Analysis of Low Temperature Process for Technical Application

Thi Minh Hao Dong, and Thanh Hai Truong

Abstract—**In the technical work on low temperature so far lacks a full analysis of the basis of thermodynamic processes using modern methods. Meanwhile, the low temperature conventions widely used in different fields. The purpose of this section is to give readers tools for thermodynamic studies and presents changes in the system on a fairly low temperature, intuitive nature and practices for analysis low-temperature processes related to cold and depth on the basis of using a unified approach. The low temperature process is applied in a number of techniques including basic process repeated. So it is best to preliminary studies the changing characteristics of our energy to then study the overall process.**

Index Terms—**Low Temperature, Thermodynamic, Ranke-Khilsa.**

I. INTRODUCTION

The thermal effect is a magnetic thermodynamic phenomenon, which is the change in temperature (heated or cooled) of a magnetic material during magnetization or demagnetization[1]. The effect of heat is actually the conversion of magnetic - thermal energy in magnetic materials[2]. When we apply a magnetic field to a magnetic material, the magnetic moments will tend to align the orientation according to the magnetic field. This orientation reduces the entropy of the magnetic moment system. If we perform this process adiabatically (the total entropy of the constant system)[3], the entropy of the lattice will have to increase to compensate for the decrease in magnetic moment entropy[4][5]. This process causes magnetic objects to heat up. Conversely, if we demagnetize (adiabatic), the magnetic moments will be returned to a disorderly state, leading to an increase in the entropy of the magnetic moment system[6]. As a result, the entropy of the lattice is reduced, and the magnetic object cools[7][8][9].

In 1745 Russian scientist Lomontôt in a famous dissertation, "Discussing the causes of hot and cold", said that the processes of living and rotting took place more quickly due to high temperatures and slowing down due to low temperature[10].

Indeed, the change of food increases rapidly at a temperature of 40 to 50^{o}C because at this temperature is very suitable for the activation of proteolytic enzymes (enzymes) of the food itself and microorganisms[11].

At low temperatures the biochemical reactions in food are inhibited. Within the normal temperature range for every 10°C reduction, the reaction rate decreases by 1/2 to 1/3 times[12].

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Refrigeration technology has been around for hundreds of years and is widely used in many very different engineering disciplines: in the food processing and storage industry, chemical industry, alcohol, beer, biology industry, automatic measurement, low temperature drying technology, construction, oil industry, material manufacturing, tools, machine design, seed handling, medicine, sports, life[13].

Today the refrigeration engineering industry has grown very strongly, used for many different purposes, the scope of expansion has become an extremely important and indispensable engineering industry in life and technology. of all countries[14].

Low temperatures affect the activity of enzymes but not destroy them. The temperature drops below 0°C, most of the enzyme activity is suspended. However, some enzymes such as lipase, trypsin and catalaza at -191^{o}C were not destroyed[15]. The lower the temperature, the lower the resolving capacity, for example lipase enzymes break down fat.

Low-temperature processes used in engineering consist of a number of repetitive basic processes. Therefore, it is best to do a preliminary study of the energy transformation characteristics in them so that a whole process can be studied[16]. An essential part of any process is "cold reception", which is based on lowering the temperature of the substance independently, without releasing heat to other objects with lower temperatures[17].

If special cooling methods that are not related to displacement and pressure reduction (electrical, electronic, chemical, etc.) are left aside, the following three methods should be considered, used individually or worked together:

a) throttle,

b) associated expansion for the external work (pressure reducing machine),

c) expansion of air in vortex tube (effect of Ranke-Khilsa effect).

The second necessary part of any low temperature process based on expansion is the preliminary compression of the material in this or another compressor for the purpose of creating the exergi necessary to carry out the process. It involves compressing existing products or pumping low temperature fluids (Oxygen, Nitrogen, Argon, etc.)[18].

The third necessary molecule of low-temperature processes is the heat transfer between gases and liquids carried out in various devices[19]. At every low temperature process, there is heat exchange at different levels related to the heat flow from the surrounding environment through insulation.

