbuilt software PID control loop processes this signal with respect to the Chilled Water set point.
- A control output signal of 4 to 20 mA is sent to Hot water control valve. This signal controls the position of the Hot water Control Valve [4 mA - 0% open, 20 mA - 100% opening].
- As the load increases, the Hot water Control Valve opens and as the load reduces, the Hot water Control Valve closes, thus regulating the flow of hot water entering the VAM.

Note: The above operations are in conjunction with crystallization control (Refer the section on crystallization control).

## 3. CHILLED WATER L-CUT CONTROL:

- Sometimes the load may fall sharply due to which the Chilled Water Outlet Temperature will start dropping below its set point.
- When the Chilled Water Outlet Temperature drops below the Chilled Water Outlet Temperature set point minus L-Cut differential set point, the Refrigerant Pump is switched OFF and Hot water Control Valve shuts off fully.
- This safety prevents further temperature drop of Chilled Water Outlet Temperature.
- The Refrigerant Pump and Hot water Control Valve will return to normal operation after the Chilled Water Outlet Temperature rises above the Chilled Water Outlet Temperature set point minus L–Cut differential set point plus the hysteresis.
- A slow opening timer of 2 minutes is provided during the reopening of Hot water control valve.

## 4. CRYSTALLIZATION PREVENTION:

- If the concentrated absorbent solution returning to the absorber from the Generator is excessively cooled, it crystallizes in the low temperature heat exchanger and the operation of the VAM may be affected.
- Crystallization occurs either when the concentration of the absorbent in relation to its temperature goes too high or the temperature of LiBr drops excessively.
- The following safety functions prevent LiBr in the VAM from crystallizing.
  a) Hot water Control Valve modulation on crystallization prevention
  b) Based on HP Absorber Level
  c) Based On Cooling Water Inlet Temperature

### a) HOT WATER CONTROL VALVE MODULATION ON CRYSTALLIZATION PREVENTION:

- The strong solution concentration is calculated in the PLC.
- The crystallization temperature for that concentration is also calculated by the PLC.
- The PLC always tries to keep the Pre-set safe distance between the crystallization temperature and Spray solution temperature.
- If the distance is less than the preset safe distance, then the PLC modulates the Hot Water Control Valve (HCV) so that the strong solution temperature will never reach crystallization temperature. When the distance is less than safe distance Hot Water Control Valve operates only on crystallization control signal and capacity control signal is overruled.
- In addition to the above, HCV opening shall also be based on strong concentration. HCV opening limit will be maximum set in HMI at 63.5% concentration and it will be 0% at 64.5% concentration. It will vary linearly in between 63.5% and 64.5% concentration. (Enable/disable option for this control has been given in the HMI (services screen). The default would be 'Enable').
- The HCV will return to normal operation only after the strong concentration goes below the concentration very high setpoint (64.5%) minus the hysteresis (1.5%). A slow opening timer of 2 minutes is provided during the reopening of Hot Water Control Valve.

### b) BASED ON HP ABSORBER LEVEL:

- In the event of LiBr getting crystallized in the spray solution line, the level of LiBr in the absorber sump starts reducing.
- To sense the level of LiBr in absorber, level transmitter is provided. There are three level (**Normal/Medium/Low**) setpoints provided in HMI service menu with respect to Absorber sight glass.
- When the level goes below **Absorber Medium Level setpoint**, Hot water 3-way Control Valve opening will be reduced by 20% of the current opening.
- Further if the level goes below **Absorber Low Level setpoint**, Hot water 3-way Control Valve opening will be reduced by 20% of the current opening and the Refrigerant solenoid valve will open to transfer refrigerant to the absorber to build the absorber level again. Also, Refrigerant solenoid valve will open only when the Refrigerant Pump is in 'ON' condition.
- If the level in absorber rises above **Absorber Low Level setpoint**, Refrigerant solenoid valve will close.
- If the level in absorber rises above **Absorber Normal Level setpoint**, Hot water 3-way Control Valve modulation returns to Chilled Water Outlet Temperature PID control.
- A slow opening timer of 2 minutes is provided during the reopening of Hot water 3-way Control Valve. This control action will come into action only when VAM is 'ON'.
- Note: Refrigerant solenoid valve should be operated in both Auto and Manual mode (Default: Auto)
- Note: Hot water 3-way Control valve and Refrigerant solenoid valve control on Absorber Level Transmitter must have 'Enable/Disable' option in settings. Default: Enable.

### c) BASED ON COOLING WATER INLET TEMPERATURE:

- The maximum opening limit for Hot water control valve is to be limited based on cooling water inlet temperature to safeguard against excessive capacity extraction from the VAM at lower cooling water inlet temperatures.
- If the incoming cooling water inlet temperature is less than Cooling water inlet temp low trip set-point ($T_{CWL}$), the control valve opening should be zero.
- If the incoming cooling water inlet temperature is equal to Cooling water inlet temp low trip set-point ($T_{CWL}$), the control valve opening should be 10% of the opening fixed @ rated capacity.
- If the incoming cooling water inlet temperature is equal to or greater than Cooling water inlet temp for Crystallization control set-point ($T_{CZL}$), the control valve opening should be 100% of the opening fixed @ rated capacity
- If $T_{CWL} < t_{cw} < T_{CZL}$, the maximum limit of opening will vary linearly as per the equation,

  $$\text{if}\ (\ t_{cw} < T_{CWL}, 0,\ \text{if}(t_{cw} < T_{CZL}, (0.1+0.9*(t_{cw} - T_{CWL})/(T_{CZL} - T_{CWL}))*CV, CV))$$

- During initial start-up, till the time Generator temperature goes above 70°C this safety shall be bypassed. However, 30 minutes after VAM start-up, this safety shall be in operation irrespective of Generator temperature.
- When crystallization control logic and the control based on cooling water inlet temperature are acting simultaneously, minimum of the two calculated control valve openings must be considered.
- This logic, like crystallization control, will always override the chilled water outlet PID.

