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# ODRŽAVANJE 2022

Budva, Crna Gora
12 - 16. septembar 2022.

# MAINTENANCE 2022

# ZBORNIK RADOVA
# PROCEEDINGS

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# Monitoring and Diagnosis of Crystallization in An Air Cooled Absorption Refrigeration System

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## ABSRACT

*The main problem to using Water-Lithium Bromide binary solution in air cooled absorption refrigeration systems is high probability occurring of crystallization when the solution temperature falls below the normal crystallization temperature for a particular salt concentration. This can occur unless special precautions are taken when the system is shutdown. This article examines monitoring and diagnosis of crystallization to resolve this problem using control strategies. In the present study, decrystallization line and intelligent digital controller which monitors and takes necessary measurements for control functions and management were added to system. Therefore, crystallization problem has been possibly solved by diluting the solution throughout the system prior to shut down.*

**Keywords:** Absorption refrigeration, decrystallization, monitoring and diagnosis

## 1. INTRODUCTION

The production of cold has applications in a considerable number of fields of human life, for example the food processing field, the air-conditioning sector, and the conservation of pharmaceutical products, etc. The conventional refrigeration cycles driven by traditional vapor compression in general contribute significantly in an opposite way to the concept of sustainable development. Two major problems have yet to be addressed: The global increasing consumption of limited primary energy and the refrigerants used cause serious environmental problems [1-2].

An absorption refrigeration cycle is a combination of those processes as shown in figure 1. The working fluid in an absorption refrigeration system is a binary solution consisting of refrigerant and absorbent. Many working fluids are suggested in literature. There are some 40 refrigerant compounds and 200 absorbent compounds available. However, the most common working fluids are Water/$NH_3$ and LiBr/Water. Two outstanding features of LiBr/Water are non-volatile as an absorbent of LiBr (The need of rectifier is eliminated) and extremely high heat of vaporization of as a refrigerant of water. However, using water as a refrigerant limit the low temperature application to that above 0 ºC. The system must be operated under vacuum conditions. At high concentrations, the solution is prone to crystallization (figure 3). As shown in figure 2, the absorption cycle is plotted in a Dühring P-T chart, a pressure-temperature graph where the diagonal lines represent constant LiBr mass fraction, with the pure water line at the left and crystallization line at the right. [3].

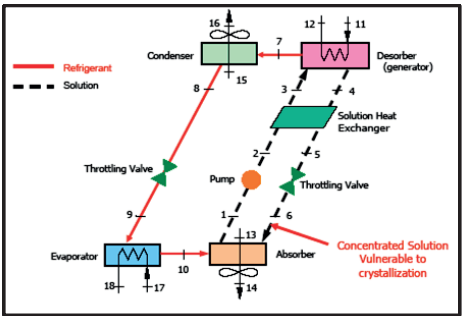

*Figure 1. Absorption refrigeration cycle*

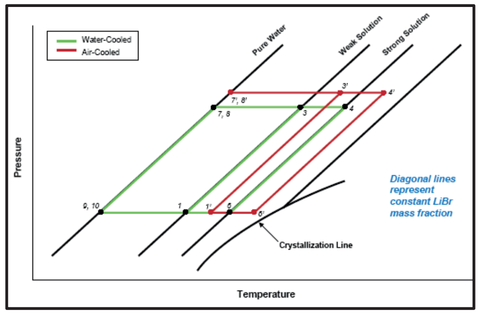

*Figure 2. Dühring chart of absorption cycle*

In absorption systems, if the solution concentration is too high or the solution temperature is reduced too low, crystallization may occur and interrupt machine operation. The vulnerable location is also decided by the mechanical structure of pipes and fittings; this is most likely to occur in the strong solution entering the absorber; that is the point 6 in figure 1, the concentrated solution at the lowest temperature. Crystallization must be avoided because the formation of slush in the piping network over time could form a solid and block the flow. If this occurs, the concentrated solution temperature needs to be raised above its saturation point so that the salt crystals will return to the solution, freeing the machine. The big difference between water-cooled and air-cooled LiBr-water absorption cycles is the temperature of the absorber. With air-cooling, one cannot achieve a temperature of the solution in the absorber sufficiently low to maintain the evaporator pressure. The only way to compensate for the high absorber temperature is to increase the concentration of LiBr in the solution, but that brings it closer to crystallization [4-8]. One of the following five causes or a combination of those causes may trigger crystallization of air-cooled absorption cycles, and the associated precautions are also suggested as well:

