Technical Document - Ejectors
Ejector and Booster Pump Selection

The ejector is a critical component of a vacuum feed system. If the ejector does not operate correctly, the system cannot function. This technical bulletin provides guidance on ejector selection and system design. Ejectors are available for injecting a range of gases and liquid chemicals. Most operate using a motive fluid, such as water, while others use air or nitrogen and are classified as pneumatically operated. For simplicity, this document focuses on water operated ejectors used to feed chlorine gas.

Ejector Overview

Function – An ejector has several very important functions within the gas feed system. It needs to generate the operating vacuum, create the chlorine solution, and prevent the back flow of water into the vacuum lines.

- Operating Vacuum - Hydro Instruments' ejectors are designed to generate sufficient suction to achieve a desired stated feed rate. Inadequate vacuum can produce unreliable gas feed.
- Chlorine Solution - The ejector throat is where the chemical is mixed into the water stream.
- Back Flow Prevention - An integral check valve prevents back flow of water during shut down.

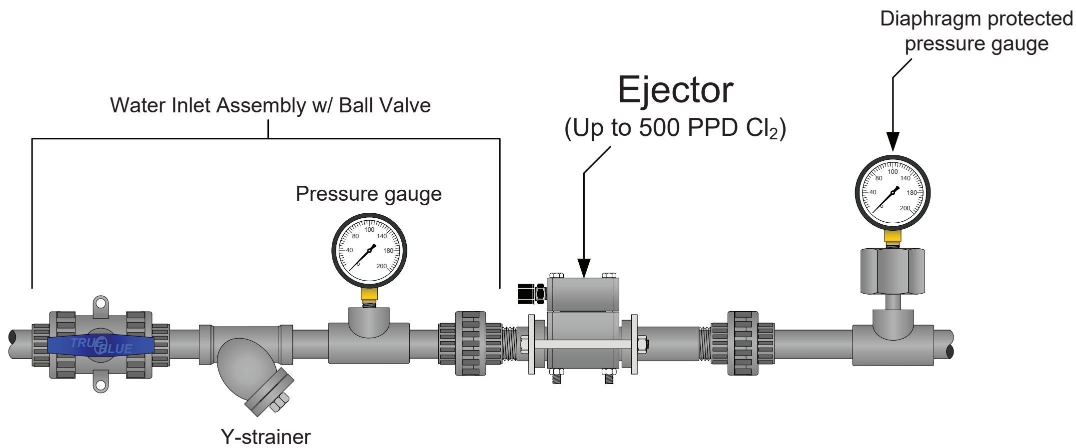
Design – Hydro Instruments' ejectors consist of the following common components:

- Water inlet and solution outlet
- One-piece nozzle or two-piece nozzle & throat (also referred to as a diffuser) combination

A one-piece nozzle is used for smaller capacity ejectors (i.e. Up to 100 PPD Cl2) and two-piece nozzle/throat combinations for larger capacity ejectors.

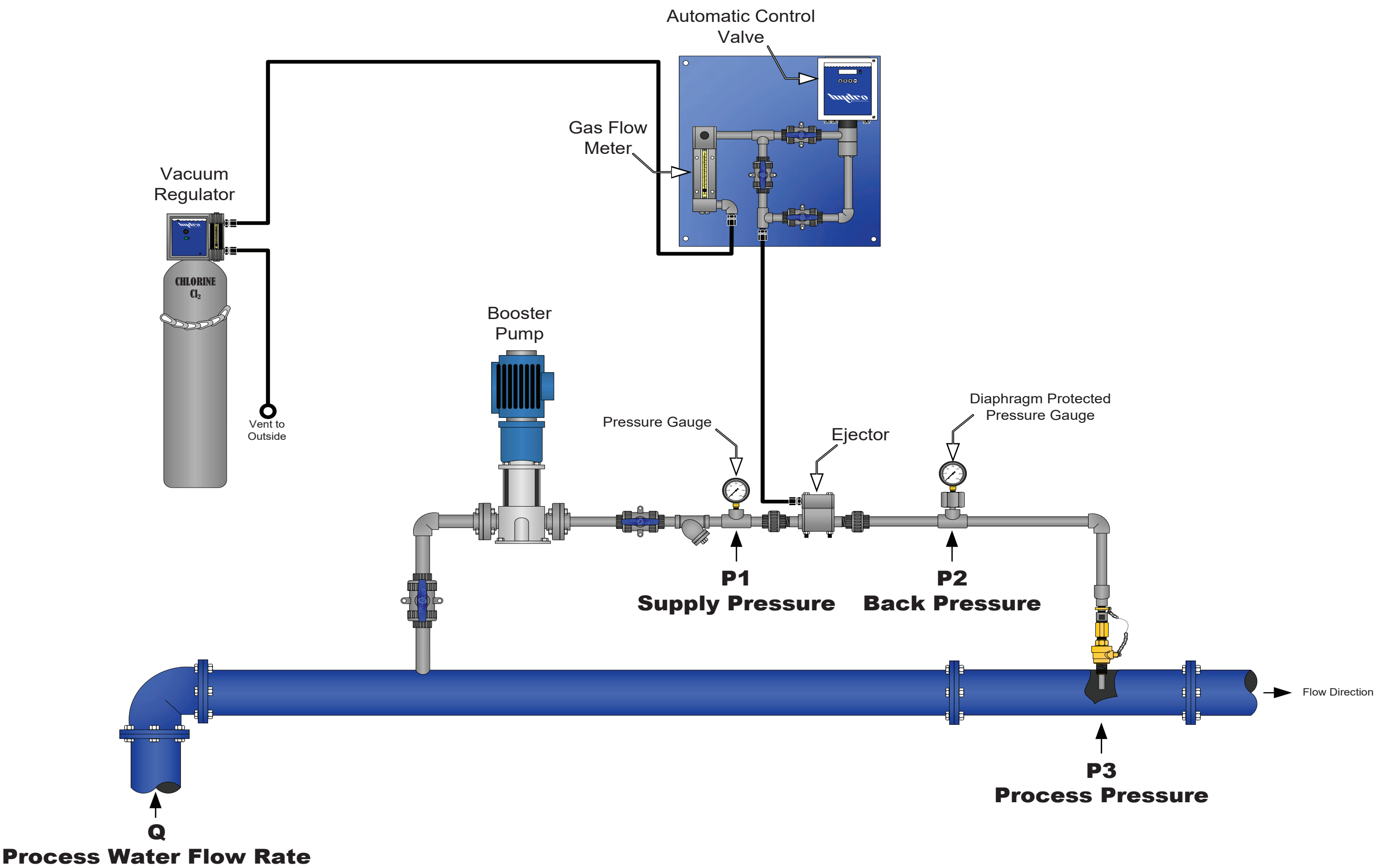
- Vacuum connection for gas inlet
- A check valve