## 5. CAVITATION PROTECTION OF REFRIGERANT PUMP:

- If the refrigerant level in the Evaporator pan falls below certain level, the pressure in the Refrigerant Pump suction drops below the saturation pressure of the refrigerant and the Refrigerant Pump starts to cavitate.
- To ensure minimum acceptable suction pressure, the refrigerant level is measured by level transmitter and Refrigerant pump start/stop operation will be controlled by PLC.
- There are three level (**Very High/Normal/Low**) setpoints provided in HMI service menu.
- When the level reaches Evaporator **Normal Level setpoint**, Refrigerant pump starts and when the level goes below Evaporator **Low Level setpoint**, the pump stops after a time delay of 10 seconds.
- If the refrigerant level goes above Evaporator **Very High Level setpoint** and remains for 60 seconds, it is an indication of tube failure or severe crystallization.
- VAM will go into 'Total Shutdown' mode. An alarm "EVAPORATOR LEVEL VERY HIGH, PLEASE ISOLATE ALL CIRCUITS. CONTACT THERMAX" will be displayed.
- This alarm can be reset when the refrigerant level goes below Evaporator **Very High Level setpoint**. This logic will be applicable for “VAM Run” condition.
- The control on Evaporator **Very High Level setpoint** must have ‘Enable/Disable’ option in settings. ***Default: Enable.***

## 6. HOT WATER CONTROL VALVE CONTROL ON GENERATOR TEMPERATURE:

- This control is provided to prevent the VAM from tripping on high temperature in the Generator.
- Whenever the Generator temperature exceeds the Generator high temperature set point minus a differential set point for controlling Hot water Control Valve, the Hot water Control Valve closes immediately. This prevents further increase in Generator temperature and LiBr concentration.
- The hot water control valve control returns to the Chilled Water Outlet Temperature control PID loop when the Generator temperature goes below the Generator high temperature set point minus the differential set point for controlling Hot water Control Valve minus its hysteresis.
- A slow opening timer of 2 minutes is provided during the reopening of Hot water Control Valve.

## 7. CHILLED WATER LOW/NO FLOW INTERLOCK WITH COOLING WATER FLOW:

- The freezing of Chilled Water inside the VAM can be prevented by stopping the Cooling water circulation through the VAM.
- Hence, in the event of VAM tripping on any of the above Chilled Water safeties, the Cooling Water Pump should be stopped and the cooling water shut-off valve is to be closed.
- Hence it is required that the Cooling Water Pump should be started or stopped through the Cooling Water Pump start/stop permissive contact of VAM control panel.
- The operation of this shut off valve should also be performed through the permissive contacts provided for the same on the control panel.

## 8. COOLING TOWER FAN CONTROL ON COOLING WATER INLET TEMPERATURE:

- When the Cooling Water Inlet Temperature to the VAM goes below the Cooling Tower OFF Set point, the start permissive for Cooling Tower is made off by the PLC after delay of 5 sec.
- The Cooling Tower permissive is put ON only after the Cooling Water Inlet Temperature is more than Cooling Tower OFF Set point plus Hysteresis.

## 9. HP ABSORBENT PUMP AC DRIVE MODULATION:

- The flow of LiBr into the Generator can be regulated by regulating the speed of the HP Absorbent Pump which pumps the LiBr into the Generator.
- The speed control is achieved by means of an AC drive which is provided for the HP Absorbent Pump motor. The speed is controlled based on the Generator temperature.
- The minimum and maximum frequencies of the drive are settable in the Operator interface of the AC drive. The low and high limits of Generator temperature are settable in the VAM PLC operator interface.
- When the Generator temperature is below the low limit temperature, the HP Absorbent Pump will run at the minimum frequency.
- When the Generator temperature is between the low limit and the high limit temperature, the HP Absorbent Pump will be under modulation and will run at an intermittent frequency between the low and high limit frequencies.
- Once the Generator temperature goes above the high limit value, then the HP Absorbent Pump will run at the maximum frequency.

## 10. LP ABSORBENT PUMP AC DRIVE MODULATION:

- There are three level (Normal/Medium/Low) setpoints provided in HMI service menu with respect to LP Absorber sight glass.
- When Level is below ***LP Absorber Low level set point***, the LP absorbent pump will run at Low frequency entered in the service menu and LP refrigerant solenoid valve will open to transfer the LP refrigerant. (LP refrigerant solenoid valve will open only when the LP refrigerant pump is running). LP refrigerant solenoid valve will close when the level in LP absorber goes above **medium level**.
- When the level is above ***LP Absorber Normal set point***, the LP absorbent pump will run at High frequency entered in the service menu.

