Schutte & Koerting

Steam Jet Vacuum Pumps

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The use of steam jet ejectors for entraining air or gases at subatmospheric pressures is increasing rapidly, particularly in the range of pressures below 400 mm absolute. This is due to several advantages:

1. Lower first cost.
2. Very low maintenance cost.
3. Construction readily adapted to special materials for corrosive or abrasive conditions.
4. No moving parts to inspect, lubricate or adjust.
5. No lubricant or sealing liquid to be affected by gases containing solvents or other contaminants.

The basic design utilizes steam under pressure. The pressure energy is expanded through a nozzle designed to secure a steam jet of maximum velocity. This high velocity steam mixes with and entrains the suction gas. The mixture passes at high velocity into a venturi diffuser or tail where the velocity is reconverted to a pressure higher than that at the suction of the ejector.

Performance

The quantity of steam required to compress a given weight of gas increases as the degree of compression increases and becomes uneconomical when this ratio approaches 15. In simpler terms, the approximate limit for a single stage is 1/15th of an atmosphere or 50 mm absolute when the discharge is atmospheric. Many applications require lower pressures and, as a consequence, the total compression required may be divided into two, three, four or five stages. For economical design, compression ratios of 7-10 to 1 are used. Curves 1, 2, 3, 4 and 5 indicate the quantity of air handled by a given weight of steam for various single and multi-stage jets. The motive steam pressure has an important effect on the single-stage, or the stage which discharges to atmosphere in a multi-stage unit. See Curve 6. Curves 7, 8 and 9 show the effect of varying molecular weight and temperature of the entrained gas. (Taken from Standard for Air Ejectors, courtesy Heat Exchange Institute).

The best steam economy is attained when the areas of the steam nozzle and diffuser are proportioned for a specified performance. No one standard design either single-stage or multi-stage, will be equally efficient over a range of conditions. This is illustrated by the included single-stage curves, see Curve 1.

Selection of ejectors may be made on several basis. Certain types may be obtained from stock when immediate delivery is essential. Since such units are designed for specific conditions, they may not have the maximum economy at the specified conditions. Ejectors may be standardized for a given plant. They may be designed for maximum economy for the average conditions and will reduce downtime and service costs by allowing for interchangeable parts and minimum spare parts inventory. On the other hand, ejectors designed for each specific condition will give minimum steam requirements although some variations may reduce first cost at the expense of an increase in steam consumption. Proper consideration of all the factors involved will enable selection of the ejector best suited to the requirements.

In multi-stage units, the proportion of motive steam to the different stages determines the shape of the air handling curve. Mention was made above that the most economical performance occurred when a jet was designed for a definite specification. Although this produces the maximum in steam economy, there may be a sharp increase in suction pressure beyond the design point. To secure a gradually falling characteristic, increasing quantities of motive steam are required for the supporting stages. See Curve 10 illustrating this point for a typical two-stage condensing unit. From this curve it is evident that if desired absolute pressure falls between 0.2 to 1.2" Hg., a smaller than normal low stage unit discharging to atmosphere can be used since a normal size low stage unit (1 1/2") uses more steam without producing a better pressure. Conversely, if the desired pressure falls between 3" and 5" Hg. absolute, a larger than normal low stage should be used since the low stage primarily controls weight of air entrained. Should the non-condensable gas handling vary over a wide range, it may be necessary to use a unit consuming more than normal steam to secure long gradually falling air handling characteristic. Beyond approximately 4" Hg. absolute, a single stage jet should be used.

The drop off of the air handling curve of a multi-stage jet, irrespective of the combination of units, is affected by temperature of the water to the condenser, as illustrated on Curve 10.

This is caused by the increased load imposed on the supporting stage by the vapor of saturation coming from the inter-condenser at higher temperatures. Most atmospheric stage ejectors are designed to operate against a back pressure of not more than 1 psig. To operate against higher back pressures, steam consumption must be increased. This is illustrated in Curve 11.

