Pumping Flammable and Combustible Vapors in Vacuum Process Applications by Dry Vacuum Pumps made by Vacuum Pumps America Inc.

Vacuum Pumps America Inc. manufactures the most reliable Dry Vacuum Pumps for safe pumping flammable vapors in vacuum process applications. Although they have contact-free pumping mechanisms and no ignition sources created in normal operations, but we must always follow all safety precautions based on local and international standards. This article explains the risks of hazards when pumping flammable vapors with dry pumps also how to safe handle the flammable vapors by our dry vacuum pumps based on the North American NEC 500, NEC505 in Canada and USA also ATEX derivatives in European countries. It is advisable to do complete "Risk Assessments" and hazards identification by reviewing all aspects of your vacuum process. You can contact us if you have any question. For any question and inquiry please contact: **1- 416-407-0350 or sales@vpamerica.com**

1- Identify the potential for explosive or flammable atmospheres: Understand where an explosive atmosphere may occur and where an ignition might take place. We should consider the external atmosphere surrounding the vacuum pump and the internal atmosphere within the vacuum pump including the process interface to the inlet of the vacuum pump and the area from the inlet on the vacuum pump to the exhaust pipe.

Codes and Standards: Depending on where you are in the world, different codes and standards may apply. Typically, whatever is the scheme, they all cover hazardous classification and the protection methods that may be used to prevent explosions in these areas.

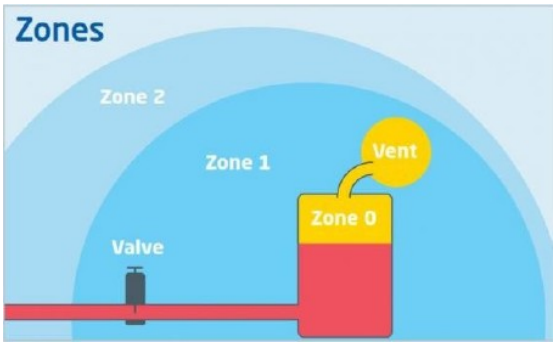
- **Worldwide**: IEC defines the most-widely adopted hazardous area standards.
- **In North America**: the NFPA (National Fire Protection Association) is the primary agency for the protection of installations from fire and explosion.
- **In Europe:** the ATEX derivatives closely follows IEC standards

1.1- What is a Hazardous Area?

A hazardous area is a location where the potential for fire or explosion exists caused by the presence of ignitable gases or dusts in the atmosphere. Examples of these locations include oil & gas facilities, chemical processing plants, pharmaceutical manufacturers and other plants that are dealing with flammable and explosives.

1.2- Definition of "Zones" in hazardous area based on worldwide IEC standards and ATEX:

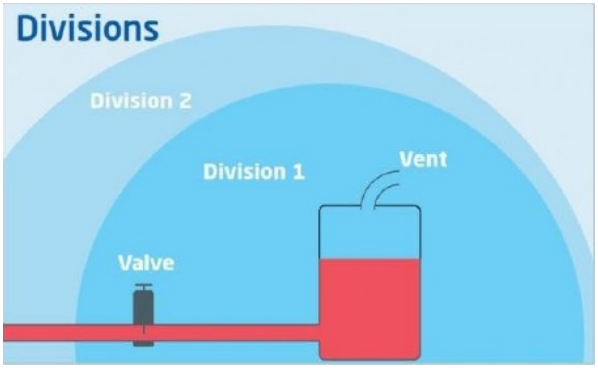
Under the **"Zone"** system, hazardous area is defined for **Gases** as **Zone 0, Zone 1 or Zone 2, with 0 as the highest hazard for flammable gassy locations.** And for **Dusts** the hazardous area will be defined as **Zone 20, Zone 21 or Zone 22, with 20 as the highest hazard for flammable dusty locations.**

