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Vacuum System Safety

Sensible precautions equal vacuum system safety. The most obvious safeguards begin with reading and following safety instructions. The rest depends on user awareness. Even though many vacuum-system components have built-in safety devices, risks are always present.

Electric shock is a common risk that can be caused by faulty or improperly connected electronic instrumentation, shorted diffusion pump hotplates, damaged heating jackets, pinched wires, exposed conductors, and ungrounded exposed feedthrough connectors. Ion- producing equipment, such as ionization gauges, mass spectrometers, and plasma sources, can provide sufficient electrical conduction via a plasma to couple a high- voltage potential to the vacuum chamber walls. If not properly grounded, any exposed conductive parts of a gauge, plasma source, controller, or vacuum chamber may attain potentially fatal voltages.

Hot-cathode ionization gauge controllers can also cause electrical shock in poorly grounded systems. Voltages as large as 150 V may be present on ungrounded insulated connectors at pressures near 1×10^{-3} torr during normal pressure measurement.

Have an operator safety check and maintain the vacuum system. Is there an intentional heavy-duty ground connected to the vacuum chamber? Are all exposed connectors and conductors on the vacuum chamber grounded? Are all ground connections properly connected to a solid earth ground?

Use a multimeter to measure for voltage differences between every instrument chassis and all metal parts of the system. If no voltages exist, measure the resistance between the grounded components of the vacuum system. The resistance should not exceed 2 ohms to assure a commonality of grounds between the different system components. If systems rely on water piping for the earth-ground connection, remember proper ground connection can be lost by inadvertently inserting a plastic interconnect. Also, O-ring cap seals without metal clamps or a bolt connection can isolate big portions of a vacuum system from its safety ground. Verify that any new component's vacuum port is electrically grounded, and use a ground lug on a flange bolt if necessary.

Electrical wiring in the vacuum system should be organized and in good working condition. Keep all cables away from vacuum ports frequently opened to air and rack-mount instruments whenever possible. The voltage from an ion gauge controller can be lethal, particularly during electron bombardment degas. Some ion gauge controllers deliver biasing voltages to the gauge electrodes and connectors even if the filament is not turned on.

Whenever possible, use electronic equipment powered by a low-voltage supply. Most commercially available OEM equipment is now available with a 24 VDC input power option.

Burns are another concern. UHV systems are routinely baked out at 200 to 250°C, and can be as hot as 450°C. Vacuum chambers can take hours to cool. Filament-based devices, such as Bayard-Alpert ionization gauges and mass spectrometers, can radiate high levels of heat to adjacent areas. Diffusion pumps have exposed heating plates that are usually not marked as harmful, and some oil-based mechanical pumps get hot during operation, particularly under heavy loads.

Vacuum ovens require their own set of precautions to minimize burn risks. Mark hot areas with warning signs and replace the signs periodically. Shield ionization gauge tubes to eliminate possible contact with personnel during operation. Monitor the temperature of your vacuum system at several points using thermocouple-based temperature readers. Continuous temperature monitoring is also efficient. Heating jackets, with built-in thermostats, are always preferable to heating tape.

Injuries from explosion are an important safety concern. Explosion is possible in systems that are routinely cycled from vacuum to pressures above atmosphere. Dangerous overpressure conditions ensue if a pressure regulator is set to the wrong value, or the wrong gauge or gauge calibration is used for positive pressure measurements, or even if a setpoint value is programmed incorrectly into an automated process control setup. Explosions can also occur if flammable or explosive gases are exposed to hot elements. Check that the right cylinders and gases are connected to the gas-handling system, the correct regulator pressure settings are selected, use pressure relief valves in the gas manifiold and in the vacuum chamber, and avoid using enhanced Pirani and thermocouple gauges in systems routinely pressurized above atmosphere (capacitance diaphragm gauges are recommended instead). Also check that the right units were used while programming the automatic process control setup.

Explosion is a risk associated with pressurized air lines used to actuate gate valves and other mechanical components in automated systems, particularly pneumatic lines pressurized up to 125 psig. Gas lines can be damaged during system modifications, causing inadvertent system shutdowns. There is also potential for injury to hands and arms caught in the path of closing gate valves.

Implosion is a risk in high-vacuum systems with glass windows, tubulation, and glass envelope gauges. Dropping a tool on a gauge under vacuum or pulling on the cables can easily break the glass. Make all windows as small and thick as possible, replace glass gauges with metal ones, and protect glass components with tape or metal shields. Cables should be stress-relieved. Finally, remember that most vacuum-system components have a finite lifetime and need to be periodically checked, serviced, or replaced.

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