1988

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Bevilacqua, P., "Mechanical Refrigeration Using an Ejector-Injector to Transfer the Working Fluid from Evaporator to Condenser" (1988). *International Refrigeration and Air Conditioning Conference.* Paper 68.
http://docs.lib.purdue.edu/iracc/68

MECHANICAL REFRIGERATION USING AN EJECTOR-INJECTOR TO TRANSFER THE WORKING FLUID FROM EVAPORATOR TO CONDENSER

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Abstract:

This refrigerating plant use the ejector-injector to suck the freezing mixture from the evaporator and send it to condenser A pump draw the liquid from condenser and send it to a vessel then before the ejector-injector, a heat exchanger preheat the refrigeratin fluid to speed-up the mixture with sicked steam coming from the evaporator.
The compression of the steam is obtained using the kinetic energy in the ejector-injector and the pump supplies a discharge pressure to get operating the plant.
The heat trasfering fluid, the condensing and evaporating pressures and the energy loss fix the operating features of the plant.
An energy saving is obtained in this plant using an ejector - injector and it let a simple realization for mechanical refrigeration.
In this study are optimized the operating work conditions and is found the feasibility of the plant.

Resumè:

Cette installation frigorifique employers l'ejecteur pur sucer le fluide de le evaporateur e l'envoyer aux condenseur.
A pompe preleve le liquide dans le condenseur e l'envoyes aux vase, avant l'ejecteur a echanger de chaleur chauffe le fluide frigorifique pur envoyer le melange avec le vapeur venant de l'evaporateur aux condenseur.
La compression du vepeur est obtenue par l'utilization de la energie cinetique du vapeur dans le ejecteur e la pumpe consente de jouer a la installation.
Le fluide frigorifique, la pression aux condenseur e aux evaporateur e la energie perdue detaille le fonctinnement de l'installation.
Avec cette installation c'est possible de economiser l'energie e de simplifier la refrigeration mecanique.
Dans cette etude sont specifiè le possibilites de functinnement e l'efficacitè de l'installation.

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NOMENCLATURE

- P_1 = High pressure;
- P_K = Condensing pressure;
- P_v = Evaporating pressure;
- T_1 = High temperature;
- T_2 = Low temperature;
- n = Polytropic exponent;
- m = Specific mass;
- r = P_v / P_1 ;
- r' = P_K / P_v ;
- φ = Loss of pressure coefficient;
- L_c = Compression work;
- L_e = Expanding work;
- η = Efficiency.

INTRODUCTION

The following theoretical work concerns the study of a freezing cycle by replacing the compressor with an ejector-injector with the task to transfer the workig fluid from the enclosure of low pressure to the high one.
The injector that is inserted in the circuit in order to perform its functions must get the liquid at a pressure higher than the one, which is in the condenser and a heat exchanger that can be fed with heat waste.
In this work the possibol work conditions can be identified taking into account all the leakage in the recompression because of the gas mass that is aspirated in the evaporator.
We have noted that for predeterminated values of polytropic exponent, same work conditions are possible also in the case that the ejector efficiency is not higher than twenty-tow %.
A system solution as the one we have showed, can have a large employment in all those uses where there is a condition disponibility of heat wastes, both in fixed and movable installations.

PLAN OF THE CIRCUIT

In picture one there is the plan of circuit that particularly points out the assembly of the ejector-injector E between the separetor of the liquid SL and the condenser K .
The auxiliary components for its work as the pump of high pressure P and the heat exchanger S are pointed out.
As we can immediately see, the liquid which is taken by the collector RL is sent trough the pump P to the excanger S where having received the heat, it gets to the ejector as a physical state of steam.
In this system the depression in the section of the highest contraction of the flow, favours the recall of the steam from the evaporetor that mixed with the drawn fluid, comes to the condenser K .
Acting on the pump we get the regulation of the circuit working on the different characteristics of the pump.
With P_1 we have shown the highest pressure of the circuit,with P_K the pressure of condensation and with P_v the pressure to the evaporetor, such as $P_1 > P_K > P_v$.
With this hypothesis the expansion in the convergent is carried out between P_1 e P_K , whereas the recompression between P_v e P_K

WORK CONDITIONS

We get the speed of going out of the fluid drawn from the converging section of the ejector :

$$\frac{C_1^2}{2} = c_p \, T_1 \left[1 - \left(\frac{P_v}{P_1} \right)^{n-1/n} \right] \qquad (1)$$

where c_p is specific heat at costant pressure.
In the section of groove, by carryng out the balance of the momentum, if we suppose that m is the mass of the steam trown at the evaporator per Kg outflowing steam, we have

$$C_1 + m \, C_a = (1 + m) \, C_2$$

Without taking into consideration the term m C_a with respect to the others, we have:

$$C_1 = \frac{C_1}{1 + m}$$

from (1) we get :

$$\frac{C_1^2}{2} = \frac{1}{(1 + m)^2} \, c_p \, T_1 \left[1 - \left(\frac{P_v}{P_1} \right)^{n-1/n} \right]$$