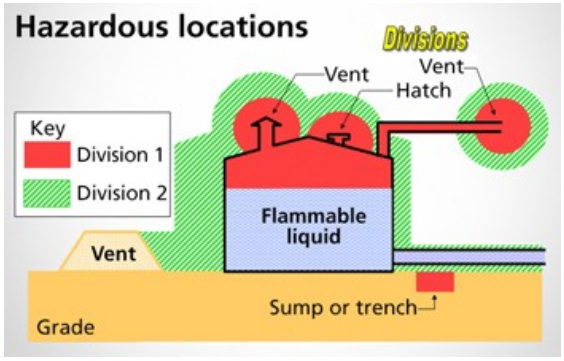


"Zones" based on IEC or ATEX Derivatives

1.3- Definition of "Divisions" for hazardous area based on North American NEC standards:

Under the **"Division"** system, hazardous area will be defined for **Gases** as **Class I** and **Division 1 or 2 with Class I, Division 1 as the highest hazard for gassy locations**. And for **Dusts** as **Class II** and **Division 1 or 2, with Class II, Division 1 as the highest hazard for dusty locations.**





"Divisions" based on NEC Standards

The classification of Zones and Divisions are related to the frequency and duration that ignitable **Gases** or **Dusts** may be present in the atmosphere.

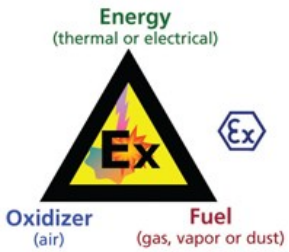
Under Zone Classification based on ATEX Standards in European countries

- Zone 0/20: The presence of flammable gases or dusts > 1000 hours / year
- Zone 1/21: The presence of flammables gases or dusts = 10 to 1000 hours / year
- Zone 2/22: The presence of flammables gases or dusts < 10 hours / year

Under Divisions Classifications based on NEC and NFPA standards in North America, USA and Canada

- Class I & II Div 1: The presence of flammable gases and/or dusts > 10 hours / year
- Class I & II Div 2: The presence of flammable gases and/or dusts < 10 hours / year

1.4- Recognized Methods for Explosion Protection:



For an explosion to happen, 3 components must exist

- Fuel must be presented in a suitable concentration
- The presence of air or Oxygen
- Source of heat or ignition

By looking at fire triangle, you will need the fuel and oxygen in correct mixture. Too little fuel, or a lean mixture, or too much fuel, a rich mixture cannot ignite. These explosive limits are defined as the "Lower Explosive Limit" (LEL) and the "Upper Explosive Limit" (UEL). Each method of protection addresses the Fire Triangle in some manner. Either by containing an internal explosion or eliminating one or more of the components necessary for an explosion to happen. The most common North American methods for protection against explosion is using explosion proof equipment for **Class I = Gas** locations, and **Class II = dust** proof equipment for these locations. Using explosion proof motors, explosion proof electrical panels, components and accessories in North America, and ATEX approved motors and ATEX approved electrical panels, components and accessories for hazardous locations in Europe are the best mandatory methods for preventing fire and explosions.

Beside at Vacuum Pumps America Inc. we design our vacuum pumps to be totally explosion resistance by using heavy gauge castings and heavy gauge materials and alloys.

2- Avoiding explosive atmospheres: Operation outside the flammable or flash point range ensures that even if an ignition source is present there will not be an explosion. Please make sure that the vacuum system and connecting pipes and hoses between the vacuum pump and vacuum system is completely leak free or the leak rate from surrounding atmosphere containing Oxygen is zero or low enough not to create explosive atmosphere.

2.2- Low pressure operation bellow 60 mbar or 45 Torr: Research has proven that it is not possible to sustain a burn in a potentially explosive atmosphere below **60 mbar or 45 Torr**. As the pressure of the system reduces, eventually a point is reached where flammability is not supported for nearly most of the flammables.