1. *Higher ambient temperature (it is higher condenser cooling water temperature for the water-cooled machine)*: The air-cooled absorbers tend to run hotter than water-cooled units due to the relatively poor heat transfer characteristics of air.
2. *Air leak into the machine or non-absorbable gases produced during corrosion:* Both deteriorate the UA and cause higher system pressure, decreased capacity and COP, and higher crystallization probability. A direct method for keeping the required pressure is to evacuate the vapor space periodically with a vacuum pump. This situation can be simulated by assuming a decreased UA, which will cause X6, the concentration of point 6, to move closer to the crystallization line limit. As a precaution to this issue, the system should be evacuated routinely.
3. *Too much heat input to the generator:* either the exhaust temperature or the flow rate is too high, which results in increased solution concentrations to the point where crystallization may occur. As a precaution to this issue, the exhaust temperature or flow rate into the generator should be maintained within a specific range.
4. *Failed dilution after shutdown:* During normal shutdown, the machine undergoes an automatic dilution cycle, which lowers the concentration of the solution throughout the machine. In such a case, the machine may cool to ambient temperature without crystallization occurring in the solutions. Crystallization is most likely to occur when the

machine is stopped due to power outage while operating at full load, when highly concentrated solutions are present in the solution heat exchanger [9].

*Figure 3. Crystallization of LiBr/Water solution*

In this study, we applied simple and technological decrystallization solution to the vapor absorption refrigeration system to prevent breakdown and to hold steady state using a preventive maintenance strategy.

## 2. MATERIAL

Figures 4 and 5 show the layout and flow diagram of experimental set-up. It was designed for continuous operation; the mixing tank receives concentrated solution and refrigerant vapor. The resultant dilute solution is pumped upward to plate heat exchanger by gear pump, and then flows to generator where it is again separated into concentrated solution and water vapor. This vapor is led to air-cooled condenser where it loses its latent heat to cooling air. The vapor changes back to liquid state and collects in condense tank. The condensed liquid drops through an electronic expansion valve into the evaporator below. While concentrated solution returns straight to the mixing tank from generator, it passes across the plate type heat exchanger where it gets the desired degree of sub-cooling before entering once again the mixing tank.

