Steam Jet Ejectors
Critical Function in Processing Fats, Oils and Related Material

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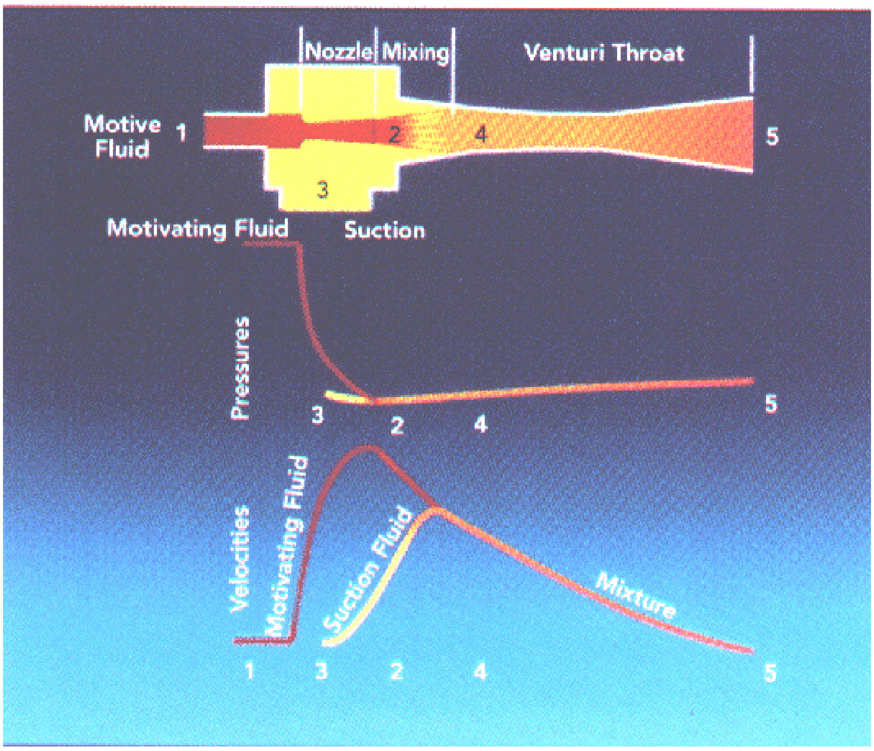
For many years, steam jet ejectors have offered a reliable and economical means of producing vacuum in fats and oils processing. They have a low installed cost and , though the simplicity of their construction, provide years of trouble-free operation. Steam ejectors continue to evolve with the development of new materials of construction, new nozzle configurations and other innovations that enhance the benefits of the basic technology.

The principle of operation of a steam jet ejector is very simple.



A high pressure motivating fluid enters at 1 and expands through the converging-diverging nozzle to 2, the suction fluid enters at 3 and mixes with the motivating fluid in the mixing chamber 4; both fluids are then recompressed through the diffuser to 5.

Then why are ejectors and the vacuum systems so different from manufacturer to manufacturer?

The answer is not difficult. The differences lie in the fact that ejectors are developed empirically. The internal profile, the relation between throat diameter, cone length and motive nozzle position are different for each manufacturer. Some of these manufacturers, like **Croll-Reynolds** have almost a century of experience. This experience means years and years of study and tests, in order to develop more efficient jets, but this is not the only consideration.

The experience in manufacturing must come together with the expertise in application engineering. To design a good vacuum system it is important to understand the customer's needs and working with the customer in order to identify what the needs are.

Today, during the development of a vacuum system, the supplier must clearly understand the customer's process, the way this process changes during the year and what are the customer's expectations.

Customers in the edible oil industry are always trying to get more from existing equipment. Every gain in capacity, in quality or tocopherol recovery is pursued.

A vacuum system should not be designed too "tight." This doesn't mean that a huge safety factor should be applied, but only that the tried and true engineering practice should be observed.

The following example shows two vacuum systems. System A is designed tight and System B using tried and true engineering practice.

Let's say that our customer is located in a tropical country and that the plant site is approximately 2625-ft (800 m) above sea level. The deodorization unit is designed for 400 tons/day of soybean oil.

