CROLL-REYNOLDS CO., INC.

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INSTALLATION, OPERATING, AND MAINTENANCE INSTRUCTIONS

FOUR STAGE EVACTOR WITH BAROMETRIC INTERCONDENSERS

FORM V-114-C Rev. 1 9/96

DESCRIPTION

Steam-Jet Ejectors are pumping devices used, in general, to evacuate fluids (gases and vapors) from one process system step and deliver them to another. A simple example is the removal of air from a closed vessel and discharging it to the atmosphere. The theory behind the steam-jet ejector involves converting high pressure motive steam into a high velocity jet in a converging-diverging nozzle. Gas and vapor molecules surrounding the high velocity jet are entrained, or swept up, under the principle of viscous drag. This continuous entrainment of molecules near the nozzle tip is what creates the vacuum and drives the pumping effect. After the molecules are swept up by the jet, the two constituents (motive steam and entrained load) are mixed violently in the converging section of the venturi throat and then compressed to a higher pressure in the straight and diverging sections. When the mixture is finally discharged, the stream is at an intermediate pressure - higher than the inlet "suction" pressure but lower than the motive steam pressure - and traveling at a velocity much lower than that of the jet.

In order to obtain lower absolute pressures for a given load, higher jet velocities (meaning more steam and thus larger components) are required. Eventually, as the required vacuum level deepens, the single stage ejector becomes too large and uses too much steam to be economically attractive. For this reason ejector systems are split into stages (Z, Y, X, etc.) and combined with intercondensers, with each ejector stage covering a given range of pressures and each intercondenser reducing the load to the next ejector. The ultimate objective is to pump a given load from the required suction pressure to the required discharge pressure using the least amount of steam possible with the most economic combination of ejector stages and intercondensers.

Four ejector stages are normally required where the absolute pressure to be maintained is less than 3 torr (3 mm Hg Abs). The stages are designated the W (lowest suction pressure), X, Y and Z (highest discharge pressure, usually atmospheric). The intercondensers are designated XY and YZ. The four stage system depicted in Figure 1 is a typical installation showing condensers, instrumentation and steam conditioning equipment, all of which can be supplied directly from the factory upon request.

INSTALLATION

Orientation - Consult the drawings supplied with the system for component listings and equipment locations. If space limitations prevent direct-coupling stages and condensers, try to avoid long lengths of interconnecting piping to minimize pressure losses. Each stage should also be independently supported. Using one stage to support another, especially with larger units, can impose excessive loads and moments on the throat sections and lead to misalignment

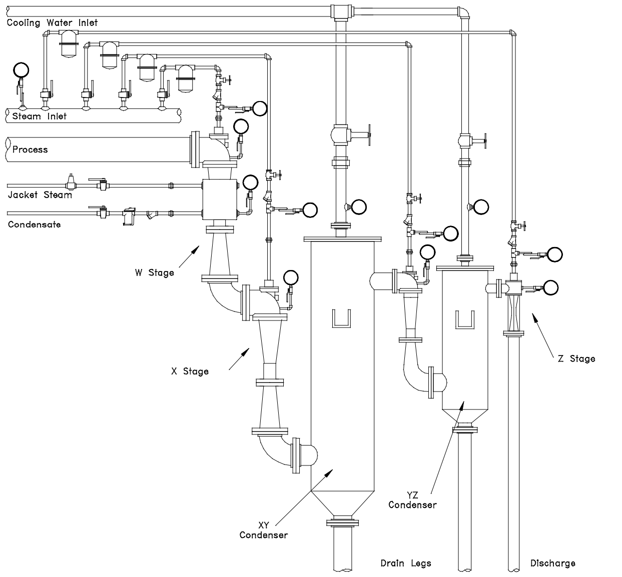

Figure 1; Typical configuration shown with optional piping and utility equipment.

The W stage ejector should be installed in a vertical position, preferably discharging downward. A horizontal W stage will not drain properly and may result in condensate pooling inside the ejector. Condensate will add an artificial load to the system and can easily freeze to the internal surfaces if not drained, both of which can severely affect performance.

Normally the W stage is noncondensing and discharges directly into the X stage. The X stage then discharges into the XY condenser, again with as little interconnecting piping as possible. The XY and YZ intercondensers are mounted vertically or horizontally, depending on the design (consult the system layout drawing), and the last two stages, the Y and Z, can be mounted in any orientation. Be sure to leave room between the piping and equipment for removing nozzle assemblies and water distributors.

