SECTION 9

THE JET PUMP

When the flow of a fluid is induced by a jet of the same fluid from a fan or pump the device is known as a jet pump or ejector. The theory underlying this action is the transfer of momentum and the energy supplied minus the total friction losses will give the energy available in the induced flow.

The efficiency of a jet pump is inherently low and it demands care in design in order to approach conditions which may be termed satisfactory. The application in air flow is chiefly exhausting of fumes from chemical hoods or from spray booths, the purpose being to spare the fan from corrosive action or prevent clogging with deposits.

Design Data

The diagram on page 351 shows a typical jet pump consisting of a primary air nozzle and fan, a throat section and a diverging cone. The discharge may consist of a duct attached to the large end of the cone or it may terminate in a stack with conventional rain cap. The suction end will usually consist of an inlet duct or simply an open hood from which the gases are drawn.

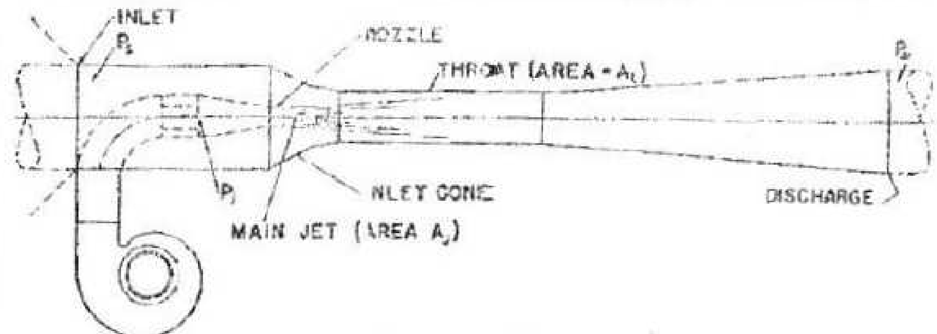
The design of the apparatus is often along purely empirical lines, the conditions of flow being required to fit some standard design. In order to avoid this difficulty it is better to know the limiting conditions of the principles involved and thus, where possible, design for maximum efficiency. We may write $E = Q_r P_r$ (273)

$$E_r = \frac{Q_s}{Q_j} \qquad P_r = \frac{P_d - P_s}{P_j - P_d} \qquad R = \frac{A_j}{A_t} \qquad (274) \quad (275) \quad (276)$$

where E = efficiency of jet pump
Q_s = quantity of secondary flow (suction)
Q_j = quantity of primary flow (main jet)
P_d = total pressure in discharge line
P_s = total pressure in secondary (suction) line
P_j = total pressure in primary (jet) line
A_j = area of jet
A_t = area of throat
Q_r, P_r and R = ratios of ratings as indicated

It may be shown that maximum efficiency depends upon the ratio R. The data given by the curves on page 352 are drawn mainly from tests on water by Gosline and O'Brien[3] at the University of California, supplemented by tests on air and water at the Buffalo Forge Company Laboratory. Curves for three conditions are given: high, average and minimum friction. The curve of high friction is that usually found in practise and means that the losses are high either from the standpoint of friction losses in the inlet or discharge lines or from the construction of the pump itself. The curve of average friction is for a well streamlined pump similar to that of the

[2] Refer to page 354.   [3] Refer to p. 354 for additional tests by Folsom.



Typical Jet Pump

accompanying illustration. The curve of minimum friction is a theoretical curve assuming no losses in inlet and discharge lines and minimum friction in the pump itself. It is not of commercial importance but represents extreme limiting conditions, about which there is still some doubt. It is seen that for best efficiency the value of R should be from .10 to .25. Since a value of $R = .15$ produces a smaller pump and one with nearly as good efficiency as one with $R = .25$ it is considered to be a more economical proportion both for the jet pump and for the fan itself.

Suggestions

For best operation the following suggestions should be observed:

a. The inlet cone should be of compound form to approximate a bell mouth shape.

