

Crystallization

All absorption chillers that use lithium bromide and water as the solution/refrigerant pair are subject to the perils of crystallization. This is due to the fact that some areas of the unit operate with solution liquid concentration levels that are only possible at higher than the normal ambient temperature surrounding the unit. For example, the solution concentration in the high temperature generator (HTG) of a double effect absorption unit is typically 64.5% lithium bromide by weight. Referring to **Figure M5**, 64.5% solution will begin to crystallize at 112°F. Since the solution temperature in the HTG normally is slightly above 300°F at full load, no crystallization will take place as long as the higher solution temperatures are maintained. Special measures do have to be taken before the unit is shutdown so that the solution is sufficiently diluted in all areas of the unit to prevent crystallization during the off cycle, since the solution temperature will eventually equal the surrounding ambient temperature. All units employ some sort of dilution cycle which fulfills this requirement. As long as the unit is allowed to dilute itself during an orderly shutdown sequence, the unit should be able to sit idle at fairly low plant room ambient temperatures for extended periods of time without any threat of crystallization. Typically, after a dilution cycle, the average solution concentration within the chiller will be below 50% lithium bromide by weight. Although the crystallization line on the chart of **Figure M7** does not extend that far, it can be seen that the solution at 50% concentration will have no tendency to crystallize at normal ambient temperatures.

Keeping the previous paragraph in mind, why then do we have problems with absorption units crystallizing?

Probably the most predominant reason for crystallization is due to fairly long duration power failures. If a chiller is running at full load and power is interrupted for a sufficient length of time, the concentrated solution in the high side of the

unit will eventually cool down. Since no dilution cycle was performed, the solution concentration in some areas of the unit may still be relatively high. If the temperature of this concentrated solution is allowed to fall low enough, the solution will reach its crystallization point. Plant room temperature, insulation quality, and the solution concentration all play a part in the determination of how long it will take before the unit will crystallize.

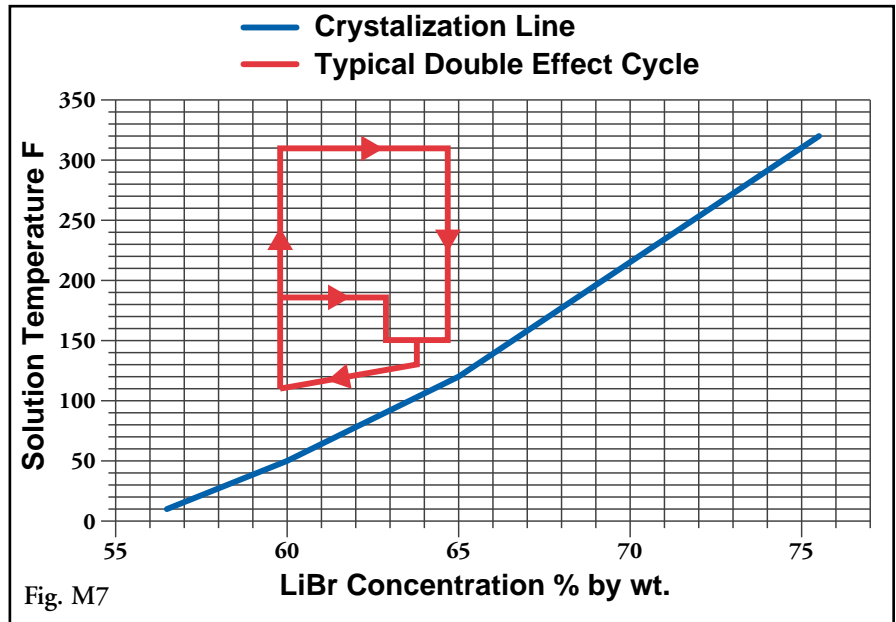
Power failures result in the unit pumps stopping completely. Without the pumps inducing flow through the various sections of the unit, concentrated solution becomes trapped in the generator section and solution-to-solution heat exchangers. If this concentrated solution

a) The higher the load, the higher the concentration.

b) A unit with dirty tubes or non-condensables will be more susceptible due to higher concentrations in the solution heat exchangers.

c) Overfiring the unit will tend to over concentrate the strong solution and make it more susceptible to crystallization.

