Section : E200
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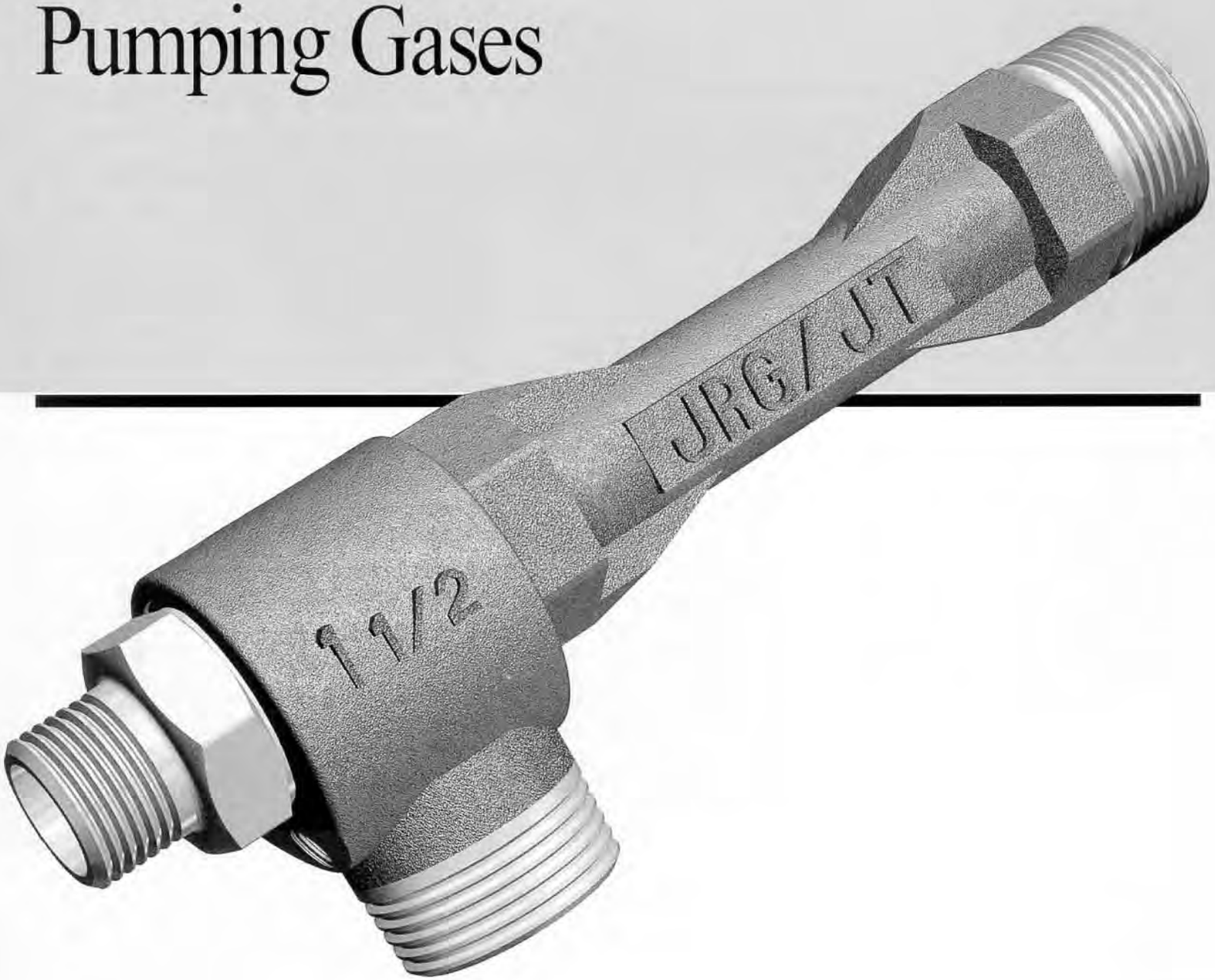
# Using Jerguson®/Jacoby-Tarbox® Eductors for Pumping Gases



# JRG/JT™ Models for Pumping Gases

## Operating Specifications

| Model | ML | MLE | SG | HG |
|---|---|---|---|---|
| Motive Media | Liquid | Liquid | Steam, Air | Steam, Air |
| Motive Pressure (PSIG) | 20-250 | 20-250 | 60-120 | 20-80 |
| Max. Vacuum (in Hg) | 29 | 29 | 24 | 24 |
| Outlet Pressure (PSIG) | 20 | 20 | 12 | 20 |
| Applications | Exhaust, Evacuate, Prime → | | | |

## Typical Applications

**Motive Fluid**

| Liquid | Steam | Air, Gas |
|---|---|---|
| Vacuum Filtration<br>Exhaust Vessels<br>Evacuate Vessels<br>Aerate Liquids<br>Distillation<br>Prime Pumps | Vacuum Filtration<br>Exhaust Vessels<br>Evacuate Vessels<br>Distillation<br>Prime Pumps | Vacuum Filtration<br>Exhaust Vessels<br>Evacuate Vessels<br>Distillation<br>Prime Pumps |
| ML, MLE | SG, HG | SG, HG |

There are two major types of applications using eductors to pump gases. These are evacuation and exhausting.

### Exhausting

This application involves removing gases at a continuous rate from an area while maintaining the pressure at a stable level. These applications often involve removing gases or fumes that are continuously recurring. An example would be removing smoke from a welding or machining area. This process also could be used for injecting oxygen into a liquid stream. If the gases being removed have undesirable characteristics, it is possible in some cases to neutralize them by using a reactive motive fluid.

### Evacuation

This application involves pulling gases from a defined volume by pumping the tank down from a starting pressure to a final lower pressure. It is generally sized by determining the amount of time it takes to reduce the pressure in the vessel to the desired final pressure. Examples of this application would be reducing the pressure in a reaction vessel to purge it of detrimental gases, or removing steam from a vessel before opening it to increase operator safety. A variation of this type of application is the use of eductors to prime piping or a system with liquid. Priming evacuations may be used to bring the level of liquid up to pump level to avoid the pump being started dry or to establish a siphon.

JRG/JT eductor models for liquids pumping gases are: ML, MLE; for gases pumping gases: SG, HG. These models can be used for both exhausting and evacuation. See the following specifications tables for operating parameters.

Other models of eductors are available for specific applications. In some cases, these specialty eductors can pump a suction volume up to 50 times the motive volume. Most JRG/JT eductors are available in sizes from 1/2″ through 3″ in a wide variety of materials. Expedited deliveries are possible if needed. Units are available in sizes up to 12″.