All of Hydro Instruments' ejectors have an integral check valve to prevent process water from entering the vacuum piping and equipment while the system is idle. Some high capacity ejectors also incorporate a water drain valve in the event the primary check valve fails.



Operation – A vacuum of 25 inches Hg or greater is produced when pressurized supply water flows through the ejector's venturi nozzle. As the water passes through a small orifice, its velocity increases and its pressure decreases. This creates a water pressure differential (ΔP) between the ejector inlet (P1, supply pressure) and the ejector outlet (P2, back pressure). When this differential is large enough, the resulting pressure drop generates a vacuum that draws the chemical into the water stream. If the pressure differential is insufficient or not maintained, the ejector will produce inadequate vacuum or no vacuum at all.

FIGURE 1 - Injection into a pressurized pipe with a booster pump.



Required System Information

Each installation will have different hydraulic conditions and the site specific conditions must be understood and considered when selecting the ejector nozzle or nozzle & throat combination. In some cases a booster pump may be required to operate the ejector.

1. Total Back Pressure – Total back pressure is the sum of P2 (back pressure) and P3 (process pressure). The piping between the ejector and the injection point must be evaluated, as these conditions are site specific and must be obtained for each installation. Consider pipe length and diameter, the number of elbows, and the presence of check valves or other fittings. These factors are used to estimate the total ejector back pressure.

2. Ejector Capacity – Ejector capacity, which is often equal to the overall system capacity, is determined after establishing the maximum process water flow rate to be treated (Q_{MAX}) and the maximum required chlorine dosage (expressed in PPM). Using these values, the following equations can be applied to calculate the required ejector capacity:

$$[Q_{MAX}(m^3/hr)] \times [\text{Dosage (PPM)}] \times [1/1000] = \text{Chlorine Gas Feed Rate (Kg/h)}$$

$$[Q_{MAX}(\text{GPM})] \times 0.012 \times [\text{Dosage (PPM)}] = \text{Chlorine Gas Feed Rate (PPD)}$$

Determine Ejector Requirements Using the Nozzle / Nozzle & Throat Performance Curves

Hydro Instruments offers multiple nozzle and nozzle & throat combinations for each ejector. Each having specific supply water flow and pressure requirements. Refer to Figure 2 for example sizing charts for nozzle and nozzle & throat combinations.

Establishing the required P1 supply pressure and water flow rate based on the system requirements. (Refer to Figure 1).

1. Select the appropriate performance curve – Using the required ejector capacity, locate the corresponding ejector performance curve in the Hydro Instruments Catalog or Instruction Manual. For example, for a 500 PPD (10 kg/h) ejector, use the 500 PPD (10 kg/h) performance curve.
2. Verify operating requirements – Using the estimated total back pressure (P2 ejector back pressure + P3 process pressure), determine the minimum required P1 supply pressure and minimum water flow rate from the performance curve.
3. Evaluate alternate nozzle options if needed – If a lower P1 supply pressure or reduced ejector water flow is required, consider an alternate nozzle or nozzle & throat combination.
    - Larger orifice nozzles require lower supply pressure but higher water flow.
    - Smaller orifice nozzles require higher supply pressure but lower water flow.

> IMPORTANT: For high altitude installations it is necessary to increase the supply pressure beyond the stated minimum requirements on the performance curves. Increasing the supply pressure by 1.0 PSI per 1,000 ft. of elevation above sea level is recommended.