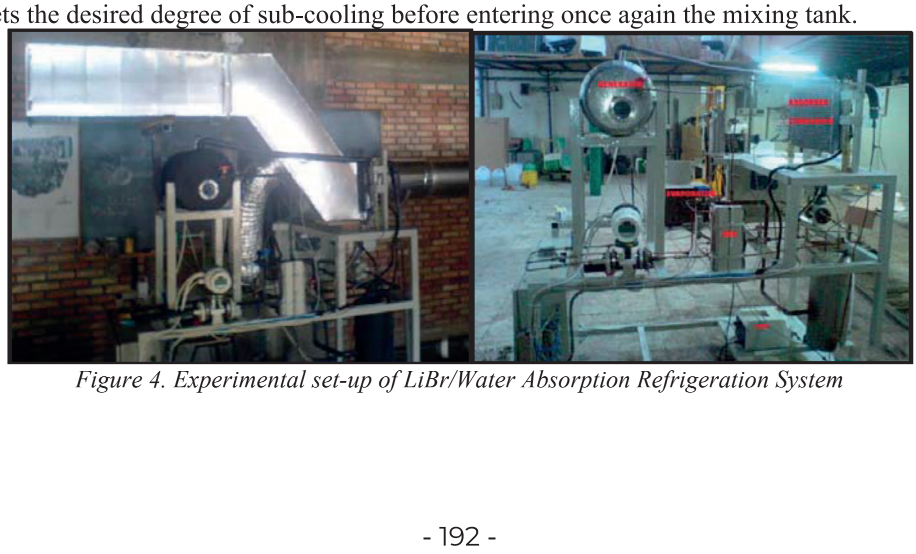

*Figure 4. Experimental set-up of LiBr/Water Absorption Refrigeration System*

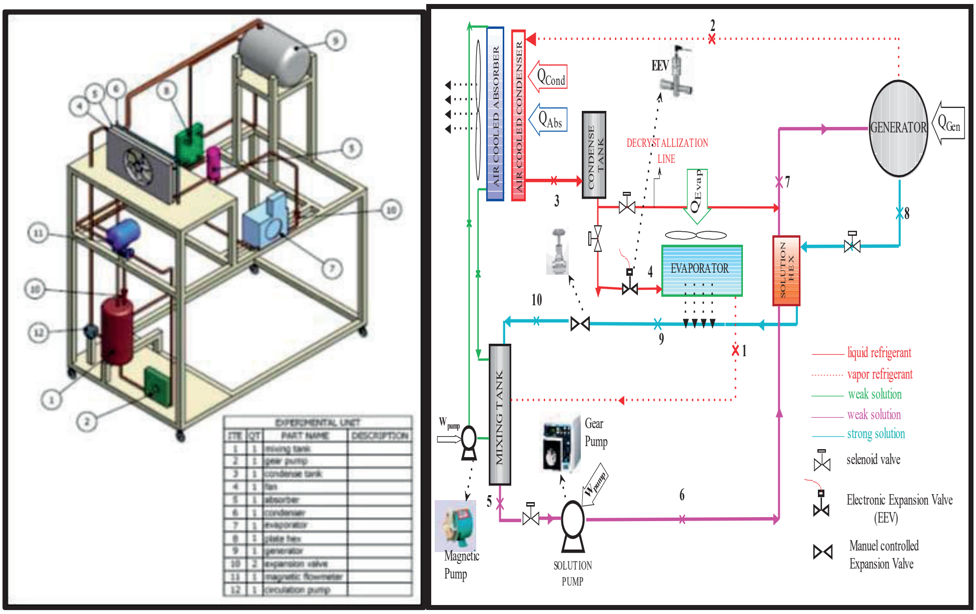


Figure 5. Detailed flow diagram of set-up

As shown in figure 6, instrumentation of the experimental set-up is composed of J type thermocouples, electromagnetic flowmeters, turbine type flowmeter, a hot wire anemometer, pressure transducers and intelligent digital controller for refrigeration system control functions and management.