- When the level is in between ***LP Absorber Normal set point*** and ***LP Absorber low set point***, the LP Absorbent pump will be under modulation and will run at an intermittent frequency between the low and high limit frequencies. (Low/High/Intermittent frequencies are settable in HMI).
- Whenever Level in HP Absorber goes below HP Absorber Low level set point, then LP absorbent pump will run at maximum frequency(50Hz) till either HP Absorber level goes above HP Absorber normal level set point or LP Absorber level goes below LP Absorber Low level set point.
- During above operation, if the LP Absorber level goes below ***LP Absorber Low level set point***, whatever may be the condition, LP Absorbent pump will run at Low frequency entered in the service menu.
- During above operation, if the HP Absorber level goes above ***HP Absorber normal level set point***, LP Absorber pump will run based on LP Absorber level logic.

## C. SAFETY MEASURES

To ensure healthy operation of the VAM certain safety measures taken by the PLC. These are divided into three categories

**1) Conditions that necessitate 'TOTAL SHUTDOWN'**

a. Chilled Water Pump Interlock trip
b. Chilled Water Flow Switch trip
c. Chilled Water Differential Pressure Switch trip
d. HP Absorbent Pump MPCB/ overload relay trip
e. HP Absorbent Pump Not Responding
f. LP Absorbent Pump MPCB/Overload relay trip
g. LP Absorbent Pump Not Responding
h. Temperature Sensor Error
i. Refrigerant Level very High (*Refer Cavitation protection of Refrigerant Pump*)

**2) Conditions that necessitate 'DILUTION'**

a. Cooling Water Low Inlet Temperature safety
b. Cooling Water High Inlet Temperature safety
c. Generator Temperature High safety
d. Refrigerant Pump MPCB/ Overload Relay trip
e. Refrigerant Pump Not Responding
f. Anti-freeze protection
g. Refrigerant Temperature Low safety
h. Power Failure resumption
i. Temperature Sensor Error

**3) Warning messages**

a. Vacuum Pump MPCB/ Overload Relay trip
b. Scaling/Cooling water Flow Low
c. Overflow Temperature High safety
d. Temperature Sensor Error

Note: All alarms shall be initiated during Vapour Absorption Machine (VAM) 'ON' condition only.

## 1. TOTAL SHUTDOWN ALARM SEQUENCE

In case of a critical trip, the VAM goes into 'TOTAL SHUTDOWN' alarm sequence. The status of VAM will read "VAM NOT READY TO START" and its condition will be "TRIP". Under the 'TOTAL SHUTDOWN' alarm sequence, the PLC performs the following actions.

1. Hot water Control Valve is closed immediately.
2. Hot Water Pump Start / Stop Permissive will be switched off immediately.
3. Cooling Water Pump/Cooling water shut-off valve start permissive will be switched OFF immediately.
4. Cooling Tower Fan Start/Stop Permissive Contact will be Switched Off immediately.
5. Both HP and LP Absorbent Pump is stopped immediately
6. Refrigerant Pump is stopped immediately.
7. Chilled Water Pump start/stop permissive is kept ON.
8. Once the fault condition has been rectified, the alarm can be reset.

- On resetting the alarm, the VAM goes into 'DILUTION'.
- If the time taken to reset the alarm is less than or equal to 5 minutes, the 'DILUTION' is not compulsory. In this case, on resetting the alarm the status changes to "VAM READY TO START" and VAM condition will be 'DILUTION'. The operator can start the VAM, if required.
- If the time taken to reset the alarm is more than 5 minutes, the 'DILUTION' is compulsory. In this case, on resetting the alarm the status changes to "VAM NOT READY TO START" and VAM condition will be 'COMPULSORY DILUTION'. The VAM can be restarted only after completion of 'DILUTION'.
- If the alarm is not reset within 15 minutes from trip, both HP and LP absorber pumps start at the end of 15 minutes. The HP and LP Absorbent pumps continue to run for 15 minutes to equalize the absorbent concentration across the VAM and then both HP and LP absorber pump will be put OFF, VAM will continue to be in trip mode. Further, whenever the alarm is reset, the status changes to "VAM NOT READY TO START" and VAM condition will be 'DILUTION'. The VAM can be restarted only after completion of 'DILUTION'.
- Dilution time will be as per the variable dilution time logic.

### a. CHILLED WATER PUMP INTERLOCK TRIP:

- If flow rate of the Chilled Water is very low or is completely stopped, freezing of Chilled Water in the Evaporator tubes can take place immediately.
- Chilled Water flow is very essential for VAM operation. Hence it is required that the Chilled Water Pump should be started or stopped through the Chilled Water Pump start/stop permissive contact of VAM control panel.
- Also, a potential free contact is to be wired from the Chilled Water Pump motor starter to VAM panel to sense Chilled Water Pump ON / OFF / TRIP status.
- During operation if the pump trips, the VAM go into 'TOTAL SHUTDOWN' alarm sequence.
- An alarm "CHILLED WATER PUMP TRIP / NOT RESPONDING" is flashed on the operator panel. The alarm can be reset only after the Chilled Water Pump run feedback is received by the PLC.

**b. CHILLED WATER FLOW SWITCH TRIP:**

- In order to ensure that the minimum required Chilled Water circulation rate is maintained, a Flow Switch has been provided on the Chilled Water outlet nozzle.
- The Chilled Water Flow Switch trip value needs to be set at 50-60% of the rated value during commissioning of the equipment.
- If the Chilled Water flow rate drops below the Chilled Water Flow Switch set point, the 'TOTAL SHUTDOWN' alarm sequence is carried out. An alarm "CHILLED WATER FLOW SWITCH TRIP" is flashed on the operator panel.
- The alarm can be reset only after the Chilled Water flow rate increases above the pre-set value.

