The procedures developed of automatic cascade non-azeotropic refrigerant selection and matching

Zheng Da-yu[(a)] , B. Chen Qiu-yan[(b)] , B. Gao Li-ping[(b)], C.Liu-Lei[(c)]

C. Chen-shuo[(c)] , D. Li Xiang[(d)] , D. Yu Hai-feng [(d)], D. Li Jie [(d)]

[(a)] School of Energy and Civil Engineering of Harbin Commercial University

Harbin, 150028, China

Fax086-451-84865269, zhengdayu2000@126.com

[(b)(c)(d)] School of Energy and Civil Engineering of Harbin Commercial University

Harbin, 150028, China

Fax086-451-84865269, superteacher73@126.com

KEYWORDS: automatic cascade, non-azeotropic refrigerant selection, matching

ABSTRACT: Draw the commonly refrigerants table for writing in the program selector working pair in tune content. Selection according to the evaporation temperature of low temperature refrigerant, based on traditional non-azeotropic refrigerant select automatic cascade principle, the preparation method of choice of refrigerant and written procedures, the use of the program to select the appropriate refrigerant refrigerant pair. Meanwhile calculated by the heat balance principle to draw a flow chart and write a program to calculate, using the program draw on the ratio of the refrigerants. VLE calculated using the number of moles of the components, the use of the program to optimize the ratio of the refrigerant. Making saving automatic cascade refrigerant selected time, choose refrigeration system is more efficient and more economic and environmental protection.Finally this paper analyzes the reason of the automatic cascade COP value is low, to improve after automatic cascade system scheme is put forward.

INTRODUCTION

With the advancement of technology, the increasing growth of the people's living standards. Whether in the biomedical community, or in the traditional manufacturing industry, more and more demand for low temperature, which is increasing the demand for equipment. With cooling temperatures require lower temperatures, the efficiency of the traditional way of using a single throttle refrigeration refrigerant is reduced, can not achieve the requirements of energy conservation, but also can not reach the desired low temperature [1]. Non-azeotropic refrigerant for refrigeration sector provides a new lower cooling world, while single machine multi-level automatic cascade makes moving parts while reducing the desired temperature is reached, and get simple safe operation of the refrigeration system. Non azeotropic due to the different boiling point in the process of heat transfer component changes, the proportion of non azeotropic evaporation temperature of the working medium is lower than any other single working medium evaporation temperature, then can get cryogenic refrigeration temperature. In order to achieve its best COP, automatic cascade refrigeration system refrigerant ratio is the primary problem, based on previous experiments show that the best ratio can improve the COP of the system[2].

Ratio of the refrigerant

Select the correct non-azeotropic refrigerant pair, and calculated their ratio. Reasonable ratio can reduce the equipment operation is damaged, longer equipment life and safer. Comparison of the ratio of the conventional method of theoretical and experimental results, only the combination of the fine-tune the ratio of the refrigerant to get the best ratio. Considered stable operation of the automatic cascade refrigeration system of internal refrigerant in vapor-liquid equilibrium. Each of the refrigeration cycle is assumed that no pressure loss in the pipeline, without heat exchange, the compression process is adiabatic isentropic compression, the gas-liquid separator liquid is pure liquid, and a uniform temperature over the gas-liquid state under a simplified refrigeration cycle. Draw its various conditions of low temperature cooling effect parameters according want to achieve.

Auto cascade refrigeration are done by a compressor cycle, with the classic cascade refrigeration cycle thermodynamic calculation as [4]:

$$G_d = \frac{Q_0}{q_0'} \qquad (1)$$

Equation: G_d - cryogenic refrigerant mass flow rate (kg/s);

Q_0 - the required cooling capacity (kW);

q_0' - Cryogenic cooling capacity per unit mass (kJ /kg).

After the low-temperature refrigerant mass flow rate calculated by the estimation of the amount of heat exchange evaporator condensate to determine the low-temperature refrigerant condensed refrigerant mass flow rate.

$$Q_{k,d} = G_d \cdot (q_0' + w_0') \qquad (2)$$

Equation: $Q_{k,d}$ - cryogenic refrigerant condensing load (kW);

G_d - Low-temperature refrigerant mass flow rate (kg / s);

w_0' - Theory cryogenic unit power in low temperature (kJ / kg).

$$Q_{o,x} = 1.2 \times Q_{k,d} \qquad (3)$$

Equation: $Q_{o,x}$ - cryogenic refrigerant condensing refrigerant evaporator load (kW);

Above, in the calculation of the mass flow rate of refrigerant condensing low temperature refrigerant, by the estimation of condensate evaporator heat transfer, and to determine the next refrigerant flow of refrigeration, the mole fraction of each component for VLE theoretical calculation of the need theory data.