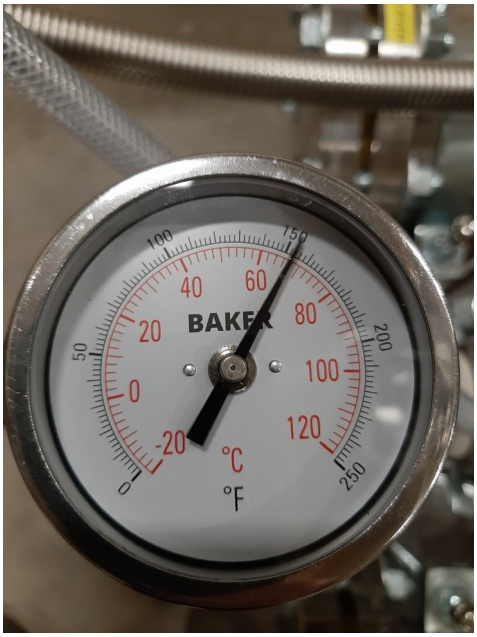
2.3- Operating above the upper explosion limit (UEL) or below the lower explosion limit (LEL): By controlling the relative concentrations of fuel and air, it is possible to keep the concentration of the vapors above the UEL or below the LEL, therefore eliminating the risk of explosion. Suitable safety margins should be used and it is common practice to use levels of 60 per cent above the UEL and below 25 per cent of the LEL.

2.4- Controlling the leak tightness of the vacuum system: It is mandatory to leak test the vacuum systems, process chambers, vacuum pipes and vacuum valves by using a Helium Leak Detector prior operation. This is normally show that the air leakage is above or below the calculated limit for flammability. Also ensure air leakage does not affect the quality of the product in vacuum chamber or system. **Vacuum Pumps America Inc.** always use Helium Leak Detector to check for leaks. We always make sure that, there is no leak from outside atmosphere to the vacuum system or vacuum pumps therefore our customers can use our vacuum pumps and vacuum systems with 100% reliability, safety and peace of mind.

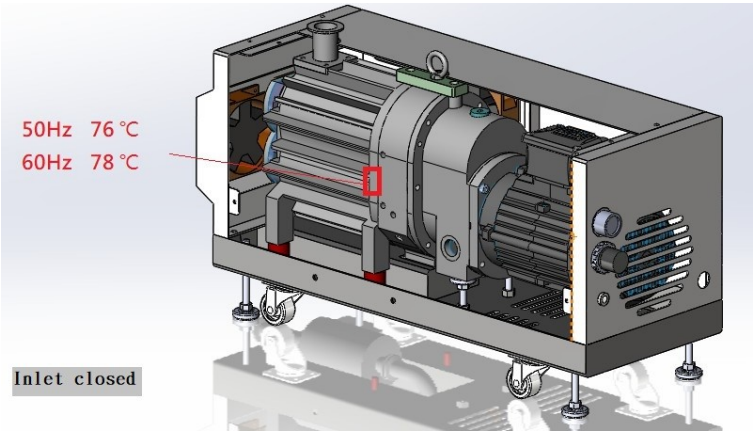
2.5- Using inert gas for purging seals and exhaust of vacuum pumps: It is mandatory to use inert gas like dry Nitrogen or Argon to purge the seals and exhaust of the vacuum pumps while pumping flammable gases especially when pumping flammables that are heavier than air. It is also advisable to purge the process vacuum chamber and vacuum lines back to atmospheric pressure by dry Nitrogen at the end of the cycle. This ensures that the subsequent evacuation for the pressure rise test is conducted and it is out of the flammable range. This inerting policy can also be applied at the end of a process to flush out flammable residues from process vessels as well.

2.6- Excluding or limiting oxidants, typically oxygen, from the vacuum pump compression chamber: The Limiting Oxidant Concentration (LOC) depends on the vapor and the type of inert gas used. In chemical, pharmaceutical and other similar plants, the inert gas is usually Nitrogen. If the concentration of Oxygen is kept below five per cent, by using Nitrogen, the atmosphere will be out of the flammable range for all but a few vapors such as ethylene oxide and carbon disulfide. You should apply a safety margin of typically 40 – 60 per cent of the LOC as the maximum oxidant concentration. Adding an inert gas to flammable gases reduces the flammability limits. The most common inert gas is N_2 but make sure that the process gases doesn't react with N_2. In case if you can't use N_2, you can also use Argon or helium. Please not that all of our explosion proof air cooled and water cooled dry screw vacuum pumps also dry scroll vacuum pumps equipped with N_2 purge and N_2 gas ballast also N_2 exhaust purge valves. **Note: It is the responsibility of the user to connect the N_2 purge and N_2 gas ballast valve to reliable source of Nitrogen.**

2.7- Low temperature vacuum pumps by Vacuum Pumps America Inc. As the temperature of the housing of vacuum pump are very important in hazardous area applications, all of our vacuum pumps work at lower temperatures compared to other competitors. You can see the exhaust temperature of our water cooled and air cooled dry screw vacuum pumps in the following pictures.