In fact, today, the compressed air supply and excess exhaust from enterprises and factories are not used, which is quite wasteful. So, using vortex effect refrigeration from the utilization of excess emission sources not only saves energy but also contributes to solving environmental problems and reducing production costs[20]. Besides, using vortex effect refrigeration can produce cold water, provide cool drinking water to workers in factories and enterprises. The method can also be applied to produce air conditioners, supply cool air to the working environment at production sites of plants and enterprises, contributing to improving labor efficiency of workers[21]. Moreover, in their research, the authors have built a vortex effec refrigerator model to be used for training and equipping specialized students with useful practical knowledge.

II. Compression Process

Compaction performance at low temperature processes can occur under different temperature conditions. In gas liquefaction and gas separation systems, as well as in refrigeration systems, compression usually occurs from the initial temperature close to T_0. So the compression process temperature is always higher than T_0, only when it is (isothermal compression) is equal to T_0. So here $\tau_e \geq 0$.

In steam-cooled cycles and in some other processes where there is no re-heating, the initial compression temperature is lower than T_0, in some cases it may not reach T_0 in the whole process, while in some cases it reverts to an area with $T > T_0$. So τ_e can it be higher or lower than zero[22].

Finally, there are several parts of the systems in which all processes take place at temperatures much lower than T_0. Here always $\tau_e < 0$.

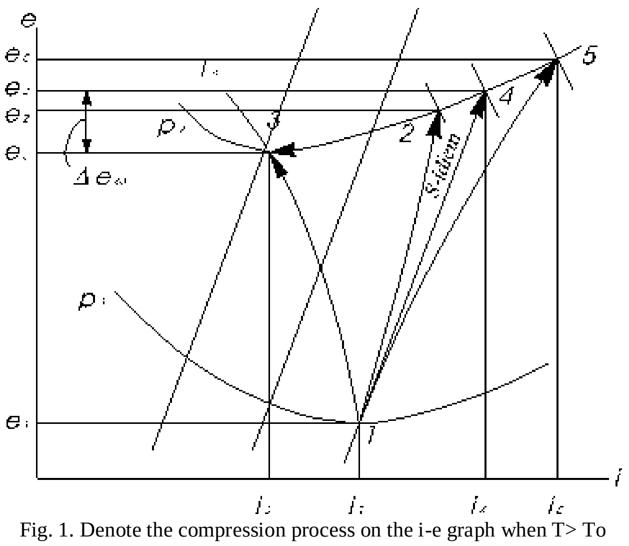

Fig. 1. Denote the compression process on the i-e graph when T> To

For all compression processes, regardless of the conditions under which they occur, the equation exergi equilibrium is realistic[23].

$$L^+ = \Delta E + Eq + \Sigma D = \Delta E + Q + \Sigma D \tag{1}$$

The L^+ consumption in compressors is costly to increase the exergi E, to exhaust or heat the gas, its exergi is equal to e, and partly to the non-reversible ΣD losses. In this case if the process is reversible ΣD = 0. We begin to analyze the compression processes from the first case: $\tau_e \geq 0$. These processes are shown on the i-e coordinates in Figure 1[24].

In reversible isothermal processes (lines 1-3), the gas temperature remains constant and is equal to T_0. So the exergi of the heat flow eq, released from the gas to the surroundings at T_0, is zero.

In non-reversible isothermal processes, the gas exergium temperature during compression is non-zero; however, regardless of this, the heat flow is transferred to the ambient at T_0. Therefore, both in this case $e_q = 0$.

