Comparison and Analysis of Lithium Bromide-water Absorption Chillers Using Plastic Heat Transfer Tubes and Traditional Lithium Bromide-water Absorption Chillers

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***Abstract*—**There are extensive applications of lithium bromide-water absorption chillers in industry, but the heat exchangers corrosion and refrigerating capacity loss are very difficult to be solved. In this paper, an experiment was conducted by using plastic heat transfer tubes instead of copper tubes. As an example, for a lithium bromide-water absorption chiller of refrigerating capacity of 35kW, the correlative performance of the lithium bromide-water absorption chiller using plastic heat transfer tubes was compared with the traditional lithium bromide-water absorption chiller. And then the following three aspects, i.e., heat transfer area, pipe resistance, and safety strength, are analyzed. The results show that plastic heat transfer tubes can be used on lithium bromide-water absorption chillers, and its prospect is very optimistic.

***Keywords*—**Absorption chillers, Comparison and analysis, Corrosion, Lithium bromide, Plastic heat exchangers.

I. INTRODUCTION

THE medium of the lithium bromide-water absorption chiller is lithium bromide solution, which is strong alkalinity. So the heat exchanger corrosion and refrigerating capacity loss are very difficult to be solved for the traditional lithium bromide-water absorption chiller. Therefore, in order to solve these problems, much research efforts have been devoted to addition inhibitor in lithium bromide solution [1], making nanophase coat of fluoroplastics on metal tube wall of heat exchangers [2], and modified plastics (like addition graphite etc.) [3]. Although these methods obtained certain results, total effect still was not satisfied. This paper puts forward to using plastic heat transfer tubes of polytetrafluoroethylene (PTFE) of thin wall and calibre instead of copper tubes, and then the corrosion problem of lithium bromide-water absorption chillers can be solved.

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II. PARAMETER CALCULATIONS, COMPARISON AND ANALYSIS OF LITHIUM BROMIDE-WATER ABSORPTION CHILLERS USING PLASTIC HEAT TRANSFER TUBES

Taking example for a lithium bromide-water absorption chiller of refrigerating capacity of 35kW, then the three aspects, i.e., heat transfer area, pipe resistance, and safety strength, are analyzed. The results show that plastic heat transfer tubes can be used on lithium bromide-water absorption chillers.

A. Calculations of Heat Transfer Area

In engineering calculations, when $d_o / d_i < 2$, the coefficient of heat transfer (reference on F_o) is given by

$$K = 1 / \left\{ \begin{array}{l} \left[\left(1/\alpha_i \right) + r_i \right] \cdot \left(d_0 / d_i \right) \\ + \left(\delta / \lambda \right) \cdot \left(d_0 / d_m \right) + \left(1/\alpha_0 \right) + r_0 \end{array} \right\} \quad (1)$$

where: K is the coefficient of heat transfer, W/(m$^2\cdot$K); α_i is the coefficient of heat transfer of the fluid of inside pipes, W/(m$^2\cdot$K); α_o is the coefficient of heat transfer of the fluid of outside pipes, W/(m$^2\cdot$K); d_i is the internal diameter of pipes, m; d_o is the external diameter of pipes, m; δ is the wall thickness, m; λ is the coefficient of heat conductivity, W/(m$\cdot$K); d_m is the arithmetical mean of internal and external diameter of pipes, m; r_i is the fouling resistance of internal surface, (m$^2\cdot$K)/W; r_o is the fouling resistance of exterior surface, (m$^2\cdot$K)/W.

The heat transfer area is given by

$$F = Q / \left[K \cdot \left(\Delta - a\Delta t_a - b\Delta t_b \right) \right] \quad (2)$$

where: F is the heat transfer area, m^2; Q is the heat quantity, W; K is the coefficient of heat transfer, W/(m$^2\cdot$K); Δ is the maximal temperature difference of heat exchangers, K; a, b respectively are the constant, relating with fluid-flow mode in heat exchangers. Generally, heat transfer of countercurrent flow, a=0.35, b=0.65; Δt_a is the temperature difference of export and import of the fluid of narrower temperature changes, K; ⊿ t_b is the temperature difference of export and import of the fluid of wider temperature changes, K.