Design data informed by the customer:

Suction flow: air = (33 #/h) 15 kg/h
water vapor = 1.5% = (550) 250 kg/h
free fatty acids = (22#/h) 10 kg/h (MW = 280)
Suction pressure: 1.5 torr at the ejector
Suction temperature: 167 ºF to 176 ºF (75 ºC to 89 ºC)
Motive steam pressure: 113 psig (8 kgf/cm² G) at the jets
Cooling water temperature: 82.4 ºF to 86 ºF (28 ºC to 30 ºC)

SYSTEM A	SYSTEM B
Suction temperature = 167 ºF	Suction temperature = 176 ºF
Equivalent vapor load as per HEI	Equivalent vapor load as per HEI
(33 x 0.81)/0.976 + 550/0.968 = 596 #/h	(33 x 0.81)/0.974 + 550/0.965 + (22 x 0.81)/(0.974 x 1.6) = 609 #/h

The load in system A is approximately 2% smaller than in system B

W stage sizing: suction 1.5 torr, discharge = 12 torr will be the same for both systems.

Steam consumption = 1332 #/h	Steam consumption = 1370 #/h
Suction connection = 30"	Suction connection = 36"
Suction velocity = 134 m/s	Suction velocity = 97 m/s
Discharge connection = 24"	Discharge connection = 30"

X stage sizing

Suction pressure = 11.5 torr	Suction pressure = 11 torr
Discharge pressure = 1.6535 in (42 torr)	Discharge pressure = 1.9685 in (50 torr)
Steam consumption = 2416 #/h	Steam consumption = 3100 #/h
Suction connection = 24"	Suction connection = 30"
Discharge connection = 22"	Discharge connection = 24"
Discharge velocity = 88 m/s	Discharge velocity = 74 m/s

Main Inter-Condenser sizing

Water vapor load = 4298 #/h Air load = 33 #/h Inlet temperature = 320 ºF Inlet cooling water = 82.4 ºF Outlet cooling water = 92.3 ºF Operating pressure = 1.6535 in Dissolved air in the cooling water = No (zero) Cooling water flow = 987 gpm Condenser diameter = 36” Air outlet temperature = 87.4 ºF	Water vapor load = 5020 #/h Air load = 33 #/h Inlet temperature = 320 ºF Inlet cooling water = 86 ºF Outlet cooling water = 97.9 ºF Operating pressure = 1.9685 in Dissolved air in the cooling water = Yes (9.72 #/h) Cooling water flow = 960 gpm Condenser diameter = 42” Air outlet temperature = 91 ºF

Y stage sizing

Air load = 33#/h Water vapor load = 77 #/h Suction pressure = 1.6535 in Discharge pressure = 6 in Steam consumption = 190 #/h Suction/Discharge connection = 4”	Air load = 33#/h + 9.72 #/h = 43 #/h Water vapor load = 77.5 #/h Suction pressure = 1.9685 in Discharge pressure = 7 in Steam consumption = 200 #/h Suction/Discharge connection = 4”

Secondary Inter-Condenser sizing

Water vapor load = 257 #/h Air load = 33 #/h Inlet temperature = 320 ºF Inlet cooling water = 82.4 ºF Outlet cooling water = 113 ºF Operating pressure = 6 in Dissolved air in the cooling water = No (zero) Cooling water flow = 13 gpm Condenser diameter =8” Air outlet temperature = 113 ºF	Water vapor load = 277.5 #/h Air load = 43 #/h Inlet temperature = 320 ºF Inlet cooling water = 86 ºF Outlet cooling water = 106 ºF Operating pressure = 7 in Dissolved air in the cooling water = Yes (1 #/h) Cooling water flow = 22 gpm Condenser diameter =9” Air outlet temperature = 106 ºF

Z stage sizing:

The barometric pressure for a site at 2625 ft (800 m) is approximately 27.295 in (691 torr)

Air load = 33#/h Water vapor load = 19 #/h Suction pressure = 6 in Discharge pressure = 27.195 in Steam consumption = 170 #/h Suction/Discharge connection = 2”	Air load = 43#/h + 1 #/h = 44 #/h Water vapor load = 13.3 #/h Suction pressure = 7 in Discharge pressure = 30.2 in Steam consumption = 180 #/h Suction/Discharge connection = 2”

Steam consumption for boosters (W and X stages)	**3748 #/h**	**4470#/h**
Steam consumption for Y and Z stages	**360 #/h**	**380 #/h**
Total steam consumption	**4108 #/h**	**4850 #/h**
Cooling water for main condenser	**987 gpm**	**960 gpm**
Cooling water for inter-condenser	**13 gpm**	**22 gpm**
Total cooling water consumption	**1000 gpm**	**982 gpm**

We have to keep in mind that a vacuum system must always be designed for the worst condition, otherwise it will not work properly if and when this condition occurs.