Estimation Of Capacity Requirements

To prime or evacuate a given volume from atmosphere to a given vacuum is a simple matter of referring to test evacuation data or curves. However, estimating the air leakage in a system is quite complicated. Certain manufacturers have endeavored to average out leakage factors and set up a formula, but the primary consideration is the care taken in the construction of joints, types of valves used in the system and type of seals where rotating shafts enter the vacuum system. Suggestion on making systems tight are given under Maintenance. A long experience in the operation of vacuum systems is necessary to estimate leakage closely. The usual place for air leaks to occur are:

(1) Stuffing boxes on agitator drives and pump shafts. These leaks can be minimized by liquid seals on agitator shafts or lantern glands in pump housings. Rotary seals are practically leak proof and should be used whenever possible. Five pounds air leakage per hour is considered not unusual for a standard stuffing box.

(2) Material charging door. To reduce this source, a protector should be placed over the edges of the material connection during charging to avoid spillage, which may adhere and cause damage to gasket surface. Care should be used to have gasket and charging door clean and smooth, drawing down bolts or clamps uniformly. Following this procedure should reduce leakage from this source to 1 to 4 pounds of air per hour, depending on size and condition of door.

(3) Valve stems. This leakage can be reduced by using the type of valve which seats the disc against the valve bonnet when valve is fully open; by renewing stuffing box packing periodically or can be eliminated by using bellows type valves or lubricated plug cocks.

Flanges in vapor lines, if flat face type, will have full gasket over entire face of flange. With this construction, bolts can be drawn down more evenly and, should there be a leak, the edge of flanges and bolts can be painted with a glyptol resin. All threaded connections should also be coated with glyptol resin as well as any joints around sight glasses.

With the above suggestions, the air leakage in large systems can be reduced to 20 pph and in small systems to 10 pph. Where the absolute pressure to be maintained is low, say 1 mm, and special precautions are made to insure tightness, air leakages can be reduced to 2 to 5 pph for moderate sized systems. These figures do not include any generation of non-condensables arising from the process. Vapor lines in vacuum systems should be properly sized to avoid excessive resistance drop between the vacuum jet and the still. Higher velocities can be used at lower absolute pressures.

The following is a list of possible troubles and the means of correcting them. This list should be carefully checked before making an installation as well as when difficulties are encountered.

(1) Air leaks in system.

Make shut off test by blanking off suction to jet. For standard units a single stage will blank off at an absolute pressure of approximately 2" Hg. absolute; a two-stage condensing approximately 1/2" Hg. absolute, and a three-stage approximately 2 to 3 mm Hg. If this is the case, the jet is good and trouble is in system. When connections are made for above tests, new gaskets should be used.

To ascertain the amount of air leaks, approximate the total volume of the system, secure a pressure somewhat less than 15" Hg. abs., then shut off valve in vapor line near jet. Measure the time required for a rise in pressure (say 2" Hg.). If the absolute pressure does not rise above 15" Hg. then formula below will give leakage.

$$\text{Leakage (lb./hr.)} = \frac{0.15 \times \text{Volume (cu. ft.)} \times \text{change in pressure (In. Hg.)}}{\text{Time (Minutes)}}$$

If air leakage is greater than load for which jet is designed, either correct the leaks or use a larger ejector.

(2) Low or fluctuating steam pressure.

Check stamped pressure on nameplate or on nozzle with an accurate steam gauge installed in steam chest with gauge syphon. If the pressure is low, the steam nozzles can probably be altered to suit the existing conditions. Low pressure causes vacuum to break.

(3) Wet Steam.

Steam nozzles are designed for 98% or better quality steam to give efficient performance. Steam separators should be used and properly drained by a steam trap or bled off of separated condensate. A bucket trap, discharging in spasms, may cause fluctuating pressure. Wear on steam nozzle orifice and longitudinal wearmarks in diffuser are evidence of wet steam.

(4) Corroded or Worn Diffusers.

Particularly of the stage discharging to atmosphere. Pock-like irregular indentations indicate corrosion, streaks indicate erosion.

(5) Clogged steam nozzle or steam strainer.

If nozzle inlet is red or black, look for a scale deposit which can be removed by careful scraping and subsequent polishing.

(6) Bad Discharge Line.

From low stage jet to atmosphere causing greater than designed or fluctuating back pressure. Check for places where condensate may accumulate.

(7) Poorly centered gasket.

At discharge of jet. This will cause undue resistance and increase back pressure.

(8) Material plugging.

Or build up, or too small diameter suction line. Check vacuum at evaporator or still and at jet to note any appreciable pressure loss.

(9) Leaks.

In barometric leg of multi-stage units, particularly at hot well water level. Periodic intercondenser "vomitting" indicates this cause.