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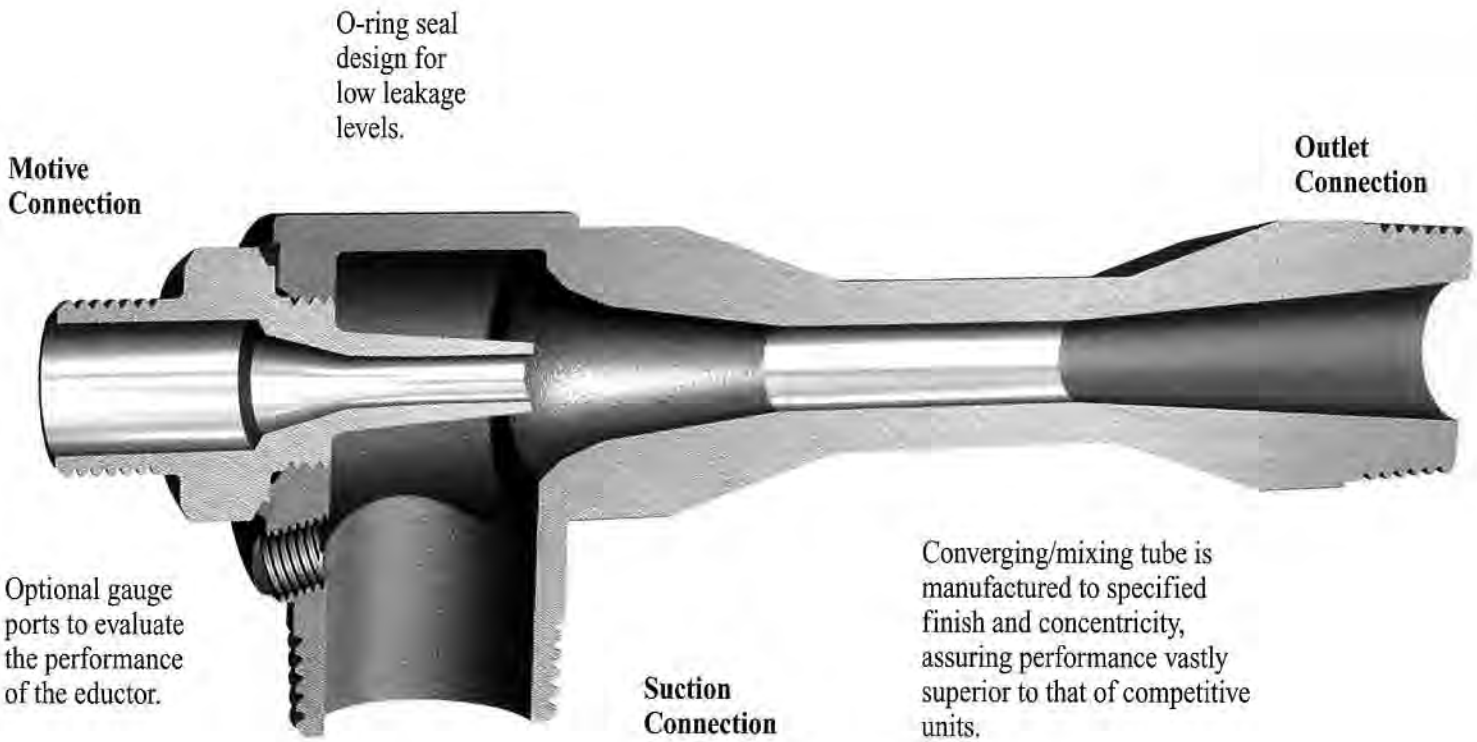
# Principles of Operation for Pumping Gases

Eductors operate on the basic principles of flow dynamics. This involves taking a high pressure motive stream and accelerating it through a tapered nozzle to increase the velocity of the fluid. Gas Motives are compressible fluids and are put through a converging-diverging nozzle. The gas can exceed the speed of sound. This fluid is then carried on through a secondary chamber where the friction between the molecules of it and a secondary gas (generally referred to as the suction fluid) causes this secondary gas to be pumped. These fluids are intimately mixed together and discharged from the eductor.

There are three connections common to all eductors.




## MOTIVE Connection

This connection is where the power for the eductor is generated, by increasing the velocity of the motive fluid. The JRG/JT nozzle in this section is manufactured to take advantage of the physical properties of the motive fluid. Eductors with liquid motives use a converging nozzle, as liquids are not generally compressible. Eductors with gas motives utilize converging-diverging nozzles to achieve maximum benefit from the compressibility of the gas. All JRG/JT nozzles for eductors have smooth flow paths. Flow paths with rough surfaces cause eductors to operate less efficiently.

## SUCTION Connection

This connection of the eductor is where the pumping action of the eductor takes place. The motive fluid passes through the suction chamber, entraining the suction gas as it passes. The friction between the fluids at the interface of the motive fluid causes the chamber to be evacuated as the gas in the chamber is removed. This allows the pressure in the suction vessel to push additional flow into the suction connection of the eductor. The high velocity of the motive stream in this section of the eductor directs the combined fluid toward the discharge section of the eductor.

## OUTLET Connection

As the motive fluid entrains the suction gas, part of the kinetic energy of the motive fluid is imparted to the suction gas. This allows the resulting mixture to discharge at an intermediate pressure. The percentage of the motive pressure that will be recovered is dependent upon the percentage of motive flow to suction flow and the amount of vacuum at the suction connection.

# How to Size Liquid Motive Eductors for Exhausting Gases

Exhausting is a continuous operation of removing gases at a constant suction pressure. The units are sized based on a desired flow rate of gas through the eductor.

***Step 1*** Before beginning to do the actual sizing, convert all pressure and flow to the units used in the sizing table. (If sizing is done regularly with other units, request a special sizing table from your representative.)

***Step 2*** First find the value that is equal to or greater than your system back pressure in the Outlet Pressure (Po) column. After locating the correct value on the sizing table, use this section of the table to size the unit.

***Step 3*** Locate the pressure that is equal to or higher than your desired suction pressure (Ps) for the outlet pressure found in Step 2. If the pressure is between two values on the sizing table, you can interpolate between them. If you don't wish to interpolate, the higher pressure will give a conservative estimate.

***Step 4*** In the row for suction pressure (Ps), locate the column where the motive pressure (Pm) is equal to your motive pressure in the flowing condition. If the pressure is between two levels on the sizing table, you can interpolate between the values. If you don't wish to interpolate, the lower pressure will give a conservative estimate.

***Step 5*** Divide your desired flow (Qs) rate by the flow rate of each model. This will give you a desired Sizing Factor (S.F.) for each model. Pick a unit with a S.F. that is equal to or larger than the one calculated above. Generally, the model with a larger suction capacity will be the more efficient unit. To calculate the actual gas flow, multiply the S.F. of the selected model by the suction flow (Qs) of the model in the table.

***Step 6*** Calculate the amount of water required to operate the eductor by multiplying the GPM in the Motive Flow (Qm) row by the S.F. of the unit selected.

***Note 1:*** In many cases, the capacity of the MLE and ML units are close. Both should be sized to find the proper unit for the application.

***Note 2:*** When using liquids to pump gases, the eductor acts as a volume displacing device. Therefore, the weight of the gas has only minimal effect on the performance of the eductor.

