THE ESTIMATE OF A THREE-STAGE EQUIPMENT VACUUM PUMP WITH BAROMETER CONDENSATION

PRORAČUN TROSTEPENE EJEKTORSKE VAKUUM PUMPE SA BAROMETARSKOM KONDEZACIJOM

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Shown in this paper is the basic calculation and dimensioning of a three stage ejectors vacuum pump (steam-gas), condensers, pipes and ejector for achieving a vacuum of 0.995 bar, an absolute vacuum of 0.005 bar for the evacuation of the resulting vapor in storage vessels of edible oil. Vapor at the entrance is a mixture of non-condensing gases (20%) and air (80%). Condensation is done in two stages with the vacuum suction of the remaining gasses via the ejector. It is necessary to achieve an inlet flow of usable fluids of 130 kg/h.

Key words: Vacuum pumps; vacuum; condensation; ejectors

U ovom radu izvršen je osnovni proračun i dimenzionisanje trostepene ejektorske vakuum pumpe (para-gas), kondezatora, cevne mreže i ejektora za ostvarivanje vakuuma od 0.995 bar tj. apsolutnog pritiska od 0.005 bar za odsisavanje nastalih isparenja u posudi za skaldštenje jestivog ulja. Isparenja na ulazu su mešavina nekondezujućih gasova (20%) i vazduha (80%). Kondezacija se vrši u dva stepena sa međuvakuumskim usisavanjem preostalih gasova pomoću ejektora. Potrebno je ostvariti ulazni protok usaivanih fluida od 130 kg/h.

Ključne reči: vakuum pumpe; vakuum; kondezacija; ejektori

1. Introduction

Ejectors as jet pumps are just some of the names for equipment where two flows with different inlet pressure, flows and velocity mixes and after mixing, they continue to move together with some medium pressure and medium speed [1].

Ejectors have very simple geometry and do not have moving parts. Also, their work does not require electric energy [2].

In ejector inlets, there are two flows of fluids, one is operating and second is passive or secondary [1]. Fluid used to produce the vacuum is a primary or drive fluid, and the one who achieved the vacuum inserts, secondary. Drive and suction fluid induce liquids, gas, steam, emulsions, suspensions, etc.

As shown in Figure 1.1, the steam as a driving fluid achieves high pressure and low speed at the inlet and increases the speed through the nozzle, which results in the secondary fluid being sucked.

The paper analyzes the situation of extracting a mixture of gases from a storage vessel for raw materials in a unit for the production of edible oil.

During the processing of a raw material to produce edible oil, the liquid phase is obtained in the middle of the process, that is stored in containers from which it goes further into production. During storage the gas phase is released, representing a mixture of non-condensing gases and water steam (moisture), which is located at the top containers for storage. These gases require removal from the container using vacuum pumps, most often in the atmosphere, which means that the vacuum is high enough to achieve the suction of the mixture of gases.

Fig. 1.1. The part of the ejector.[4]

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2. Method

The subject of this research is a dimensioning system for extracting a mixture of gases from storage vessels in which raw material for producing edible oil is stored, according to the requirements for the flow on the suction. In this paper, equipment, which is an assembly of three-stage ejector vacuum pump with barometer condensation, was dimensioned.

Drive fluid is steam and secondary fluid is a mixture of gases in composition (20% non-condensing gases, 80% water steam).

Input data for three-stage ejector vacuum pump:

- Water steam pressure $P_1=13\text{bar}$ (absolute pressure),
- Temperature of water for condensation $T=15\text{ }^{\circ}\text{C}$,
- Evaporative flow at the entrance 130 kg/h ,
- Evaporative pressure at the entrance $P_2=0.995\text{ bar}$, absolute 0.005 bar .
- Contribution is 20% of gases at the inlet of sucked fluid.

Scheme of the system is shown in figure 2.1, where appropriate numbers of inputs and outputs are provided with counts for calculation of flow, pressure, temperature, driving steam, water and gases.

At the location number 2, the suction (required flow of 130 kg/h) of the gases from the container in which the raw material is stored is carried out by means of a vacuum obtained by passing the vapor (1) through the ejector. At the exit from the ejector, a mixture of steam and gases is obtained, which goes further to the condenser in which the condensation of 70-85% of the moisture takes place. At the exit of the first condenser (3), the non-condensing mixture of gases and water steam is re-pulled into the second ejector, resulting in a new mixture (6). In the second condenser, the process is repeated, whereby the task of this paper is achieved output pressure higher than atmospheric.

In table 1.1. The basic equations for getting properties of fluid in the corresponding cross section are given in Table 1.1.

Table 1.1. Equations for calculating the basic quantities of fluid states

Equations
$P_3 = \frac{P_2}{\left[1 - \frac{\psi \frac{k_1}{k_1 - 1} R_1 T_1 \left(1 - \left(\frac{P_2}{P_1}\right)^{\frac{k_1 - 1}{k_1}}\right)}{\frac{k_2}{k_2 - 1} R_2 T_2}\right]^{\frac{k_2}{k_2 - 1}}}$
$T_3 = \frac{T_1 + T_2 \mu}{1 + \mu}$
$Q_3 = Q_1 + Q_2$

3. Results

This section provides a basic view of the size of the mixture in the characteristic inputs and output cross sections.