**c. CHILLED WATER DIFFERENTIAL PRESSURE (DP) SWITCH TRIP:**

- In order to ensure that the minimum required Chilled Water circulation rate is maintained, a Differential Pressure (DP) Switch has been provided between the Chilled Water inlet and outlet nozzles.
- The Chilled Water DP switch trip value needs to be set at a value corresponding to 50-60% of the rated flow rate during commissioning of the equipment.
- If the Chilled Water flow rate drops below the Chilled Water DP switch set point, the 'TOTAL SHUTDOWN' alarm sequence is carried out.
- An alarm "CHILLED WATER DP SWITCH TRIP" is flashed on the operator panel. The alarm can be reset only after the Chilled Water flow rate increases above the pre-set value.

**d. HP ABSORBENT PUMP MPCB/OVERLOAD RELAY TRIP:**

- If HP Absorbent Pump motor draws more than its rated current, the overload relay trips and the 'TOTAL SHUTDOWN' alarm sequence is carried out.
- An alarm "HP ABSORBENT PUMP TRIP" is flashed on the operator panel. The alarm can be reset only after the MPCB/ Overload relay has been reset.

**e. HP ABSORBENT PUMP NOT RESPONDING:**

- If HP Absorbent Pump contactor doesn't respond to the HP Absorbent Pump ON/OFF command, the VAM trips and 'TOTAL SHUTDOWN' alarm sequence is carried out.
- An alarm "HP ABSORBENT PUMP NOT RESPONDING" is flashed on the operator panel.

**f. LP ABSORBENT PUMP MPCB/OVERLOAD RELAY TRIP:**

- If LP Absorbent Pump motor draws more than its rated current, the overload relay trips and the 'TOTAL SHUTDOWN' alarm sequence is carried out.
- An alarm "LP ABSORBENT PUMP TRIP" is flashed on the operator panel. The alarm can be reset only after the MPCB/ Overload relay has been reset.

**g. LP ABSORBENT PUMP NOT RESPONDING:**

- If LP Absorbent Pump contactor doesn't respond to the LP Absorbent Pump ON/OFF command, the VAM trips and 'TOTAL SHUTDOWN' alarm sequence is carried out.
- An alarm "LP ABSORBENT PUMP NOT RESPONDING" is flashed on the operator panel.

**h. TEMPERATURE SENSOR ERRORS:**

- In case of temperature sensor errors (for the sensors listed below), the VAM trips and the 'TOTAL SHUTDOWN' alarm sequence is carried out.
- An alarm "***SENSOR ERROR" is flashed on the operator panel. The alarm can be reset only after the problem has been rectified. [*** Name of the temperature sensor that has failed]
- Sensor list:
  i. CHILLED WATER OUTLET TEMPERATURE

**2. DILUTION ALARM SEQUENCE**

- When the VAM trips on any of the below safeties and goes into 'DILUTION' alarm sequence, the status of the VAM will read "VAM NOT READY TO START" and its condition will be 'DILUTION'.
- Once the alarm has been reset the status will read as "VAM READY TO START" while the VAM condition remains the same. The operator can start the VAM, if required.
- Under the 'DILUTION' alarm sequence, the PLC performs the following actions.

i. Hot water control Valve is closed immediately.
ii. Hot water pump start/stop permissive is switched off immediately.
iii. Cooling Tower Fan start/stop permissive will be switched OFF immediately.
iv. Cooling Water Pump/Cooling water shut-off start permissive will be switched OFF after 4 minutes.
v. Refrigerant Pump runs based on Cavitation protection Control logic, and stopped after 4 minutes.
vi. Both HP and LP Absorbent Pumps continue to run and are stopped at the end of “Dilution time”.

The dilution time is to varied based on strong concentration measured at VAM stoppage,

- If Xconc >= 62, dilution time = “ 15 “ mins
- If Xconc <= 58, dilution time = “ 7 “ mins
- If 58 < Xconc < 62 , dilution time = “ 7 + (Xconc - 58)*2 “ mins

**i.e. Dilution time = “*if (Xconc <58,7, if (Xconc >62,15,7+( Xconc -58)*2))* “ mins**

- Residual duration of Dilution time shall be displayed on the HMI.

vii. After 2 minutes from the completion of dilution process, if LP Absorber level is above AL1, then LP Absorbent pump shall run at minimum frequency entered in service menu for settable time irrespective of HP Absorber level.
viii. Chilled Water Pump start/stop permissive is put OFF at the end of “Dilution time”.

- If the alarm is reset, then after completion of ‘DILUTION’, the status of the VAM will read “VAM READY TO START” and its condition will be “OFF”.
- Else the status will be “VAM NOT READY TO START” and condition will be “OFF”.
- This logic shall be applicable for normal dilution as well as compulsory dilution.

**a. COOLING WATER INLET TEMPERATURE LOW SAFETY:**

- If the temperature of the cooling water entering the VAM drops, the LiBr solution coming to the absorber may crystallize.
- To prevent this, whenever the Cooling Water Inlet Temperature goes below the cooling water low temperature set point, the ‘DILUTION’ alarm sequence is carried out.
- An alarm “COOLING WATER INLET TEMP. LOW” is flashed on the operator panel.
- The VAM can be restarted only after the Cooling Water Inlet Temperature rises above the cooling water low temperature set point plus the hysteresis set value.
- During initial startup, till the time Generator temperature goes above 70$^{o}$C, this safety is bypassed. However, 30 minutes after VAM startup, this safety will be in operation irrespective of Generator temperature.