(10) Hot well.

Filling up with mud preventing proper drainage of condensing water.

(11) Water to Condenser.

Insufficient quantity evidenced by hot condenser and tail pipe caused by insufficient water pressure or clogged water line or nozzle. Too much water flooding condenser, evidenced by cold condenser and by fluctuating vacuum. Carryover may cause scaling to subsequent stage causing entrance losses and reduced capacity. A direct contact condenser may bypass if internals are worn. Check hot and cold areas on shell. Non-uniform temperatures around shell at any level indicates by-passing.

(12) Poor Installation.

Small and long vapor lines, having sags or loops which collect condensate or carryover liquid; horizontal runs in barometric discharge legs, sharp bends and jet discharge. Correction: follow manufacturer's installation instructions.

(13) Changing Steam Nozzles.

In removing nozzles for inspection, check to insure their return in same stage with clean thin copper gasket, to insure against leakage of steam between steam chest and vacuum chamber. If a new gasket is not available, the old one should be annealed.

(14) Trying.

To secure higher vacuum than the vapor pressure of liquid in evaporator or still.

(15) Scale.

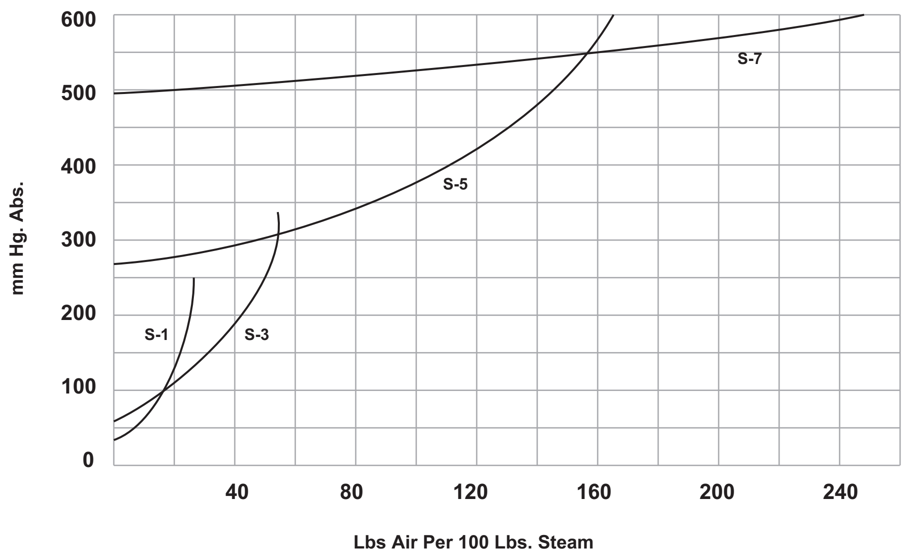
Formation or process material carryover plugging barometric discharge pipes from inter-condensers or inlets to exhausters.

(16) High Water Temperature.

To condensers. Check design specifications.

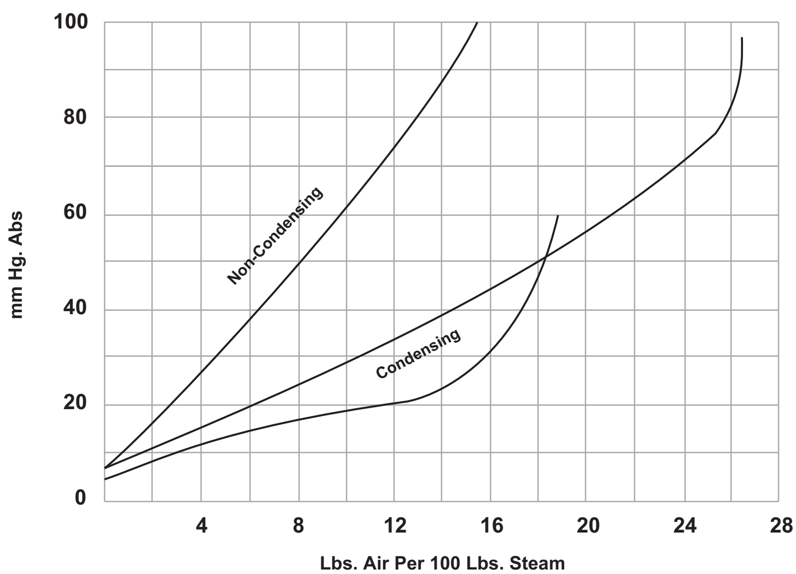
NOTE: Every Jet is performance tested to specifications before leaving the Schutte & Koerting factory and is correct. It will give long and good service. If trouble occurs, check the above points. If still not successful, call for a Schutte & Koerting representative.