Adjusting the coefficient of flow ratio of the drive and vacuum fluid $\mu = 0.5$ and from Figure 3.1, the value is read $\psi=0.32$.

Figure 3.1. The ratio of the energy of the mixture and the drive energy is reduced to 1 kg of the mass flow of the mixture and 1 kg of mass flow of the drive fluid, depending on the ratio of mass flows $\mu=Q_2/Q_1$. [5]

Based on the adopted ratio of flow, coefficient $\mu=0.5$, the value of the required flow of the primary fluid (water steam) is obtained.

Table 3.1. Values of the flow of the drive and sucked fluid

Paremeter	Value
The flow of the drive fluid (water steam)	$Q_1=Q_2/\mu=130/0,5=260$ kg/h
The flow of the sucked fluid	$Q_2=130$ kg/h
The ratio of the flow drive and secondary fluid	$\mu=0.5$

The basic equations for getting properties of fluid in the corresponding cross section are given in Table 3.2.

Table 3.2. Equations for calculating the basic quantities of fluid states

Equations
$P_3 = \frac{P_2}{\left[1 - \frac{\psi \frac{k_1}{k_1 - 1} R_1 T_1 \left(1 - \left(\frac{P_2}{P_1}\right)^{\frac{k_1 - 1}{k_1}}\right)}{\frac{k_2}{k_2 - 1} R_2 T_2}\right]^{\frac{k_2}{k_2 - 1}}}$
$T_3 = \frac{T_1 + T_2 \mu}{1 + \mu}$
$Q_3 = Q_1 + Q_2$

The results of mixture structure are given in tables 3.3, 3.4, 3.5.

Table 3.3. Values of the output parameters for the ejector 1.

Output from ejector 1	
Pressure - P_3	0.08183 bar
Flow - Q_3	390 kg/h
Temperature - T_3	418,483K

Табела 3.4. Values of the output parameters for the ejector 2.

Output from ejector 2	
Pressure - P_6	0,3925 bar
Flow - Q_6	374,206 kg/h
Temperature - T_6	425,206 K

Табела 3.5. Values of the output parameters for the ejector 3.

Output from ejector 3	
Pressure - P_9	1,606 bar
Flow - Q_9	359,424 kg/h
Temperature - T_9	425,206 K

Table 3.6 gives the values for the required quantity of water and the dimensions of condensers 1 and 2.

Figure 3.2. Input / input flow diagram for the condenser.

Table 3.6. The basic data for condensers 1 u 2.

	Condenser 1	Condenser 2
Input pressure- P_5/P_8	0,08183 bar	0,3925 bar
The water flow for condensarion- W_4/W_7	1,967 kg/s	1,877 kg/s
The flow of non-condensing mixture- W_5/ W_8	124,8 kg/h	119,808 kg/h
Output temperature- T_5/T_8	353,317K	356,678K

4. Discussion of results

The results related to pressure value, output temperature from the three-stage ejector vacuum pump lead to the conclusion that the application of the system in this case is satisfactory.

According to the conditions of the investor to achieve desire value of vacuum and secondary fluid flow, and for the adopted coefficient μ , the necessary water steam flow at the entrance to the ejector is reached. Values calculated in Table 3.3 represent the output parameters of the mixture from the ejector 1, which also relate to the input parameters of condenser 1.

From the mass and energy balance, the necessary flow of water at the input of condenser 1 and 2 was obtained to achieve a condensation of 70-85% moisture from the residues of the combustion. In further fluctuations, the assumed partly mixture (non-combustible gases with a part of the residual pairs) entered the ejector 2 and produced the characteristics of the mixture, and the output from the second vacuum level is given in Table 3.4.

The process in the second condenser acted as a tea outlet mix, which was vacuumed several times with the ejector 3, and as a system exit, the pressure was higher than the atmospheric pressure of 0.6 bar, the absolute pressure.

5. Conclusion

For the drive of the ejector, the energy of the drive fluid at the entry into the ejector is used. By passing the propulsion fluid to the flow of the ejector carrier, the pressure of the energy of the drive fluid is transformed into kinetic energy.

The advantages of the applied ejector for the proposed site entrances to its multiple removal include: simple designs, small masses and small dimensions, easy to handle and maintain, are simply mounted in all positions, there is no need to move parts and therefore do not involve masking, stable and noiseless work and has a ghost life. A great advantage is the reliance on the inexhaustible use of electrical power to start and operate these devices.

In alignment with a vacuum pump that uses electricity to create a vacuum, the installation of the ejector uses a pump that drives the primary fluid, steam for which the acquisition does not consume energy from the level of small-scale corruption in the plant.

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