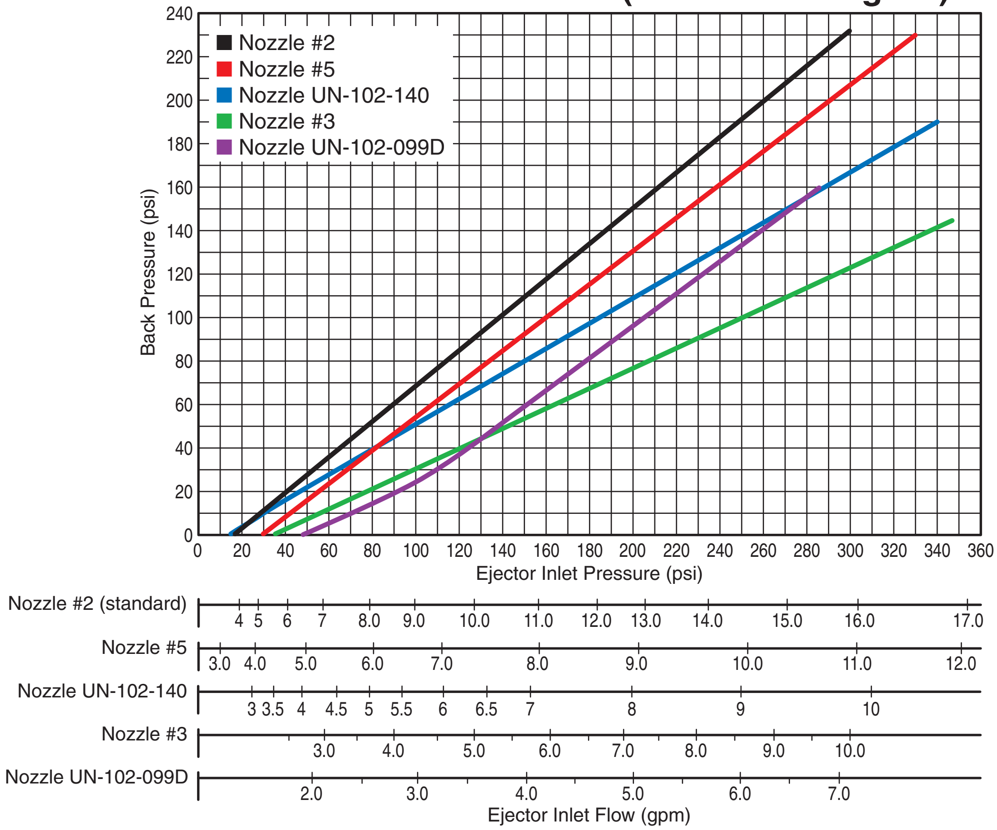
Site Specific Installation Considerations

Each installation has unique operating conditions. In some systems, the chlorine solution leaving the ejector is discharged into an open chamber and can use existing system pressure. In others, a booster pump is required to provide the pressure differential (ΔP) needed across the ejector.

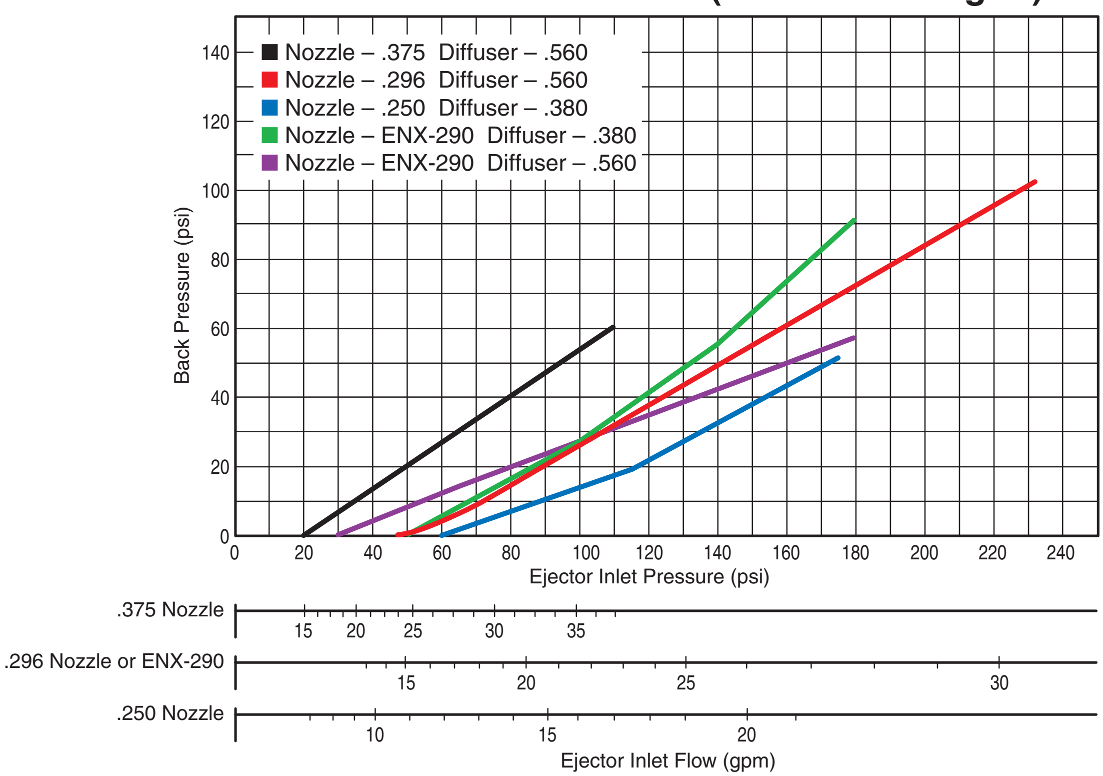
1. Identify all available ways to provide the minimum P1 supply pressure and water flow established in the previous section. A site water source may already meet these requirements. If not, a booster pump may be needed.
2. Determine whether the P2 back pressure at the ejector can be reduced. Lower back pressure reduces the required supply pressure. In most cases, this can be achieved by moving the ejector closer to the injection point or by increasing the diameter of the piping in the P2 section.
3. Review alternate nozzle or nozzle & throat options if the required pressure or flow conditions cannot be met.