2. The ambient temperature of the machine room and the amount of thermal insulation on the solution to solution heat exchangers will also determine the likelihood of crystallization. Improper or inadequate thermal insulation on the hot sections of the unit will allow heat loss to



is allowed to cool down to a low enough temperature, it may turn to a slushy liquid and eventually to a solid substance.

The potential for a York *ParaFlow*™ Chiller to crystallize during a power interruption is directly related to the following:

1. The concentration of the solution in the solution heat exchangers is very important. The higher the concentrations at the time of the power failure, the more likely the unit is to crystallize.

progress rapidly and therefore shorten the amount of time before the concentrated solution cools down to its crystallization temperature. Outside air dampers that remain open during a power failure may allow the plant room to cool down quickly which will hasten crystallization.

3. The duration of the power interruption is very important. Although it is very difficult to quantify the acceptable time before crystallization occurs, it is doubtful that harmful crystallization will occur if the power interruption is less than fifteen minutes. Thirty minute or longer

power interruptions have been experienced during full load operation of some machines with no problems.

Although a more rare occurrence, units can also crystallize during operation. Two of the chief causes of crystallization during operation are non-condensables in the absorber and rapidly fluctuating tower water temperature.

Non-condensables in the absorber result in less refrigerant being absorbed by the solution. The solution never gets as diluted as it should. It leaves the absorber and is heated in the HTG. If the unit's heat input is at or near full load, the leaving solution concentration may exceed the level at which it can remain liquid when passing through the solution to solution heat exchanger. For example, the normal concentration of solution leaving the absorber at full load is between 58% and 59%. If there are non-condensables present in the absorber, the solution concentration may exceed 61%. Since the unit is attempting to operate at full load, the firing rate will be sufficient to raise the solution concentration in the HTG by at least the same amount as when the absorber solution was normal, which was approximately 5%. Raising the solution concentration by 5% would result in 6% solution leaving the HTG. Referring to **Figure M7**, it can be seen that the crystallization temperature for 66% solution is slightly above 140°F. Since the HTG temperature is higher than 140°F, the solution will be okay while it is still in the HTG. The problem occurs when this concentrated solution passes through the Solution to Solution Heat Exchangers on its way back to the absorber sprays. Since this solution concentration remains constant as it passes through the High Temperature Solution to Solution Heat Exchanger, if it is cooled below 140°F at any point in the route, crystallization will begin. The cool solution leaving the absorber eventually ends up being the heat exchange medium (after passing through the Low Temperature Solution to Solution Heat Exchanger) that cools the concentrated solution leaving the HTG as it passes

through the High Temperature Solution to Solution Heat Exchanger. This relatively cool solution's temperature is the determining factor of whether crystallization occurs. Tower water inlet temperature will greatly affect the leaving solution temperature of the absorber. If the tower water temperature is lower than design or is allowed to fluctuate in a downward trend fairly rapidly, the potential exists to over cool the concentrated solution in the High Temperature Solution to Solution Heat Exchanger. Crystallization will then result. To further compound this type of situation, if the absorber is not performing well due to the presence of non-condensables, the amount of solution flowing to the HTG will be less than normal since there is less refrigerant in it. Since the unit is attempting to make design capacity, the firing rate will be sufficient to raise the solution concentration higher than the design 5 per cent. This will result in even higher solution concentrations leaving the HTG. The temperature of the solution leaving the absorber will also be lower than normal due to the amount of subcooling that will be present as a result of the lack of mass transfer taking place. This will result in a greater potential for over cooling the concentrated solution in the High Temperature Solution to Solution Heat Exchanger.

Fluctuating Tower Water Temperature

Rapidly fluctuating tower water temperature can also cause crystallization. The reasons are essentially the same as described in the previous example. Rapidly falling tower water temperature will cause the leaving solution temperature from the absorber to drop quickly. This cool solution may over cool the concentrated solution leaving the HTG as it passes through the High Temperature Solution to Solution Heat Exchanger. This can happen at normal HTG solution concentrations although of course the problem would be compounded if there were already abnormally high solution concentrations in the HTG. The tower water temperature should not be

allowed to change more than 0.5°F per minute.