**ML, MLE** **Liquids Exhausting Gases** **1-1/2″ Unit**

Gas Flow, Qs (SCFM)

| Outlet Pressure, Po (PSIG) | Suction Pressure, Ps (In Hg Abs) | Motive Press, Pm (PSIG) 20 | | 40 | | 60 | | 80 | | 100 | | 140 | | 200 | | 250 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | ML | MLE | ML | MLE | ML | MLE | ML | MLE | ML | MLE | ML | MLE | ML | MLE | ML | MLE |
| 0 | 30 | 8.4 | 7.3 | 10.5 | 9.4 | 13.6 | 12.6 | 14.7 | 13.6 | 18.9 | 14.7 | 19.9 | 18.9 | 22.0 | 19.9 | 30.8 | 21.9 |
| | 25 | 1.7 | 3.1 | 3.7 | 5.8 | 6.0 | 8.4 | 8.9 | 10.7 | 10.4 | 12.0 | 13.2 | 15.0 | 17.5 | 18.1 | 24.5 | 19.9 |
| | 20 | 0.9 | 1.7 | 2.0 | 3.7 | 3.5 | 5.9 | 5.2 | 8.1 | 6.5 | 9.2 | 9.7 | 11.8 | 13.6 | 14.7 | 19.0 | 16.2 |
| | 15 | 0.5 | 0.8 | 1.2 | 2.5 | 1.9 | 3.9 | 1.9 | 5.8 | 3.9 | 6.6 | 5.5 | 8.8 | 9.2 | 11.0 | 12.9 | 12.1 |
| | 10 | | | 0.9 | 1.3 | 0.9 | 2.7 | 1.4 | 3.8 | 2.1 | 4.1 | 2.7 | 6.2 | 5.4 | 7.3 | 7.6 | 8.0 |
| | 5 | | | 0.3 | 0.6 | 0.4 | 1.6 | 0.7 | 2.1 | 0.8 | 2.3 | 1.2 | 3.2 | 2.1 | 3.6 | 2.9 | 4.0 |
| 5 | 30 | | | 2.6 | 5.2 | 3.9 | 8.4 | 5.7 | 10.5 | 10.5 | 13.6 | 13.6 | 16.8 | 19.9 | 18.9 | 27.9 | 20.8 |
| | 25 | | | 1.8 | 3.7 | 2.9 | 6.2 | 4.0 | 8.4 | 6.4 | 10.5 | 8.9 | 14.7 | 14.9 | 17.7 | 20.9 | 19.5 |
| | 20 | | | 1.3 | 2.5 | 2.2 | 4.6 | 2.9 | 6.6 | 4.2 | 8.0 | 5.8 | 11.3 | 10.8 | 14.4 | 15.1 | 15.8 |
| | 15 | | | 0.8 | 1.6 | 1.4 | 3.2 | 2.0 | 5.1 | 2.6 | 6.2 | 3.6 | 8.4 | 6.8 | 10.8 | 9.5 | 11.9 |
| | 10 | | | 0.5 | | 0.8 | 2.1 | 1.2 | 3.1 | 1.4 | 4.0 | 2.1 | 5.8 | 3.8 | 7.2 | 5.3 | 7.9 |
| | 5 | | | | | 0.3 | 1.2 | 0.5 | 1.8 | 0.6 | 2.2 | 1.0 | 3.1 | 1.5 | 3.6 | 2.1 | 4.0 |
| 10 | 30 | | | | | 3.1 | 6.2 | 4.1 | 8.4 | 6.0 | 11.5 | 8.9 | 15.7 | 16.8 | 18.8 | 23.5 | 20.7 |
| | 25 | | | | | 2.3 | 4.9 | 3.1 | 7.0 | 4.3 | 9.4 | 6.4 | 13.5 | 11.2 | 17.6 | 15.7 | 19.4 |
| | 20 | | | | | 1.6 | 3.6 | 2.3 | 5.5 | 3.2 | 7.5 | 4.6 | 10.7 | 7.7 | 13.9 | 10.8 | 15.3 |
| | 15 | | | | | 1.1 | 2.7 | 1.6 | 4.0 | 2.3 | 5.6 | 3.1 | 7.8 | 4.9 | 10.6 | 6.9 | 11.7 |
| | 10 | | | | | 0.7 | 1.5 | 1.0 | 2.8 | 1.3 | 3.8 | 1.8 | 5.6 | 2.9 | 7.0 | 4.1 | 7.7 |
| | 5 | | | | | 0.3 | | 0.5 | 1.5 | 0.6 | 2.2 | 0.8 | 3.0 | 1.2 | 3.6 | 1.7 | 4.0 |
| 15 | 30 | | | | | | | 3.3 | 7.4 | 4.6 | 9.9 | 6.5 | 14.7 | 11.5 | 18.9 | 16.1 | 20.8 |
| | 25 | | | | | | | 2.6 | 6.0 | 3.5 | 8.1 | 5.2 | 12.3 | 9.0 | 16.7 | 12.6 | 18.4 |
| | 20 | | | | | | | 2.0 | 4.8 | 2.7 | 6.7 | 4.0 | 10.4 | 6.7 | 13.5 | 9.4 | 14.9 |
| | 15 | | | | | | | 1.4 | 3.7 | 1.9 | 5.2 | 2.7 | 7.6 | 4.5 | 10.4 | 6.3 | 11.4 |
| | 10 | | | | | | | 0.9 | 2.5 | 1.2 | 3.6 | 1.6 | 5.5 | 2.5 | 6.9 | 3.5 | 7.6 |
| | 5 | | | | | | | 0.4 | 1.0 | 0.6 | 2.1 | 0.8 | 3.0 | 0.9 | 3.6 | 1.3 | 4.0 |
| 20 | 30 | | | | | | | 3.0 | | 3.8 | 8.9 | 5.8 | 13.6 | 8.9 | 17.8 | 12.5 | 19.6 |
| | 25 | | | | | | | 2.3 | | 3.1 | 7.5 | 4.6 | 11.7 | 7.2 | 16.4 | 10.1 | 18.0 |
| | 20 | | | | | | | 1.6 | | 2.4 | 6.3 | 3.5 | 9.6 | 5.4 | 13.2 | 7.6 | 14.5 |
| | 15 | | | | | | | 1.1 | | 1.6 | 4.9 | 2.5 | 7.5 | 3.7 | 10.1 | 5.2 | 11.1 |
| | 10 | | | | | | | 0.7 | | 1.1 | 3.4 | 1.4 | 5.5 | 2.3 | 6.9 | 3.2 | 7.6 |
| | 5 | | | | | | | 0.2 | | 0.6 | 1.9 | 0.8 | 3.0 | 0.9 | 3.6 | 1.3 | 4.0 |
| Motive Flow, Qm (GPM) | | 18.8 | 18.0 | 25.4 | 24.2 | 30.4 | 28.2 | 34.7 | 31.7 | 38.5 | 34.7 | 45.2 | 40 | 53.2 | 45.9 | 59.2 | 50.3 |

**ML, MLE, SG, HG** **Sizing Factors (S.F.)**

| Unit Size | 1/2″ | 3/4″ | 1″ | 1-1/4″ | 1-1/2″ | 2″ | 2-1/2″ | 3″ | 4″ | 6″ | 8″ | 10″ | 12″ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| S.F. | 0.12 | 0.21 | 0.34 | 0.61 | 1.00 | 1.82 | 3.17 | 5.92 | 11.8 | 24.0 | 49.0 | 71.0 | 123.0 |

