Steam Jet Ejectors in Pilot and Production Plants

Since pilot plant work is on a small scale, the types of steam jet ejectors that are used are not necessarily scaled-down versions of production plant ejectors. Economy of steam and water is not the governing factor; first cost is of more interest.

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STEAM JET EJECTORS ARE EMPLOYED in the chemical process industries and refineries in numerous and very often unusual ways. They provide, in most cases, the best way to produce a vacuum in these process plants because they are rugged and of simple construction—therefore, easily maintained. Their capacities can be varied from the very smallest to enormous quantities. Because of their simplicity and the manner of their construction, difficulties are unusual under the most extreme conditions. They are simple to operate. Ejectors which are properly designed for a given situation are very forgiving of errors in estimated quantities to be handled and of upsets in operation and are found to be easily changed to give the exact results required.

In pilot plant operations all of these are important functions, because in a pilot plant a great deal of information is usually unknown, and something must be selected which will operate over a very wide range.

Therefore, this article will outline the differences between ejectors for a pilot plant and those for a production plant, pointing out that pilot plant ejectors are not just small editions of production plant ejectors.

In order to become fully versed in the essential elements that make up a steam jet ejector, the principle of operation will be considered first.

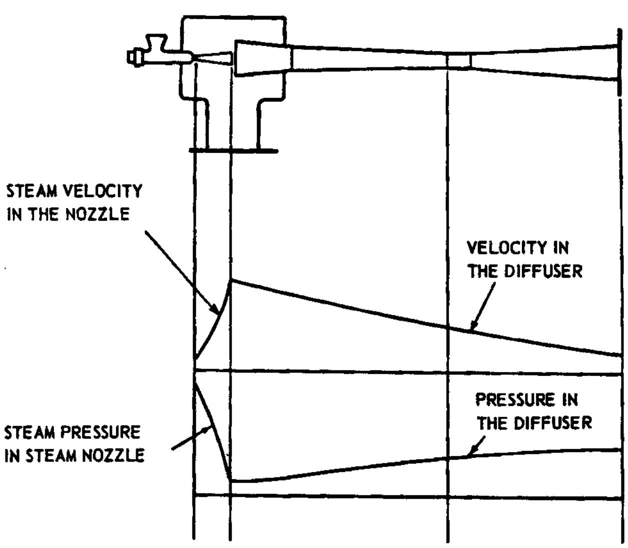

Figure 1. Conversion of steam pressure into velocity in the steam nozzle and conversion of velocity into pressure in the diffuser.

In reference to Figure 1, there are the following parts:

1. The steam chest through which the propelling steam is admitted
2. The steam nozzle through which the propelling steam expands and converts its pressure energy into kinetic energy
3. The air chamber through which the air, gas, or vapor to be evacuated enters and distributes itself around the steam nozzle
4. The diffuser through which the steam and entrained load is compressed and discharged at some pressure higher than the suction

All steam ejectors, no matter how many stages and whether they are condensing or noncondensing, operate on this principle, each stage being another compressor.

TYPES OF EJECTORS

Ejectors may, in one sense, be put into two categories: condensing and noncondensing. Figure 2 illustrates a three-stage condensing air ejector and a three-stage noncondensing air ejector.

The condensing type utilizes condensers between ejector stages to remove condensable vapor and, therefore, require a source of cooling water. The noncondensing ejector has its stages connected directly together, with succeeding stages handling the motive steam from preceding stages. This type requires no cooling water. However, it uses considerably more steam than the condensing type to handle a given load.

Ejectors for pilot plants differ from production plant units inasmuch as noncondensing~type units are normally recommended wherever possible. However, they may be, and sometimes are, similar. Of course, pilot plant ejectors are smaller, since they are designed to handle a smaller load than handled by full-size production plant ejectors.

In Figure 3, note the plot of ejectors which have been selected for standard-size plants. To make up this family of curves, steam and water consumption have been considered, and the ejector type shown is one that has a reasonable steam consumption with a reasonable first cost. Usually, higher first cost means lower steam consumption and better economy in the long run.

