TAC S1 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 VAM is powered on, the status of VAM as displayed on the HMI will be “VAM READY TO START”, provided VAM has completed the ‘DILUTION’ cycle before control panel was powered off.
- This status indicates that VAM can be started now. Else VAM will first undergo ‘DILUTION’ as described in the Power Failure resumption described below.
- When VAM is started, the PLC sends signal to start the Chilled Water Pump immediately.
- The PLC then waits for activation of Flow switch, Flow healthy based on Chilled water inlet and outlet pressure transmitters and Chilled Water Pump feedback Signal for 10 minutes time.
- During this time, whenever these safeties become healthy, PLC will initiate start sequence & Steam Control Valve will start its slow opening simultaneously.
- The Absorbent Pump switches ON immediately.
- After a span of 15 seconds from start, the PLC sends signal to start the Cooling Water Pump /to open the cooling water automatic shut off valve.
- 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, Flow switch, Flow healthy based on Chilled water inlet and outlet pressure transmitters and Chilled Water Pump feedback Signal safeties are not healthy, then chilled water pump will be stopped, VAM status will return to “VAM READY TO START”, the start command would have to be given again on the panel/by remote for 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. Crystallization prevention
5. Cavitation protection of Refrigerant Pump
6. Solution pump AC Drive modulation (If Applicable)
7. Steam Control Valve control on Generator temperature
8. CT fan control on Cooling Water Inlet Temperature

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

- This control is to prevent the sudden rush of steam to the Generator during cold start and to protect VAM from thermal shock.
- For this, the Steam Control Valve is opened gradually over a span of 7 minutes from VAM start up or whenever the Generator temperature is less than 70°C (158°F).
- After the slow opening duration is over, the control is switched over to Chilled Water 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 VAM is the total heat extracted from the Chilled Water. If the Chilled Water flow rate to 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 inlet Chilled Water temperature rises or falls, the outlet Chilled Water 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 control valve. This signal controls the position of the Steam Control Valve [4 mA - 0% open, 20 mA - 100% open].
- As the load increases the Steam Control Valve opens and as the load reduces the Steam Control Valve closes, thus regulating the quantity of steam entering VAM.
- Note: The above operation is 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 Steam Control Valve shuts off fully.
- This safety prevents further temperature drop of Chilled Water Outlet Temperature.
- The Refrigerant Pump and Steam 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 steam control valve.

4. CRYSTALLIZATION PREVENTION:

- If the concentrated absorbent solution returning to the absorber from the low temperature generator is excessively cooled, it crystallizes in the low temperature heat exchanger and the operation of 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 VAM from crystallizing.
  a) Steam Control Valve modulation on crystallization prevention
  b) Absorber level control
  c) Based On Cooling Water Inlet Temperature

a) STEAM 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 Preset safe distance between the crystallization temperature and strong solution temperature of LTHE outlet.
- If the distance is less than the preset safe distance (15°C), then the PLC modulates the Steam Control Valve so that the strong solution temperature will never reach crystallization temperature.
- When the distance is less than safe distance Steam Control Valve operates only on crystallization control signal and capacity control signal is overruled.
- In addition to the above, SCV opening shall also be based on strong concentration. SCV 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.
- The SCV 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 Steam Control Valve.

b) ABSORBER LEVEL CONTROL:

- 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, four level electrodes have been provided in the absorber level box, namely – AE1, AE2, AE3 and AE4. The length of the electrode increases from AE1 to AE4. AE4 is the reference electrode.
- When the absorber level goes below AE2 (corresponding to 25% of sight glass level), Steam Control Valve opening will be reduced by 20% of the current opening.
- Further if the LiBr level in absorber goes below AE3 (corresponding to 0% of sight glass level), the Steam 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 AE2 (corresponding to 0% of sight glass level), Refrigerant solenoid valve will close.
- If the level in absorber rises above AE1 (corresponding to 50% of sight glass level), Steam Control Valve modulation returns to Chilled Water Outlet Temperature PID control.
- A slow opening timer of 2 minutes is provided during the reopening of Steam Control Valve. This control action will come into action only when VAM is 'ON'.

c) BASED ON COOLING WATER INLET TEMPERATURE:

- The maximum opening for steam control valve is to be limited based on cooling water inlet temperature to safeguard against excessive capacity extraction from VAM at lower cooling water inlet temperatures.
- If the incoming cooling water inlet temperature (T_{CW}) 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 (T_{CW}) 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 (T_{CW}) 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,

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

Where, CV - Control Valve Opening %

- This control will come into action immediately after VAM is started. That is, like crystallization control, during the initial slow opening duration if the control becomes live, the slow opening will be bypassed.
- 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 level of refrigerant is not allowed to fall below a certain level. This is done by the four level electrodes mounted in the refrigerant level box namely – RE1, RE2, RE3, and RE4.
- Of these RE1 is the shortest and RE4 is the longest.
- The level is maintained between RE2 and RE3. RE4 acts as a reference electrode.
- When the level reaches RE2, the pump starts and when the level goes below RE3 the pump stops after a time delay of 10 seconds.
- If the refrigerant level goes above RE1 and remains for 60 seconds, it is an indication of tube failure or severe crystallization.
- VAM will go into 'Total Shutdown' mode. An alarm "REFRIGERANT LEVEL VERY HIGH, PLEASE ISOLATE ALL CIRCUITS. CONTACT THERMAX" will be displayed.
- After 2 minutes, the chilled water pump start permissive is also switched OFF. This alarm can be reset when the refrigerant level goes below RE1.
- The control on RE1 must have 'Enable/Disable' option in settings. Default: Enable.

6. SOLUTION PUMP AC DRIVE MODULATION: (IF APPLICABLE)

- The flow of LiBr into the Generator can be regulated by regulating the speed of the 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 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 VAM PLC operator interface.
- When Generator temperature is below the low limit temperature, the Absorbent Pump will run at the minimum frequency.
- When Generator temperature is between the low limit and the high limit temperature, the Absorbent Pump will be under modulation and will run at an intermittent frequency between the low and high limit frequencies.
- Once Generator temperature goes above the high limit value, then the Absorbent Pump will run at the maximum frequency.
- During Dilution mode, the speed of Absorbent pump will be based on Generator temperature logic.
- During Passivation mode, Absorbent pump will run at minimum frequency.
- AC drive Enable / Disable mode shall be there in settings menu. ***Default mode: Enable.***
- If AC drive is disabled, then Absorbent Pump will always run at maximum frequency.

7. STEAM CONTROL VALVE CONTROL ON GENERATOR TEMPERATURE:

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

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

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

C) SAFETY MEASURES:

To ensure healthy operation of 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 Low trip
d. Absorbent Pump overload relay / AC drive trip
e. Absorbent Pump / AC Drive not responding
f. Refrigerant temperature low safety
g. Temperature sensor errors
h. Evaporator level very high *[Refer Cavitation protection of Ref pump]*

2. **Conditions that necessitate 'DILUTION'**

a. Cooling water low inlet temperature safety
b. Cooling water high inlet temperature safety
c. Generator high temperature safety
d. Refrigerant Pump overload relay trip
e. Refrigerant Pump not responding
f. Anti-freeze protection
g. Power failure resumption
h. Temperature sensor errors
i. Cooling water pump interlock trip

3. **Warning messages**

a. Purge Pump overload relay trip
b. Overflow temperature high
c. Scaling/Cooling water flow low
d. Temperature sensor errors
e. Pump bearing wear monitor

Note: All alarms shall be initiated during VAM 'ON' condition only.

1. 'TOTAL SHUTDOWN' ALARM SEQUENCE:

- In case of a critical trip, 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.
  - i. Steam Control Valve is closed immediately
  - ii. Cooling Water Pump/Auto shut off valve start permissive will be switched OFF immediately.
  - iii. Cooling Tower Fan start permissive will be switched OFF immediately.
  - iv. Absorbent Pump is stopped immediately.

v. Refrigerant Pump is stopped immediately.
vi. Chilled Water Pump permissive is kept ON (except Evaporator level very high safety).