The kinetic energy of the mixture, works, without the losses in recovery of pressure in the diffuser and, without considering the kineting energy at the drain, we have:

$$\frac{C_2^2}{2} = c_p\, T_2 \left[\left(\frac{P_K}{P_V} \right)^{n - 1/\,n} - 1 \right] \qquad (\ 3\ )$$

The working condition is due to the equality between the report (2) and (3).
Stating:

$$r = P_V / \, P_1$$

$$r' = P_K / \, P_V$$

and keeping into account the losses in the converging and in the diverging and considering that the mass m has been drown from the evaporetor it result that:

$$r' < \frac{1}{r}$$

keeping into account this fact we can insert a reducing cœfficent such as

$$r' = \varphi \, \frac{1}{r}$$

then stating :

$$\Theta = \varphi^{n - 1/\,n}$$

The connection determining the possible point of work is:

$$\frac{T_1}{T_2} \; \frac{1}{(\ 1 + m\ )^2} \left[1 - r^{n - 1/\,n} \right] = \Theta \left(\frac{1}{r} \right)^{n - 1/\,n} - 1 \qquad (\ 4\ )$$

The solution of equality (4) changing ratio r, can be fixed for prefixed values of the polytropic index n and and of the ratio $T_1 / \, T_2$ in function of the drawn mass m and of the loss pression coefficient φ .
The point of intersection of the two curves locates the point of working, having considered as simplifyng hypothesises:

that n polytropic index remaining costant
that c_p remains invariable in expantion and compression.

GRAPHS OF WORKING

We have considered a value of the polytropic index n equal to 1,4

and a ratio $T_1/T_2 = 1,3$ (also these two values can become parameters) and four different values for the mass $m = 0,05; 0,10; 0,15; 0,20$ and four values for the loss pressure coefficient of reduction $\varphi = 0,40; 0,50; 0,60; 0;70$.
On the graphs on the axis of the abscissas we show the ratio $r = p_v / p_1$ and in ordinates, changing parameters φ and m the two values:

$$A = \frac{T_1}{T_2} \frac{1}{(1 + m)^2} \left[1 - r^{n - 1/n} \right]$$

and

$$B = \vartheta \left(\frac{1}{r} \right)^{n - 1/n} - 1$$

The points of intersection of the two curves state the value of r, therefore the equality is satisfied, that the working condition is determined.
From the graphs of figure (2) it is possible to get the conditions for different values of m and of to which correspond values of r and we can se that the working field is wide enough.
Its further delimitation is made utilizing the graph of figure (3) that sets out the efficiency.
In the above shown graph we have found out the limit efficiency for this kind of device equal to 0,22 .

VALUATION OF EFFICIENCY AND LOSSES

The work of expantion that gets lost to compress the mass m is

$$L_e = c_p T_1 \left[1 - \left(\frac{p_K}{p_1} \right)^{n - 1/n} \right]$$

The work of compression that is carried out on the mass m per Kg of drawn steam is:

$$L_c = m c_p T_2 \left[\left(\frac{p_K}{p_v} \right)^{n - 1/n} - 1 \right]$$

The efficiency is:

$$\eta = \frac{L_c}{L_e} = m \frac{T_2}{T_1} \frac{\vartheta (1/r)^{n - 1/n} - 1}{1 - \vartheta}$$

For prefixed values of the ratio T_1 / T_2 and of the polytropic index n , the efficiency η is a function of the mass m and of the coefficient of reduction .
Increasing the ratio T_1 / T_2 the curves move down and up.
The losses are calculated in function of the reduction coefficient with the nondimensional relaction:

$$\text{Losses} / c_p T_1 = (1 - \eta)(1 - \vartheta)$$

From the graph of the efficiency we can get the value of the losses just in the point of working that is found out in the graph of figure (2).

CONCLUSIONS

This Theoretical study allows to find out possible conditions of working in a frigorific system in which an ejector-injector is used for the recompression.
What is important is comparing the experimental values in order to get the best cycle changing the operating fluid and the out line conditions.
A result like this gives the following advantages:

- Recovery of heat wastes from other tecnological processes;
- Better seal on the liquid in comparison with those on the gas;
- Absolute lack of the greezing oil in the operatig fluid;
- Building simplification also in the adjustment
- Cheaper cost of installation.

Such a solution can be used both in the fixed and movable installation provided that heat recovery with level of temperature above 60 - 70 C° is available.