Choosing the external diameter of plastic tubes of PTFE of 4 × 10^{-3} m, the wall thickness of 3 × 10^{-4} m, the coefficient of heat conductivity of 0.15 W/(m · K), the density of 2200 kg/m^3, the cost of plastic materials of 130 RMByuan/kg (considering processing factor) and combining calculations of (1), (2), the comparison of correlative component parameter of the plastic lithium bromide-water absorption chiller and the copper (the external diameter of 1.6 × 10^{-2} m, the wall thickness of 1 × 10^{-3} m, the coefficient of heat conductivity of 379.31 W/(m · K), the density of 8700 kg/m^3, and the cost of 30 RMByuan/kg) lithium bromide-water absorption chiller is shown as table 1 as follows.

TABLE I
COMPARISON OF CORRELATIVE COMPONENT PARAMETER

Parameter	Materials	Evaporator	Absorber	Condenser	Solution Heat Exchanger	Totals
Coefficient of Heat Transfer	Plastics	406	334	415	258	—
(W/(m^2 · K))	Copper	2090	988	2320	528	—
Heat Transfer Area	Plastics	18.2	13.9	14.7	6.3	53.1
(m^2)	Copper	3.5	4.7	2.6	3.1	13.9
Weight	Plastics	11.1	8.5	9.0	3.8	32.4
(kg)	Copper	38.8	52.0	28.8	34.3	153.9
Cost	Plastics	1444	1105	1170	494	4213
(RMByuan)	Copper	1164	1560	864	1029	4617

Base on table 1, it is seen that:

1) The coefficient of heat conductivity of PTFE plastics is only 1/2529 of that for copper materials. Compared with the outside-inside copper tubes, the thermal resistance of plastic heat transfer tubes of thinner wall is basically an order of magnitude. Thus plastic tubes can be used on lithium bromide-water absorption chillers.

2) The coefficient of heat transfer of plastic heat exchangers is 1/5-1/2 of that for copper materials, and the heat transfer area of plastic heat exchangers is from twice to quintuplet as large as copper materials. However, when used plastic heat transfer tubes of thin pipe diameter, the heat transfer area per unit volume of heat exchangers will considerably increase. According to the preliminary estimation, the heat transfer area per unit volume of plastic heat exchangers of thin pipe diameter reaches 290 m^2/m^3, but the heat transfer area per unit volume of heat exchangers of copper materials only reaches 132 m^2/m^3. Generally, due to processing technic demand, wall thickness of copper materials can not be much too thin. Because of corrosion influence, the pipe diameter can not be too thin. Therefore, it is more difficult to increase the heat transfer area per unit volume. However, the plastic tubes easily reach. Thus, compared with the traditional lithium bromide-water absorption chiller, the volume of the lithium bromide-water absorption chiller using plastic heat transfer tubes can not expand greatly.

3) The weight of plastic heat transfer area is about 1/5 of that for copper materials, and then the unit weight is consumedly lightened. This is also one of the remarkable advantages of the unit of plastic tubes.

4) Compared with the copper heat transfer area, the cost of the plastic heat transfer area slightly decreases. There is greatly reduced price space after manufacture process matures. Thus lithium bromide-water absorption chillers using plastic heat transfer tubes will have strong market competition.

5) The well corrosion resistance of plastic tubes can consumedly prolong service life of lithium bromide-water absorption chillers and operating life of lithium bromide solution, eliminate the problem of refrigerating capacity loss of units led by contaminative heat transfer surface, raise running performance of units and reduce expenses of maintenance.

From table 1, it can be seen that the thin and thin plastic tubes are used to increase heat transfer area per unit volume and performance of heat transfer. Then the pipe resistance

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increases. Thus it is considerable for the problems of pipe resistance and safety strength.

B. Calculations of Pipe Resistance

The piping resistance loss is given by

$$H = h_f + h_\xi \quad (3)$$

where: H is the piping resistance loss, Pa; h_f is the follow distance resistance loss, Pa; h_ξ is the local resistance loss, Pa.