The plot in Figure 4 illustrates pilot plant ejectors. In this plot, note that two- and three-stage condensing units have been eliminated, shutoff pressures of various other units have been altered, and a four-stage noncondensing curve has been added.

In order to illustrate the differences between the application of jets to pilot plants and to full-size facilities, suppose one is choosing an ejector for operating at 20 mm. Hg abs. For a pilot plant, one would select a two-stage noncondensing ejector. However, as can be seen from the curve, if it were being selected for a production plant, one would probably choose a two-stage condensing system.

Further, if one were selecting an ejector to run on a pilot plant at 5 mm., a two- or possibly three-stage noncondensing jet would be used. In reference to the production plant chart, note that economy requires the use of a three- or perhaps four-stage condensing jet, the four-stage unit being more economical to run.

Should one desire a 1-mm. system, one would use a three- or four-stage noncondensing ejector on the pilot plant. For the production plant, one would need a four-stage condensing unit.

Many processes today are being investigated at 500 micron or lower in absolute pressure. For the small loads that would be encountered in the pilot plant, a four-stage non-condensing unit may do, yet the curve shows that for the production plant a four- or five-stage condensing unit would be required.

When an ejector is required for pilot plant operation below 500 micron, it normally becomes necessary for the ejector manufacturer to supply intercondensers of some type. For the pilot plant, the direct contact, or barometric condenser is probably the most satisfactory, since it is the most trouble-free condenser. However, if conditions require that the condensate be recovered, the surface type is necessary. When surface-type units are selected, they should be of such a design that the process side may be readily cleaned and inspected.

These considerations all revolve around economy. For small ejectors handling pilot plant loads, it is possible to supply a piece of equipment with a low first cost and a reasonable steam consumption, yet if one were selecting a unit sized for, say, ten times the capacity, one would approach the problem in a different manner, since the cost of steam used always amounts through the years to far more than the original cost of the equipment. In the pilot plant, the ejector is not used very often over long periods of time. Therefore, steam consumption is not an essential consideration when selecting an ejector, and the non-condensing type is normally recommended. Though it may lack economy, the noncondensing type is relatively inexpensive and extremely simple. Since it requires no condensing water, it offers another advantage in that there is no problem of condensate removal. It can be mounted at ground level, as opposed to the required barometric leg on the condensing type with the barometric condenser and, of course, when the surface-type intercondenser is used, a condensate removal pump, or other means, is required to drain the intercondensers.

MATERIALS OF CONSTRUCTION

In the selection of ejectors for pilot plants, it is recommended that alloys or corrosion-resistant materials always be selected. This recommendation is made for the following reasons:

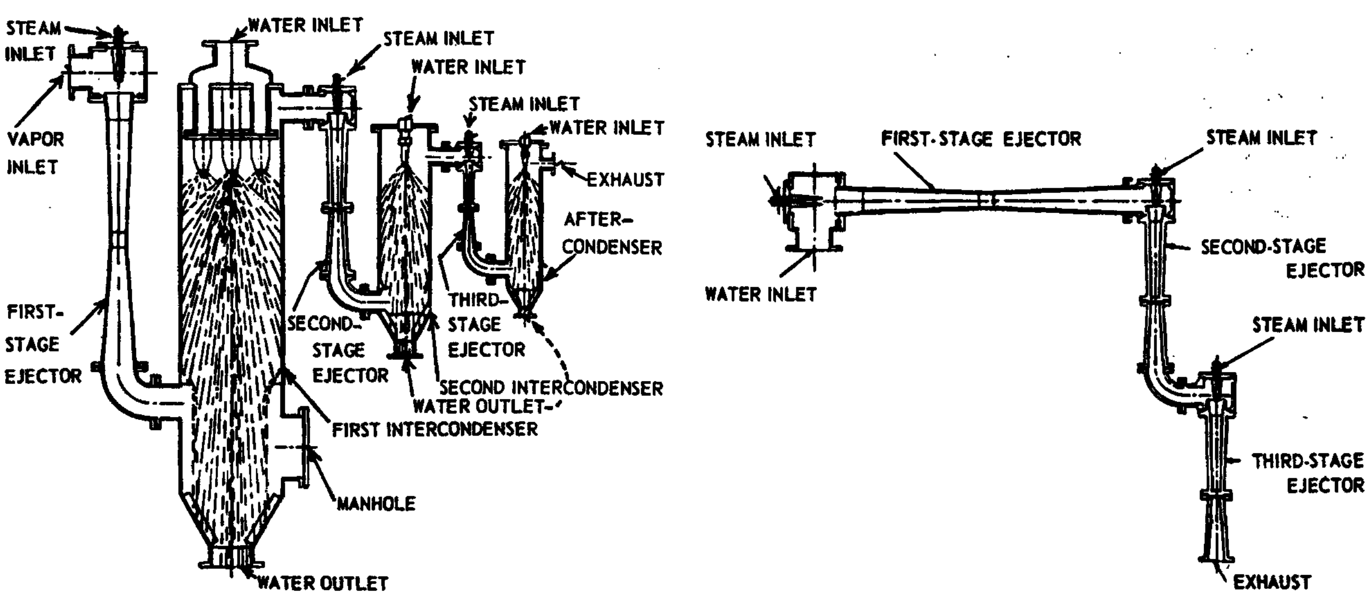

Figure 2. Three-stage condensing air ejector (right) and three-stage noncondensing air ejector (left).

1. Many times the pilot plant will be used for only a short period of time, and if the ejector is purchased as manufactured from one of the more corrosion-resistant alloys, it can be used again at another location.
2. This type of ejector is so small that the alloy from which it is manufactured has relatively little to do with the overall price.
3. Many times it is impossible to determine under what conditions the pilot plant will operate, and it is unknown just exactly the service to which the ejector will be subjected. An alloy gives the best protection for this situation.

In order to give some idea as to the installed costs of ejectors, Table 1 shows estimated installed costs for production plant ejectors. In Table 2 are estimated installed costs for pilot plant ejectors. These estimates are based on the ejectors shown in Figures 3 and 4 and indicate ejectors which use approximately 1,000 lb./hr. steam and have capacities as shown.

The curves in Figures 3 and 4 are for a noncondensable load. For units which have a condensable and noncondensable load combined, these curves will not apply and may be much different.

Figure 5 shows a portable pilot plant ejector which many process plants find expedient and extremely economical. A four- or five-stage ejector has been selected for a nominal capacity and has a typical operating curve as indicated in Figure 4. It has been selected for the largest probable load that the pilot plant will have and is so arranged that it can be operated as a five-stage ejector with its characteristic curve, a four-stage ejector with its characteristic curve, etc., down to a single-stage unit. The unit is self-contained and has found wide use in plants where many different pilot operations are run in a short time period.