Curve 1 - Single Stage 115 psig

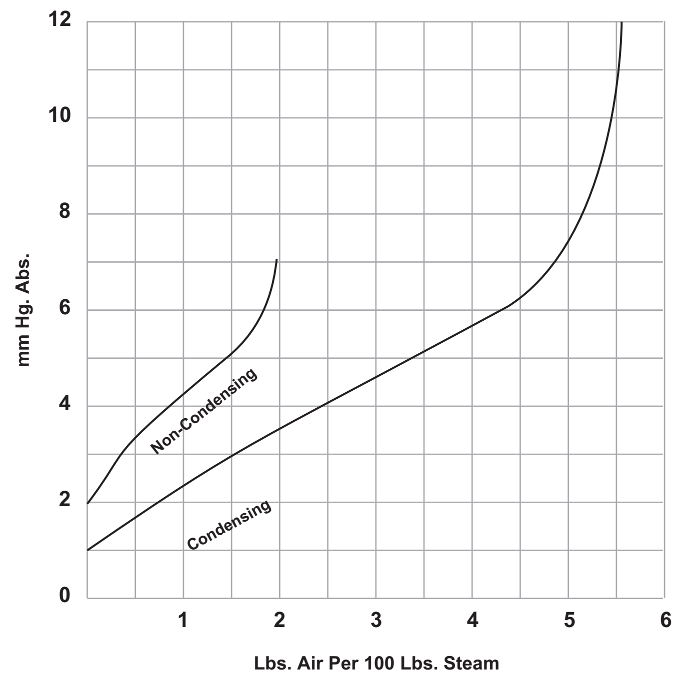


Allowable Vapor Velocities	Absolute Pressures	
300 ft./sec.	1-	5 mm
275 ft./sec.	5-	10 mm
250 ft./sec.	10-	20 mm
225 ft./sec.	20-	40 mm
200 ft./sec.	40-	60 mm
175 ft./sec.	60-	100 mm
150 ft./sec.	100-	150 mm