**b. COOLING WATER INLET TMPERATURE HIGH SAFETY:**

- If Cooling Water Inlet Temperature goes above Cooling Water Inlet Temperature High Set point, VAM will go into Dilution.
- An alarm "COOLING WATER INLET TEMPERATURE HIGH" is flashed in the operator panel.
- This alarm can be reset only after the Cooling Water Inlet Temperature goes below Cooling Water Inlet Temperature High set point minus hysteresis.
- This safety will be in operation 5 minutes after VAM startup.

**c. GENERATOR TEMPERATURE HIGH SAFETY:**

- If the Generator temperature goes very high, the concentration of the LiBr solution can go up leading to crystallization.
- Hence, if the Generator temperature exceeds the Generator high temperature set point, the ‘DILUTION’ alarm sequence is carried out.
- An alarm “GENERATOR TEMPERATURE HIGH” is flashed on the operator panel. The VAM can be restarted only after the Generator temperature drops below the Generator high temperature set point minus the hysteresis set value.

**d. REFRIGERANT PUMP MPCB/ OVERLOAD RELAY TRIP**

- If the Refrigerant Pump motor draws more than its rated current, the overload relay trips and the ‘DILUTION’ alarm sequence is carried out.
- An alarm “REFRIGERANT PUMP TRIP” is flashed on the operator panel. Resetting the MPCB/ overload relay resets the alarm.

**e. REFRIGERANT PUMP NOT RESPONDING:**

- If the Refrigerant Pump contactor doesn’t respond to the Refrigerant Pump ON/OFF command, the VAM trips and the ‘DILUTION’ alarm sequence is carried out.
- An alarm “REFRIGERANT PUMP NOT RESPONDING” is flashed on the operator panel.

### f. ANTIFREEZE PROTECTION/ ANTIFREEZE THERMOSTAT:

- In case the Chilled Water Outlet Temperature goes below freezing point of water, the water in the Chilled Water header will freeze.
- So, when the Chilled Water Outlet Temperature as measured by the Chilled Water Outlet Temperature sensor drops below the Antifreeze set point, dilution sequence is carried out.
- An alarm “ANTIFREEZE TRIP” is flashed on the operator panel. The alarm can be reset only after the Chilled Water Outlet Temperature rises above the antifreeze set point plus the hysteresis set point.

### g. REFRIGERANT TEMPERATURE LOW SAFETY:

- In case the Refrigerant Temperature goes very low, the water in the Chilled Water tubes may freeze. So, when the Refrigerant Temperature as measured by the Refrigerant Temperature sensor drops below the Refrigerant temperature Low set point, dilution sequence is carried out. An alarm “REFRIGERANT TEMPERATURE LOW TRIP” is flashed on the operator panel.
- The alarm can be reset only after the Refrigerant Temperature rises above the Refrigerant temperature low set point plus the hysteresis set point.

### h. POWER FAILURE RESUMPTION:

- In case of Power Failure during VAM operation, there is chance of LiBr crystallizing in the heat exchangers.
- To avoid this, when the VAM resumes after Power Failure, it goes into ‘DILUTION’ immediately. An alarm “POWER FAILURE” is flashed on the operator panel.
- In case the duration of Power Failure is less than 5 minutes, the VAM status will show “VAM READY TO START”. In such case, ‘DILUTION’ can be bypassed and VAM can be put back to normal operation after resetting the alarm. If there is specific requirement of auto reset, the option can be provided, that is, once the power returns, the VAM will auto-restart normal operation.
- But if the duration of Power Failure is more than 5 minutes, the VAM status will be “VAM NOT READY TO START”. In this case, ‘DILUTION’ is compulsory and the VAM can be started only after completion of ‘DILUTION’.

### i. TEMPERATURE SENSOR ERRORS:

- In case of temperature sensor errors (for the sensors listed below), the VAM trips and the ‘DILUTION’ alarm sequence is carried out.
- An alarm “***SENSOR ERROR” is flashed on the operator panel. The alarm can be reset only after the problem has been rectified.
- Sensor list:
  i. COOLING WATER INLET TEMPERATURE
  ii. CONDENSING TEMPERATURE
  iii. SPRAY SOLUTION TEMPERATURE
  iv. GENERATOR TEMPERATURE
  v. REFRIGERANT TEMPERATURE

## 3. WARNING MESSAGES:

### a. VACUUM PUMP MPCB/OVERLOAD RELAY TRIP:

If the Vacuum Pump motor draws more than its rated current, the overload relay trips and an alarm “VACUUM PUMP TRIP” is flashed on the operator panel. Resetting the MPCB/overload relay resets the alarm.

### b. SCALING/COOLING WATER FLOW LOW:

- When the difference between condensing temperature and cooling water outlet temperature is more than Scaling setpoint entered in service menu, an alarm "Cooling water Flow low / Scaling in Cooling water circuit" will be flashed.
- VAM will keep running normally, this alarm will be reset on acknowledgement.
- The alarm will reappear after 10 AM every day, if the condition persists. This logic will be applicable only above Generator temperature of 65°C. The first instance of the alarm appearing will be logged with date and time in the utility screen.
- The first instance of the alarm appearing will be logged with date and time in the utility screen.
- The alarm will auto reset if the difference between condensing temperature and cooling water outlet temperature falls below the scaling set point, provided the Generator temperature is still above 65$^{o}$C.
- If the scaling condition reappears after auto reset during the same day, there will be no immediate alarm, the alarm will pop up only the next day after 10 am if the condition persists.
- Only the first instance will have a hooter, for reappearance, alarm will be only flashed.