FIGURE 2 - Ejector Nozzle & Throat Performance Curves.

NOZZLE SIZING CHART (50 PPD / 1000 gr/hr)



NOZZLE SIZING CHART (500 PPD / 10 kg/hr)



Booster Pumps

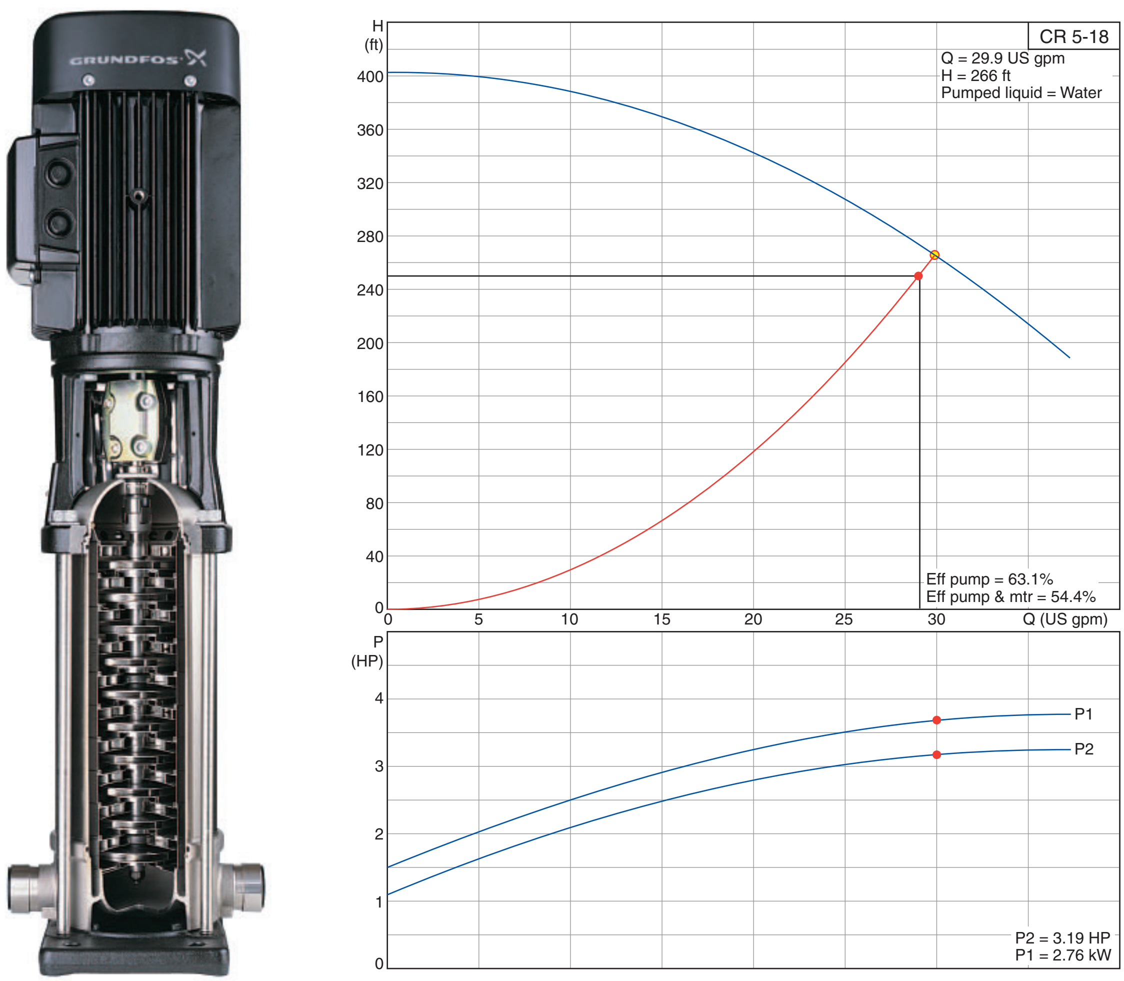
Booster pumps are available in many types and sizes. Use a pump designed for continuous, long term operation; centrifugal multistage pumps are the most common choice. Select pump materials according to the manufacturer's recommendations and the application specifications.

Booster pumps are sized based on power limits. Each pump has a performance curve showing the pressure boost at a given water flow rate. As flow rate increases, pressure boost decreases. Consult the pump manufacturer to confirm the operating pressure and flow conditions.

IMPORTANT: The booster pump output pressure equals the inlet water pressure plus the pump's pressure boost.