Therefore, for isothermal processes, equation (1) in the general case has the form:

$$L_T^+ = \Delta e_{3\text{-}1} + \Sigma D \tag{2}$$

In particular, when the process is reversible ΣD = 0 and so $L_T^+ = \Delta e_{3\text{-}1}$. Thus, it is possible to obtain the L_T^+ of the reciprocal isothermal compression process without calculation from the i-e graph of the substrate, which is equal to the difference of exergi values at the beginning and end of the process. When knowing from the experiment or according to the actual calculation data of L^+ of the isothermal cooling compressor, the quantity $\Delta L_{3\text{-}1}$ can be calculated to calculate its isothermal efficiency η_T, equal to η_e.

$$\eta_T = \eta_e = \frac{\Delta e_{3-1}}{L^+} \tag{3}$$

The quantity of losses due to non-reversibility will be determined by the expression:

$$\Sigma D = L - \Delta e_{3\text{-}1}. \tag{4}$$

In the actual adiabatic process, a part of the compressor is used to overcome friction and convert it into heat for gas transmission. Therefore, the exergium of the gas at the end of the process increases (point 5). However, the quantity $\Delta e_{5\text{-}1}$ is not equal to the actual adiabatic process. $\Delta e_{5\text{-}1}$ corresponds to the total exergi that needs to be transferred to gas in the form of machining and thermal exergi to reversibly perform the process 1-5[25].

$$\Delta e_{5\text{-}1} = L^+ + e_q \tag{5}$$

The actual work of the adiabatic process lóni5-1 is greater than $\Delta e_{5\text{-}1}$ because the heat transferred to the gas is due to machining, which leads to exergi losses. Adiabatic efficiency bằngad is equal to:

$$\frac{\Delta e_{5-1}}{L_{ad}^+} = \frac{\Delta e_{5-1}}{\Delta i_{5-1}} \tag{6}$$

Process 1-2 takes an intermediate position between isothermal and isotropic processes and differs from process 1-5, which is accompanied by heat exhaustion. So in the reversible process 1-2:

$$\Delta e_{1\text{-}2} = L^+ - e_q \tag{7}$$

The work of process 1-2, as well as the effort required to perform any non-reversible process, cannot be taken from the graph, except for the work of the adiabatic process where $\delta q = 0$. At all compression (and expansion) involving heat exchange, the non-reversible success of the heat conversion cannot be expressed on the state graph. The amount of labor cost in the same top and bottom states can increase or decrease depending on the heat released into the surrounding environment.

III. The Processes of Expansion

A. *Throttling*

Actual airflow in the positive Jun– Tomson effect states is one of the main cooling methods.

Throttle is often considered the classic form of non-reversible process. This is true only in two cases - for ideal gases or for real gases in the inverse region (inversion); under these conditions the Jun-Tomson effect is zero[26].

In all other cases, the temperature difference generated by the throttle result can be used to obtain work, since it can return a portion of the material to its original state. Therefore, in the general case, real air circulation is partially reversible.

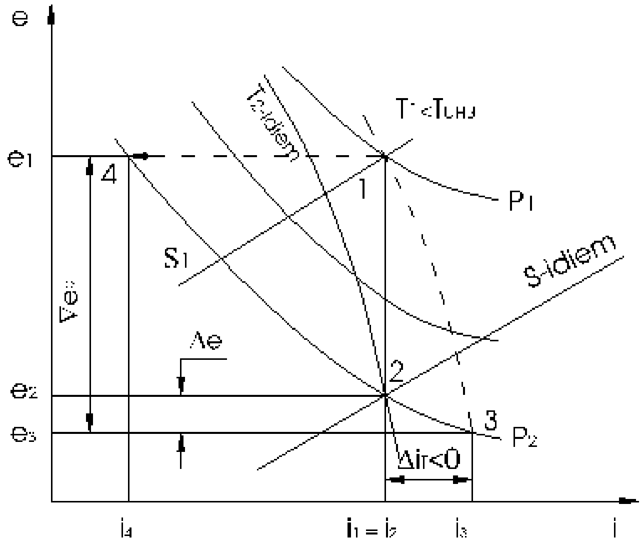

Fig. 2. Expressions of throttle processes at i-e coordinates when $\alpha_i > 0$

We will examine the excretion process by exergi i-e graph.