### c. OVERFLOW TEMPERATURE HIGH SAFETY:

- When the Overflow temperature goes above the overflow temperature high setpoint (Dilute temperature + 15°C) and remains there for more than 5 minutes, an alarm "Overflow temperature high" will be flashed.
- VAM will keep running normally, this alarm will be reset only when the Overflow temperature drops below Overflow temperature high setpoint minus hysteresis.

### d. TEMPERATURE SENSOR ERRORS:

- In case of temperature sensor errors (for the sensors listed below), an alarm "***. SENSOR ERROR" is flashed on the operator panel. The VAM keeps running normally. The alarm can be reset only after the problem has been rectified.
- Sensor list:
  i. CHILLED WATER INLET TEMPERATURE
  ii. COOLING WATER OUTLET TEMPERATURE
  iii. HOT WATER INLET TEMPERATURE
  iv. HOT WATER OUTLET TEMPERATURE
  v. DILUTE TEMPERATURE
  vi. OVERFLOW TEMPERATURE

## D. SHUT DOWN SEQUENCE:

- After the completion of operation, when the VAM is switched off from the operator panel it goes into 'DILUTION'. This is done to avoid any chances of crystallization.
- While the VAM is in operation, different parts of the VAM are at different concentration and temperature. 'DILUTION' helps in making them even.
- After completion of 'DILUTION' the VAM status reads as "VAM READY TO START" and VAM condition will be "OFF".

## E. AUTO PURGING

| | |
|---|---|
| **General Description** | The Auto Purging Valve assembly consists of 2 Nos. of Solenoid Valves & one Vacuum Transmitter .<br><br>The whole operation of Auto Purging is PLC controlled. The mode of Purging in the operator panel should be put in 'AUTO' to enable Auto Purging. |
| **Automatic Tank Side Purging** | This operation is based on the Pressure inside the tank side of the Purge Tank. The Vacuum Transmitter, will sense the Pressure of Purge Tank. When this Pressure increases above the Tank Side Purge Start Setpoint, Auto Purging operation will start. The sequence of operation is described in the table given below. Once the Pressure goes below Tank Side Purge Stop Setpoint, the Tank Side Purge operation stops. The Auto Purging operation will be carried out only when the Machine is in 'ON' condition. |

| S.No. | Automatic Tank Side Purging | Tank purging will now be time based for starting the Auto purging time. |
|---|---|---|
| 1 | Machine Power OFF | All Solenoid Valves will be in closed condition. |
| 2 | Machine power ON | After Settable Time, The Purging Solenoid Valve-2 opens; Purging Solenoid Valve-1 remains closed. Purging Solenoid Valve-2 will remain open for 120 sec. The tank side pressure is read by Vacuum Transmitter and is displayed on the operator panel. |
| 3 | Tank Side Purge Start | Purging Solenoid Valve-2 is open & When the Tank Pressure exceeds the Tank Side Purge Start Setpoint and remains for 1 minute, Purging Solenoid Valve-2 closes immediately. The Purge Pump starts and runs dry for 10 minutes.<br><br>After this duration, Purging Solenoid Valve-1 opens if the Purge Pump is running. After 1 minute, based on The Vacuum Transmitter reading PLC checks if the Purge Pump is developing Ultimate Vacuum<br>In case of Purge Pump OFF/TRIP, Purging Solenoid Valve-1 will not open; in case it is already open, it will close immediately. |
| 4 | If Purge Pump does not develop Ultimate Vacuum | If the measured Tank Pressure is greater than the Ultimate Vacuum Setpoint, PLC will give an alarm that "PURGE PUMP NOT DEVELOPING VACUUM, PLEASE PERFORM MAINTENANCE". This alarm will stop the Auto Purging operation and goes into Manual Purging Mode (All 2 Solenoid Valves will be in closed condition, the Purge Pump stops immediately), but will not trip the Machine.<br><br>After completing the maintenance, check whether the Purge Pump is developing Ultimate Vacuum, using the Diaphragm Valves. If yes, the mode of purging should be changed to 'AUTO' by operator. |
| 5 | If the Purge Pump develops Ultimate Vacuum | If the measured Tank Pressure is lesser than the Ultimate Vacuum Setpoint, Purging Solenoid Valve-1 will continue to remain open and Purging Solenoid Valve-2 opens. Now the Tank Side Purging is performed. |
| 6 | If the tank side purging doesn't complete within 15 minutes | In case the Purge Pump malfunctions, then the Auto Purging operation stops and the purging shifts to 'MANUAL' mode. An alarm "PLEASE CHECK THE PURGE PUMP; PURGING SHIFTED TO MANUAL MODE" is flashed on the operator panel. Once the problem has been rectified, the operator can put the purging back to 'AUTO' mode. |
| 7 | Tank Side Purge Stop | After a time delay of 10 seconds from the opening of Purging Solenoid Valve-2, if the measured pressure goes below the Tank Side Purge Stop Setpoint, Both Purging Solenoid Valves closes immediately. The Purge Pump keeps running dry for 5 minutes. The details of last purge done, gets updated in the PLC. |
| 8 | Tank side purging frequency high | If the Tank Side Purging is performed more than 2 times in a calendar day, it indicates possibility of leakage in the Machine. So when the Tank Side Purging starts for the third time in a day, an alarm "TANK PURGING FREQUENCY HIGH" is flashed on the operator panel. This logic is valid for the purging done in 'AUTO' mode only. |