Suction and discharge piping - Suction piping must be independently supported and made full size to match the W stage suction line. Avoid filters, valves or other pressure drops in the suction line that were not accounted for in the specification and design phases, or a loss in vacuum will result. Avoid low points or loops that might accumulate condensate or process solids or, if unavoidable, install condensate drains and clean-out connections. Discharge piping from the Z stage can be directed to any number of places, as long as the backpressure does not exceed anything more than a few inches of water above atmospheric pressure. Knock-out pots (with properly sized vents), dip legs, aftercondensers and silencers are all suitable for normal operation. When discharging into a hot well dip leg or receiver, be sure that the insertion length below the surface of the water does not exceed 12 inches.

Steam Quality and Supply - The absolute pressure at the W stage suction is normally less than that of the vapor pressure of water at 32°F, so any moisture in the motive steam will freeze the instant it discharges from the nozzle. The ice particles will coat the internal surfaces of the venturi section and seriously interfere with the performance of the system. To ensure that the steam supply is as dry as possible, separators with traps must be installed in the steam lines as close to the motive connections as possible. Also highly recommended is the installation of an electric superheater in the W stage motive line after the separator, providing 15 to 25 degrees of superheat. Separators, traps, and superheaters can be supplied by the factory upon request.

To further safeguard against icing, most W stage ejectors are supplied with low pressure steam jackets to heat the entrance section of the venturi. Care must be taken to prevent the jacket from being exposed to steam pressures exceeding 15 psig, and that the jacket is properly drained (preferably with a float-type trap or automatic drain valve). If the W stage has not been supplied with a steam jacket, heat tracing is strongly recommended. All heating jackets or tracings should be fully insulated.

Steam lines should also be fully insulated, made full size as indicated on the drawings supplied with the unit, and installed with separators and superheaters placed as close to the ejector as possible. Valves should be installed to shut off the steam to each stage in any location convenient for operation, and unions or flanged connections should be incorporated to allow for easy nozzle assembly removal.

Cooling Water and Condensate - Cooling water should be piped to the intercondensers from a convenient supply of water with control valves for easy operation. A water pressure of 1 psig is sufficient for normal operation. Condensate can be removed with either a properly sized condensate pump or through barometric drain legs to a hot well or receiver, with the drain legs sealed under at least 2 feet of water. The drain line should have no horizontal runs, and should be as direct as possible with a slope of not less than 45 degrees in any one section (see Figure 2). The height from the hot well water level to the intercooler should be at least 34 feet. Request Croll-Reynolds Form V-220, "Barometric Drainlegs and Hotwells", for more information.

Instrumentation - Steam gauges with 1/4 turn ball valves and syphon loops are recommended for each stage, whether installed in the main steam line leading to the ejector stage or on the steam chest itself. Vacuum gauges with isolating valves and test hose connections are also recommended for the suction line and between stages. Water temperature gauges should also be installed in the water inlet and outlet lines.

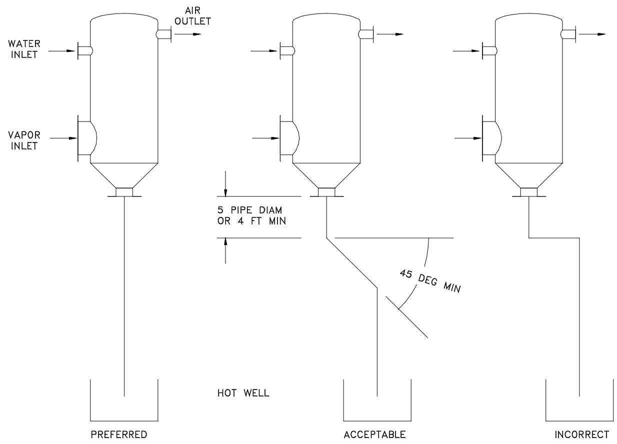

Figure 2

When measuring the pressure at any point in the ejector system, care should be taken that the taps be properly located. Taps are provided on the nozzle assemblies (for steam pressure) and on the ejector suction heads (for vacuum). Taps in the interconnecting and process lines can be located anywhere except directly opposite an ejector discharge. Vacuum gauges reading inches of mercury may be used, but be sure to correct for atmospheric pressure (absolute pressure = current barometer reading - vacuum gauge reading). Bourdon tube gauges are not recommended. Contact the factory or a local representative for help in selecting the proper instrumentation.