York *ParaFlow*[™] chillers have several features that will help prevent crystallization from occurring. The refrigerant charge is adjusted at full load, with no non-condensables present so that refrigerant is just ready to spill over from the evaporator pan to the absorber. Therefore, if the absorber ever begins to malfunction due to the presence of non-condensables or dirty tubes, as the solution concentration increases the refrigerant quantity resident in the evaporator pan also increases and begins to spill over into the absorber solution resulting in a concentration reduction. This self correcting mechanism is built into every *ParaFlow*[™] unit. The Micro-Panel software (version 7.0) constantly calculates the HTG solution concentration (if the HTG temperature is at least 250°F). If the calculated concentration exceeds 66%, the firing rate of the unit is reduced to minimum until the solution concentration falls below 65% again. If the HTG solution concentration continues to rise, the unit is shut down on a safety shutdown and put through a dilution cycle.

Measures to Prevent Crystallization

Good practices to help prevent crystallization should be employed. These include:

1. Solution to Solution Heat Exchangers, the HTG Float Box, and all interconnecting piping should be well insulated. Do not insulate the unit prior to commissioning and never use weld pins to secure insulation.
2. Tower water (absorber cooling water) must be controlled to prevent rapid fluctuations in temperature. The maximum rate of tower water temperature change should not exceed 0.5°F per minute. Tower water temperature should not exceed the design absorber inlet temperature (normally 85°F) nor should it be lower than 68°F unless the unit is specially equipped.

3. Keep absorber, condenser and evaporator tubes clean.

4. Do not allow non-condensables to accumulate in the unit. Proper purging techniques and solution chemistry control will greatly reduce the likelihood of crystallization.

5. Be sure that the refrigerant charge is adjusted so that refrigerant spill will occur if solution concentrations exceed the norm. Refrigerant may need to be adjusted after several years of operation due to the amount of refrigerant vapor removed during purging.

How to Determine if a Unit is Crystallized

The classic sign of a crystallized *ParaFlow*[™] unit is that the solution level in the absorber disappears and the solution level in the HTG is above the sight glass level.

If a unit is crystallized, ninety-nine per cent of the time, the blockage will be between the HTG and the outlet of the High Temperature Solution to Solution Heat Exchanger. Sometimes, the inter-connecting pipe between the High Temperature Solution to Solution Heat Exchanger and the Low Temperature Solution to Solution Heat Exchanger (*G* units only) where valve V2 and VC (gas fired units only) are located will be crystallized. This is especially true if that pipe is not insulated. Blockage in any of these areas will result in the concentrated solution “stacking” in the HTG since it cannot return to the absorber due to the blockage. It may not be so easy to tell by observing the solution sight glass in the HTG if the level is already past that level.

Decrystallization Procedures

Should the need arise to de-crystallize a *ParaFlow*[™] unit, the following methods should be employed. It is highly recommended that only trained York Service technicians perform these de-crystallization procedures. There are several

degrees of crystallization. Borderline or mild crystallization begins as the solution is turning to “slush”. Gradually as the amount of slush increases, blockage will begin to occur. If you are present when this begins to happen, you will see the absorber level dropping and may observe the level in the High Temperature Generator (HTG) rising through the sight glass. You can normally de-crystallize a unit quickly if you adhere to the following steps.

All Direct Fired units EXCEPT *ParaFlow*[™] S series units with cooling only and standard heating options. Valves VB and VC are not present on these units.

1. Do not stop the tower water flow or chilled water flow.

2. Put the unit in the heating mode.

3. Jumper the hot water flow switch.

4. On *ParaFlow*[™] *G* units up to 19GL, close valves VA, VB, and VC (refer to flow schematics and valve location diagrams). On larger *G* units Valve V4 must also be closed.

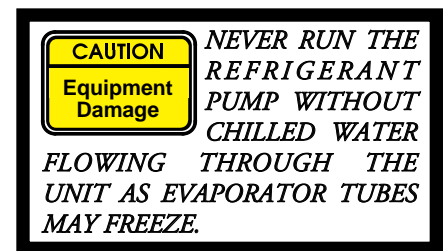
5. Start the burner on low fire and allow the pressure of the HTG to increase to 660 mmHg absolute (12.76 psia). Stop the burner immediately. Be very careful during this step. It is very easy to overshoot and burst the rupture disk. The carbon rupture disk may blow at pressures as low as 6 psig. The stainless rupture disk may blow at pressures as low as 8 psig.