Non-azeotropic mixed refrigerant boiling point no common element in each group. Evaporation or condensation in certain conditions, the vapor and liquid phases of different composition and temperature are constantly changing.

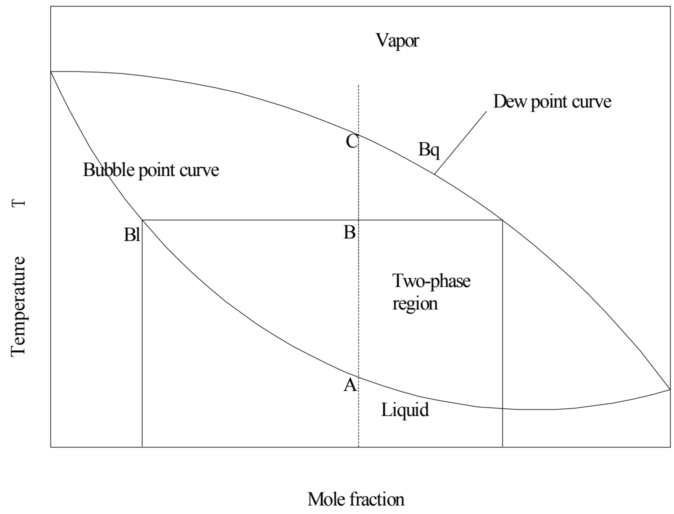

Figure1 Non-azeotropic refrigerant(T-ε) figure

Non-azeotropic mixed refrigerant occurs in the temperature change when the change in the phase constant pressure, the condensation temperature increases at constant pressure to the bubble point temperature of the dew point temperature, the evaporation pressure is fixed to the dew point temperature becomes from the bubble point temperature. According to the characteristics of the mixed refrigerant is widely used in the temperature difference between heat source to match the occasion, in order to achieve approximate Lorentz cycle in order to achieve the energy saving effect. The nature of the mixed refrigerant approximates the average properties of each component [4].

Vapor-liquid equilibrium is an interrelated and mutually independent co-ecology. For the multi-component system, heat balance refers to the equilibrium force balance and equilibrium conditions are satisfied, that is, each phase of the temperature, pressure and chemical potential of the components in the respective phases are equal. Method for calculating vapor-liquid equilibrium still discussed, but it is still the most commonly used method is still more precise use of the equation of state of pure refrigerant to be introduced into a suitable mixing ingredients variable to study the rules of the VLE features. Select fugacity coefficients calculated PR equation of state, that is, from the P-V-T relationship or measured data of the substance calculated with high accuracy [5].
PR equation of state is:

$$P = \frac{RT}{V - b} - \frac{a(T)}{v(v + b) + b(V - b)} \qquad (4)$$

Where

$$a(T) = a_c a(T) \ , \quad a_c = 0.45724 \frac{R^2 T_C^2}{P_C} \ , \quad b = 0.07780 \frac{RT_C}{P_C}$$

$$a(T) = \left[\begin{matrix} 1 + (0.37464 + 1.54226w - 0.26992w^2) \\ \left(1 - (\frac{T}{T_C})^{0.5} \right) \end{matrix} \right]^2$$

Equation R is the universal gas constant, T is the temperature, V is the molar volume, a function of the temperature, b is a function of the volume.

Mixing rule to select different computing has a great impact on the fugacity coefficient of component. First select a classic mix of single-class rule Vander Waals mixing rule [6]:

$$a = \sum_i \sum_j X_i X_j a_{ij} \qquad (5)$$

$$b = \sum_i \sum_j X_i X_j b_{ij} \qquad (6)$$

$$a_{ij} = (1 - K_{ij})(a_{ii}a_{jj})^{\frac{1}{2}} \quad (7)$$

$$b_{ij} = (b_i + b_j)/2 \quad (8)$$

The (3-5) into (3-2) have:

$$b_m = \sum_{i=1}^{n} x_i b_j \quad (9)$$

According to the unique nature of mixed refrigerants, vapor-liquid equilibrium theory can be used to calculate the bubble point, seeking vapor phase components; dew point calculation, seeking liquid components; calculation of two-phase region, seeking equilibrium vapor and liquid phases group dryness, equilibrium constants, quantitative standards for each component of volatility.