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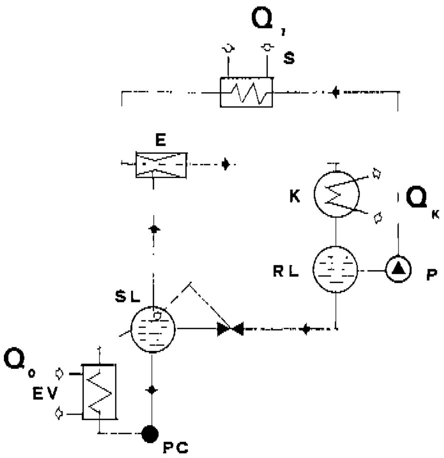
Figure 1



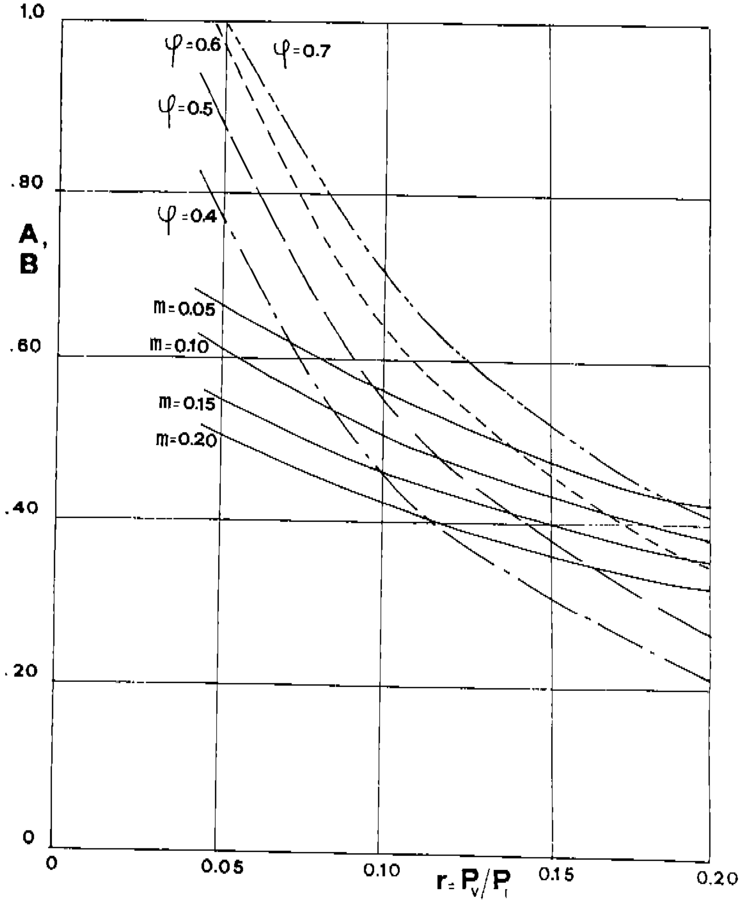
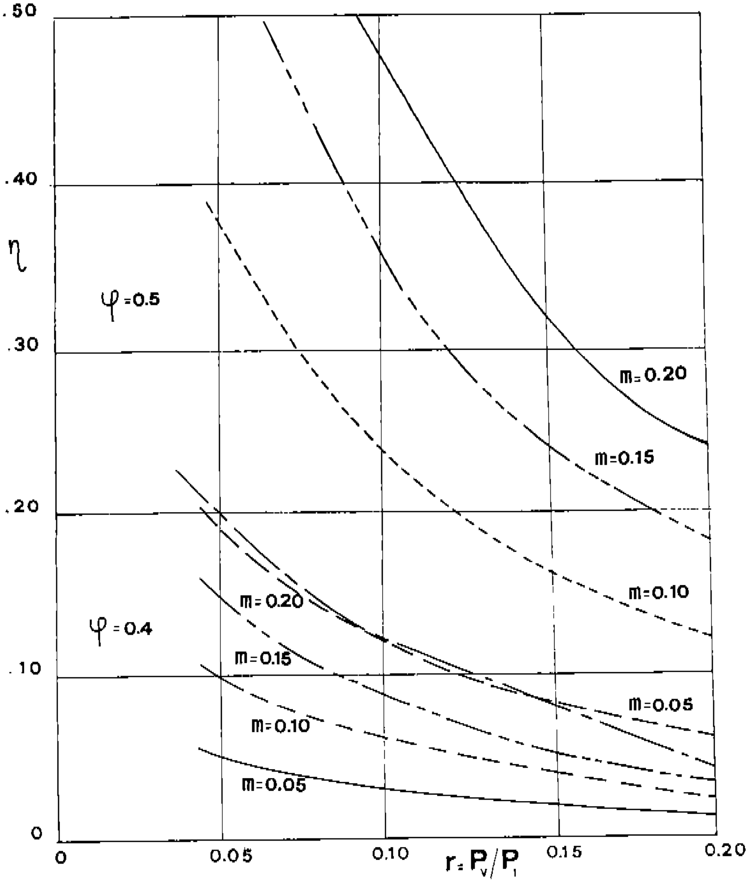


Figure 2

Figure 3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.40
.30
.20
.10
0
η
φ=0.5
φ=0.4
m=0.20
m=0.15
m=0.10
m=0.05
m=0.20
m=0.15
m=0.10
m=0.05
0
0.05
0.10
0.15
0.20
r=P_v/P_1