1988

A New Cycle for Energy Saving of LiBr Double Effect Absorption Refrigeration

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A NEW CYCLE FOR ENERGY SAVING OF LiBr

DOUBLE EFFECT ABSORPTION REFRIGERATION

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Abstract

Recently the LiBr absorption refrigerating machine has rapidly developed in China. In this paper a new cycle of LiBr double effect absorption refrigerating machine - the series parallel compound cycle was presented and discussed. It has the advantages of higher C.O.P. up to 10% in comparison with the parallel cycle. At the same time, in the parallel cycle greater pressure difference exists between the strong solution of the high-stage and low-stage generators and direct mixture will cause unnecessary energy losses. This can be avoided for the series parallel compound cycle.

To use the available sensible heat of steam condensation to the fullest extent, the arrangement and position of the condensation heat exchanger in the system was also discussed in detail.

The new system was adopted for the SXZ-50 LiBr double effect absorption refrigerating machine, which is now is operation and good results have been achieved. According to the operating tests, its chilled water leaving temperature is equal to 7°C; cooling water entering temperature, 32°C; and the pressure of working steam, 5.88 Bar (gauge), which, as operating conditions, are much worse than that of some machines operated at higher pressure of 8 Bar (gauge) or at higher chilled water leaving temperature of 10-13°C, but the working steam consumption rate achieves 1.26 Kg/Kw. Its cooling water flow rate is 0.28 M^3/Kw. Because SXZ-50 machine adopts a new cycle, its C.O.P. is raised by 10%; at the same time, the steam condensation heat is fully made use of. Therefore, comparing with other machines, although SXZ-50 is operating under much worse conditions, but still its unit steam consumption rate and other related data are in comparatively better levels.

UN NOUVEAU CYCLE POUR ECONOMISER L'ENERGIE DANS LE REFROIDISSEMENT PAR ABSORPTION A DOUBLE EFFET AU LiBr

RESUME : La machine frigorifique à absorption au LiBr a connu récemment en Chine un développement rapide. Ce rapport présente et examine un nouveau cycle, composé en série et parallèle, pour machine frigorifique à absorption à double effet au LiBr. Il présente l'avantage d'un COP jusqu'à 10 % supérieur à celui d'un cycle en parallèle. En même temps, dans le cycle en parallèle, il existe une plus grande différence de pression entre la solution riche de l'étage haute pression et les générateurs basse pression et le mélange direct provoque des pertes d'énergie inutiles. On peut l'éviter avec le cycle composé en série et parallèle.

Pour utiliser au maximum la chaleur sensible disponible de la condensation de vapeur, on a aussi examiné en détail la disposition et l'emplacement dans le système de l'échangeur de chaleur pour la condensation.

Le nouveau système a été adopté pour la machine frigorifique SXZ-50 à absorption à double effet au LiBr, qui est maintenant en service et qui fournit de bons résultats. D'après les essais de fonctionnement, la température de sortie de l'eau refroidie est de 7°C ; la température d'entrée de l'eau de refroidissement est de 32°C ; et la pression de la vapeur active de 5,88 bars (effective), conditions

de fonctionnement bien plus mauvaises que celles des machines fonctionnant à une pression supérieure, 8 bars (effective), ou délivrant de l'eau froide à une température supérieure de 10 à 13°C, mais la consommation spécifique de la vapeur active est de 1,26 kg/kWh. Son débit d'eau de refroidissement est de 0,28 m3/kWh. Le COP de la machine SXZ-50 est, selon le nouveau cycle, augmenté de 10 % ; en même temps, la chaleur de condensation de la vapeur est entièrement utilisée. Donc, si l'on compare avec les autres machines, bien que la machine SXZ-50 fonctionne dans des conditions nettement plus sévères, son taux unitaire de consommation de vapeur et autres valeurs associées sont à des niveaux relativement meilleurs.

A NEW CYCLE FOR ENERGY SAVING OF LiBr DOUBLE EFFECT ABSORPTION REFRIGERATION

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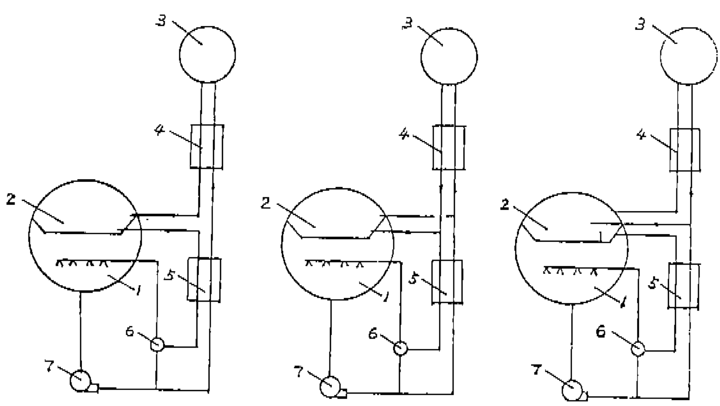
1. INTRODUCTION

LiBr double effect absorption refrigerating machine is a machine of high efficiency whose C.O.P. is about 1.5 - 2 times of the single effect machine from which it was developed. A series of standard machines of both single and double effect have been produced in America and Japan. At the same time, the LiBr absorption refrigerating machine has also a rapid development in China and finds wide uses in recent years. Hence it is very important to improve the performance of the machine. In designing a double effect absorption refrigerating machine of higher performance, the selection of cycle is very essential and important. A new cycle of LiBr double effect absorption refrigeration of higher C.O.P. was presented in this paper.