The follow distance resistance loss is given by

$$h_f = \lambda \cdot (L / d_i) \cdot (\rho\ v^2 / 2) \quad (4)$$

where: L is the pipe length, m; d_i is the internal diameter of pipes, m; ρ is the density, kg/m^3; v is the current velocity, m/s; λ is the coefficient of friction, λ =0.003-0.004.

The local resistance loss is given by

$$h_\xi = \sum \xi \cdot (\rho\ v^2 / 2) \quad (5)$$

where: ξ is the local resistance coefficient.

From table 1, it can be approximately calculated the ratio of length of plastic tubes and copper tubes. According to (3), (4), and (5), it can be approximately calculated the ratio of follow distance resistance and the ratio of local resistance. The detailed data are shown as table 2.

TABLE II
COMPARISON OF CORRELATIVE PARAMETER OF PLASTIC HEAT EXCHANGERS AND COPPER HEAT EXCHANGERS

Component	Ratio of Pipe Length	Ratio of Current Velocity	Ratio of Follow Distance Resistance	Ratio of Local Resistance
Evaporator	20.8	1.5	191.4	2.3
Absorber	11.8	2.4	273.8	5.8
Condenser	22.6	1.5	207.9	2.3
Solution Heat Exchanger	8.1	2.0	129.6	4.0

If plastic heat exchangers are disposed according to the mode of metal heat exchangers, the resistance of plastic heat exchangers will at least be over 130 times of that for metal heat exchangers. Hence, high power pump is required to push liquid flow. Then a great deal of electric energy will be consumed or the engine sets do not work. Therefore it is necessary to use a new layout mode for solving this problem. Generally using mode of many short-tube parallel connection, the length of plastic tubes at least can reduce by 1/8-1/4 of that for copper tubes. Thus the pipe resistance can consumedly reduce and attain practical degree.

C. Verification of Safety Strength

The equations are used for verification of safety strength as follows

$$\begin{aligned}\sigma_r = &-q_a \cdot \left[\left(b^2 / r^2\right) - 1\right] / \left[\left(b^2 / a^2\right) - 1\right] \\ &-q_b \cdot \left[1 - \left(a^2 / r^2\right)\right] / \left[1 - \left(a^2 / b^2\right)\right]\end{aligned} \quad (6)$$

$$\begin{aligned}\sigma_\theta = &\,q_a \cdot \left[\left(b^2 / r^2\right) + 1\right] / \left[\left(b^2 / a^2\right) - 1\right] \\ &-q_b \cdot \left[1 + \left(a^2 / r^2\right)\right] / \left[1 - \left(a^2 / b^2\right)\right]\end{aligned} \quad (7)$$

Where: σ_r is the compression stress, MPa; σ_θ is the tension stress, MPa; a is the internal diameter of pipes, m; b is the external diameter of pipes, m; r, θ are the polar coordinate; q_a is the internal pressure, MPa; q_b is the external pressure, MPa.

The operating temperature of the lithium bromide-water absorption chiller ranges from 275 K to 453 K, and the absolute pressure ranges from 0 MPa to 0.5 MPa. Supposing the vacuum of outside of heat transfer tubes, there is maximal tension stress of 2.6 MPa and maximal compression stress of 0.5 MPa. However, the tensile strength of PTFE plastics is 10.3 MPa and its compression strength is 4.1 MPa [4]. Taking assurance coefficient for 3.5, the maximal tension stress still is under safe tensile strength, and the maximal compression stress is under safe compression strength. Therefore, the heat exchangers of plastic heat transfer tubes meet the need of safety strength.

III. CONCLUSION

In this paper, the correlative performance of the lithium bromide-water absorption chiller using plastic heat transfer tubes is compared with the traditional lithium bromide-water absorption chiller. And the three aspects, i.e., heat transfer area, pipe resistance, and safety strength are analyzed. The results show that it is feasible to use plastic heat transfer tubes on lithium bromide-water absorption chillers. The lithium bromide-water absorption chillers using plastic heat transfer tubes are very significant for the development and application of absorption refrigeration.

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