6. Open valve VC. If the crystallization is mild, the high pressure and temperature of the solution in the HTG should be enough to push the blockage back through the heat exchanger. Freeing up the blockage will be accompanied by a rapid increase in the pipe temperature leading from the High Temperature Solution to Solution Heat Exchanger to the Low Temperature Solution to Solution Heat Exchanger. The sound of rapidly expanding steam may also be

heard as the refrigerant expands into the low pressure of the absorber.

7. As soon as flow is established from the HTG to the absorber, reset all valves to their original positions and manually start the solution pump (P1) so that the weak solution in the absorber is sent to the HTG. This will further dilute the strong solution.

Watch the solution level in the absorber. If the level drops, repeat steps 4 through 6 above. Providing the solution level does not drop, blow down the refrigerant by manually starting the refrigerant pump and opening the refrigerant blow down valve. Shut off the refrigerant pump and close the blow down valve as soon as the refrigerant level drops into the



bottom sight glass of the refrigerant tank.

8. Remove the jumpers and return the unit to the cooling mode.

9. Run the unit in the cooling mode and determine; a) that the unit is fully decrystallized, b) the cause of the crystallization.

S series Direct Fired units with standard heating (VD and VE must be set for the cooling mode).

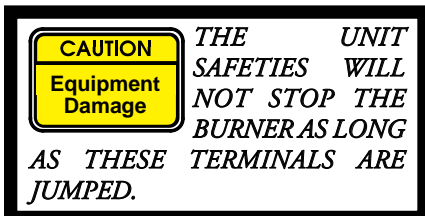
1. No Tower Water Flow.

2. Make sure there is chilled water flow.

3. Blow down the refrigerant until a level is seen in the refrigerant tank sight glass. In the service mode use the PUMP STATUS and MANUAL PUMP Keys to cycle the pump on and off. Open valve VP8 (Refrigerant Blowdown Valve) once pump is turned on. Close valve and shut off pump when desired level is achieved. When level rises, repeat above procedure.

4. Start the solution pump and watch the absorber level. When a level can be seen in the absorber sight glass stop the pump. Restart the solution pump if the level returns. In the service mode use the PUMP STATUS and MANUAL PUMP Keys to cycle the pump on and off.

5. Turn the burner control power switch off. Install a temporary jumper between terminals 4 and 5 in the burner panel.



Turn the burner control power switch on.

6. Start the burner in low fire and allow the pressure of the HTG to increase to 660 mmHg absolute (12.76 psia). The Micro-Panel should be put into the service mode and the LOAD, UNLOAD and HOLD keys should be used to lock the burner in low fire (30%). Stop the burner immediately and remove the jumper. Be very careful during this step. It is very easy to overshoot and burst the rupture disk. The carbon rupture disk may blow at pressures as low as 6 psig. The stainless rupture disk may blow at pressures as low as 8 psig.

7. Continue repeating steps 3 through 6 until the unit is decrystallized.

Steam Fired Units

1. Make sure that both the tower and chilled water flow is established.

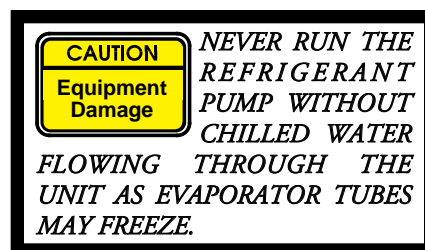
2. Jumper the condensate drain solenoid and the automatic steam shut off valve.

3. On G series units up to 19GL, close valves VA, VB and V2 (note that V2 is a flow setting valve and special care should be made to return the valve to its exact factory setting after this procedure is complete. On larger G series units valve V4 must also be closed.

4. Open the steam valve and allow the pressure in the HTG to increase to 660 mmHg (12.76 psia). Close the steam valve immediately and remove the jumper across the solenoid condensate drain valve once these conditions are reached. Use the LOAD, UNLOAD and HOLD keys in the service mode to operate the steam control valve. Be very careful during this step. It is very easy to overshoot and burst the rupture disk. The carbon rupture disk may blow at pressures as low as 6 psig. The stainless rupture disk may blow at pressures as low as 8 psig.