- Once the fault condition has been rectified, the alarm can be reset. On resetting the alarm, 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 VAM, if required.
- Also, 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 'DILUTION'. VAM can be restarted only after completion of 'DILUTION'.
- If the alarm is not reset within 15 mins from trip, the absorber pump starts at the end of 15 mins. The pump continues to run for 15 mins to equalize the absorbent concentration across VAM and then absorbent 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'. VAM can be restarted only after completion of 'DILUTION'. Dilution time will be as per the variable dilution time logic.

1A. 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.
- If the pump trips during operation, VAM goes into 'TOTAL SHUTDOWN' alarm sequence.
- An alarm "CHILLED WATER PUMP TRIP / NOT RESPONDING" is flashed on the HMI. The alarm can be reset only after the Chilled Water Pump run feedback is received by the PLC.

1B. 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 HMI.
- The alarm can be reset only after the Chilled Water flow rate increases above the preset value.

1C. CHILLED WATER DIFFERENTIAL PRESSURE LOW TRIP:

- In order to ensure that the minimum required Chilled Water flow rate, Pressure transmitters have been provided at Chilled Water inlet and outlet nozzles.
- The rated chilled water flow rate, friction loss and static head should be provided in HMI, with respect to the unit.
- The actual chilled water flow rate will be calculated based on the above setpoints and chilled water inlet & outlet pressure.
- When the actual chilled water flow rate value drops below 50% of the rated flow rate, 'TOTAL SHUTDOWN' alarm sequence is carried out.
- An alarm "CHILLED WATER DIFFERENCIAL PRESSURE LOW" is flashed on the HMI. The alarm can be reset only after the actual chilled Water flow rate increases above the 60% of the rated flow rate.

1D. ABSORBENT PUMP OVERLOAD RELAY / AC DRIVE TRIP:

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

1E. ABSORBENT PUMP / AC DRIVE NOT RESPONDING:

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

1F. 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, 'TOTAL SHUTDOWN' alarm sequence is carried out. An alarm "REFRIGERANT TEMPERATURE LOW TRIP" is flashed on the HMI.
- The alarm can be reset only after the Refrigerant Temperature rises above the Refrigerant temperature low set point plus the hysteresis set point.

1G. TEMPERATURE SENSOR ERRORS:

- In case of temperature sensor errors (for the sensors listed below), VAM trips and the 'TOTAL SHUTDOWN' alarm sequence is carried out.
- An alarm "*** TEMP. SENSOR ERROR" is flashed on the HMI. The alarm can be reset only after the problem has been rectified.
- Sensor list:

i. CHILLED WATER OUTLET TEMPERATURE

*** Name of the temperature sensor that has failed.

2. 'DILUTION' ALARM SEQUENCE:

- When VAM trips on any of the below safeties and goes into 'DILUTION' alarm sequence, the status of 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 VAM condition remains the same. The operator can start VAM, if required.
- Under the 'DILUTION' alarm sequence, the PLC performs the following actions.

i. Steam Control Valve is closed immediately.
ii. Cooling Tower Fan start permissive will be switched OFF immediately.
iii. Cooling Water Pump/Auto shut off valve start permissive will be switched OFF after 4 minutes.
iv. Refrigerant pump runs based on Evaporator level and is stopped after 4 minutes.
v. Absorbent pump runs and is 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

vi. The speed of absorbent pump will be based on Generator temperature logic during Dilution mode.
vii. Chilled Water Pump permissive is put OFF at the end of "dilution time".

- If the alarm is reset, then after completion of 'DILUTION', the status of 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".

2A. COOLING WATER INLET TEMPERATURE LOW SAFETY:

- If the temperature of the cooling water entering 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 HMI.
- 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°C (158°F) this safety is bypassed. However, 30 minutes after VAM startup this safety will be in operation irrespective of Generator temperature.

2B. 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 HMI.
- This alarm can be reset only after the Cooling Water Inlet Temperature goes below Cooling Water Inlet Temperature set point minus hysteresis.
- This safety will be in operation from 5 minutes after VAM startup.

2C. GENERATOR TEMPERATURE HIGH SAFETY:

- If Generator temperature goes very high, the concentration of the LiBr solution can go up leading to crystallisation.
- Hence, if Generator temperature exceeds Generator high temperature set point, 'DILUTION' alarm sequence is carried out.
- An alarm "GENERATOR TEMPERATURE HIGH" is flashed on the HMI. VAM can be restarted only after the Generator temperature drops below the Generator high temperature set point minus hysteresis set value.