Table 1 The method to calculate VLE by equation of state

Known variables	The unknown variables	Question classification
P, Xi	T, yi	Bubble point temperature
P, yi	T, Xi	Dew point temperature
T, Xi	P, Xi	Bubble point pressure
T, yi	P, Xi	Dew point pressure

The specific calculation should have a small amount of experimental data, first using the theory of traditional matching of components instead of data generation into the process. According to the above formula for calculation program block diagram[7]:

1 - Given P and x_i values, identified calculate the required physical constants. Temperature and phase composition of the unknown.
2 - Selected equation of state to derived fugacity coefficient equations, and calculated vapor-liquid equilibrium ratio;
3 - From the new calculated value obtained, the values are normalized with the previous iteration until the difference is less than a predetermined allowable value (0.01);
4 - Judgment the difference is less than a predetermined value, if less than the end of the calculation process, output, if more than, need to continue to adjust the temperature, until meets the requirement.

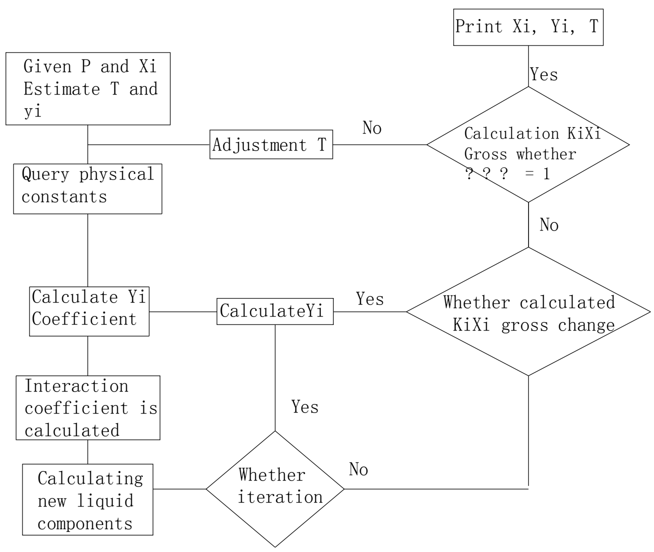

Figure2 VLE calculation flowchart

CONCLUSIONS

Automatic cascade refrigeration energy efficiency ratio of the size of the refrigerant has a great impact on energy conservation to reduce the amount of refrigerant charge while not reducing the cooling capacity is the most important current research. The filling should have the flexibility to master refrigerant refrigeration equipment use different rules in certain procedures to quickly select a refrigerant pair and proportion, save time and be more accurate. That is according to the required refrigeration temperature, the refrigeration capacity can directly select the quality and levels of non-azeotropic ratio. And can be based on objective factors given in a variety of refrigerants pair targeted selection, not only to meet the demand for cooling, but may well reduce the use of refrigerants, improve its efficiency, economy and reduce the influence of refrigerants on the environment. Effect of non-azeotropic refrigerant automatic cascade COP of the refrigeration cycle as well as an important reason for the refrigerant heat exchanger separation factor. With decreasing evaporation temperature, but the temperature of the evaporator to reduce the slip, which shows the value of the refrigerant in the dryness of the throttle is large, a serious loss of latent heat of vaporization, in order to avoid this situation, should increase the degree of subcooling.

Acknowledgements

Heilongjiang Province Natural Science Fund Project: NumberE201231
Heilongjiang Province Graduate Innovation Fund Project: NumberYJSCX2013-240HSD

REFERENCES

[1] Weidang Liu. Ternary non-azeotropic automatic cascade cryogenic equipment research [D]. Harbin University of Commerce, 2012.
[2] Bingfeng Yu. Refrigeration and air conditioning application of new technology [M]. Chemical Industry Press, 2002.
[3] Yitai Ma, Zhiming Gao, Dong Chen. Multivariate mixed refrigerants screening and matching principle [J] Engineering Thermophysics, 1997, 18 (1): 17-20.
[4] Yezheng Wu. Refrigeration principles and equipment [M]. Xi'an Jiaotong University Press, 1987.
[5] Junsheng Wu. Chemical Separation Engineering [M]. Science Press, 2000.
[6] Ziqiang Zhu, Youting Wu. Chemical Thermodynamics [M]. Chemical Industry Press, 2010.
[7] Jun Wang, Min Li, Erxi Cheng. Mixed refrigerant chiller design principle and calculation [J] Journal of Beijing University of Aeronautics and Astronautics, 1982, 4: 005.