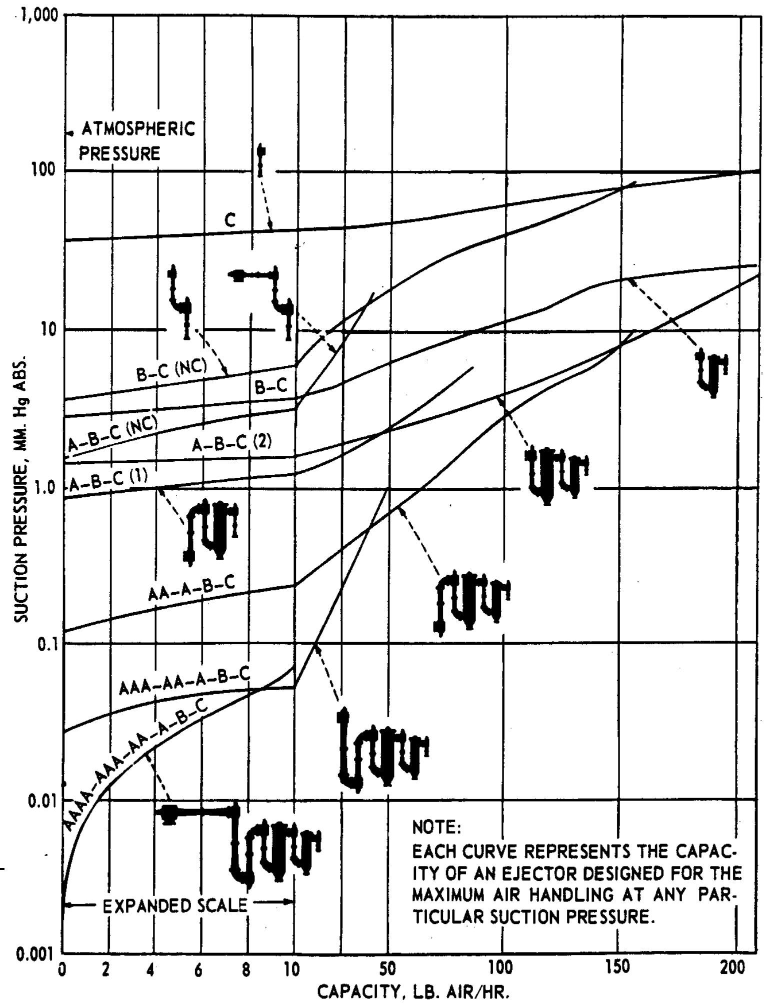

Figure 3. Plot of production plant ejectors.

Table 1. Installed costs of Figure 3 production plant ejectors using barometric-type condensers (approximately 1,000 lb./hr. steam), with estimates for other capacities.

Ejector	Figure 3	2X	4X	1OX
Single-stage, noncondensing	$ 1,200	$ 1,400	$ 1,850	$ 2,800
Two-stage, noncondensing	1,800	2,200	3,150	4,700
Three-stage, noncondensing	2,400	2,900	4,150	6,500
Two-stage, one-condenser	4,200	5,800	8,200	12,600
Three-stage, two-condenser	6,600	8,700	12,400	18,800
Three-stage, one-condenser	5,800	7,900	10,800	16,600
Four-stage, two-condenser	10,600	13,400	19,500	29,800
Five-stage, two-condenser	16,300	23,800	34,000	53,600
Six-stage, two-condenser	19,200	27,300	39,200	60,600

***Note**: The above figures are based on the load being totally noncondensable and will not apply when a mixture of condensable and noncondensable vapors is present. Multistage ejectors are based on nominal suction pressures, and figures will vary slightly for higher or lower pressures.*

OPERATION AND MAINTENANCE

There are a few rather simple rules to follow in the operation and maintenance of any ejector equipment, and if the operator will adhere to these rules, little or no difficulty may be expected.

1. It is essential that the joint between the steam nozzle and the steam chest be tight so that there are no steam leaks at this point. A steam leak at the back of the nozzle acts like an additional load on the ejector and will tend to decrease the vacuum that this apparatus can produce.
2. Be sure that steam is supplied at the design pressure and temperature. Lower steam pressures cannot be tolerated under any circumstances on most ejectors, and higher steam pressures cause them to use more steam with no increase in capacity. Best results are obtained when the operating pressure is held as close as possible to the design pressure.

3. Keep the nozzles clean. It will be found that when a new system is started pipeline chips and other foreign matter are carried in the steam lines to the ejector strainer and that certain particles may pass through this strainer and plug up the steam nozzle. This will show up in loss of vacuum. It is advisable to blow out the strainer frequently upon first starting up and, if necessary, to check the nozzles by removing the plug at the back of the steam chest and passing the proper reamer through each nozzle to make sure it is not plugged.