# How to Size Liquid Motive Eductors for Exhausting Gases

**Example:**

| | |
|---|---|
| Desired Suction Flow, Qs | 5 Lb/Hr air |
| Desired Suction Pressure,Ps | 5 In Hg Vac |
| Motive Water Pressure, Pm | 40 PSIG |
| Outlet Pressure, Po | 11 Ft Head |

***Step 1*** Convert the figures from given units to units used in the performance tables.

**5 Lb/Hr x 13.35 $Ft^3$/Lb/60 Minutes = 1.1 SCFM Air**

**5 In Hg Vac = 29.92 In Hg Abs – 5 In Hg = 24.92 In Hg Absolute**

**40 PSIG is available**

**11Ft Head/2.31(Ft/PSIG)=4.8 PSIG**

***Step 2*** Look down the Outlet Pressure (Po) column until the row is reached that has 5 PSIG outlet pressure.

***Step 3*** Locate the suction pressure (Ps) that is equal to the desired suction pressure for the chosen outlet pressure. In this case, go to the section with a suction pressure of 25 In Hg Abs.

***Step 4*** Find the column in the 25 In Hg row that has a motive pressure (Pm) of 40 PSIG.

***Step 5*** Divide the suction flow desired by the Tabulated Suction Flow of each of the units to determine the desired S.F.

**1.1 SCFM Desired/1.8 ML Tabulated Suction Flow = .65 Desired S.F.**

**1.1 SCFM Desired/3.7 MLE tabulated flow = .30 Desired S.F.**

From the S.F.'s above, it appears that the MLE will be more efficient. The 1" unit has a S.F. of .34. When we multiply the S.F. by the suction flow for the 1-1/2" unit, we find an actual suction flow of:

**.34 x 3.7 = 1.3 SCFM Actual Suction Flow**

***Step 6*** The water needed to operate the MLE 1" will be 24.2 GPM x .34 S.F. = 8.2 GPM.

**SG, HG** **Gases Exhausting Gases** **1-1/2" Unit**

Gas Flow, Qs (SCFM)

| Suction Pressure, Ps (In Hg Abs) | Motive Press, Pm (PSIG) 20 | | 40 | | 60 | | 80 | | 100 | | 120 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | SG | HG | SG | HG | SG | HG | SG | HG | SG | HG | SG | HG |
| 30 | | 42 | | 33 | 61 | 31 | 59 | 29 | 56 | | 52 | |
| 25 | | 30 | | 28 | 50 | 25 | 47 | 23 | 44 | | 41 | |
| 20 | | 16 | | 21 | 39 | 19 | 35 | 17 | 33 | | 30 | |
| 15 | | 1 | | 13 | 28 | 11 | 24 | 10 | 23 | | 11 | |
| 10 | | 0 | | 5 | 17 | 2 | 14 | 0 | 12 | | 11 | |
| 5 | | 0 | | 0 | 0 | 0 | 1 | 0 | 0 | | 0 | |
| Max Outlet Pressure, Po (PSIG) | | 0 | | 6 | 2 | 15 | 6 | 20 | 10 | | 12 | |
| Motive Flow, Qm | | | | | | | | | | | | |
| Steam (Lb/Hr) | | 237 | | 367 | 222 | 499 | 278 | 626 | 335 | | 392 | |
| Air (SCFM) | | 78 | | 123 | 74 | 167 | 92 | 209 | 112 | | 131 | |

# How to Size Steam or Gas Motive Eductors for Exhausting Gases

**Using the Models SG and HG**

The JRG/JT models SG and HG are general purpose eductors used to pump gas with a gas as the motive stream. They can be used to pull both liquid and gas suction loads. In this case, we will deal with gas suction stream applications. The model SG is generally used with higher pressure motive flows in the ranges of 60 to 120 PSIG. It is possible to use lower pressures with these units if the outlet pressures are strictly controlled. The model HG is designed to be operated with motive pressures of 20 through 80 PSIG. Because of the increased motive flow rate in this unit, it generally will discharge against higher pressures. In general, the SG will pull a deeper vacuum on the suction connection than the model HG. If it is possible to meet the discharge conditions with the model SG, this unit is generally more efficient. Both SG and HG models can be used to evacuate, exhaust, or prime a given area. (See discussion on page 1, dealing with the difference in these applications.)

If the suction gas is not air at 70°F, refer to page 8 to convert the suction gas to Dry Air Equivalent. If the suction units are not in Lb/Hr, refer to the back cover to convert from other units to Lb/Hr. If your units are not found here, go to a conversion table in a book of chemical standards.

**Instructions on Sizing Steam or Gas Motive Eductors for Exhausting Gases**

***Step 1*** Before beginning any application, convert all pressure and flow units into the units used in the sizing table (Page 4). (If sizing is done on a regular basis with other units, request special sizing tables.)

***Step 2*** Find the motive pressure (Pm) column on the table that is equal to the motive pressure available at the eductor under flowing conditions.

***Step 3*** Locate the desired suction pressure (Ps) from the left-hand side of the performance table. Follow this across the table until it intersects the pressure (Pm) column selected in Step 2. This is the suction flow (Qs) of the 1-1/2″ unit for model SG, HG.

***Step 4*** Determine the outlet pressure (Po) of the eductor, and then determine which eductor(s) will meet these outlet conditions. If the SG will meet the outlet conditions, choose this unit to minimize motive consumption.

***Step 5*** Take the desired suction flow for the eductor divided by the actual flow for a 1-1/2″ unit found in Step 4. The result will be the desired S.F. for the eductor. Choose a standard eductor that has a Tabulated S.F. (page 3) that meets or exceeds the desired S.F.

***Step 6*** Determine the motive flow (Qm) required, by going to the performance charts. Then multiply the number found there by the S.F. of the unit selected in Step 5.

**Example:**

| | |
|---|---|
| Desired Suction Flow (Qs) | 17 SCFM |
| Desired Suction Pressure (Ps) | 7 In Hg Vac |
| Motive Gas Media | Steam |
| Motive Pressure (Pm) | 80 PSIG |
| Outlet Pressure (Po) | 5 PSIG |

***Step 1*** Convert the desired conditions into the units used in the sizing table. See the conversion factors on back cover of this manual. Convert 7 In Hg Vac to In Hg Abs:
29.92 In Hg Abs – 7 In Hg Vac = 22.92 In Hg Abs
All other units are in the terms used in the sizing table.

***Step 2*** Locate the columns for both SG and HG models with 80 PSIG motive pressure.

***Step 3*** Locate desired suction pressure, (Ps) of 25 In Hg Absolute on the left-hand side of the table. Follow this line across the table until it intersects the column for 80 PSIG operating pressure. In this case, this is at a suction flow of 47 SCFM for the model SG 1-1/2″ unit.

***Step 4*** While determining that both models will work against the outlet pressure (Po), the model SG will require less motive resource. Choose the model SG unit.

