KINNEY®

CASE STUDY

VACUUM PUMPS FOR EVACUATION OF GAS CYLINDERS

COMPRESSED GAS

OSHA defines a compressed gas as having a pressure in a container exceeding 40 psia at 70°F. The use of bottled cylinders containing compressed gas is prevalent in many of the various industrial sectors including general industrial, medical and healthcare, food and beverage, pharmaceutical, laboratory, science and research, etc. Most of these have OSHA, DOT and CGA regulations or recommendations and some also fall under FDA regulations or guidelines. Many of these, particularly the highly purified gases, require a pre-evacuation to insure removal of residual gases and possible contaminants before refilling. It is recommended by the gas supplier that the gas cylinders not be completely emptied to avoid drawing in contaminants such as air or water vapor that could cause contamination and other problems such as corrosion or explosive mixtures, which would drive the need for re-evacuation before refilling. The most common compressed gases for industrial use are Acetylene, Argon, Carbon Dioxide, Helium, Hydrogen, Nitrogen, and Oxygen. Various specialty mixes for welding and beverage use are also available.

Specialty gases of high purity or composition for pharmaceutical or scientific research require special handling. Various grades of gas purity may be required for the industrial, medical, aviation, and scientific research sectors.

VACUUM PUMPS

Some of the standard equipment in gas refilling stations includes vacuum pumps for the pre-evacuation step. In many cases the typical refilling procedure may include vent the residual gas to atmospheric pressure, purge with an inert gas such as Nitrogen, evacuate to a set pressure, and backfill with the pressurized gas.

The most common vacuum pumps used are small oil sealed vane or rotary piston pumps which in many cases may be used as a common vacuum source for evacuation of multiple gas cylinders except for Oxygen and Oxygen rich gas mixtures which requires the use of a vacuum pump without a hydrocarbon lubricant. The pumping capacity required per cylinder evacuated is relatively small because of the small cylinder volume to be evacuated as well as the orifice conductance limitation due to the small size valves used on the cylinders. Because of the orifice limitation, the evacuation time is limited by the conductance and not the pump capacity.

For viscous flow of an air equivalent gas at 20°C where P2/P1 < 0.5 the valve orifice conductance can be approximated by Co = 212 D2/(1-P2/P1) where the Co is the orifice conductance in cfm, D is the diameter in inches of the valve orifice or smallest orifice in the connecting piping between cylinder and vacuum pump, and P1 and P2 are the inlet and outlet pressures respectively. When P2/P1 < 0.1 Co ≈ 212 D2 for air equivalent gas. For a ¼" diameter orifice the conductance would be Co = 212 (0.25)2 = 13 cfm and for a 1/8" diameter orifice Co = 3.3 cfm. A larger vacuum pump with an average pumping capacity of 100 acfm would still have a lower effective pumping capacity at the gas cylinder of Se = CSp/(C + Sp) = (13 x 100)/(13 + 100) =11.5 acfm if limited by the ¼" orifice in the gas cylinder valve.

KVA - Oil Sealed Rotary Vane Vacuum Pump

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In some cases the supplier of the gas cylinder or service valve used on top may only provide the Cv factor for the valve which can still be used in determining the maximum orifice conductance Co from Co = 6.8Cv/ (1-P2/P1) for air equivalent and similarly as P2/P1 < 0.1 Co ≈ 7Cv where Cv is the flow coefficient for the valve in scfm per psi pressure drop (P1 – P2). Since typical gas cylinders can have small volumes of less than 2 ft3 the evacuation time from initial pressure P1 to final pressure P2 can still be relatively quick and be determined from t = V/Se ln (P1/P2) where t is pumpdown time in minutes, V is cylinder volume in ft3, Se is effective pumping capacity at the gas cylinder in acfm (actual cubic feet per minute), and P1 and P2 are the initial and final pressure respectively in consistent units.

Evacuating cylinders containing Oxygen or an Oxygen enriched gas (defined by CGA as a gas mixture greater than 23% by vol of Oxygen and by U.S. OSHA as greater than 23.5% by vol Oxygen) requires that the pumping equipment be free of hydrocarbon lubricants. Oil sealed rotary piston or vane pumps would need to use an Oxygen inert lubricant such as the perfluorinated lubricants containing Fluorine in place of Hydrogen on the Carbon atoms. Examples are Fomblin, Krytox, and Halocarbon lubricants which are not only resistant to Oxygen but are almost chemically inert. Because of the high cost of these lubricants Dry Pumps have been used as an alternative.

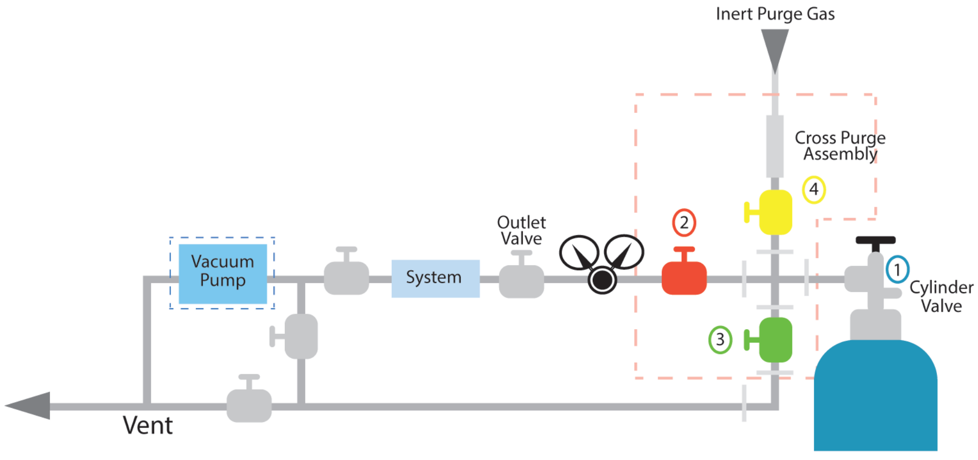
Specifications For Gas Cylinder Pumping By Cylinder Size

HP Steel	DOT	Service Pressure	Approximate Capacity†		Outside Diameter	Height*	Tare Weight**	Internal Water Volume††	
Cylinder Size	Specification	psig	cu. ft.	liters	inches	inches	lbs.	cu. in.	liters
50	9809-1***	2900	335	9373	9	58.2	130	3051	50
49	3AA	2400	277	7844	9.25	55	143	2990	49
44	3AA	2265	232	6570	9	51	133	2685	44
44H	3AA	3500	338	9571	10	51	189	2607	44
44HH	3AA	6000	433	12261	10	51	303	2383	43
16	3AA	2015	76	2152	7	32.5	63	976	16
7	3AA	2015	33	934.6	6.25	18.5	28	427	7
3	3AA	2015	14	396.5	4.25	16.75	11	183	3
LB/LBX(NR)	3E	1800	2	53.8	2	12	3.5	27	0.4

** Without valve.*
*** With valve, nominal.*
****UN/ISO specification.*

† For N_2 at 70°F 1 atm.
†† Nominal.
(NR) Nonreturnable cylinder.
Note: LBX is an LB cylinder with a OGA valve other than 170 or 180.

Typical Connections on Gas Cylinders



Example of gas cylinder filling system.

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