Commissioning - Before final connections are made, be sure to blow out the steam and water lines thoroughly. New pipe contains dirt and scale which can be carried over into the ejector and clog the nozzles.

After installation, check the system thoroughly for leaks with a 15 psig hydrotest. As a final check, use the following test procedures for a vacuum leak test:

1. Isolate the W stage from the process with a slip blind.
2. Fill the hotwell with water.
3. Using only the Z stage, vacuum-test the installation for leaks. The Z stage should be able to pull 70 to 80 torr (check the Z stage performance curve) in this condition.
4. If a leak is evident, begin systematically blinding off the flanged connections between the stages and condensers, starting at the W stage discharge.
5. Determine the source of the leak and correct. Continue on until the Z stage has been dead-headed and all leaks have been corrected.

Leak testing is an important part of commissioning an ejector system. If a stage cannot prime down to the back pressure the preceding stage is designed to operate against (or down to the corresponding condensing pressure), the equipment will not perform as designed. The cause must be located and corrected before the system is put into service.

OPERATION

Whether or not the system should be started with an open line to the process depends on the application and is at the discretion of the operator. The following procedures assume for the most part that the system can be isolated for testing but open during start-up. The procedures can also be easily applied system dead-head testing.

Before opening any steam valves, turn on the water to the intercondensers and establish the proper flow. Never open the steam valves without the water running to the intercondensers. Damage may occur to the equipment. If barometric drainlegs are being used, check for drain leg seal in the hotwell (water may need to be added). Condensate pumps should be tested prior to start-up. Also check the system datasheet for the correct cooling water temperature.

With proper cooling water flow established to the XY and YZ intercondensers, turn the steam on to the Z. Check the datasheet for correct steam pressure. Let the Z stage prime down to 75 torr. At that point, turn on the Y stage and let the two prime down to 25 or 30 torr. Priming may take a while, depending on the volume of the system. For this reason larger hogging stages are sometimes used to prime the system down quickly. A hogger will prime down much quicker than a stage designed for the operating condition, and using all of the stages at once will not save time. Regardless, the stages may operate in the broken mode - characterized by a “whoosh” or chugging sound - until the load comes down into the ejectors’ stable range, at which point the noise level will drop significantly to a low whine.

At this point the operator may find it necessary to “warm up” the W and X stages by bleeding steam through partially opened W and X stage steam valves. This step ensures that whatever condensate flushes through to the W and X stage nozzles is boiled off completely prior to the start of a production cycle. Several minutes of warm-up time should be sufficient.

With the Y and Z stages pulling 25 torr, turn the steam on fully to the X stage. When the pressure drops below 10 to 15 torr, turn on the steam to the W stage. If a superheater is being used, turn it on only after the steam is flowing to the ejector. Once the vacuum level has stabilized, check the dead-head suction pressure (if isolated) of the system with the performance curve or data sheet. If the unit is performing as designed, note the position of the steam and water valves for future reference.

The ejector stages are designed to operate at a specified steam pressure, and vacuum level cannot be controlled by throttling steam pressure. When the steam pressure is throttled, the stages may simply cease working altogether. If the unit is not producing the proper vacuum, check for leaks and problems with steam pressure and water temperature. Also note that the capacity cannot be controlled by throttling steam pressure, unless otherwise specified.

System performance can be checked at any time with “no-load” or “dead-head” tests. With a blind in the W stage inlet or isolating valve closed and water flowing to the intercondensers, the Z stage should pull down to 75 torr in one minute. With the Y and Z stages running, 25 to 30 torr should be obtained. Check with the factory for W and X no-load performance, or consult the system datasheet. If the desired vacuum is not obtained, it is probably due to one of the following causes:

1. Low Steam Pressure - An ejector will operate with a higher than specified steam pressure, but not with a lower pressure. Excessive superheat will have the same effect as low pressure.

2. Wet Steam - Wet steam will cause a noticeable loss in vacuum. Steam with a quality of 98% or less is considered wet. Check the steam separator and trap. Check insulation.