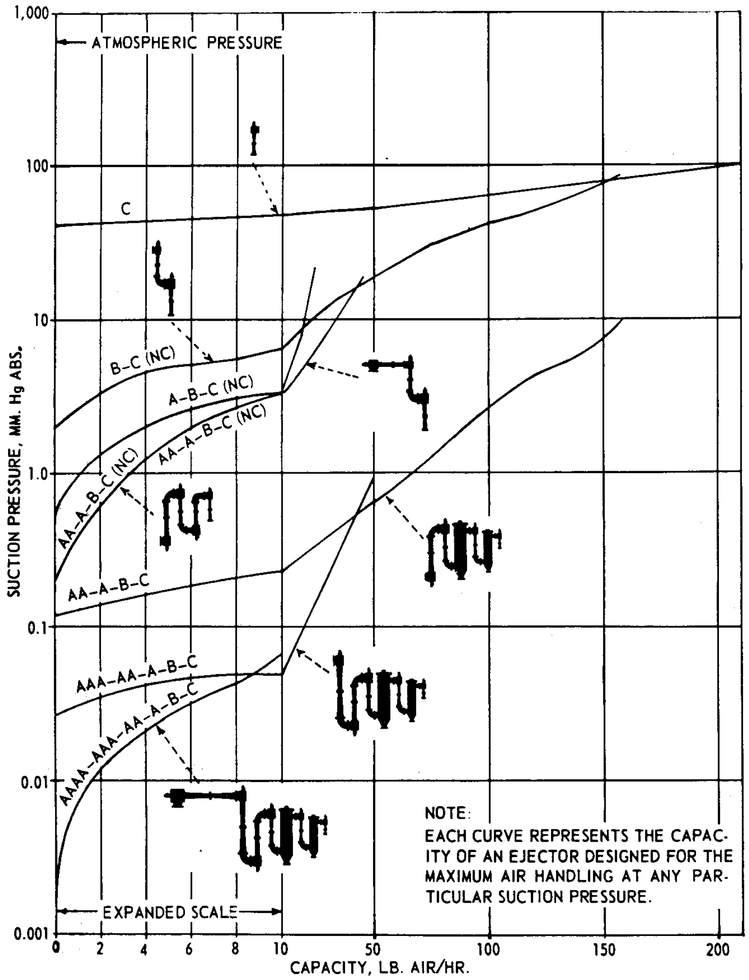

Figure 4. Plot of pilot plant ejectors.

Table 2. Installed costs of Figure 4 pilot plant ejectors (approximately 1,000 lb./hr. steam), with estimates for other capacities.

Ejector	Figure 4	0.25X	0.5X	2X
Single-stage, noncondensing	$ 1,200	$ 600	$ 850	$ 1,400
Two-stage, noncondensing	1,800	860	1,250	2,200
Three-stage, noncondensing	2,400	1,200	1,800	2,900
Four-stage, noncondensing	3,200	-	2,950	4,100
Four-stage, two-condenser	10,600	5,500	7,100	13,400
Five-stage, two-condenser	16,300	8,600	11,100	23,800
Six-stage, two-condenser	19,200	-	14,600	27,300

Note:*The above figures are based on the load being totally noncondensable and will not apply when a mixture of condensable and noncondensable vapors is present. Multistage ejectors are based on nominal suction pressures, and figures will vary slightly for higher or lower pressures.*

4. The steam supply piping to the ejector should be of sufficient size to pass the steam required by the ejector with no appreciable pressure drop. The steam supply piping should also be short enough to assure design operating pressure. The ejector will operate most efficiently on dry steam; thus, the steam supply piping should be insulated to prevent excessive condensation before the steam reaches the ejector. Shortness of steam pipe will also reduce condensation. If there is any doubt as to whether the steam is dry, a moisture separator should be installed in the line.

5. If the unit has an intercondenser or aftercondenser of the surface type, the tubes should be kept clean on the water side. When these tubes foul up, they will fail to transfer sufficient heat to condense the steam, in which case steam will discharge to the next-stage ejector or to the air vent of the aftercondenser. In the case of an intercondenser, this, of course, means loss of vacuum.