Notes :

1. The Purging Solenoid Valves can be opened in AUTO/MANUAL mode, only when the Purge Pump is running.
2. In case of Purge Pump TRIP/OFF, Both Purging Solenoid Valves closes immediately
3. In case of Purge Pump TRIP, Purging Shifted to Manual Mode if is in Auto Mode.
3. For Manual Purging using diaphragm valves, please refer 'Operating Instructions' section.
4. Do not open the service valves, other than those connected to Vacuum Transmitter

## F. PASSIVATION PROCEDURE & LOGIC:

- Passivation mode will be available in the service menu.
- Once the Passivation mode is selected, following note will be displayed on the PLC:

BEFORE STARTING PASSIVATION PROCESS

- CONNECT A HOSE PIPE BETWEEN THE SERVICE VALVES ON REFRIGERANT PUMP OUTLET AND HP ABSORBENT PUMP OUTLET AND THEN OPEN THE SERVICE VALVES.
- DRAIN THE WATER FROM CHILLED WATER AND COOLING WATER HEADERS AND KEEP THE VENTS OPEN.

- There will be a settable timer for **Passivation duration** Range: 4 - 12 hours | Default: 8 hours
- On selecting the Passivation mode, the chilled water Flow switch, DP switch/DP transmitter, CHW pump permissive, COW pump permissive, COW shut off valve permissive, CT fan permissive shall not be given by PLC & CHW pump feedback shall not be checked.

Passivation Mode:

- Upon start of VAM in Passivation mode, both HP and LP absorbent pumps will run as per respective level control logics.
- The refrigerant pump will run based on Evaporator level only.
- The HWCV opening limit will be settable as required. There will be a slow opening timer of 7 minutes.
- There will be a set point for **Spray solution temperature high** Range: 60 - 90°C | Default: 80°C
- If the spray solution temperature goes above this set point, the heat input will stop.
- The heat source will re-open once the spray temperature goes below high set point minus **Hysteresis** Range: 3 - 15°C, default: 10°C

- All chilled water & cooling water temperature related safeties will not come into picture.
- Purge pump ON/OFF will be disabled.
- Refrigerant solenoid valve will remain closed during this mode.
- Cooling water shut-off valve will remain closed in this mode.
- In case of power failure, once the power resumes, the VAM will start back in Passivation mode.
- Once the Passivation duration is completed, the heat source will stop, both HP and LP absorbent pumps & refrigerant pump will stop.
- VAM operation will automatically shift to normal mode.
- While shifting from Passivation mode to normal mode, following message would appear

BEFORE STARTING THE VAM
ALLOW THE VAM TO COOL DOWN BEFORE CHARGING WATER INTO THE CHILLED WATER AND COOLING WATER CIRCUIT.

- The activity will be logged with date & time

**CONDITIONS THAT WOULD NECESSITATE STOPPAGE:**

In this mode, for any of the below conditions, the heat source & both HP and LP Absorbent pumps and Refrigerant pumps will stop immediately and corresponding anomaly alarm will be flashed. Once the alarm is reset, the Passivation process will restart from where it was left.

a. Generator temperature high
b. Spray solution temperature sensor error
c. Generator temperature sensor error
d. HP Absorbent pump trip
e. LP Absorbent pump trip
f. Refrigerant pump trip

**CONDITIONS THAT WOULD NECESSITATE ALARM:**

If either chilled water or cooling water flows through the VAM during Passivation mode, the heat will be dissipated and the Passivation process will be ineffective.

So, if in the Passivation mode, the chilled water or cooling water flows are observed to be healthy, an alarm " Chilled/Cooling water flow not allowed in Passivation mode, please stop the chilled/cooling water flow" shall be flashed on the HMI. The VAM will continue to run in Passivation mode.

## G. HMI & FIELD SET POINTS:

The field instruments and the components in the control panel are to be set as follows:

| Sl. No. | Description | Set points |
|---|---|---|
| 1. | Chilled Water Flow Switch | 50-60% of rated flow |
| 2. | Chilled Water D.P. switch | 50-60 % of rated flow |
| 3. | Absorbent Pump over current relay | As per pump rating +10% |
| 4. | Refrigerant Pump over current relay | As per pump rating +10% |
| 5. | Vacuum Pump over current relay | As per pump rating +10% |

The operator terminal settings are as follows:

| Sr. No. | Description | Set points | | | Remarks | Control |
|---|---|---|---|---|---|---|
| | | Default | Low Limit | High Limit | | |
| 1 | Chilled Water Temperature Low Limit Set point | As per specs | 3.5 | 60 | As per specs | Capacity Control |
| 2 | Temperature Set point for HWCV PID control | CHW Temp Low Limit | CHW Temp Low Limit - 1°C | 60 | Adjustable | Capacity Control |
| 3 | L-cut Differential Set point | 1°C | 0.5 | 5 | Adjustable | L-cut control |
| | Hysteresis | 0.5°C | 0.5 | 2 | Adjustable | |
| 4 | Antifreeze Set point | 3.5°C | 3.5 | 10 | Adjustable | Antifreeze protection |
| | Hysteresis | 2°C | 0.3 | 5 | Adjustable | |
| 5 | Refrigerant Temperature Low Set point | 3°C | 2 | 20 | Adjustable | Antifreeze protection |
| | Hysteresis | 1°C | 0.5 | 5 | Adjustable | |
| 6 | HWCV Opening Modulation Limit | 100% | 0 | 100 | Adjustable | - |
| 7 | Chilled Water temperature modulation control settings (HWCV): | | | | | Capacity Control |
| | a) Proportional Band | 35 | -32000 | 32000 | Adjustable | |
| | b) Integral Band | 800 | 0 | 32000 | Adjustable | |
| | c) Derivative Band | 0 | 0 | 32000 | Adjustable | |
| 8 | Generator Temperature Trip Set point | 95°C | 50 | 120 | Adjustable | Generator temp High Safety |
| | Hysteresis | 5°C | 3 | 30 | Adjustable | |
| 9 | Generator Temperature Differential Set point for Hot Water Control Valve | 3°C | 1 | 5 | Adjustable | HCV control on Generator Temperature |
| | Hysteresis | 2°C | 1 | 10 | Adjustable | |
| 10 | Generator Temperature Set point for HP Absorbent Pump AC Drive Minimum Frequency | 70°C | 60 | 100 | Adjustable | HP Absorbent Pump AC Drive Modulation |
| | Generator Temperature Set point for HP Absorbent Pump AC Drive Maximum Frequency | 90°C | 60 | 100 | Adjustable | |
| 11 | LP Absorbent Pump Reference Frequency | 40Hz | 30 | 50 | Adjustable | LP Absorbent Pump AC Drive Modulation |
| | LP Absorbent Pump Low Frequency wrt Reference Frequency | Reference Freq - 5Hz | 30 | Reference Freq | Adjustable | |
| | LP Absorbent Pump High Frequency wrt Reference Frequency | Reference Freq + 5Hz | Reference Freq | 50 | Adjustable | |
| 12 | Conc. Very High setpoint | 64.5% | - | - | Not accessible | Crystallization Prevention |
| | Hysteresis | 1.5% | - | - | | |
| | Preset safe distance | 15°C | - | - | | |
| 13 | Cooling Water Inlet Temperature setpoint for crystallization control | 25°C | 10 | 60 | Adjustable | Crystallization prevention |
| 14 | Cooling Water Inlet Low Trip Set point | 18°C | 10 | 40 | Adjustable | Cooling water Inlet temp. low safety |
| | Hysteresis | 3°C | 0.5 | 10 | Adjustable | |
| 15 | Cooling Water Inlet High Trip Set point | 36°C | 25 | 60 | Adjustable | Cooling water Inlet temp. high safety |
| | Hysteresis | 2°C | 1 | 5 | Adjustable | |
| 16 | Cooling Tower Off Set point | 25°C | 18 | 35 | Adjustable | CT Fan control CW In temp |
| | Hysteresis | 3°C | 0.5 | 10 | Adjustable | |
| 17 | Scaling setpoint for Cooling water flow | 3°C | 0 | 20 | As per specs | Scaling control |
| 18 | Overflow temperature high setpoint | Dilute + 15°C | 5 | 40 | Adjustable | - |
| | Hysteresis | 5 | 5 | 40 | Adjustable | |
| 19 | Datalog sampling time | 60 min | 1 | 60 | Adjustable | |
| 20 | Trip log sampling time | 1 min | - | - | Not accessible | |
| 21 | Anti-chattering timer for FS, DPS & INTERLOCK of Chilled Water. | 2 sec | - | - | Not accessible | |
| 22 | Anti-chattering timer for temperature sensors and dependent alarms/safeties | 2 sec | - | - | Not accessible | |
| 23 | Anti-chattering timer for instruments | 1 sec | - | - | Not accessible | |
| 24 | Dilution cycle timer | Variable (min) | 7 | 15 | Not accessible | |

| Sr. No. | Description | Set points | | | Remarks | Control |
|---|---|---|---|---|---|---|
| | | Default | Low Limit | High Limit | | |
| 25 | LP Absorbent Pump run timer after Dilution process | 15 sec | 0 | 60 | Adjustable | |
| 26 | OFF delay timer for LP Absorbent Pump | 10 sec | - | - | Not accessible | |
| 27 | OFF delay timer for HP Absorbent Pump | 10 sec | - | - | Not accessible | |
| 28 | OFF delay timer for Refrigerant Pump | 10 sec | - | - | Not accessible | |
| 29 | Waiting time for chilled water flow healthy feedback | 10 min | - | - | Not accessible | |
| 30 | Refrigerant Solenoid Valve Scheduler Check | 168 hrs | 4 | 248 | Adjustable | |
| | Refrigerant Solenoid Valve Open Duration | 15 min | 1 | 30 | Adjustable | |
| 31 | Passivation Duration | 8 hrs | 4 | 12 | Adjustable | Passivation Process |
| | Spray Solution Temperature High Set point | 80°C | 60 | 90 | Adjustable | |
| | Hysteresis | 10°C | 3 | 15 | Adjustable | |
| 32 | Tank Purging Start Set point | 75mmHg | 20 | 90 | Adjustable | Auto Purging Process (If Applicable) |
| | Tank Purging Stop Set point | 10mmHg | 5 | 15 | Adjustable | |
| | Ultimate Vacuum Set point | 3mmHg | 2 | 5 | Adjustable | |
| | Tank Pressure Check Interval | 4 hrs | 2 | 60 | Adjustable | |