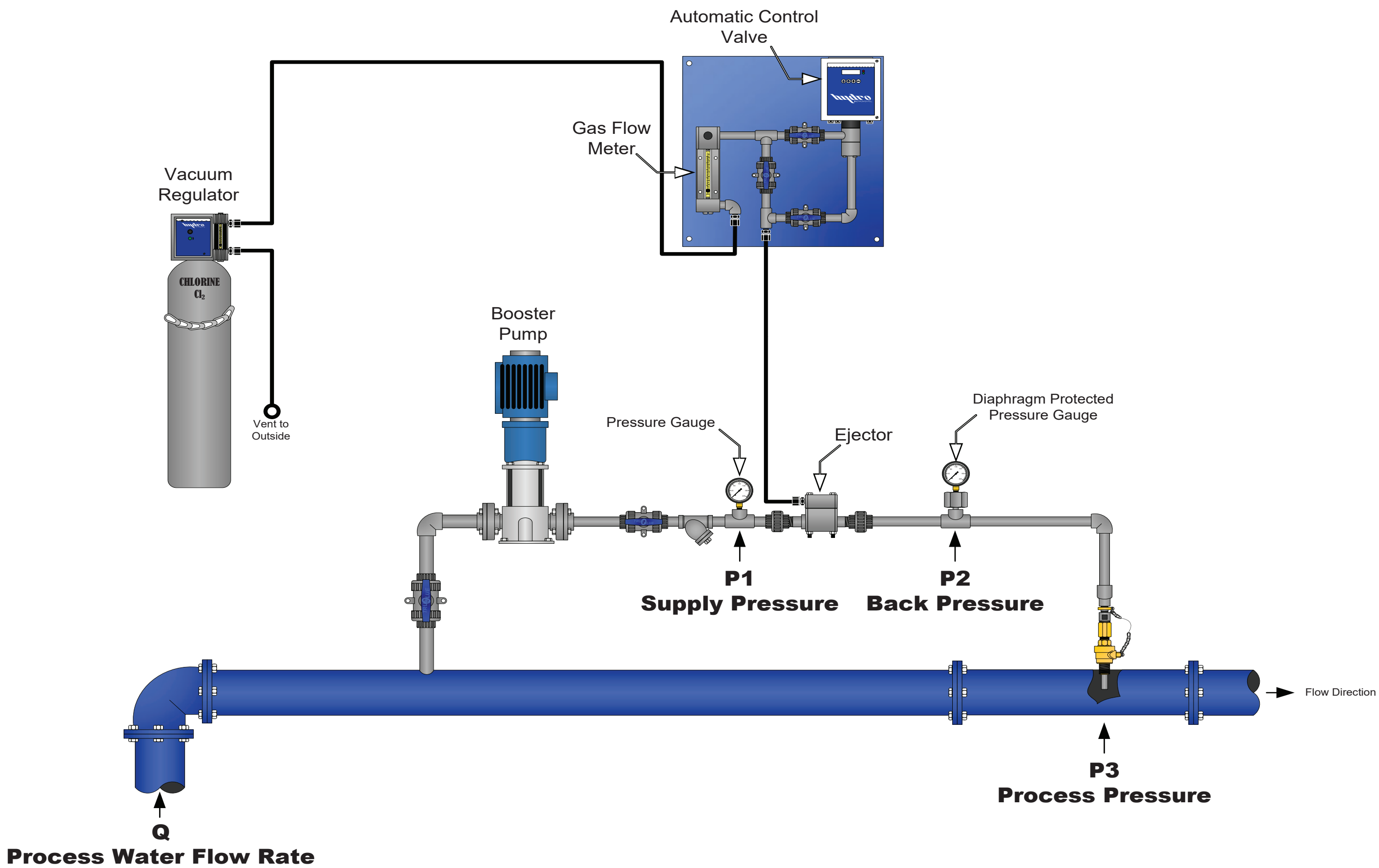
NOTE: Booster pumps also have a maximum inlet pressure limit. Consult the pump manufacturer for the allowable value.

FIGURE 3 - Multi-stage centrifugal booster pump and performance curve.



Examples

1. Pressurized Water Pipe injection (such as a water well):



NOTE: In this type of installation, the booster pump will be set to turn on and off with the well pump. In this way, the chlorine gas feed is also turned off and on with the well pump.

Standard Units

a. Typically the P2 back pressure is only slightly higher than the P3 process pressure.

b. In this example, P3 = 58 PSI. Therefore, we will estimate P2 = 60 PSI.

c. In this example, Q = 1,760 GPM and Dosage = 2 PPM. Therefore, the required chlorine gas feed rate is 42 PPD.

   [1,760 (GPM)] x [0.012] x [2 PPM] = 42 PPD

   Therefore, we can select a 50 PPD ejector.

d. Looking at the 50 PPD ejector performance curve (Figure 2) and using a P2 back pressure = 60 PSI, we can see that the minimum required P1 supply pressure = 90 PSI and the minimum water flow rate is 8.5 GPM for nozzle #2.

e. The booster pump inlet pressure will be the same as P3 process pressure = 58 PSI. If the required P1 supply pressure = 90 PSI, the booster pump will need to increase the P3 pressure by 37 PSI at a flow rate of 8.5 GPM.

Metric Units

a. Typically the P2 back pressure is only slightly higher than the P3 process pressure.

b. In this example, P3 = 4 bar. Therefore, we will estimate P2 = 4.2 bar.