Exhaust Temperature of water cooled VPA-VSS60/Ex is 68°C



Exhaust Temperature of air cooled VPA-ASP50/Ex is 78°C

Moreover, the cantilever design and hidden seals and bearings in our vertical **VPA-VSS-Ex, VPA-VSS-Ex-SUS** vacuum pumps prevents any spark or ignition propagation to the working chamber of vacuum pump or process chamber. Also, we always provide Nitrogen purge gas after the exhaust check valve for all of our dry vacuum pumps to keep the outside atmosphere that contains Oxygen away from flammable gases and vapor leaving the exhaust. This combination cools down the exhaust gases also keeps Oxygen away from the working chamber of vacuum pump also the inlet and the process system making sure that, no Oxygen can reach the process system in case of power failure or when you shot down the vacuum pump.

3- Eliminating both spark and auto-ignition sources: We already diminished the risk of auto-ignition and potential spark in our **air cooled VPA-ASP and water cooled VPA-VSS series** dry screw vacuum pumps by adjusting the clearances in a way to prevent any contact between the screw rotors and the internal housing while creating the highest vacuum achievable by the screw technology. The cantilever design make our Vertical Dry Screw **VPA-VSS/Ex-SUS and VPA-VSS/Ex,** are best choice for handling flammable vapors. Also our air cooled **VPA-ASP/Ex** series has the best heat transfer to the housing and unique air cooling system. Using fine particle filters, water cooled traps and flame arrestors can also prevent both autoignition sources by preventing hot spots caused by particles and gummy stuff build up inside the vacuum pump and around the screw rotors. By knowing the vapor pressure, flash points, condensation point and other physical and chemical characteristics of the gases and vapors involve in your process you can use our dry vacuum pumps with peace of mind. Even if condensation occurs the liquid can drain from the exhaust by gravity to the exhaust catch pot also you can wash the working chamber of our vacuum pump by solvents or steam.

4- Limit the effects of a potential ignition: There are 2 ways to limit the effects of potential ignition. First by using explosion proof Electrical components and second by containment.

4.1- Protection by using Explosion Proof Electrical Components: It is mandatory to use certified explosion proof electrical components designated for that specific hazardous area for higher protection. Using explosion proof electric motor rated for designated hazardous area along with explosion proof solenoid valves, explosion proof control panels, explosion proof vacuum gauges and controls will guarantee the safe use of your vacuum pump and safety of the operators and maintenance people. In the photo below you can see