***Step 5*** Determine the Sizing Factor for the unit.
**17 SCFM Desired/47 SCFM Actual = 0.362 Desired S.F.**
If the desired flow is the absolute minimum flow, as in this case, choose the next larger S.F. This would be the model SG 1-1/4″, with a S.F. of 0.61. If a slightly lower suction flow would be acceptable, choose the model SG 1″.

***Step 6*** Calculate the actual performance of the unit selected. For the SG 1-1/4″ unit: Steam Motive Flow = 278 Lb/Hr Steam x 0.61 = 170 Lb/Hr Suction Flow = 47 SCFM x 0.61 = 28.7 SCFM.

For the model SG 1″ unit: Motive Flow = 278 Lb/Hr Steam x 0.34 = 94.5 Lb/Hr Suction Flow 47 SCFM x 0.34 = 16.0 SCFM. Choose the unit the will best meet your application conditions.

# How to Size Liquid Motive Eductors for Evacuating Gases

The times given in the ML, MLE evacuation charts below are the time in minutes to evacuate 1 $Ft^3$ to the pressure (vacuum) listed, from atmospheric pressure.

***Step 1*** Before beginning to do the actual sizing, convert all pressures and flows to the units used in the sizing table. (If sizing is being done regularly with other input units, request a special sizing table from your representative.)

***Step 2*** Divide the desired time to evacuate the volume by the number of $Ft^3$ to be evacuated.

**Desired evacuation Time**

**$Ft^3$ to be Evacuated**

**= Desired Time per $Ft^3$**

***Step 3*** Locate the value equal to or less than the available flowing pressure for your system in the Motive Pressure (Pm) column. If your available system motive pressure is between the listed pressures, you may interpolate between them. Choosing a lower pressure will yield a more conservative estimate.

***Step 4*** Locate the Suction Pressure (Ps) row that corresponds to the suction pressure that you need. If your desired suction pressure is between the listed pressures, you can interpolate between them. This will result in a more accurate sizing. At the intersection of the row you have located and the column from Step 3 is the time per $Ft^3$ for a 1-1/2″ unit.

***Step 5*** Choose a S.F. (Pg. 3) that when divided into the time/$Ft^3$ from Step 4 will yield a time/$Ft^3$ equal or lower than the Desired time/$Ft^3$ from Step 2.

***Step 6*** To determine the time required, multiply the $Ft^3$ of the suction vessel by the time per $Ft^3$ determined from the table in Step 5. This will give the time required to evacuate the vessel under actual conditions.

***Step 7*** To determine the motive water required, refer to the same column in the row labeled Motive Flow(Qm). Multiply this number times the Sizing Factor (S.F.) for the unit selected. The result will be the GPM of motive water required to operate the selected unit.

***Note:*** Eductors for evacuations are sized at atmospheric outlet pressure. For liquid motives, these values calculated can be used with higher outlet pressures provided they do not exceed 5% of the motive pressure or 5 PSIG, which ever is lower. If higher outlet pressure is being used, consult the factory or your representative.

## Adjusting Formulas for Priming

***Step 1*** Multiply the $Ft^3$ to be evacuated by 2, then go to Step 1 under Evacuation and proceed through the procedure described above.

## Example:

| | |
|---|---|
| Required Time to Evacuate Vessel | 4 Minutes |
| Motive Pressure, (Pm) | 60 PSIG |
| Size of Vessel to be Evacuated | 45 $Ft^3$ |
| Outlet Pressure, (Po) | 1 PSIG |
| Desired Final Suction Pressure,(Ps) | 10 In Hg Abs |

***Step 1*** All units are in pressures and flows used in charts.

***Step 2*** 4 minute desired evacuation time/45 $Ft^3$ = .089 minute/$Ft^3$

***Step 3*** Motive Pressure, Pm is 60 PSIG.

***Step 4*** Go to the ML and MLE table to find an MLE operated at 60 PSIG and pulling down to 10 In Hg Abs will evacuate each $Ft^3$ in 0.14 minutes.

***Step 5*** The S.F. for a 2″ MLE gives .14/1.82 = .077 minutes per $Ft^3$, the first number below .089, the desired time from Step 2.

***Step 6*** The actual time to evacuate will be 45 $Ft^3$ x .077 minutes = 3.47 minutes.

***Step 7*** The motive flow (Qm) required will be 26.2 gal. x 1.82 S.F. = 47.7 GPM.

Will the outlet pressure effect the unit?
60 x .05 = 3 PSIG.

Therefore, as the outlet pressure (Po) does not exceed 5% of the motive pressure or 5 PSIG it should have little effect on the performance of the unit.

**ML, MLE** **Liquid Motive Evacuating Gases in Times** **1-1/2″ Unit**

| Suction Press | Motive Press, Pm (PSIG) | | Minutes per cubic foot | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 20 | | 40 | | 60 | | 80 | | 100 | | 140 | |
| Ps, (In Hg Abs) | ML | MLE | ML | MLE | ML | MLE | ML | MLE | ML | MLE | ML | MLE |
| 30 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 25 | 0.07 | 0.14 | 0.02 | 0.02 | 0.01 | 0.01 | 0.01 | 0.01 | 0.06 | 0.01 | 0.01 | 0.01 |
| 20 | 0.25 | 0.14 | 0.10 | 0.06 | 0.05 | 0.04 | 0.03 | 0.03 | 0.02 | 0.03 | 0.01 | 0.02 |
| 15 | 0.51 | 0.30 | 0.24 | 0.14 | 0.01 | 0.08 | 0.07 | 0.06 | 0.06 | 0.05 | 0.03 | 0.04 |
| 10 | 0.95 | N/A | 0.45 | 0.26 | 0.28 | 0.14 | 0.17 | 0.10 | 0.11 | 0.08 | 0.07 | 0.06 |
| 5 | N/A | N/A | 0.91 | 0.47 | 0.59 | 0.25 | 0.41 | 0.17 | 0.29 | 0.14 | 0.13 | 0.11 |
| Motive Flow, Qm (GPM) | 18.9 | 16.3 | 25.3 | 21.8 | 30.4 | 26.2 | 34.8 | 30 | 38.7 | 33.3 | 45.4 | 39.2 |

# How to Size Gas or Steam Motive Eductors for Evacuating, Including Adjustments for Priming

**Priming**

Priming is simply a special type of evacuation where the reduction of pressure in the vessel is used to draw liquid into the vessel. A good rule of thumb for priming applications is that they take twice as long as an evacuation for the same volume and pressure.

***Step 1*** Before beginning to do the actual sizing, convert all pressures and flows to the units used in the SG, HG sizing table below. (If sizing is being done on a regular basis with a variety of units, request a special sizing table from your representative.) A list of common con- version factors can be found on the back cover of this brochure.

***Step 2*** After determining the required suction pressure to be achieved, divide the desired time to achieve this vacuum by the number of $Ft^3$ to be evacuated. This will result in a time per $Ft^3$ to perform the evacuation.