2D. REFRIGERANT PUMP 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 HMI. Resetting the overload relay resets the alarm.

2E. REFRIGERANT PUMP NOT RESPONDING:

- If the Refrigerant Pump contactor doesn't respond to the Refrigerant Pump ON/OFF command, VAM trips and the 'DILUTION' alarm sequence is carried out.
- An alarm "REFRIGERANT PUMP NOT RESPONDING" is flashed on the HMI.

2F. ANTI-FREEZE PROTECTION:

- 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 Anti-freeze set point, dilution sequence is carried out.
- An alarm “ANTI-FREEZE TRIP” is flashed on the HMI. The alarm can be reset only after the Chilled Water Outlet Temperature rises above the anti-freeze set point plus the hysteresis set point.

2G. 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 VAM resumes after Power Failure, it goes into ‘DILUTION’ immediately. An alarm “POWER FAILURE” is flashed on the HMI.
- In case the duration of Power Failure is less than 5 minutes, 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.
- But if the duration of Power Failure is more than 5 minutes, VAM status will be “VAM NOT READY TO START”. In this case, ‘DILUTION’ is compulsory and VAM can be started only after completion of ‘DILUTION’.

2H. TEMPERATURE SENSOR ERRORS:

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

2I. COOLING WATER PUMP INTERLOCK TRIP:

- Cooling water flow is very essential for VAM operation. 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.
- Also, a potential free contact is to be wired from the Cooling Water Pump motor starter to VAM panel to sense cooling water pump ON / OFF / TRIP status.
- VAM after giving the permissive to start the Cooling Water Pump waits for 7 seconds for feedback.
- In case the feedback is not received, ‘DILUTION’ alarm sequence is carried out. An alarm “COOLING WATER PUMP TRIP” is flashed on the HMI. The alarm can be reset only after the Cooling Water Pump run feedback is received by the PLC.

3. WARNING MESSAGES:

3A. PURGE PUMP OVERLOAD RELAY TRIP:

If the Purge Pump motor draws more than its rated current, the overload relay trips and an alarm “PURGE PUMP TRIP” is flashed on the HMI. Resetting the overload relay resets the alarm.

3B. 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.

3C. 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 70^{o}C (158°F).
- The first instance of the alarm appearing will be logged with date and time in the utility screen.

3D. TEMPERATURE SENSOR ERRORS:

- In case of temperature sensor errors (for the sensors listed below), an alarm “*** TEMP. SENSOR ERROR” is flashed on the HMI. 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. DILUTE TEMPERATURE
  iv. STEAM CONDENSATE TEMPERATURE
  v. OVERFLOW TEMPERATURE

*** Name of the temperature sensor that has failed.

3E. PUMP BEARING WEAR MONITOR:

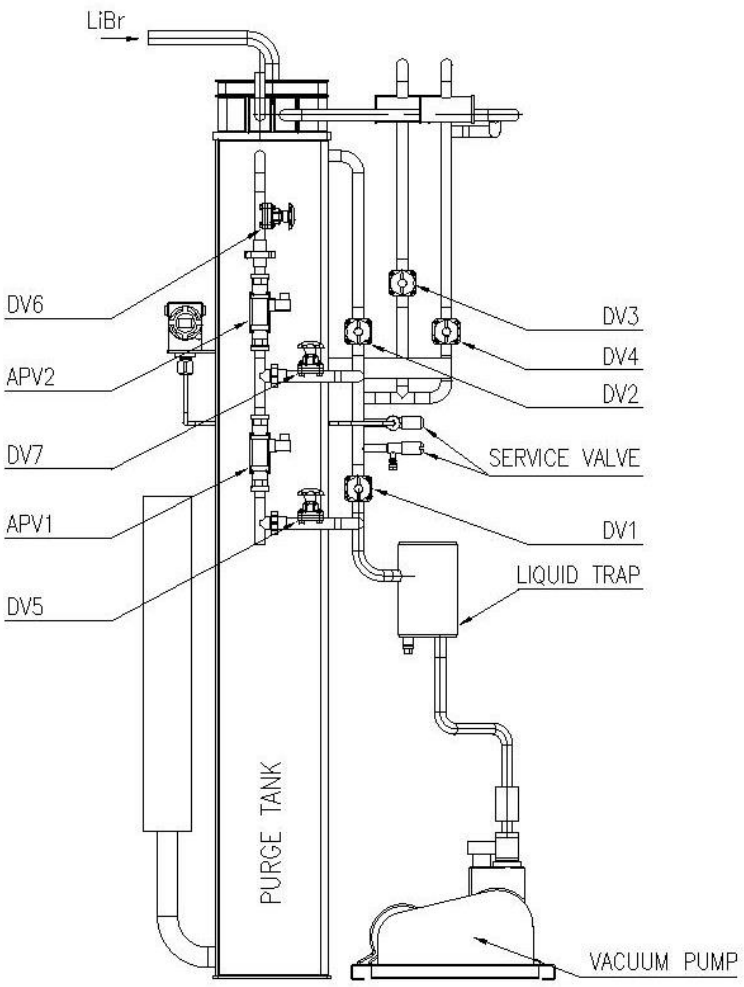
- The signal from TRG meters mounted on both, absorber and refrigerant pumps will read by the PLC once every 24 hours.
- For abnormal readings, an alarm will be flashed.
- When the TRG Meter enters the yellow range i.e. (5 - 7.5 V), an alarm “increased wear of Abso/Ref pump bearings. Please replace the bearings to avoid pump damage” will be flashed.
- When the TRG Meter enters the red range i.e. (7.5 – 10.0 V), an alarm “Faulty bearings Abso/Ref pump. Immediately replace bearings to avoid severe damage to the pump.” Will be flashed
- VAM will keep running normally, this alarm will be reset on acknowledgement. The alarm will reappear after 1 day, if the condition persists.
- The first instance of each of the alarm appearing will be logged with date and time in the utility screen.

D) SHUT DOWN SEQUENCE:

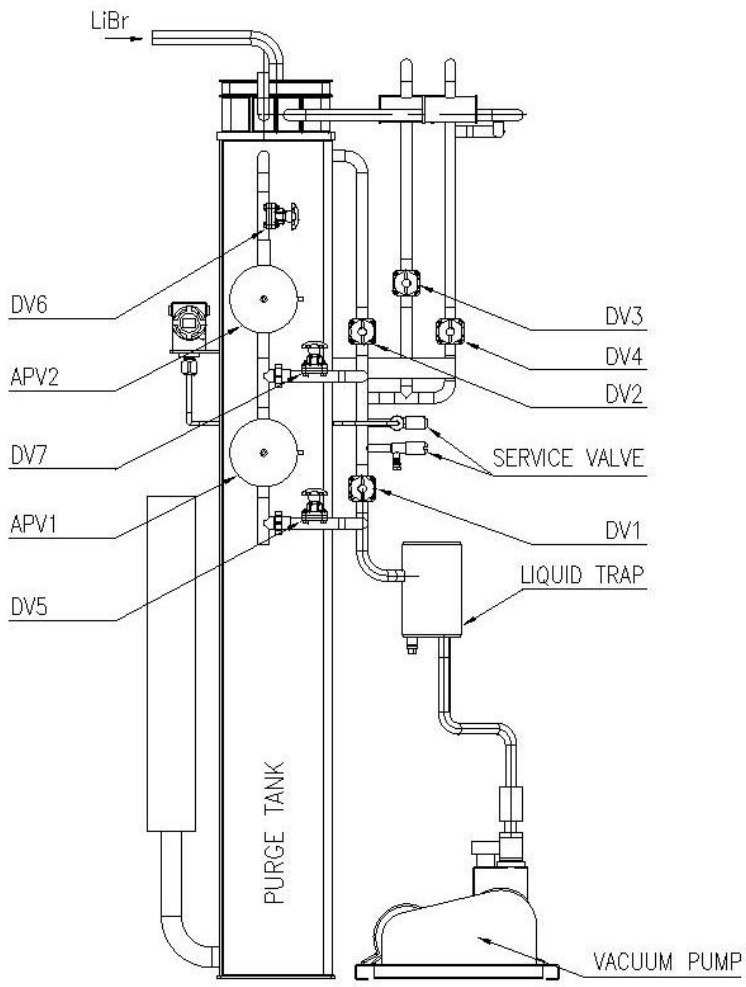
- After the completion of operation, when VAM is switched off from the HMI it goes into ‘DILUTION’. This is done to avoid any chances of crystallisation.
- While VAM is in operation, different parts of VAM are at different concentration and temperature. ‘DILUTION’ helps in making them even.
- After completion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