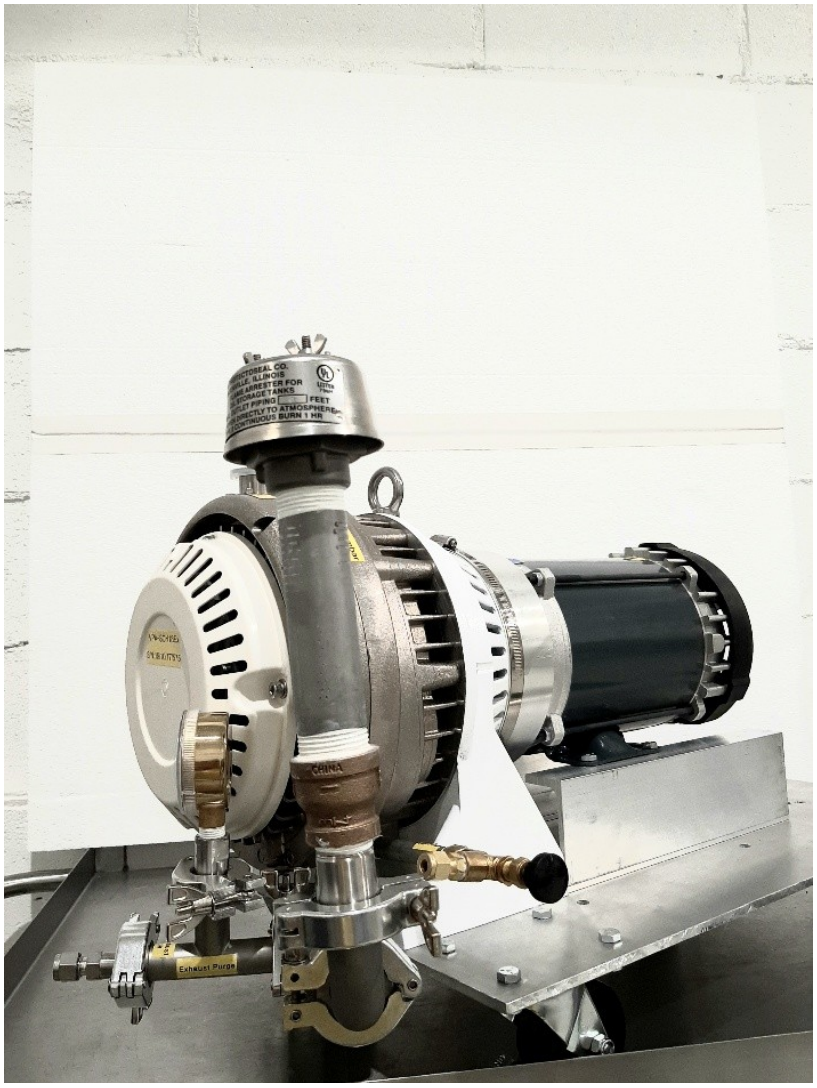
VPA-VSS60/Ex dry screw vacuum pump with certified explosion proof motor and certified explosion proof electrical panel rated for Class I, Division 1, Group C&D. Our dry vacuum pumps are safest vacuum pumps in the market.

VPA-VSS60/Ex with integrated explosion proof motor and explosion proof panel

VPA-VSS60/Ex-SUS with explosion proof motor

Very Important Note: Even if the surrounding area of the vacuum pump isn't hazardous but when you are pumping flammable vapors, it is a good practice to use a vacuum pump rated for hazardous area because in case of any accidental leakage through the the exhaust pipes then you will have flammable gases or vapors leaking in the surrounding area and change the non-hazardous area to hazardous area.

4.2- Protection by Containment: Containment in a vacuum system requires the prevention of flame propagation to the external atmosphere or process chamber and the exhaust pipework. Preventing propagation along the pipework requires individual consideration. The design of our dry screw vacuum pumps prevents flame propagation from inside the pump out to the atmosphere regardless of the zone. One of the best ways to prevent flame propagation is flame arrestors. Flame arrestors have been used effectively for many years in the chemical, pharmaceutical and associated industries to prevent the propagation of internal explosions. However, their performance is dependent on the length of the connecting pipes and vacuum pump. Therefore, it is essential that the performance of the flame arrestors is tested with the pumps to prove that as a combination they will contain any explosion. It is proven that flame arrestors can prevent the propagation of flames in case if any ignition or combustion happens. Flame arrestors available in 2 shapes: In-Line and end of the line. In-Line flame arrestors will be used for inlet of vacuum pumps while the end of the line flame arrestors will be used at the exhaust side of the vacuum pumps to outside atmosphere. Please contact **Vacuum Pumps America Inc.** for consultation.



In the above photo you can see VPA-SCH18/Ex dry scroll vacuum pump with stainless steel exhaust flame arrestor

Summery: Our air cooled and water cooled dry screw vacuum pumps can provide ultra clean vacuum and very good ultimate vacuum needed to successfully drive chemical and pharmaceutical processes in clean CIP and GMP plants. A range of features and benefits enables our dry vacuum pumps to perform the best results in such environments.