2. SERIES PARALLEL COMPOUND CYCLE

The available cycle of LiBr double effect machines used in different countries can be divided into two types: the series cycle (Fig.1a) and the parallel cycle (Fig.1b). In the case of series cycle all the weak solution flows into the high-stage generator and then into the low-stage generator. It has the advantage of easy to control and reliable operation. But the solution citculation ratio is higher. The high-stage generator has a higher heat load. Besides, the temperature of refri-



a. Series cycle b. Parallel cycle c. Series parallel compound cycle

1-Absorber, 2-Low-stage generator, 3-High-stage generator,
4-High temperature heat exchanger, 5-Low terperature heat exchanger,
6- Ejector, 7-Solution pump,

Fig. 1

gerant vapour in the low-stage generator is low and the solution concentration is high. The low-stage generator or high temperature heat exchanger has a larger heat transfer surface area. In the parallel cycle the weak solution flows into both the high-stage and low-stage generator simultaneously. The solution circulation ratio reduces while the C.O.P. rises. But the two parts of solution flow should be controlled in a definite ratio. Besides, the higher pressure of strong solution at high temperature heat exchanger and the mixture with the exit solution of low-stage generator complicates the control and operation of the machine.

The new cycle presented in the paper is a combination of series and parallel cycle (Fig.1c) to overcome the disadvantages of both cycles mentioned above. Its C.O.P. is higher than that of parallel cycle.

The weak solution from the absorber passes through the low temperature heat exchanger and then one part of them flows into the low-stage generator while another part flows into the high-stage generator through the high temperature heat exchanger. The generating strong solution passes through high temperature exchanger to reduce its temperature and then flows into the low-stage generator too. At this time, a part of refrigerant vapour is flashed. The remaining solution is mixed with the strong solution of low-stage generator, and after reducing its temperature in the low temperature heat exchanger returns to the absorber.

3. C.O.P.

In this cycle a part of refrigerant vapour is received by the flashing of the strong solution in the low-stage generator. The generating amounts of refrigerant vapour in low- and high-stage generators are smaller than the total refrigerant circulation rate of the machine, and the circulation ratio is lower than that in parallel cycle. Thus the high-stage generator has a low heat load. It results in a higher C.O.P. than that of a parallel cycle.

The refrigerant circulation ratio in high- and low-stage generators should be

$$\frac{D_H}{D_L} = 1.05 \frac{q_{g1}}{h_3'' - h_{3H}}$$

where q_{g1} -- specific heat load of low-stage generator,

$h''-h$ -- enthalpy difference of refrigerant vapour and condensate in high-stage generator.

For the parallel cycle, the total amount of refrigerant circulation rate is

$$D = D_H + D_L$$

so the refrigerant circulation rate for high-stage generator is

$$D_H = D - \frac{D}{1 + 1.05 \dfrac{q_{g1}}{h_3'' - h_{3H}}}$$

For the series parallel compound cycle

$$D_H = D - D^* - D_L$$

$$= D - D^* - \frac{D - D^*}{1 + 1.05 \dfrac{q_{g1}}{h_3'' - h_{3H}}}$$

where D^* - the flashing refrigerant vapour rate of strong solution of the high-stage generator in low-stage generator.

The heat load of high-stage generator

$$Q_{gH} = D_H q_{gH}$$

$$C.O.P. = \frac{Q_o}{Q_{gH}}$$

The following is a comparison made of the principle cycle for parallel and series parallel compound under the same design conditions and parameters, the same heat recovery temperature of solution and heat transfer surface area, which has a unnegligible influence to C.O.P..

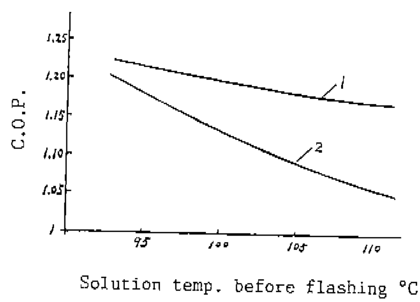
The calculating results for the parallel and series parallel compound cycles are given in Table 1, while the operating steam pressure is equal to 5.88 Bar(gauge); cooling water entering temperature, 32°C; chilled water leaving temperature, 7°C; condensing temperature, 40°C; evaporating temperature, 5°C; and temperature of strong solution before flashing, 95°C.