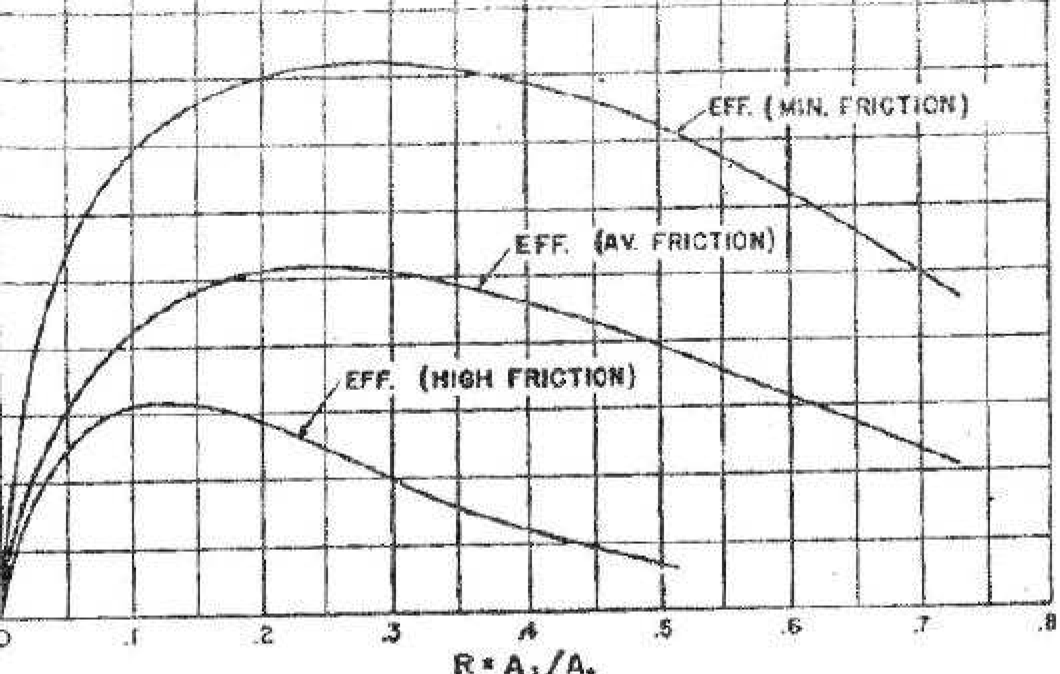
b. The throat should be of uniform section. This is the mixing chamber and its length will depend to some extent upon the pressure ratio P. High ratios will require longer lengths in order to bring the velocities to reasonable uniformity before entering the diverging cone and to obtain the maximum benefit of the latter. Generally the length of the throat section will vary from 1 to 6 times its diameter.

c. The diverging cone should have a total included angle of from 4 to 6 degrees. 10 to 15 degrees are sometimes used but these and larger angles may be used only at a sacrifice in efficiency.

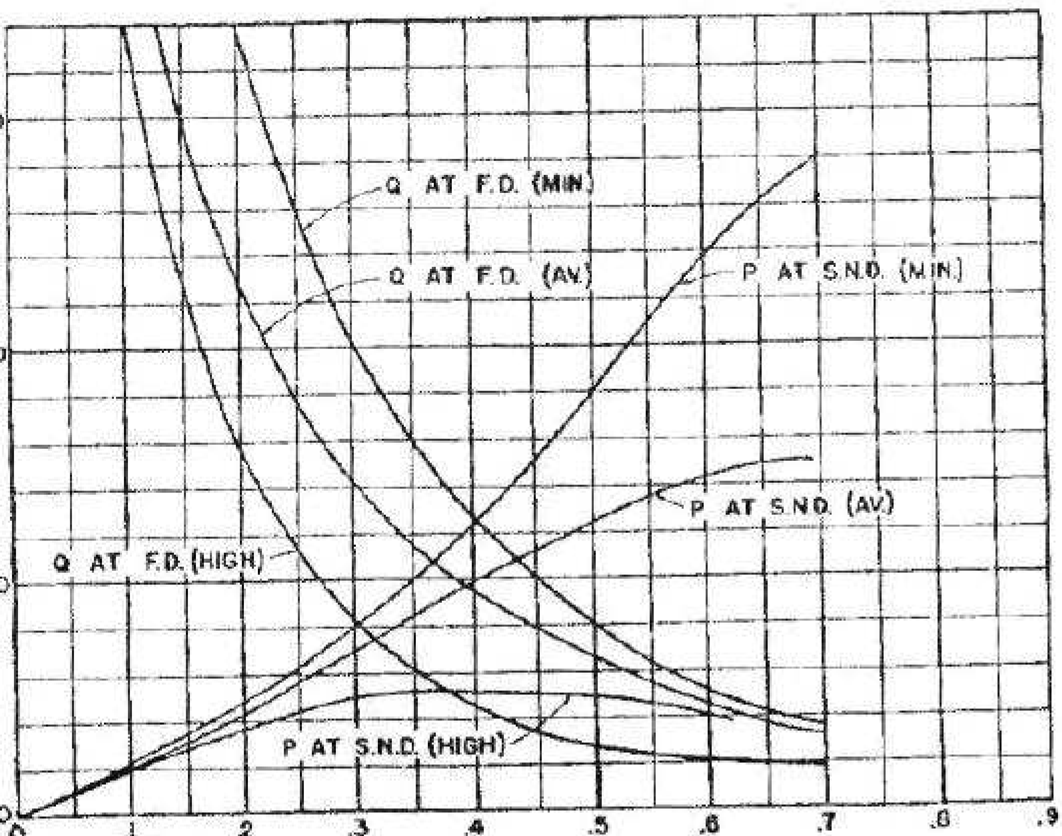
d. The ratio of the nozzle diameter to the diameter of the throat should be in the neighborhood of 1/3 to 1/2 for best efficiency. Where conditions make it necessary to use other proportions the curves on page 352 may be followed.