3. High Back Pressure - If a stage has a higher back pressure than it was designed for (see the system datasheet), a loss in vacuum will result. Check for restrictions or obstructions in the exhaust lines, such as accumulating condensate. Also check water flow and temperatures. If a discharge pot is being used, make sure that is designed large enough to pass the volume of vapor being handled. If the exhaust line discharges into a hotwell, check that the insertion length is no more than 12 inches.

4. Excessive Air Leakage - Inspect the assembly for openings, split pipes, missing gaskets, leaky valves, etc. Hydrotest with water to locate leaks. If a hotwell is used, make sure drain lines are sealed. An air leak will tend to overload the successive intercoolers, creating a high back pressure condition.

5. Clogged Steam Nozzles - With a new installation, pipe scale or dirt from the steam lines can clog the EVACTOR steam nozzles, even when a strainer is used. Remove the nozzles for inspection and clean thoroughly with emery cloth, particularly the orifices. Note that additives to the boiler water have been known to clog nozzles. The deposits collect on the nozzle walls, and can be easily missed during inspection.

6. Varying water pressure - Especially in the smaller Barometric Intercoolers, changing water pressure can cause trouble either by flooding or starving the unit. Any surging in the Intercooler water pressure will usually reflect in the performance of the complete two stage unit.

MAINTENANCE

Vacuum equipment maintenance is relatively straight forward, but can vastly improve reliability and performance if approached systematically. Some users get by with swapping out parts in periods of dire emergency: performance slowly erodes over a period of time and nothing is done until the unit ceases to effectively operate altogether. At that point spare parts are installed to correct the problem (if the problem is in fact known and the correct spare parts are in the plant's inventory), and the unit is returned to service. The period of degraded performance leading up to failure and the downtime itself, however, can result in higher operating costs from longer cycle times, increased steam usage and production outages. For this reason a systematic preventative maintenance (PM) program is highly recommended. See Croll-Reynolds Form V-212. "Steam Jet Vacuum Equipment Maintenance Procedures" for more information.

An effective PM program begins with documentation. Serial numbers, parts lists, performance curves, operating histories and maintenance procedures should be kept up to date by the maintenance or engineering departments for quick reference. Croll-Reynolds vacuum equipment components all bare nameplates with the equipment serial numbers and model numbers. Should the plant's documentation lack a performance curve or drawing, one phone call will connect plant personnel to over seventy five years of design and performance records for every piece of equipment ever sold by Croll-Reynolds, each referenced by individual serial numbers and safely stored in a fire-proof vault at our Westfield, NJ offices.

An effective PM program also includes periodic inspection and tests. Yearly shut downs are perfect opportunities to perform such tests, but an ejector or barometric condenser can be disassembled in minutes for a thorough visual inspection. A typical PM procedure should include the following:

- Disassemble and inspect gaskets for evidence of leaks
- Check for and document regions of corrosion and wear
- Check nozzle bores and throat diameters against original specifications
- Clean all internal surfaces (nozzles, heads, throats, diffusers) thoroughly
- Check for evidence of wet steam (grooves in nozzle bore and diffuser) and correct
- Reassemble with new gaskets and required spare parts, avoiding misalignment of the components
- Blow down steam strainers and inspect separators and traps
- Record what spare parts were taken from inventory and order replacements
- Inspect the condensers for evidence of fouling and clean thoroughly.
- Calibrate the vacuum, pressure and temperature gauges and replace if necessary
- Test the unit in-line against the performance curve with either a blanked suction or orifice meter

A properly stocked inventory of spare parts is necessary regardless of the extent of the PM program. At least one nozzle (or set of nozzles for multi-nozzle units) for each ejector stage should be kept in stock. Water distributors and a complete Z stage should also be kept in stock. Relaying process, boiler chemical, steam quality and water hardness information to the engineers at Croll-Reynolds will result in the proper selection of spare parts.

WARNING

Steam Jet Ejector systems are mechanically designed for 15 psig and full vacuum at 450o F on the process side, unless otherwise specified by the customer. Pressure relief devices are necessary on ejector systems where the potential exists for the pressure and/or temperature to exceed the design of any of the system components. These protective devices shall be supplied by and are the responsibility of the customer. Mechanical failure and possible injury to personnel may result if these precautions are not taken.

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