**Desired Evacuation Time**

**$Ft^3$ to be Evacuated**

**= Desired Time Per $Ft^3$**

***Step 3*** Find the column from the performance table that corresponds to your motive pressure. Find the row with the desired suction pressure on the left-hand side of the performance table. By dropping down to this intersection, the time for evacuating 1 $Ft^3$ in minutes is found for the 1-1/2" unit.

***Step 4*** Take the tabulated time per $Ft^3$ found in Step 3 and divide it by the desired minutes per $Ft^3$ found in Step 2. The result will be a Desired Sizing Factor (S.F.). Go to the Table on Pg. 3 and pick the unit that will meet or exceed the factor found above.

***Step 5*** Divide the tabulated time per $Ft^3$ by the S.F. of the unit selected. Multiply this by the number of $Ft^3$ to be evacuated. The result will be the actual time required to evacuate the vessel with the eductor selected.

***Step 6*** To determine the motive flow required, go to the chart for the motive gas you are using. Then find the motive pressure you are using under this column and locate the model of unit you are using. Multiply this flow by the S.F. of the unit you selected in Step 4.

***Notes:*** The models SG and HG are sized using the same steps as the ML and MLE; the only difference is the motive force is provided by steam or gas.

**Example:**

| | |
|---|---|
| Area to be Evacuated | 35 $Ft^3$ |
| Time to Evacuate | 12 minutes |
| Desired Suction Pressure (Ps) | 15 In Hg Abs |
| Gas to be Removed | Air |
| Motive Gas | Steam |
| Motive Pressure (Pm) | 60 PSIG |
| Outlet Pressure (Po) | Atmospheric Pressure |

***Step 1*** No conversions are needed as all units are the same as the units in the tables.

***Step 2*** 12 minutes desired time / 35 $Ft^3$ = 0.343 minutes per $Ft^3$.

***Step 3*** The model SG 1-1/2" unit will evacuate 1 $Ft^3$ in 0.012 minutes, as the performance table for 60 PSIG reads.

***Step 4*** 0.012 minutes per $Ft^3$ actual/0.343 minutes per $Ft^3$ required = 0.035 Desired Sizing Factor. In this case, choose the SG 1/2" which exceeds the Desired S.F.

***Step 5*** The time per $Ft^3$ for the 1-1/2" unit 0.012/0.12 S.F. = 0.100 minutes per $Ft^3$ x 35 $Ft^3$ = 3.5 minutes to evacuate the given volume to 15 In Hg Abs.

***Step 6*** The chart says the motive flow (Qm) for an SG 1-1/2" unit is 222 Lb Hr at 60 PSIG motive pressure x 0.12 S.F. = 26.6 Lb/Hr of motive steam required to operate the unit.

**SG, HG** **Steam Motive Evacuation Times** **1-1/2" Unit**

Models: SG & HG
Minutes per cubic foot

| Suction Pressure, Ps (In Hg Abs) | Motive Press, Pm (PSIG) SG 60 | 80 | 100 | 120 | HG 20 | 40 | 60 | 80 |
|---|---|---|---|---|---|---|---|---|
| 25 | 0.003 | 0.003 | 0.003 | 0.003 | 0.007 | 0.005 | 0.005 | 0.006 |
| 20 | 0.007 | 0.006 | 0.007 | 0.008 | 0.014 | 0.012 | 0.014 | 0.015 |
| 15 | 0.012 | 0.012 | 0.014 | 0.016 | 0.026 | 0.025 | 0.028 | 0.029 |
| 10 | 0.023 | 0.024 | 0.026 | 0.027 | 0.045 | 0.047 | 0.057 | 0.060 |
| Motive Flow, Qm | | | | | | | | |
| Steam (Lb/Hr) | 222 | 278 | 335 | 392 | 294 | 378 | 499 | 626 |
| Air (SCFM) | 74 | 92 | 112 | 131 | 97 | 125 | 167 | 209 |

# How to Correct For Different Gases – Dry Air Equivalent

Performance for steam-air eductors is determined by tests using gases of a specific molecular weight and temperature. The term Dry Air Equivalent (DAE) is a way of presenting data so that corrections can be made for temperature and molecular weight. The actual gas being pumped will generally be at some temperature and composition other than air at 70°F. As it is not practical to maintain testing facilities for an infinite number of gases and temperatures of those gases, the method described here has been devised to correct all gases to a standard set of conditions. This allows eductors to be designed under given circumstances, then applied to the actual process conditions they will work under.

This method is described by the Heat Exchange Institute HEI in the book "Standards for Steam Jet Vacuum Systems, Fourth Edition 1988" and is synopsized below. If a more detailed explanation is needed, please refer to the previously mentioned publication.

## Calculating average molecular weight of the mixture and finding correction factors

This method deals with the gases in terms of weight of flow in a given period of time. The most commonly used is Lb (of gas)/Hr. To proceed, the units of each gas component should be converted to Lb/Hr. (Conversion Factors for several different units are found on the back cover of this brochure.) Water vapor (steam) is handled as a separate component in this calculation because the temperature correction factor is different for condensable gases.

To find the average molecular weight for the gas components, take the Lb/Hr flow for each gas component and divide it by the molecular weight of that component. This will result in the number of moles of each component. Then add together the Lb/Hr flows of each component (except the water vapor). This will result in the total Lb/Hr flow of gas to be pumped. Then add together the total moles of each component. The result will be the total moles of gas to be pumped. Finally, divide the total Lb/Hr flow to be pumped by the total moles to be pumped. The result will be the average molecular weight of the mixture. The average molecular weight of the mixture is then used to obtain a gas weight correction factor from the "Molecular Weight Entrainment Ratio Table" found on page 9 of this brochure.

The correction factor of the water vapor is obtained by reading the correction factor from the "Molecular Weight Entrainment Ratio Table."

For the more common gases the molecular weight of each component may be obtained from this page. If your gas is not here, you can calculate it by adding the weight of the atoms of each element in the gas. (Then if the gas is diatomic, multiply by 2, etc.)

## Finding Temperature Correction Factors

Go to the "Temperature Entrainment Ratio Table" on page 9 and find the temperature of the suction gas. From the table, obtain the temperature correction factors for gas and steam. These will be put into the correction calculation.

## Final Correction Formula

Take the total flow rate (Lb/Hr) of the gases to be pumped minus the flow rate (Lb/Hr) of the water vapor, divide this by the gas flow rate (Lb/Hr) correction factor times the gas temperature correction factor. The result will be the non-condensable gas load for the ejector.

Then take the weight of the water vapor, divide it by the molecular weight correction factor times the temperature correction factor for steam.

Then add the results of these two calculations together. The final result will be the total gas load Lb/Hr required of the eductor in Dry Air Equivalent. This number is used as the desired suction flow (Qs) in the table.

## Example:

50 Lb/Hr of a mixed gas and steam at a temperature of 300°F contains 15 Lb/Hr of $O_2$, 10 Lb/Hr of Air, 5 Lb/Hr of $H_2$, 5 Lb/Hr Of $CO_2$, and 15 Lb/Hr of steam.