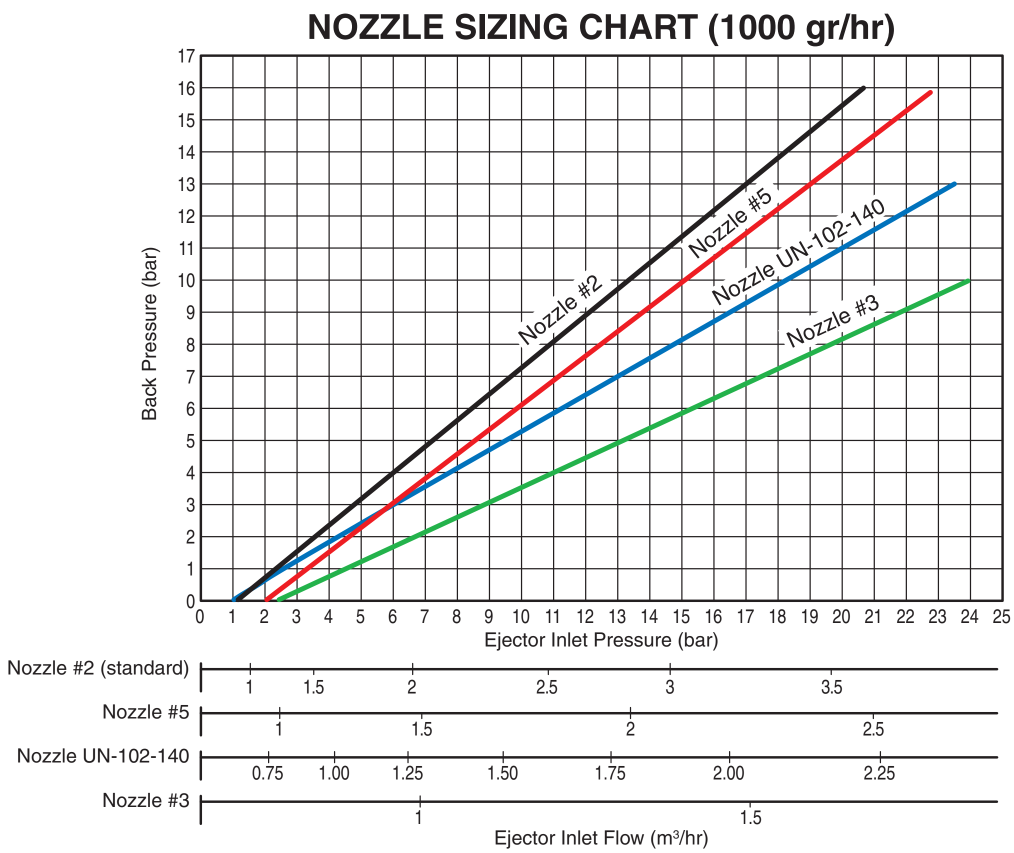
c. In this example, Q = 400 m³/hr and Dosage = 2 PPM. Therefore, the required chlorine gas feed rate is 800 gr/hr.

[400 (m^3/hr)] x [2 PPM] x [1/1000] = 0.8 kg/hr = 800 gr/hr

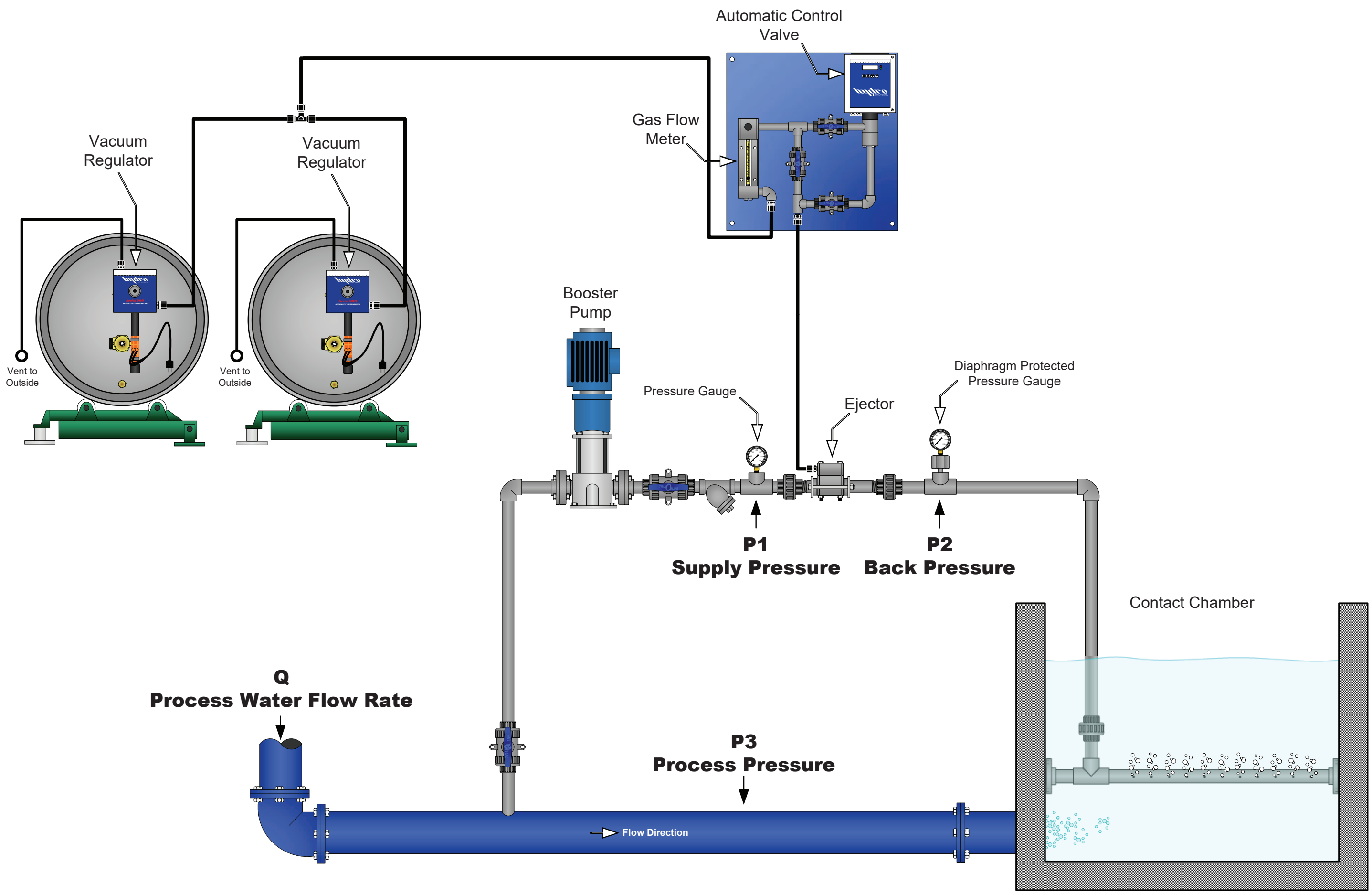
Therefore, we could select a 1,000 gr/hr ejector.