AUTO PURGING PROCESS: (IF APPLIABLE)

General Description	Auto Purging Valve assembly consists of 2 nos. Auto Purging Valves (APV1 & APV2) (Electric/Pneumatic type) & one Vacuum Transmitter. The whole operation of Auto Purging is PLC controlled. The mode of Purging in HMI 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. Vacuum Transmitter will sense the purge tank pressure. When this pressure increases above the ***Tank Side Purge Start Set-point***, 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 Set-point***, the tank side purge operation stops. Auto Purging operation will be carried out only when the Machine is in 'ON' condition.



(ELECTRIC TYPE)



(PNEUMATIC TYPE)

S. No.	Automatic Tank Side Purging	Tank purging will now be time based for starting the Auto purging time.
1	Machine Power OFF	All Auto Purging Valves will be in closed condition.
2	Machine power ON	After Settable Time, APV-2 opens; APV-1 remains closed. APV-2 will remain open for 120 sec. The tank side pressure is read by Vacuum Transmitter and is displayed on HMI.
3	Tank Side Purge Start	APV-2 is open & When the tank pressure exceeds the ***Tank Side Purge Start Set-point*** and remains for 1 minute, APV-2 closes immediately. Purge pump starts and runs dry for 10 minutes. After this duration, APV-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. In case of purge pump OFF/TRIP, APV-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 Set-point***, 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 (Both Auto Purging Valves (APV-1&2) will be in closed condition, the purge pump stops immediately), but will not trip VAM. 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 Set-point, APV-1 will continue to remain open and APV-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 HMI. 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 APV-2, if the measured pressure goes below the ***Tank Side Purge Stop Set-point***, Both Auto Purging Valves (APV-1&2) close 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 HMI. This logic is valid for the purging done in 'AUTO' mode only.

Notes:

1. Auto Purging Valves can be opened in AUTO/MANUAL mode, only when the purge pump is running.
2. In case of purge pump TRIP/OFF, Both Auto Purging Valves (APV-1&2) close 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.

PASSIVATION PROCESS:

- Passivation mode is 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 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, Chilled water Flow switch, Flow healthy based on Pressure Transmitters, CHW 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, Absorbent pump will run based on absorber level.
- The refrigerant pump will run based on Evaporator level only.
- If Absorber level is normal (above AE1), Absorbent pump will be switched ON.
- Once the level goes low (below AE3), Absorbent pump will stop.
- The Absorbent pump will run always at minimum frequency (if AC drive mode is enable).
- The SCV opening limit will be settable as required. There will be a slow opening timer of 7 minutes.
- There will be a setpoint for Spray solution temperature high. Range: 60 - 90^{0}C | Default: 80^{0}C.
- If the spray solution temperature goes above this setpoint, the heat input will stop.
- The heat source will reopen once the spray temperature goes below high setpoint minus Hysteresis. Range: 3 - 15^{0}C, default: 10^{0}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, VAM will start back in Passivation mode.
- Once the Passivation duration is completed, the heat source will stop, both Absorbent pump and 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 VAM**
>
> - ALLOW 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 ALARM:

- In this mode, for any of the below conditions, the Heat source, Absorbent pump and Refrigerant pump 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.
- Generator temperature high
- Spray solution temperature sensor error
- Generator temperature sensor error
- Absorbent pump trip
- Refrigerant pump trip

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 Flow Low (Based on PT's) Trip	50% of rated flow
3.	Chilled Water Flow Low (Based on PT's) Trip Reset	60% of rated flow
4.	Absorbent Pump over current relay	As per pump rating +10%
5.	Refrigerant Pump over current relay	As per pump rating +10%
6.	Purge Pump over current relay	As per pump rating +10%