The molecular weights of these gases are as follows:

$O_2$ = 32 Lb/Mole
Air = 29 Lb/Mole
$H_2$ = 2 Lb/Mole
$CO_2$ = 44 Lb/Mole
$H_2O$ = 18 Lb/Mole

To find the moles of gas per Hr take the actual flow and divide by the Lb/mole

15 Lb/Hr of $O_2$/32 Lb/Mole = 0.469 Moles/Hr $O_2$

10 Lb/Hr of Air/29 Lb/Mole = 0.345 Moles Hr Air

5 Lb/Hr of $H_2$/2 Lb/Mole = 2.500 Moles/Hr $H_2$

5 Lb/Hr of $CO_2$/44 Lb/Mole = 0.114 Moles/Hr $CO_2$

(15 + 10 + 5 +5)/(0.469 + 0.345 + 2.50 + 0.114) = 10.21 Average Mole Weight of mixed gases

Gas Molecular Weight Correction Factor for 10.21 = 0.61 (by interpolation)

Steam Molecular Weight Correction Factor for 18 = 0.81 (by interpolation)

Temperature Correction Factor for Gases at 300°F = 0.945

Temperature Correction Factor for Steam At 300°F = 0.925

## Final Calculation of Example:

((15 + 10 + 5 + 5)/(0.61 x 0.945)) + (15/(0.81 x 0.925) ) = 80.74 Lb/Hr Dry Air Equivalent.

To choose the correct eductor, pick a unit that will pump 80.74 Lb/Hr of DAE at your desired suction pressure.

***Note:*** **Gases with low molecular weight will cause the DAE to be higher than the actual weight being pumped. It is imperative the actual DAE be calculated for gases containing these low molecular weight gases.**

## Temperature Entrainment Ratio

| Entrainment Ratio | Gas Temperature, °F | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 100 | 200 | 300 | 400 | 500 | 600 | 700 | 800 | 900 | 1000 |
| Steam | 0.992 | 0.958 | 0.925 | 0.892 | 0.860 | 0.818 | 0.792 | 0.760 | 0.728 | 0.692 |
| Air | 0.994 | 0.970 | 0.945 | 0.923 | 0.898 | 0.874 | 0.850 | 0.825 | 0.803 | 0.778 |

$$\text{Entrainment Ratio} = \frac{\text{wt. of air/steam (at actual temp.)}}{\text{wt. air/steam (at 70 deg F)}}$$

## Molecular Weight Entrainment Ratio

| | Molecular Weight | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 10 | 20 | 30 | 40 | 50 | 60 | 70 | 80 | 90 | 100 | 110 | 120 | 130 | 140 |
| Entrainment Ratio | 0.58 | 0.85 | 1.02 | 1.14 | 1.23 | 1.32 | 1.38 | 1.43 | 1.46 | 1.49 | 1.52 | 1.55 | 1.57 | 1.60 |

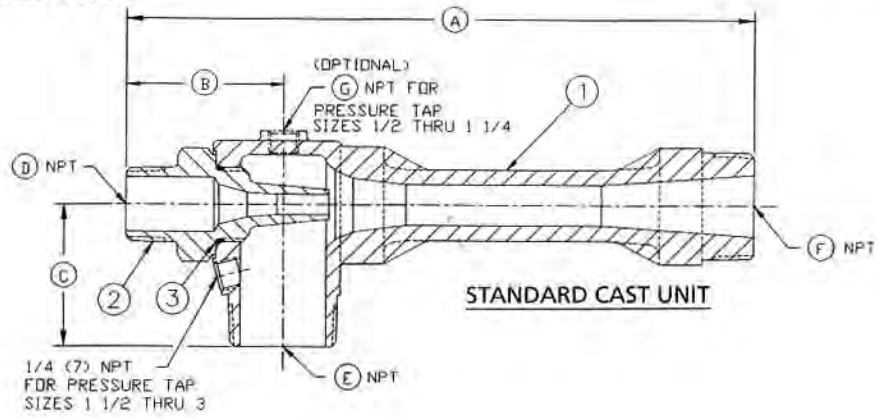
$$\text{Entrainment Ratio} = \frac{\text{weight of gas}}{\text{weight of air}}$$

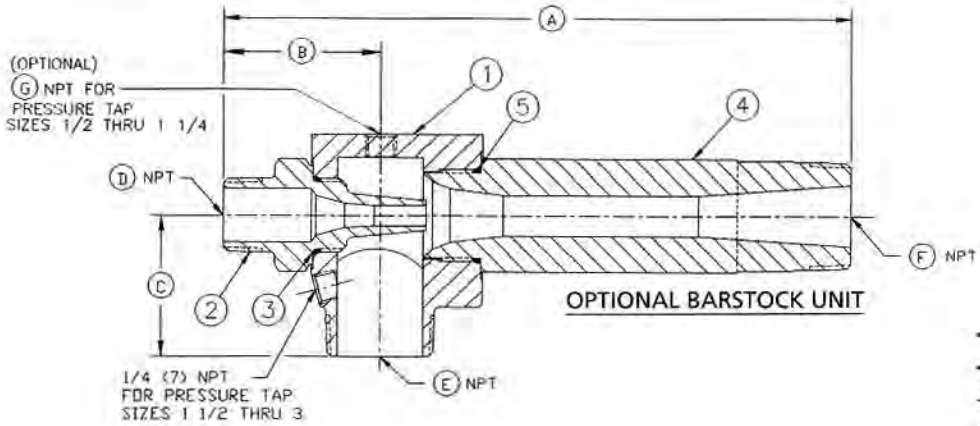
## Molecular Weights of Common Gases

| Name | Formula | Molecular Wt. |
|---|---|---|
| Ammonia | $NH_4$ | 18.038 |
| Ammonium | $NH_3$ | 17.03 |
| Benzene | $C_6H_6$ | 78.12 |
| Carbon Dioxide | $CO_2$ | 43.999 |
| Carbon Monoxide | CO | 28.01 |
| Chlorine | $Cl_2$ | 70.906 |
| Ethane | $C_2H_6$ | 30.07 |
| Hydrogen | $H_2$ | 2.016 |
| Methane | $CH_4$ | 16.043 |
| Oxygen | $O_2$ | 31.998 |
| Sulfer Dioxide | $SO_2$ | 64.058 |
| Water | $H_2O$ | 18.015 |

# Dimensions

## Models ML, MLE, SG, HG




**Parts List**

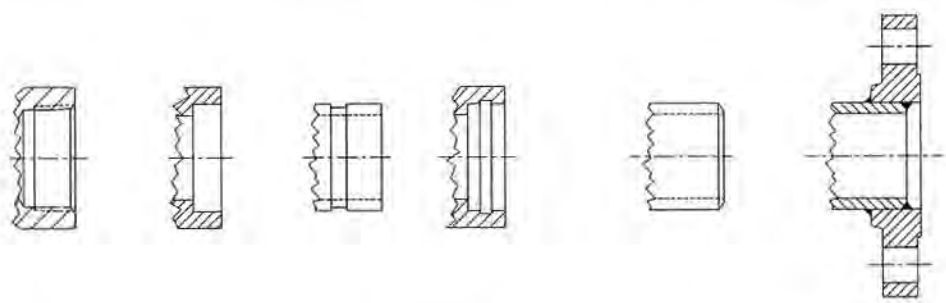
| ITEM | DESCRIPTION |
|---|---|
| 1 | BODY |
| 2 | NOZZLE |
| 3 | O-RING, NOZZLE |
| 4 | DISCHARGE |
| 5 | O-RING, DISCHARGE |