6. The ejector should be placed as close as possible to the vessel which is to be evacuated to minimize pressure drop.

It should be emphasized that the steam jet ejector is one of the most foolproof, trouble-free pieces of apparatus that operate in any vacuum cycle. This does not mean that the apparatus can be abused beyond all limitations, nor does it mean that it can be ignored indefinitely, insofar as inspection, maintenance, and repair are concerned. It simply means that it is one of the most dependable sources of vacuum that can be purchased.

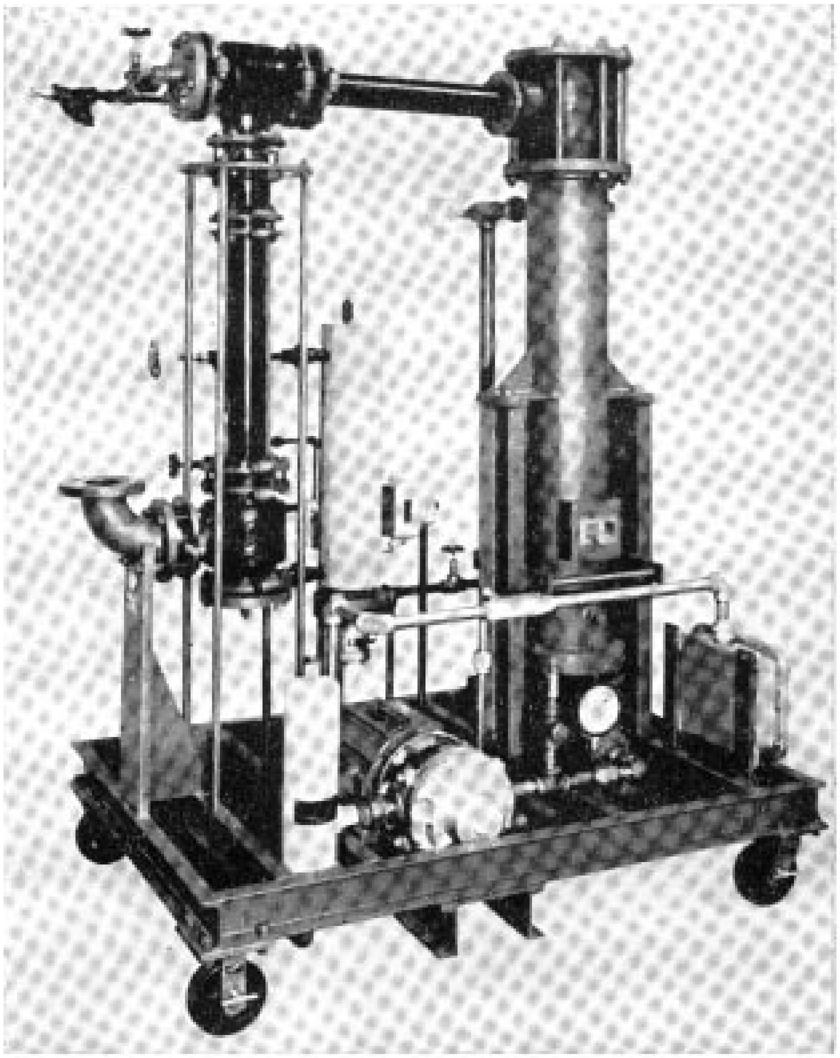

Figure 5. Portable pilot plant ejector.

CONCLUSIONS

1. Pilot plant ejectors should be as simple as practical, and where possible noncondensing type ejectors are recommended.
2. For the pilot plant, little consideration should be given to steam and water consumption of the ejector, since it will be used for such a short period of time. Usually, first cost is the most important consideration. This is not the manner in which production plant ejectors should be selected. In this case, ejectors should be selected for economy of operating costs.
3. When it is necessary to use a condensing-type ejector in a pilot plant, the surface type is normally not recommended unless the condensate must be recovered. The barometric type is simpler and more trouble-free, and there is little hazard from contaminating water supplies, because the quantities handled are so small.
4. It is suggested that for pilot plant ejectors corrosion-resistant or alloy materials always be selected which are compatible with all the known fluids to be handled. Since these ejectors are small, these materials have little to do with the original cost and may save shutdown.

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