Depending on the form and its parameters, throttle may take place with a decrease in temperature (α_i>0), accompanied by an increase in temperature (αi <0) and no change in temperature ($\alpha_i = 0$). (invertion parameters) *
* Note: di - effect - differential throttle.

The throttle valve is used in refrigeration system with the main use is to adjust the amount of fluid in the hydraulic system, thereby regulating the engine speed. When the fluid flow passes through the valves on the pipe in the flowmeter, capillary tubes or the throttle in the refrigeration system ... that's the process of throttle. Then the broker pressure will be reduced due to strong eddies and friction. This pressure drop depends on the dirt, the state of the broker, the pipe shrinkage and the speed of the air stream.

The secretion process is often accompanied by a decrease in the efficiency of the medium and this is harmful. Air flow rate will increase in the hole. After going through the hole, the gas speed drops again, and the pressure increases but not by the beginning[18]. Variable velocity will lead to an increase in the density of the gas due to reduced pressure.

B. *Air expansion in vortex tube*

The Rank - Khilsa effect, performed by expanding the air in a vortex, is used for cooling as well as for heating. From a thermodynamic point of view, the vortex effect has something in common with the process in a pressure reducer, which is performed with any gas, independent of the effect of the throttle effect; Gas chilling is caused as a result of the partial exhaust of energy in it. However, unlike the pressure drop, the energy released is not in the form of external work but is transferred to other gases or into the surrounding environment in the form of heat flow. Therefore, the energy obtained is always lower than the value: e_q is always less than l when q = l and η_e of the vortex tube is smaller than that of the pressure reducing machine.

The energy balance diagram of the vortex tube is shown in Figure 3. The index 1 for all parameters (p, T, i, e) will be related to the compressed air, 2– hot air flow out of the pipe at intermediate pressure and 3-cold air[27].

The agent used in the vortex effect is a gas with high pressure and temperature corresponding to or approximately equal to the ambient temperature, used in industrial enterprises with excess compressed air flow.

The energy balance of the process takes the form:

$$\mu(i_1 - i_2) = (1-\mu)(i_2 - i_1) + g(i_5 - i_4). \qquad (8)$$

Expansion process performance:

$$\eta_e = \frac{\mu(e_3 - e_0) + (1-\mu)(e_2 - e_0)}{e_1 - e_0} \qquad (9)$$

The exergi efficiency characteristics of the vortex effect are necessary in cases where the optimum operating conditions of the pipe are needed[28]. For this purpose, if the cooling output q=μ (i_1–i_3) or the cooling coefficient calculated on it $\varepsilon = \frac{\mu(i_1 - i_3)}{L^{+}_{nén}}$ is used, the change in temperature of the heat flow will not be taken into account.