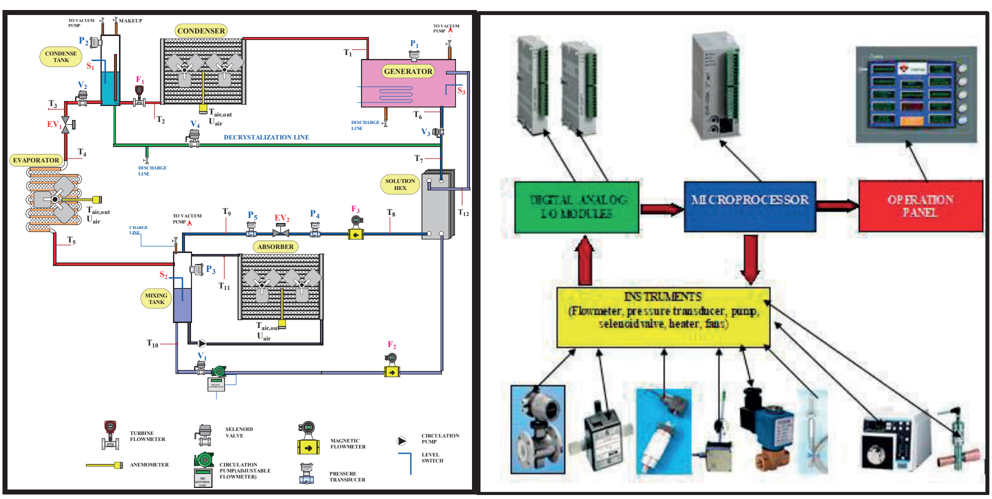


Figure 6. Instrumentation of the experimental set-up

As seen figure 7, the operation panel allows monitoring of data, access to reports via the touch sensitive screen and colour LCD display. The touch-screen operation panel is easily used by operators. All actions like manual control parameters, contact timing limits and definable temperature limits are menu driven. Operators can rapidly configure certain functions. Screen displays allow the operator to determine optimum running states correctly. The required configurations are done by panel's compiler.

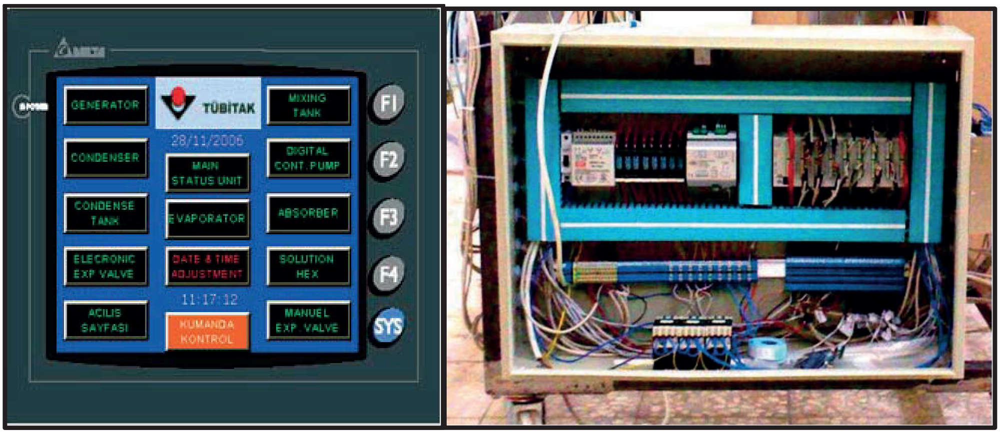


*Figure 7. Operation and Control panel of the experimental set-up*

The control of set-up was designed and programmed with respect to two alternative states. The first state is manual control. According to this state, the system's entire points can be controlled as manual. For example, the valves can be open, turn on or off pumps and heater and fan, EEV can be adjusted to set pressure drop. The second sate is automatic control. In this state, the system runs automatic with respect to default parameter.

### 3. Monitoring and Prevention of Crystallization

Crystallization ordinarily commences when the solution temperature falls below the normal crystallization temperature for a particular salt concentration. This can occur unless special precautions are taken when the system is shutdown. Even though the operating points of the system are far from the crystallization limit of LiBr, monitoring of the working condition is necessary for the potential risk. Since crystallization limit is defined by the concentration and temperature of a solution, a control system should constantly monitor both parameters and give warning or take necessary measures. But because a measuring device of concentration or density is not cheap, the system's working condition was set to over crystallization limit curve. In the present work, as shown figure 8, decrystallization line was added on the return line from generator. This method determines based on solution temperatures and the solution flow rate variation on the crystallization limit for different conditions at the critical point. Therefore, crystallization problem can be avoided by diluting the solution throughout the system prior to shut down.


*Figure 8. Decrystallization line of the experimental set-up*

## 4. CONCLUSION

In LiBr-$H_2O$ absorption refrigerator, crystallization is a serious problem. Crystallization of LiBr-$H_2O$ solution prevents the solution flow of the refrigerator and damages to operating system. The developed crystallization control system and by-pass line is applied to system to detect crystallization due to unexpected situations. The model successfully represented the solution concentration as the solution concentration approaches the crystallization line. This feature can be used to monitor machine operation to avoid machine downtime and resulting low maintenance costs.

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