Table 1

Term		Series parallel compound cycle	Parallel cycle
Refrigerating capacity (KW)		580	580
Heat Load	Low-stage generator (KW)	319.82	329.6
	High temp. heat exchanger (KW)	224.57	331.43
	High-stage generator (KW)	477.16	491.75
	Low temp. heat exchanger (KW)	237.39	244.65
	Condenser (KW)	312.39	303.03
	Absorber (KW)	744.78	768.71
flow rate	High-stage generator weak sol. (Kg/h)	7705.93	7941.44
	Low-stage generator weak sol. (Kg/h)	5594.58	5765.53)
C.O.P.		1.216 (1.17)	1.179 (1.055)
Total heat transfer surface area (m^2)		291.64	297.22

The figures in brackets are the C.O.P., when the temperature of strong solution before flashing is 110°C.

As can be seen from this table, the heat load of all the components for series parallel compound cycle are lower than that of the parallel cycle except the condenser. But the C.O.P. rises from 1.179 to 1.216, i.e. about 3%. When the temperature of strong solution before flashing is rising, this figure will be further enlarged (see Fig.2). Generally, the temperature of strong solution before flashing in the operating machine is about 110°C. Thus the C.O.P. is raised about 10%.



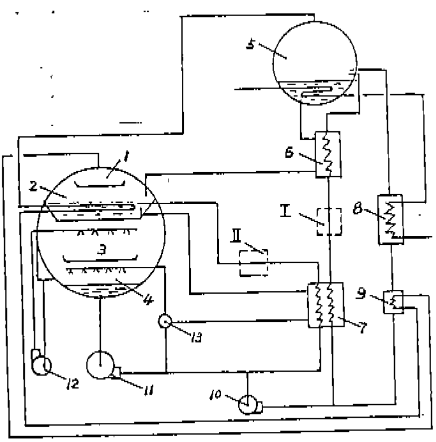
1-Series parallel compound cycle
2-Parallel cycle

Fig.2

4. THE COLLECTION OF TWO PART SOLUTION

In the parallel cycle, greater pressure difference exists between the strong solution of the high-stage and low-stage generators and direct mixture will cause unnecessary energy losses. This can be avoided for the series parallel compound cycle. In the series parallel compound cycle only one ejector is needed instead of an absorber pump. The new system is shown in Fig.3.

Attention must paid to the new cycle, that is, the parameter of the solution after flashing should approach as much as possible to the generated solution of low-stage generator; also, the low-stage generator should have enough space for flashing to separate the vapour and liquid sufficiently.



1-Condenser,
2-Low-stage generator,
3-Evaporator,
4-Absorber,
5-High-stage generator,
6-High temperature heat exchanger,
7-Low-temperature heat exchanger,
8-Condensate heat exchanger,
9-Subcooler,
10-Solution pump,
11-Solution pump,
12-Refrigerant pump,
13- Ejector,

Fig.3

5. THE AVATLABILITY OF SENSIBLE HEAT OF STEAM CONDENSATE

In LiBr double effect absorption refrigerating machine, the temperature of the condensate is high. Its sensible heat should be used when the steam piping system is allowed. For the compound cycle, when the flashing temperature is higher, the condensate sensible heat can be used to minimize the heat load of high-stage generator and further reduce the steam consumption rate. Because the temperature of weak solution at the inlet of high-stage generator is often relatively low, thus the sensible heat of the condensate can be adequately used to raise the temperature of the weak solution causing the condensate leaving temperature to be lower.

The degree of condensate leaving temperature reduction depends upon the position of the condensate heat exchanger in the system. The dotted block I in Fig.3 indicate the position where the condensate heat exchangers are usually located in some series cycle machines. In parallel cycle machines, the condensate heat exchangers are often located between the low temperature heat exchanger and low-stage generator, as indicated by the dotted block II in Fig.3. Thus the ratio of heat transfer surfaces of high and low temperature heat exchangers can be improved ard the condensate leaving temperature is lower than that in the case of dotted block I. But in both systems mentioned above, the condensate heat exchangers are arranged tandem and their condensate leaving temperatures cannot be sufficiently lowered. The condensate leaving temperature of practically operating machines is in the range of 95 - 110°C for the former case; for the later case the minimum temperature is 87°C. In the new system the condensate heat exchangers are parallelly arranged(see Fig.3). Thus the condensate leaving temperature can be greatly reduced. According to the operating data of machine (model SXZ-50) it is as low as 77°C.

6. CONCLUSION

The new system was adopted for the SXZ-50 LiBr double effect absorption refrigerating machine and good results have been achieved. According to the operating tests, its chilled water leaving temperature is equal to 7°C; the cooling water entering temperature, 32°C; and the pressure of working steam, 5.88 Bar(gauge), which, as operating condition, are much worse than that of some machines operated at higher pressure of 8 Bar(gauge) or at higher chilled water leaving temperature of 10—13°C. But the working steam consumption rate achieves 1.26 Kg/Kw. Its cooling water flow rate is 0.28 M^3/Kw, Because SXZ-50 machine adopts a new cycle, its C.O.P. is raised by 10%; at the same time, the steam condensate sensible heat is fully made use of. Therefore, comparing with other machines, although SXZ-50 is operating under much worse conditions, but still its unit steam consumption rate and other related data are in comparatively better level.

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