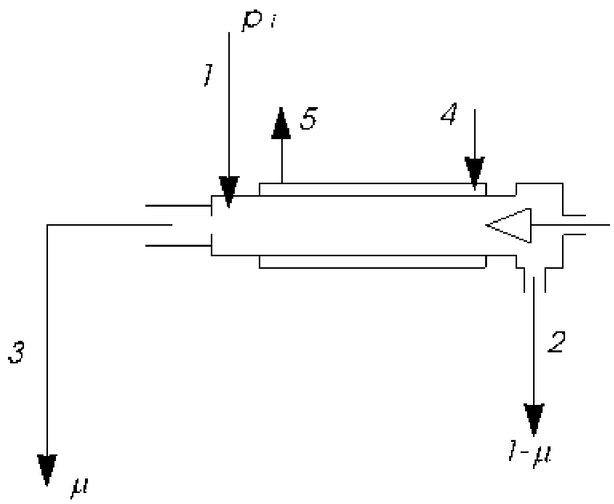

Fig. 3. Energy balance diagram of the vortex tube

High pressure air goes through nozzle 3 into the helical pipe, tangent line 3 is installed close to the barrier 2. This spiral flow will expand in tube 1. In the process of moving inside the vortex, the vortex will gradually decrease. The layers in the center have a great angular velocity to create eddy currents. The angular speed at the boundary is small and moves to ty 4, which means that there is a dynamic transmission from the inner layers to the outer layers. Upon arrival at valve 4, the airflow is divided into two parts, one outside the boundary (adjacent to the pipe casing) following the gap between valve 4 and tube 1 outside with the surrounding environment having 3x parameters. A small portion of the gas in the inner layer near the center of the pipe smashes into valve valve 4 and creates a vortex, the movement bounces back to the barrier 2. In the process of opposite movement between the outer periphery and the inner ring occurs heat exchanger from the central ring to the periphery[29]. The outer layer of air receives kinetic energy, so the airflow in the peripheral layer heats up, while the airflow in the center that goes against it loses energy so it is cooled down gradually.

IV. HEAT EXCHANGE PROCESSES

The process of heat exchange in equipment and machines of low temperature systems can be divided into two groups.

The heat exchanger that leads to an increase of exergi of one substance by reducing the exergi of another substance of the first group. In this case, the exergi of the substrate is increased when heated if its temperature T> T0 and when it cools if T <T0. Basically, the low temperature technique is the second case. This "useful" heat exchanger is an essential element of any low temperature process and is carried out in one or another structural heat exchanger. This process is always partially reversible and its exergi performance in the ideal case will be equal to 1[2].

Heat exchange of substrate with the environment belongs to the second group, it always leads to reduced exergi. When the temperature T> T_0, such heat exchange leads to cooling of the material, while T <T_0- leads to heating. This harmful heat exchange is often associated with imperfections of insulation, with thermal bridges, with the thermal conductivity of the materials of machines, equipment, and spare parts etc. The process is always non-reversible. and its efficiency η_e = 0. In practical processes occurring on heat exchangers, in addition to losses occurring due to temperature and hydraulic resistance, there are losses due to Heat exchanger results with the surrounding environment. We will examine each type of loss separately.

A. Loss due to temperature effect

The ratio of exergi temperature losses not only allows the determination of losses in heat exchangers in general and in any part of them, but also allows the selection of the optimum dynamic temperature difference. under given conditions resulting from permissible losses when exchanging heat.

Thus, the use of exergi temperatures allowed together with the calculation of economic-technical measures in a basis of solving the problem of selecting the temperature head column when calculating the diagrams and selecting heat exchangers.

If the pressure losses are large and cannot be ignored, then $q.\bar{\tau}_e \neq \sum \delta q.\bar{\tau}_e$ and determine e_q, in order to calculate the losses associated with the finite temperature difference and the performance associated with them, it is necessary to proceed according to the areas on the graph q-τ_e, they are always equal $\sum \delta_q.\tau_e$.

B. Losses due to hydraulic resistance

In most heat exchangers, hydraulic resistance losses are of great value, especially when dealing with large amounts of gas at low pressures.

On Figure 4 represents the i-e coordinate of state changes of A and B through the heat exchanger with great resistance.

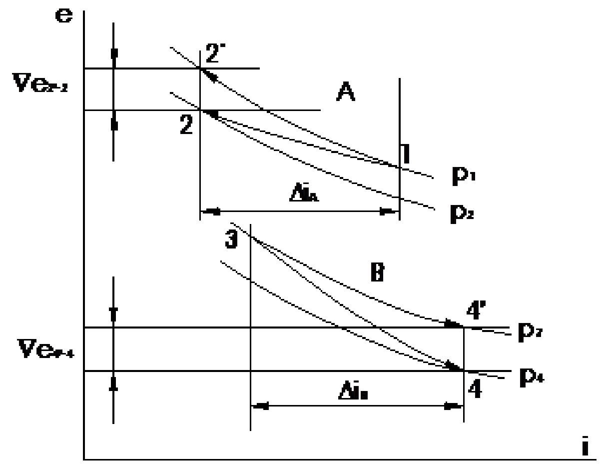

Fig. 4. Identify hydraulic resistance losses

Formula A enters the device at pressure p_1^A. If there is no resistance, then the cooling process is ended suppose at point 2 'at the same pressure P_1^A. The actual pressure $\nabla P_A = P_1^A - P_2^A$ is reduced and the process ends at point 2. Exergi losses are related to hydraulic resistance:

$$D_A = G_A(e_2^{'} - e_2) = G_A.\nabla e_{2^{'}-2} \tag{10}$$

Similar loss to substance B:

$$D_B = G_B(e_4^{'} - e_4) = G_B.\nabla e_{4^{'}-4} \tag{11}$$

Total loss:

$$D = D_A + D_B = G_A.\nabla e_{2^{'}-2} + G_B.\nabla e_{4^{'}-4} \tag{12}$$

Losses due to hydraulic resistance are not shown on the q-τ_e chart, where only losses related to heat flow are shown.

C. Loss due to heat exchange to the surrounding environment

At low temperature processes these losses occur due to additional heating of the B series and by cooling of A series due to heat flow from the outside. Depending on the structure of the system, this effect may have different values, but in all cases the loss quantities are determined by the quantity of heat flow through thermal insulation qis and the temperature T at That heat is transferred to the refrigerant. The exergi flow corresponds to this heat flow directed from the refrigerant into the surrounding environment (because $\overline{\tau_e}$ <0) and is completely lost[30].

The total amount of loss

By calculating the individual loss components according to the above method, it is possible to determine their proportion in the total quantity.

Heat exchanger efficiency takes into account all losses:

$$\eta_e = \frac{G_A \Delta e_{1-2}}{G_B \Delta e_{3-4}} = \frac{G_B \Delta e_{3-4} - (d_T + d_p + d_{is})}{G_B \Delta e_{3-4}} \tag{13}$$

Including indicators that reflect these or other losses in equation (13) can determine the effect of each loss on the heat exchanger performance η_e.

Thermal efficiency η_q is often used to evaluate heat exchangers. It is the ratio of the actual heat transmitted through the heat exchanger to the amount of heat that should have been transmitted in the ideal case, when the minimum temperature difference at one of the points of the device is zero, and the heat will not have $\eta_q = \frac{Q_{thucte}}{Q_{lytuong}}$.

In some foreign constructions people use a temperature coefficient, where Q is replaced by ΔT the same condition as above $\eta_T = \frac{\Delta T_{1-2thucte}}{\Delta T_{1-2lytuong}}$.

The difference is particularly sharp between η_e -, on one side η_q and η_T -, on the other side on the heat exchanger 1. The low value η_e is explained by the large temperature difference on the cold end of the device (59 K), which leads to almost half the exergi loss. The values η_q and η_T, though, are still very large.

This difference is specific to other heat exchangers, the lower the temperature, the more pronounced it is, the coefficient η_q is always 100%, and it η_T loses meaning because ΔT_A and ΔT_B is zero.

V. Conclusion

Thermal efficiency is often used to evaluate heat exchangers. It is the ratio of the actual heat transmitted through the heat exchanger to the amount of heat that would otherwise be transmitted in the ideal case, when the minimum temperature difference at one of the points of the device is zero, and insulation losses will be unavailable. Performance has the disadvantage that it does not take into account the temperature plane of the heat, ie its "quality". Therefore, individual losses due to their existence are not counted, and technical losses are skewed. In some foreign buildings a temperature coefficient is used, where Q is replaced by the same condition as above.

From the results of theoretical research and experimental manufacturing of air-conditioning models thanks to vortex effect, compared to current air-conditioning models, we see that each type of air conditioner has different advantages and disadvantages. The use of air-conditioning systems thanks to the vortex effect helps save some energy, contributes to improving the environment, avoiding waste. At the same time, through this research, the experimental fabrication model can be applied to teaching students in the Thermal Refrigeration field. Experimental models should be tested and measured with technical parameters such as wind speed, compressed air pressure, air flow rate, air temperature at the outlet, and additional dynamic calculations are needed. study and aerodynamics to make more reasonable design adjustments to serve the actual needs when there is an excess of compressed air exhaust, contributing to energy saving and environmental protection.

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