e. The diameters of the jet pump at inlet and outlet are usually from 2 to 2½ times the throat diameter. The diameter is a compromise between the use of large ducts for low loss and small ducts for economy of material. The duct on the inlet side may be smaller than this and enlarged [illegible] joins the pump. The outlet of the pump should not be lar[illegible] discharge duct.

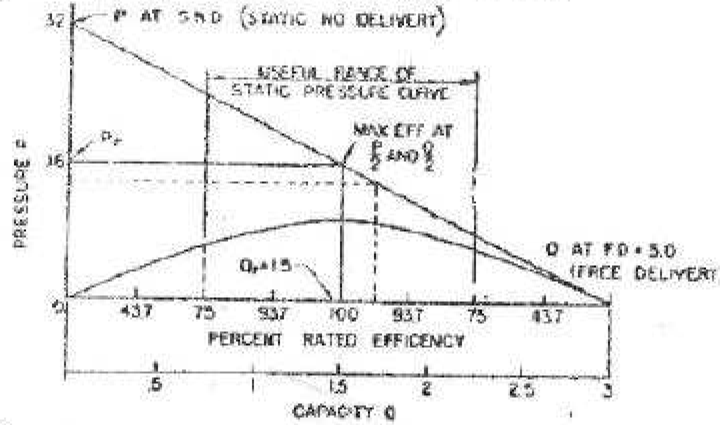
f. The air nozzle should be well centered in the duct and should preferably have straighteners ahead of it to reduce turbulence. The face of the nozzle from the beginning of the throat section will vary from 1 throat diameter for low values of R to 1 nozzle diameter for high values of R.



Efficiency of Jet Pumps



relatively low velocity and low elbow loss. Where the va
is large it may be necessary to modify this so that the e
not take up a large portion of the inlet duct.



Pressure Curve

The pressure-capacity curve for a jet pump is substa
straight line, sloping from maximum pressure at zero capac
is, static no delivery or *SND*) to maximum capacity at z
sure (that is, free delivery or *FD*). Although for large val
the curves are concave upward and for small values, co
ward, the middle half in each case can be very closely rep
by straight lines whose intercepts on the two axes are give
lower curves on page 352. Since maximum efficiency w
midway along these lines we may assume

$$P_r = \tfrac{1}{2}\, P \text{ at } SND \text{ and } \qquad Q_r = \tfrac{1}{2}\, Q \text{ at } FD \qquad (277$$

As an **example** of the design of a jet pump assume we
induce a flow of 2500 cfm and the static resistance of the
suction line is 1 125″ with free discharge, what air and pressu
be used at the fan nozzle and what are the best proportion
for the construction of the venturi? The velocity pressu
suction line for the above conditions is .125″ so the total pre
at the inlet to the jet pump $=1.125+.125=1.25''$. If w
jet pump that is fully streamlined, as shown in the accom
illustration we may assume an overall efficiency of 24 per ce
$R=.15$ which will produce an economically proportioned
the ratio of the nozzle to throat area $R=.15$ then the rat
nozzle to throat diameter $=\sqrt{.15}=.388$. From the curves
352 we can obtain the constants, Q at FD and P at SND, fo
of $R=.15$ and accordingly find Q at $FD=3$ and P at SN
Taking the mid-point for best conditions (24 per cent. e
as read from the efficiency curve for $R=.15$), $Q_r=1.5$ and
Substituting in formula *274*, $1.5=2500/Q_j$ and $Q_j=2500/1.$

cfm. Substituting in equation *275*, $.16=\dfrac{0-(-1.25)}{P_r-0}$ and th of throat section should be about 3 diameters long or about nches. If we assume a diverging angle of 8 degree the length he diverging cone will be 11 feet. The end of the nozzle can be 10 inches from the throat.