HMI SET POINTS:

The operator terminal settings are as follows:

S. No.	Description	Setpoints			Remarks	Control
		Default	Low Limit	High Limit		
1	Chilled Water Temperature Low Limit Setpoint	As per Specs	3.5	60	Adjustable	Capacity Control
2	Temperature Setpoint for PID control	CHW Temp Low Limit	CHW Temp Low Limit – 1°C	60	Adjustable	
3	L-cut differential setpoint	1°C	0.5	5	Adjustable	L-cut control
	Hysteresis	0.5°C	0.5	2	Adjustable	
4	Anti-Freeze setpoint	3.5°C	3.5	10	Adjustable	Anti-Freeze protection
	Hysteresis	2.0°C	0.3	5	Adjustable	
5	Refrigerant temperature low setpoint	3°C	2	20	Adjustable	Anti-Freeze protection
	Hysteresis	1°C	0.5	5	Adjustable	
6	SCV Opening Limit	100%	0	100	Adjustable	SCV control
7	Chilled Water temperature modulation control settings (SCV):					
	a) Proportional Band	35	-32000	32000	Adjustable	Capacity Control
	b) Integral Band	800	0	32000	Adjustable	
	c) Derivative Band	0	0	32000	Adjustable	
8	Generator Temperature High setpoint	100°C	50	130	Adjustable	Generator Temp. High safety
	Hysteresis	5.0°C	3	50	Adjustable	
9	Generator differential setpoint for controlling SCV	3°C	1	5	Adjustable	SCV control on Generator Temp
	Hysteresis	2°C	1	10	Adjustable	
10	Generator temperature setpoint for AC drive minimum frequency	65°C	50	100	Adjustable	AC Drive modulation
11	Generator temperature setpoint for AC drive maximum frequency	85°C	50	100	Adjustable	AC Drive modulation
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 Temperature low setpoint	10°C	10	40	Adjustable	Cooling water In temp. low safety
	Hysteresis	3°C	0.5	10	Adjustable	
15	Cooling Water Inlet Temperature High Setpoint	36°C	25	50	Adjustable	

S. No.	Description	Setpoints			Remarks	Control
		Default	Low Limit	High Limit		
	Hysteresis	2°C	1	5	Adjustable	Cooling water In temp. high safety
16	CT Fan OFF setpoint	25°C	15	35	Adjustable	CT Fan control CW In temp.
	Hysteresis	3°C	0.5	10	Adjustable	
17	Scaling differential setpoint for Cooling water flow	2°C	0	5	Adjustable	Scaling control
18	Overflow temperature high setpoint	Dilute + 15°C	5	40	Adjustable	
	Hysteresis	5	5	40	Adjustable	
19	Data log sampling time	60 min	1	60	Adjustable	
20	Anti-chattering timer for FS, DPS & INTERLOCK of Chilled Water	2 sec	-	-	Not accessible	
21	Anti-chattering timer for temperature sensors and dependent alarms / safeties	2 sec	-	-	Not accessible	
22	Anti-chattering timer for instruments	1 sec	-	-	Not accessible	
23	Dilution cycle timer	Variable	7	15	Not accessible	
24	OFF delay timer for Absorbent Pump	2 sec	-	-	Not accessible	
25	OFF delay timer for Refrigerant Pump	10 sec	-	-	Not accessible	
26	Waiting time for chilled water flow healthy feedback	10 min	-	-	Not accessible	
27	Refrigerant solenoid valve scheduler interval	168 hours	4	168	Adjustable	
	Refrigerant solenoid valve opening duration	15 mins	15	60	Adjustable	
28	Tank Purging Start Set point (If Applicable)	75 mmHg	20	90	Adjustable	Auto Purging (If Applicable)
	Tank Purging Stop Set point (If Applicable)	10 mmHg	5	15	Adjustable	
	Ultimate Vacuum Set point (If Applicable)	3 mmHg	2	5	Adjustable	
	Tank Pressure Check Interval (If Applicable)	120 mins	30	600	Adjustable	