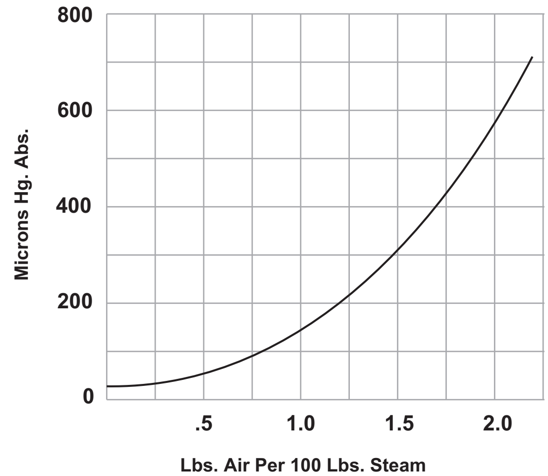
Curve 2 - Two-Stage 115 psig



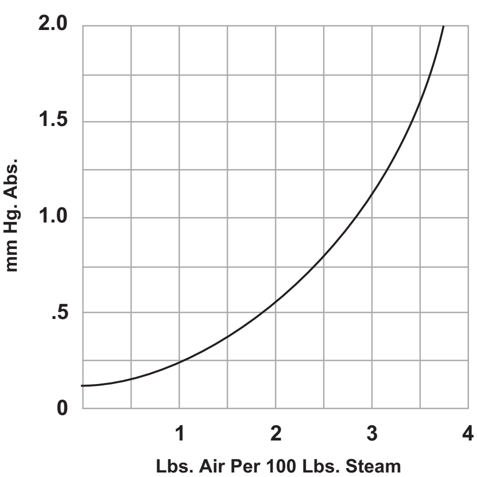
Curve 3 - Three-Stage 115 psig



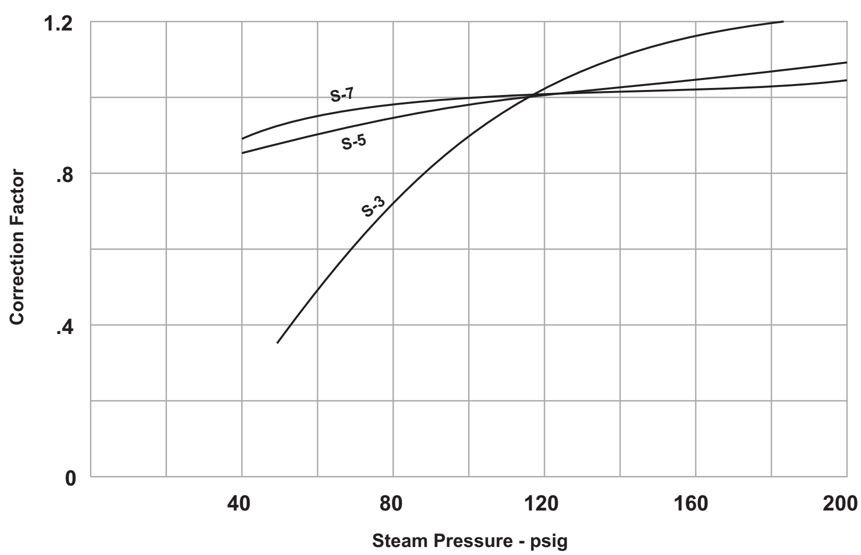
Curve 5 - Five-Stage 115 psig



Curve 4 - Four-Stage 115 psig



Curve 6 - Effect of Steam Pressure on Single-Stage Exhausters



Curve 7

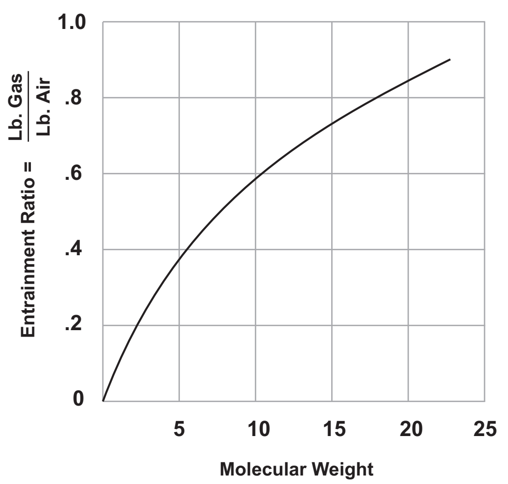
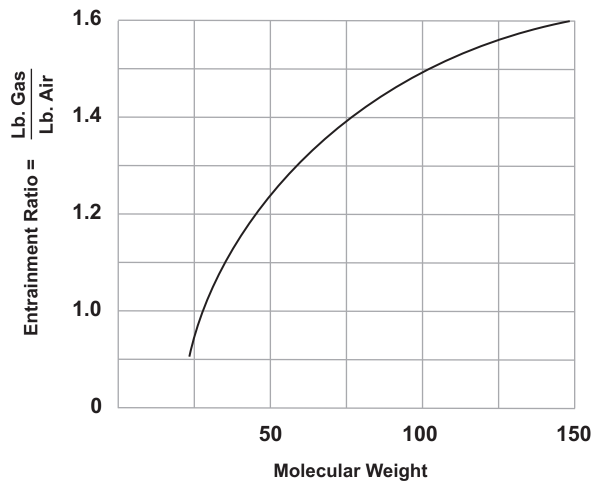
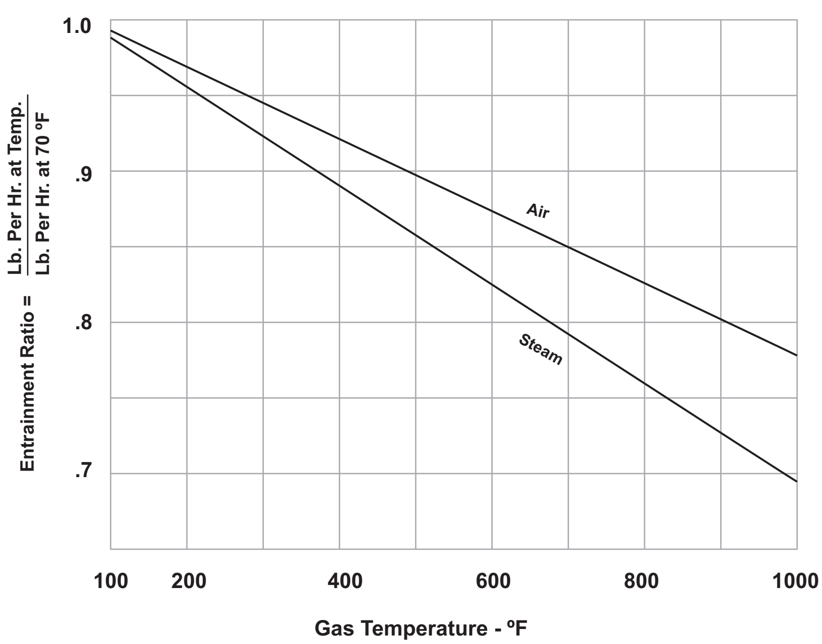