**ML, MLE, SG, HG** — **Assembly Dimensions**

Inches (mm)

| SIZE | A | | B | | C | | D | | E | | F | | G | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1/2 | 4.500 | (114) | 1.625 | (41) | 1.250 | (32) | 3/8 | (10) | 1/2 | (15) | 1/2 | (15) | 1/8 | (3) |
| 3/4 | 5.875 | (149) | 2.000 | (51) | 1.500 | (38) | 1/2 | (15) | 3/4 | (20) | 3/4 | (20) | 1/4 | (7) |
| 1 | 7.125 | (181) | 2.250 | (57) | 1.750 | (44) | 3/4 | (20) | 1 | (25) | 1 | (25) | 1/4 | (7) |
| 1 – 1/4 | 9.000 | (229) | 2.500 | (64) | 2.250 | (57) | 1 | (25) | 1 – 1/4 | (32) | 1 – 1/4 | (32) | 1/4 | (7) |
| 1 – 1/2 | 11.000 | (279) | 2.750 | (70) | 2.500 | (64) | 1 | (25) | 1 – 1/2 | (40) | 1 – 1/2 | (40) | – | |
| 2 | 14.375 | (365) | 3.125 | (79) | 3.000 | (76) | 1 – 1/4 | (32) | 2 | (50) | 2 | (50) | – | |
| 2 – 1/2 | 18.125 | (460) | 3.500 | (89) | 4.125 | (105) | 1 – 1/2 | (40) | 2 – 1/2 | (65) | 2 – 1/2 | (65) | – | |
| 3 | 23/875 | (606) | 4.000 | (102) | 5.000 | (127) | 2 | (50) | 3 | (80) | 3 | (80) | – | |

### OPTIONAL CONNECTIONS FOR MOTIVE, SUCTION AND OUTLET CONNECTIONS



FEMALE NPT SOCKET WELD VICTAULIC SILBRAZE SCH 80 BUTT WELD 150# FLANGE

NOTE: OPTIONAL CONNECTIONS WILL INCREASE A, B, AND/OR C. CONSULT FACTORY FOR DETAILS.

| TO CONVERT | INTO | MULTIPLY BY |
|---|---|---|
| | **A** | |
| atm | cm Hg | 76 |
| atm | ft $H_2O$ | 33.9 |
| atm | in Hg | 29.92 |
| atm | PSI | 14.7 |
| | **B** | |
| bar | atm | 0.9869 |
| bar | kg/sq meter | $1.020 \times 10^{-4}$ |
| bar | PSI | 14.50 |
| barrel | gal | 42 |
| | **C** | |
| Centigrade | Fahrenheit | (C x 9/5)+32 |
| cm Hg | atm | 0.01316 |
| cm Hg | ft $H_2O$ | 0.4461 |
| cm Hg | lb/sq ft | 27.85 |
| cm Hg | PSI | 0.1934 |
| centistokes | centipoise | 1.0 |
| cu in | cu cm | 16.39 |
| cu in | cu ft | $5.787 \times 10^{-4}$ |
| cu in | gal | $4.329 \times 10^{-3}$ |
| cu in | liter | 0.01639 |
| cu ft | gal | 7.48 |
| cu ft/sec | GPM | 448.83 |
| cu ft/sec | liter/min | 1699.3 |
| cu ft $H_2O$ | lb $H_2O$ | 62.425 |
| | **F** | |
| ft | cm | 30.48 |
| ft | meter | 0.3048 |
| ft $H_2O$ | atm | 0.02950 |
| ft $H_2O$ | in Hg | 0.8826 |
| ft $H_2O$ | kg/sq cm | 0.03048 |
| | **G** | |
| gal | cu cm | 3,785.0 |
| gal | cu ft | 0.1337 |
| gal | cu in | 231.0 |
| gal | liter | 3.785 |
| gal (Imp.) | gal | 1.20095 |
| gal | gal (Imp.) | 0.83267 |
| gal $H_2O$ | lb $H_2O$ | 8.3453 |
| | **H** | |
| hectoliter | liter | 100.0 |
| | **I** | |
| in | cm | 2.540 |
| in Hg | atm | 0.03342 |
| in Hg | ft $H_2O$ | 1.133 |
| in Hg | kg/sq cm | 0.03453 |
| in Hg | PSI | 0.4912 |
| in $H_2O$ | atm | $2.458 \times 10^{-3}$ |
| in $H_2O$ | in Hg | 0.07355 |
| in $H_2O$ | kg/sq cm | $2.540 \times 10^{-3}$ |
| in $H_2O$ | PSI | 0.03613 |

| TO CONVERT | INTO | MULTIPLY BY |
|---|---|---|
| | **J** | |
| joule/cm | lb | 22.48 |
| | **K** | |
| kiloliter | liter | 1,000.0 |
| kg | lb | 2.206 |
| | **L** | |
| liter | cu cm | 1,000.0 |
| liter | cu ft | 0.03531 |
| liter | cu in | 61.02 |
| liter | gal | 0.2642 |
| | **M** | |
| meter | cm | 100.0 |
| meter | ft | 3.281 |
| meter | in | 39.37 |
| micron | meter | $1 \times 10^{6}$ |
| mm | ft | $3.281 \times 10^{-3}$ |
| mm | in | 0.03937 |
| | **O** | |
| ounce | lb | 0.0625 |
| ounce (fluid) | cu in | 1.805 |
| ounce | g | 28.35 |
| | **P** | |
| poise | gram/cm sec | 1.00 |
| lb $H_2O$ | cu ft | 0.01602 |
| lb $H_2O$ | cu in | 27.68 |
| lb $H_2O$ | gal | 0.1198 |
| lb | g | 453.59 |
| lb/cu ft | kg/cu m | 16.018 |
| PSI | atm | 0.06804 |
| PSI | ft $H_2O$ | 2.307 |
| PSI | in Hg | 2.036 |
| PSI | kg/sq cm | .0703 |
| | **S** | |
| sq mm | sq cm | 0.01 |
| sq mm | sq ft | $1.076 \times 10^{-5}$ |
| sq mm | sq in | $1.550 \times 10^{-3}$ |
| | **T** | |
| temp (°C) | abs temp (°K) | (°C)+273 |
| temp (°C) | temp (°F) | 9/5(°C)+32 |
| temp (°F) | abs temp (°R) | (°F)+460 |
| temp (°F) | temp (°C) | 5/9 (°F-32) |

Notes:

1) $H_2O$ at 4°C
2) Hg at 0°C
3) gal = gal (U.S.) unless otherwise noted

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