the diameter of the suction and discharge lines to the jet pump made 2 to 2½ times the throat diameter we will have low entrance and effective regain in the diverging cone. Let us assume a 28″ ion and 32″ discharge. The 18 inch suction line should be coned to the 28″ suction inlet of the pump by a diverging connec. This will reduce the velocity around the jet elbow and minie disturbance. The diameter of the fan duct will be approxiely 2 times the nozzle diameter and may be 10″ in this case. btain the pressure at the fan the losses in the nozzle straightener, w and duct should be added to the 7.8″ nozzle pressure. These be calculated independently but in general will be from 5 to er cent. of the nozzle pressure. Assuming 7½ per cent., the fan e will be $1.075 \times 7.8 = 8.4''$.

may prove that the values of Q, and P, for the mid-point do work out as desired, in which case any other point may be ted using the oblique line as if it were a fan test curve. Thus, $= .6$ of $3 = 1.8$ is taken as the volume ratio than $P = .4$ of $.32 =$ may be taken as the pressure ratio. Note that if .4 of Q at FD ken, then the value to be taken for pressure is (1 − .4)² at SND P at SND. The efficiency as given from the efficiency curves is he mid-point. To find efficiency for other than mid-point rating tiply relative capacity by relative pressure and divide by former

$$\text{eff} = 24 \times \frac{.6 \times .4}{.5 \times .5} = 24 \times .96 = 2\ \text{per cent.}$$

luct. Thus in this case, eff $= 24 \times \frac{.6\times.4}{.5\times.5} = 24 \times .96 = 2$ per cent.

he effect of temperature on the performance of a jet pump is well established. If both primary and secondary air are at the e temperature but elevated above normal, the rule given here ld seem to apply but the pressures would vary directly as the sity for the same volume flow and inversely as the density for same weight flow. If the primary air is room air and the secondary is at elevated temperature, as is frequently the case, the exit city must be based on mean temperature of the mixture. Goff Coogan² in tests of this character show that as the ratio of mary to secondary density goes up, the weight ratio goes down not as fast as might be anticipated by the density change alone.

liography

The Water Jet-Pump". J. E. Gosline and M. P. O'Brien. University of Cali a Publications in Engineering. Vol. 3, No. 3, pp. 167-190.
Some Two-Dimensional Aspects of the Ejector Problem". J. F. Goff, C. H an. A.S.M.E. Journal of Applied Mechanics. Dec. 1942.
Theory of Ejectors". H. G. Elrod, Jr. A.S.M.E. Jour. of App. Mech. Sept. 1945.
A Simple Air Ejector". J. H. Keenan, E. P. Neumann. A.S.M.E. Journal of

The field of air conditioning encompasses the subjects of he ventilating, humidity control, cooling and refrigeration and ... fication. Comfort air conditioning has been defined by the A.S.H... as "the process by which simultaneously the temperature, mo... content, air movement and quantity of air in enclosed spaces be maintained within required limits. If an installation canno... form all these functions it shall be designated by a name ... describes only the function or functions performed." The pa... applications to comfort and industrial air conditioning are ... ered in the following sections. Problems involving drying, ... tion, and industrial exhaust systems have proved of such imp... that each has been allotted a separate section. In each ... applications the importance of the fan as an integral part ... air conditioning system justifies the inclusion of the subject.

SECTION 1

HEATING

Heat is usually transferred to bodies to be heated by radi... or convection. Radiant heat from an open fire was probably ... first attempt to utilize fuels in an attempt to keep comfort... Later the addition of a chimney and a fireplace materially imp... the efficiency of his heating system and permitted some cont... heat flow.

Modern heating methods are much more elaborate. The he... of buildings can be accomplished by many methods and the ... mental requirements and the results desired are the same i... systems, namely to provide sufficient heat to take care of the ... tion and infiltration losses, and if ventilation is required, to ... the air required for that purpose. The art of heating compri... the oldest of air conditioning applications, and in this the ... playing an increasingly important part.

Methods of Heating Radiation

The common radiator has been briefly discussed (see page 71) is used in hot water and steam systems. As such, only a part o... heat is given off by radiation the remainder by natural convec... The development of the indirect heating system arose from natural desire to augment the heating capacity by increasing th... circulation, first by properly designed enclosures and second by systems. This decreased the proportion of heat purely radiated very small amount.

The newer type of radiant heating called "panel heating" another form of heating by direct radiation. It depends prima... upon imbedding heating coils in various portions of the floor, ...