Let us now check the differences between the two systems:

1. The velocities inside the scrubber lies between 40 to 60 m/s. The suction velocity of the W stage should not be higher than 120 m/s, in order to avoid the conveying of small droplets of oil and fatty material from the scrubber through the jets.

Higher velocities will also generate a high pressure drop in the scrubber, reducing its efficiency.
The oil and fatty acids conveyed into the vacuum system, depending on the layout of the boosters, will rest in the bottom of the head of the jets and sometimes also in the first and second cones of the diffuser, reducing the performance of the system.
The oil and fatty acids will also contaminate the cooling water and the cooling tower.

2. The discharge pressure of the W stage and the suction of the X stage, in theory are exactly the same but the performance of the system as a whole depends on the interstage pressures and these two jets are not allowed to fail. In order to prevent failure, an overlap between the two pressures is mandatory.

3. The main condenser must be designed for the maximum cooling water temperature, even if this temperature happens only some weeks of the year. A good condenser should be designed to operate at a safe pressure. It is not reasonable to buy a system using a lower steam consumption and having to change the jet nozzles, using more steam in order to try to reach the available condenser pressure.

4. The load to the Y stage must also consider the added load of air, that is released by the cooling water. This is more critical in the main condenser.

5. The velocity at the inlet of the condensers must also be limited to 80 m/s. Higher velocities will also cause problems of pressure drop, poor operation and fast material wear.

6. The discharge pressure of the Z stage must always consider a safety factor, because this last stage hardly discharge directly to the atmosphere. It is very common to discharge it into the hotwell.

These are the basic technical points that are rarely checked by the buyers and users of a steam jet vacuum system. Remember to check these points the next time you receive a quote in order to fairly compare different bidders.

In this example we considered the use of a direct contact condenser. The use of surface condensers is also possible but a little more complicated. The perfect selection of the operating pressure of a surface condenser must take into consideration the following:

A. If the vacuum system will use only ejectors, or if the Y and Z stages will be replaced by a liquid ring vacuum pump.

B. The highest cooling water available.

C. The quality of the cooling water.

D. The fouling factor that should be applied to both sides (tubes and shell).

The operation of the vacuum system with surface condenser will be smooth if a recirculation circuit with soda + condensate driven constant to the top bonnet of the condenser is kept at the bottom bonnet with a PH of 10.

Price differences are easy to explain once we already know the technical differences. Well designed equipment is physically larger than others, and as consequence will cost more.
There is also the factor “manufacturing quality” and this include the quality of the labor and the quality of the plates, welding material, manufacturing facilities, etc.
The mechanical design of the equipment and corrosion allowance will also affect pricing once thicker plates will be used.
Another important consideration when comparing prices is the level of technology involved. State of the art equipment will cost more than a cloned one as well as an equipment that had its performance checked in a test bench.
Therefore, it is easy to understand that even equipment of the same size will have different prices, due to the global quality of the manufacturing.

Any time a system is quoted, please use the following list so that equivalent proposals are obtained:

- The application of your vacuum system and the capacity of the plant (deodorization, bleaching, hydrogenation, extraction, etc).
- Suction mass flow for each component, even if in small amounts or traces.
- Suction pressure at the suction of the ejector. Always the absolute pressure. Never the pressure inside the equipment.
- Suction temperature.
- Maximum cooling water temperature, and admissible delta T.
- Motive steam pressure at the ejector. Never at the boiler or at the inlet of the building.
- Barometric pressure of the plant site.
- Where are you going to discharge the last stage.

Conclusion

Steam jet ejectors provide the most reliable and economical means to perform many of the core processes in processing fats and oils. Of all vacuum-producing devices, the steam jet ejector is the most forgiving.

Steam jet ejectors are a reliable and economical means of producing vacuum with a low installed cost and, provide years of trouble-free operation. They will continue to evolve with the development of new materials of construction, new nozzle configurations and other innovations that will enhance their benefits.