Excellent performance characteristics:

Continuous operation from atmospheric pressure down to 3 x 10^{-3} mbar

Excellent temperature control for the housing and exhaust compatible to T6 requirements

Safe and compliant operation, capable of handling:

Flammable, Corrosive and Precious Gases

Low auto-ignition temperature gases compatible to T4, T5 and T6

Completely leak tight down to 1 x 10^{-7} mbar.l/s

Environmentally safe operation:

No effluent generated

Dry running mechanism

Efficient solvent recovery

Low power consumption, low carbon foot print

Reduced maintenance and cost of ownership:

Very low cost of ownership means nearly maintenance free

CIP and GMP compatible for fine chemicals and pharmaceutical plants

Flushable with water, solvent or steam

Safe to use in hazardous area:

Configured for hazardous area installations based on North America standards with Explosion Proof Motors and Explosion Proof Electrical Components. ATEX versions available upon request. No requirement for complex control systems.

Applications:

Our air cooled and water cooled dry vacuum pumps are now the most preferred technology across all range of industries and market segments, including: Pharmaceutical, Fine Chemicals, Bulk Chemical, Oil & Gas, Specialty Chemicals, Petrochemicals, Oleochemicals, etc…

Vacuum Pumps America Inc. is the sole manufacturer of small size water cooled TEFLON coated, stainless steel and small air cooled dry screw vacuum pumps from 50 m^3/h up to 100 m^3/h used in lab scale through pilot and API contract manufacturing to full scale process plants up to 3000 m^3/h. Typical applications where our dry vacuum pumps used are: Drying, including filter & freeze drying, Lyophilizers, Evaporation, Pilot plants, Per-Evaporation, Polymerization, Reactor service, Solvent recovery, Sterilization with Ozone, Ethylene Oxide or Plasma, Bio-Diesel and Bio-Fule production, Crystallization, Deodorization, Desorption, Distillation, Molecular Distillation, Short path Distillation,Hydrogen pumping, pumping Oxygen and Isotopes, etc…

Vacuum system design for hazardous applications:

Designing and manufacturing vacuum systems for hazardous area is a challenging task, while you have to keep highest standards and safety features protecting operators working in the area and at the same time utilizing the highest efficiency of vacuum systems to perform the job perfectly, besides you need to keep the costs reasonable. In order to settle on a robust solution, the vacuum system designer will consider many factors to ensure an optimally efficient, safe and reliable vacuum system is delivered for use in a specific application. Factors considered in system design include:

- Process parameters like: Volume, Pressure, Temperature, type of gases, physical and chemical characteristics of gases and vapors, reactivity, flammability, etc…
- Equipment specification and selection: Type of vacuum pumps, vacuum valves, vacuum pipes, material of construction, etc...
- Safety and operating procedures according to local standards: Identifying hazards and Risk assessment
- Vacuum system and control integration
- Commissioning and installation
- Operation and Qualification

This will typically include a dry pump system with a series of accessory modules including:

- Dry Vacuum Pumps: Dry Screw Vacuum Pump or Dry Scroll Vacuum Pumps or their combinations with Roots Pumps.
- Gas purges for seals and exhaust: To dilute flammables and extends seal life also carrying heavy fumes.
- Safety devices: Solvent flush, inlet isolation valves, flame arrestors, safety switches, etc..
- Recovery vessels for solvents or other fluids
- Monitoring and controls units.

At the end, business success depends on maximum equipment uptime and minimum cost of ownership. The cost of ownership includes the capital investment, installation, operating, and maintenance costs. Our dry vacuum pumps offer the best thermal efficiency for any vacuum process system reduced power consumption results in a lower carbon footprint and low environmental impact. The final choice of a vacuum system should be based on safety, low cost of ownership and payback. Despite the initial cost of dry vacuum pump systems, the lower cost of ownership often means these vacuum pumps pay for themselves pretty much quickly.

Typical stainless steel dry vacuum pumping systems designed for fine chemical industry

Vacuum Pumps America Inc. is the proud manufacturer and supplier of vacuum pumps and vacuum pumping stations for many customers and helping them reaching their goals in faster production time with no down time and cost effective ways with highest safety standards.

For inquiries please contact: **sales@vpamerica.com or phone: 1- 416-407-0350.**