d. Looking at the 1,000 gr/hr ejector performance curve below and using a P2 back pressure = 4.2 bar, we can see that the minimum required P1 supply pressure = 7 bar and the minimum water flow rate is 35 liters/minute (2.1 m^3/hr) for nozzle #2.

e. The booster pump inlet pressure will be the same as P3 process pressure = 4 bar. The required P1 supply pressure = 7 bar, the booster pump will need to increase the P3 pressure by 3 bar at a flow rate of 2.1 m^3/hr.



2. Injection into an open tank (such as a contact chamber):



NOTE: Locate the ejector as close to the contact chamber as practical to minimize P2 back pressure. Reducing the length of this piping section also improves safety by minimizing the amount of pressurized, highly concentrated chlorine solution contained in the line.

Standard Units

a. In this example, P3 = 15 PSI, the water level head pressure from the contact chamber is 2 PSI, the open channel diffuser will add approximately 4 PSI, and we will assume that the ejector is located within 25 feet of the contact chamber. Therefore, we will estimate P2 = 7 PSI

b. In this example, Q = 17,600 GPM and Dosage = 2 PPM. Therefore, the required chlorine gas feed rate is 422 PPD.

   [17,600 (GPM)] x [0.012] x [2 PPM] = 422 PPD

   Therefore, we can select a 500 PPD ejector.

c. Looking at the 500 PPD ejector performance curve, nozzle & throat combination .296/.560 (Figure 2) and using a P2 back pressure = 7 PSI, we can see that the minimum required P1 supply pressure = 72 PSI and the minimum water flow rate is 18.3 GPM.

d. The booster pump inlet pressure will be the same as P3 process pressure = 15 PSI. If the required P1 supply pressure = 72 PSI, the booster pump will need to increase the P3 pressure by 57 PSI at a flow rate of 18.3 GPM.

e. Going back to the 500 PPD ejector performance curve (Figure 2), we can see that there are several nozzle & throat options that will have different booster pump requirements.

- ENX-290/.560 nozzle & throat booster pump requirements = 52 PSI at 15.5 GPM
- .375/.560 nozzle & throat booster pump requirements = 35 PSI at 20.0 GPM

Metric Units

a. In this example, P3 = 1 bar, the water level head pressure from the contact chamber is 0.1 bar, the open channel diffuser will add approximately 0.3 bar, and we will assume that the ejector is located within 25 feet of the contact chamber. Therefore, we will estimate P2 = 1.4 bar

b. In this example, Q = 4,000 m³/hr and Dosage = 2 PPM. Therefore, the required chlorine gas feed rate is 8 kg/hr.