5. Open Valve V2. If the crystallization is mild, the high pressure and temperature of the solution in the HTG should be enough to push the blockage back through the heat exchanger. Freeing up the blockage will be accompanied by a rapid increase in the pipe temperature leading from the High Temperature Solution to Solution Heat Exchanger to the Low Temperature Solution to Solution Heat Exchanger. The sound of rapidly expanding steam may also be heard as the refrigerant expands into the low pressure of the absorber.

6. As soon as flow is established from the HTG to the absorber, reset all valves to their original positions and manually start the solution pump (P1) so that the weak solution in the absorber is sent to the HTG. This will further dilute the strong solution. Watch the solution level in the absorber. If the level drops, repeat steps 3 through 5 above. Providing the solution level does not drop, blow down the refrigerant by manually starting the refrigerant pump and opening the refrigerant blow down valve. Shut off the refrigerant pump and close the blow



down valve as soon as the refrigerant level drops into the bottom sight glass of the refrigerant tank.

7. Remove the jumpers.

8. Run the unit on low fire and determine; a) that the unit is fully decrystallized, b) the cause of the crystallization.

Stubborn Crystallization Problems

For more stubborn crystallization problems, where the unit has sat for some time and the crystallization is believed to be more solid than slush, it may be possible to break through the strong solution return piping. The *ParaFlow*[™] unit is designed so that the strong solution is on the tube side of the high temperature solution to solution heat exchanger. The strong and weak lines from the HTG Float Box to the high temperature solution to solution heat exchanger and is also designed so that the weak solution line is inside the strong solution line. Both of these features will help in the de-crystallization procedure. It is necessary to back flow high temperature solution from the HTG through the weak solution piping, back to the absorber. This will heat up the strong solution circuit and hopefully re-liquefy the crystallized areas so they will break free. Follow the steps below.

The following procedure applies to all units EXCEPT S Units with (Cooling Only and Standard Heat Options). The two exceptions above do not have a VB valve.

1. Be sure that there is chilled water flow through the unit.

2. Blow down the refrigerant until a level is seen in the refrigerant tank sight glass. In the service mode use the PUMP STATUS and MANUAL PUMP Keys to cycle the pump on and off. Open valve VP8 (Refrigerant Blowdown Valve) once pump is turned on. Close valve and shut off pump when desired level is achieved.

3. Close the solution supply valve to the

low temperature generator (V3 on G units and V1 on S units).

4. Start the solution pump and watch the absorber level. When a level can be seen in the absorber sight glass stop the pump. Restart the solution pump if the level returns. In the service mode use the **PUMP STATUS** and **MANUAL PUMP** Keys to cycle the pump on and off.

5. Using the applicable previous procedure, follow steps 1 through 6, but instead of opening valve VC or V2 open VB in an attempt to back flow weak solution. It may be necessary to wait several minutes and repeat the heating cycle to keep the high temperature generator's pressure and temperature up. If flow does not develop within twenty minutes or three heating cycles, there may be blockage in the exposed piping between the low and high temperature solution heat exchangers. Using a steam lance, soft flame torch or other heating device, heat the piping and continue to maintain high temperature and pressure in the high temperature generator using the above procedures.

6. When the flow begins through VB, allow the solution to flow and heat up the heat exchangers and strong solution side piping. As soon as this has occurred, quickly pump solution back to the high temperature generator, close VB and repeat steps 1 through (7-9) of the applicable procedure above.

Note: With the exception of the series S units without valves VA and VB, there is no requirement to shut off the tower water during the above procedures and it is always highly preferable to keep the chilled water flowing through the unit during the process. Actual testing has shown little or no advantage in shutting off the tower water since the areas where heat is being applied are not affected by tower water flow. If tower water is shut off during the decrystallization procedure, be aware that the water in the unit tubes will be very hot after the procedure is complete. Take care in sending this water slowly to the cooling tower so that the plastic fill is not damaged. Most fill

is rated for approximately 125°F.

For units where the crystallization is extremely bad, it may be necessary to pump de-ionized water into the high temperature solution heat exchanger through valve V18 or directly into the high temperature generator. A high pressure pump could be used. Hot water would be preferable if available.

Note: Remember to record the amount of water added as it will later have to be removed.

The above methods will be effective nearly all of the time. If a particularly difficult situation exists where the above methods do not work, contact York Factory Service for advice.