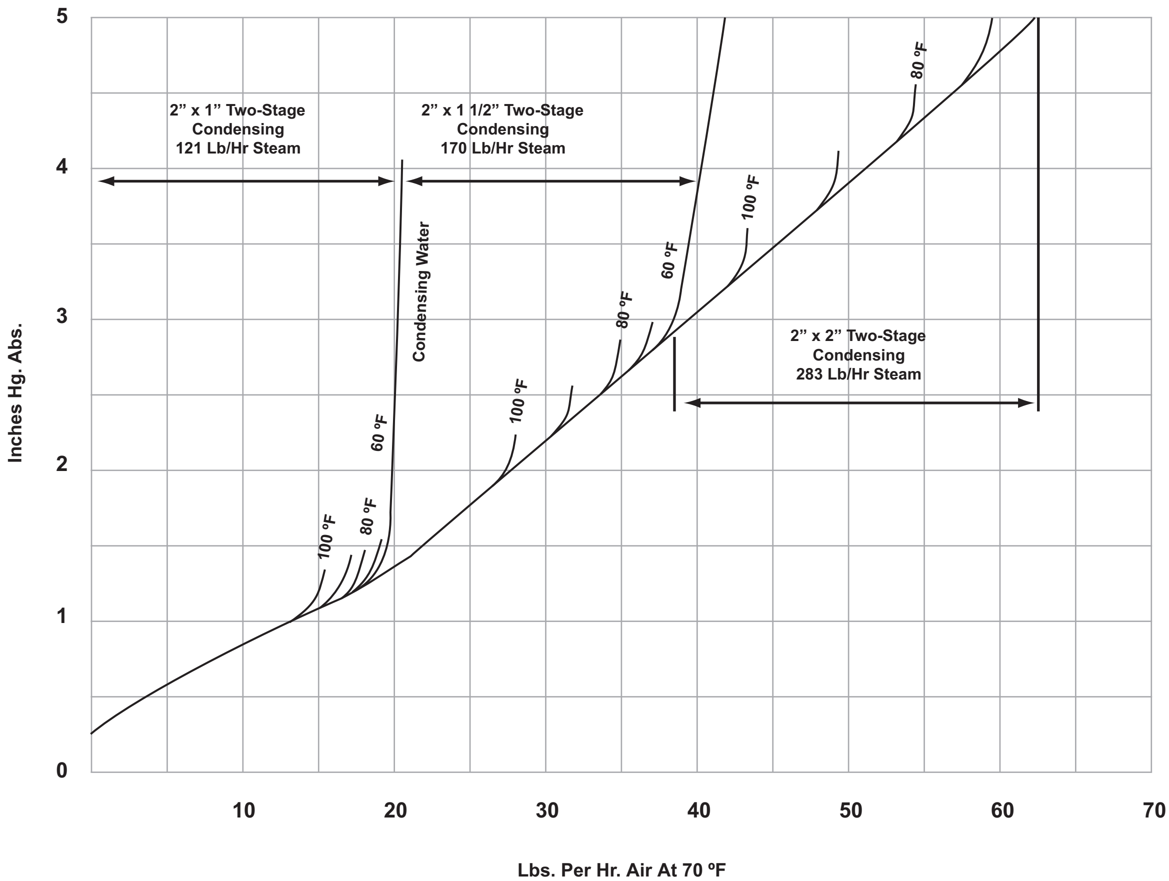
Chart 8



Curve 9



Curve 10 - Steam 115 psig



Curve 11 - Effect of Back Pressure on Single Stage Exhausters