[4,000 (m^3/hr)] x [2 PPM] x [1/1000] = 8 kg/hr

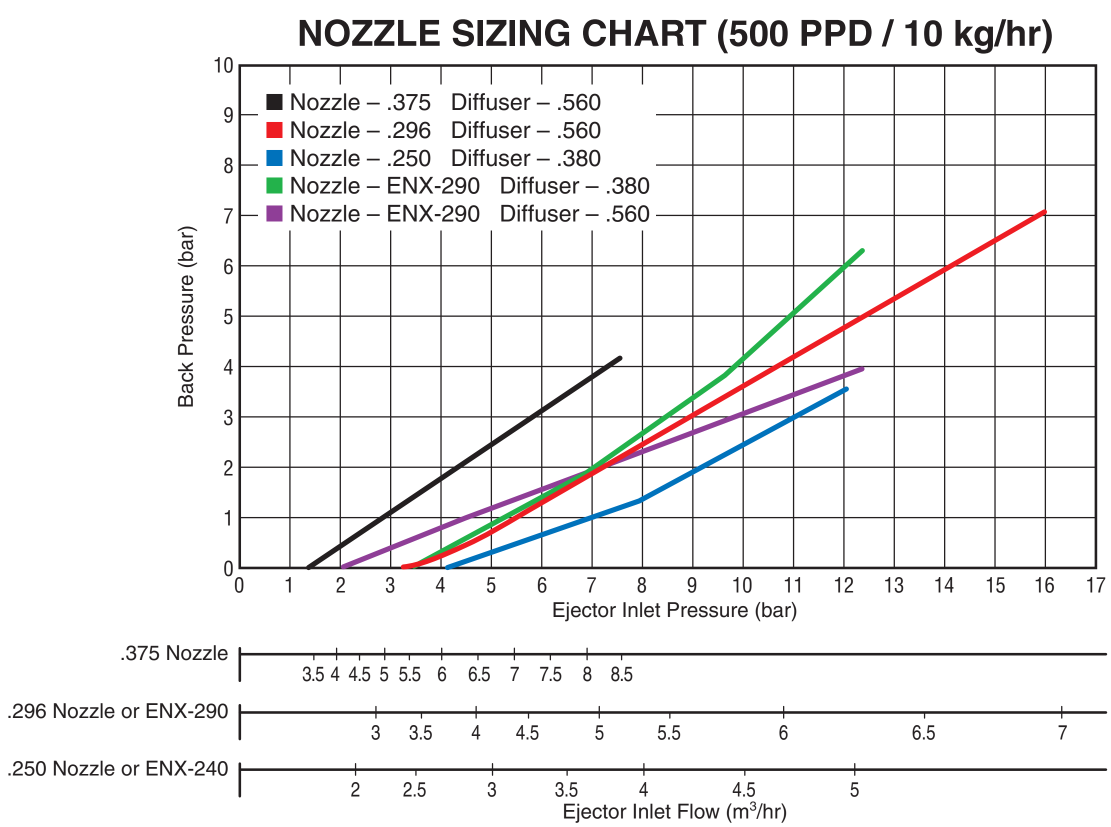
Therefore, we can select a 10 kg/hr ejector.

c. Looking at the 10 kg/hr ejector performance curve below, nozzle & throat combination .296/.560 and using a P2 back pressure = 1.4 bar, we can see that the minimum required P1 supply pressure = 7 bar and the minimum water flow rate is 83 liters/minute (5 m³/hr).

d. The booster pump inlet pressure will be the same as P3 process pressure = 1 bar. If the required P1 supply pressure = 7 bar, the booster pump will need to increase the P3 pressure by 6 bar at a flow rate of 5 m³/hr.

e. Going back to the 10 kg/hr ejector performance curve below, we can see that there are several nozzle & throat options that will have different booster pump requirements.

- ENX-290/.560 nozzle & throat booster pump requirements = 6 bar at 4.7 m³/hr
- .375/.560 nozzle & throat booster pump requirements = 4 bar at 6 m³/hr
- .250/.380 nozzle & throat booster pump requirements = 9 bar at 4.25 m³/hr



Types of Ejectors

Hydro Instruments offers a comprehensive range of ejectors to accommodate specific application requirements. Proper ejector selection is essential for reliable and efficient gas feed system operation. Selecting an unsuitable ejector may result in operational problems and unplanned downtime. Application specific ejector designs such as: variable orifice, anti-siphon, and diaphragm-less models can improve system performance, enhance safety, and reduce maintenance requirements.

Standard Ejectors

General purpose ejectors recommended for most applications.

Anti-Siphon Ejectors

Anti-siphon ejectors are used in systems where shutting off the ejector supply water could create a negative head (siphon) at the application point. For example, if the solution line or water main drains when the supply water is turned off.

This siphon can keep the vacuum regulator operating and allow gas to feed directly into the water piping. Hydro Instruments anti-siphon ejectors include an anti-siphon valve and a specially designed nozzle to break the siphon and prevent unintentional chemical draw into the piping.

Diaphragm-less Ejectors

Diaphragm-less ejectors are primarily used in applications with high back pressure and/or frequent start-stop cycling that would stress an ejector with a rubber diaphragm.

These ejectors incorporate a spring-loaded check valve that functions without the use of a rubber diaphragm.

High Capacity Fixed Orifice Ejectors

General purpose ejectors recommended for most high capacity feed applications.

High Capacity Variable Orifice Ejectors

Variable orifice ejectors are best suited for applications that require a wide range of gas feed rates. They allow manual external adjustment of the nozzle orifice to increase or decrease ejector capacity while minimizing water use.

High Capacity Enhanced Performance Ejectors

High capacity enhanced performance ejectors can feed chemical with lower supply pressure and reduced water use, helping decrease booster pump power consumption. They also use an integral spring-less check valve to prevent vacuum reduction in the gas feed system and an external drain valve to keep vacuum lines and equipment free of water more reliably.

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APPENDIX

Terms and Unit Conversions

Refer to Figure 1 for the following:

- P1 – We refer to this as the “supply pressure” because this is the water pressure at the inlet of the ejector.
- P2 – We refer to this as the “back pressure” because it is the water pressure at the exit of the ejector.
- P3 – We refer to this as the “process pressure”.
- Q – Process Water Flow Rate

Unit Conversions:

- Pressure:

  14.5 PSI = 1 bar = 1 kg/cm^2
- Volume:

  1 m^3 = 1,000 liters

  1 m^3/h = 16.6 liters/minute

  1 gallon = 3.78 liters