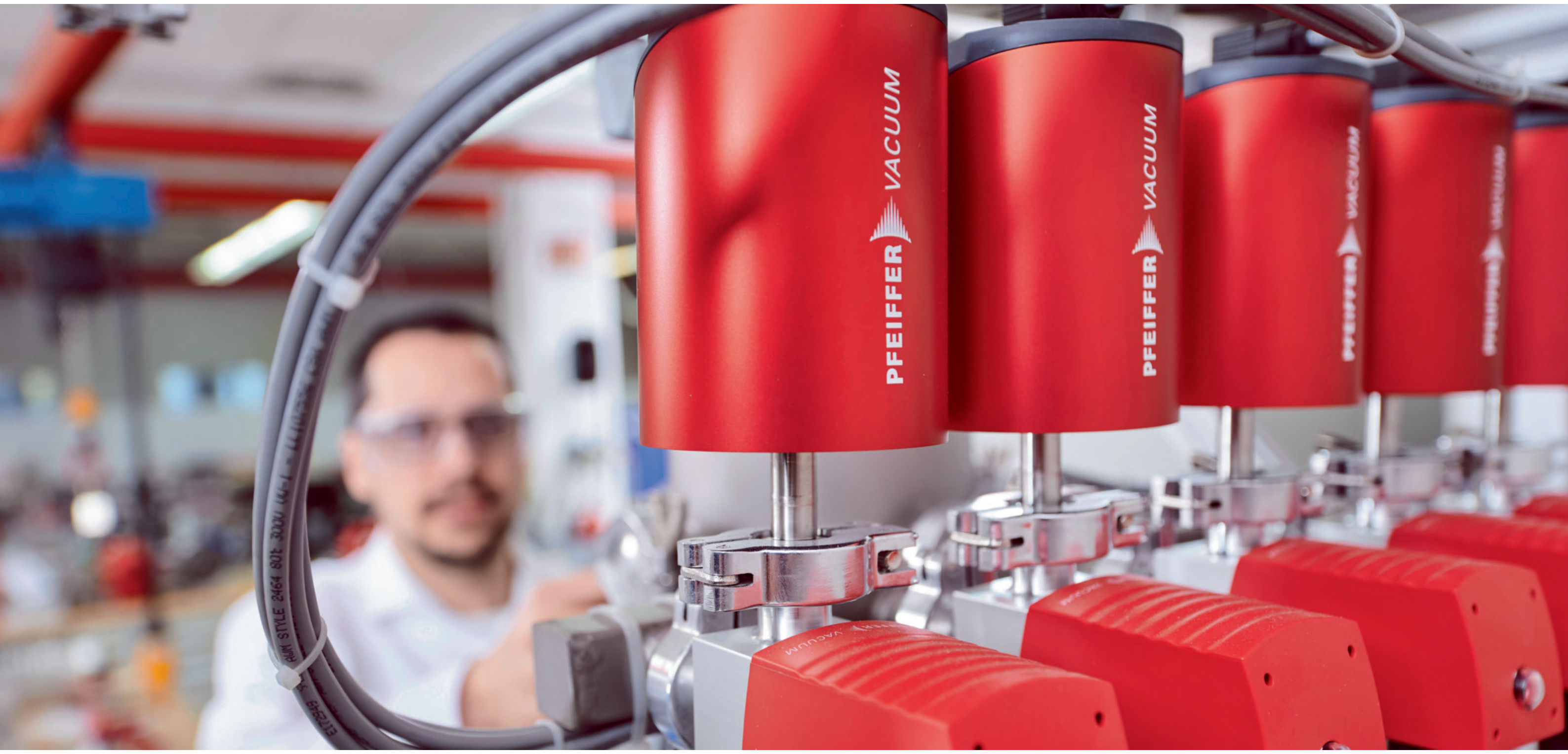
Whitepaper

How Do I Clean Vacuum Gauges Correctly?



Notes, guidelines and instruction for cleaning

PFEIFFER VACUUM

Content

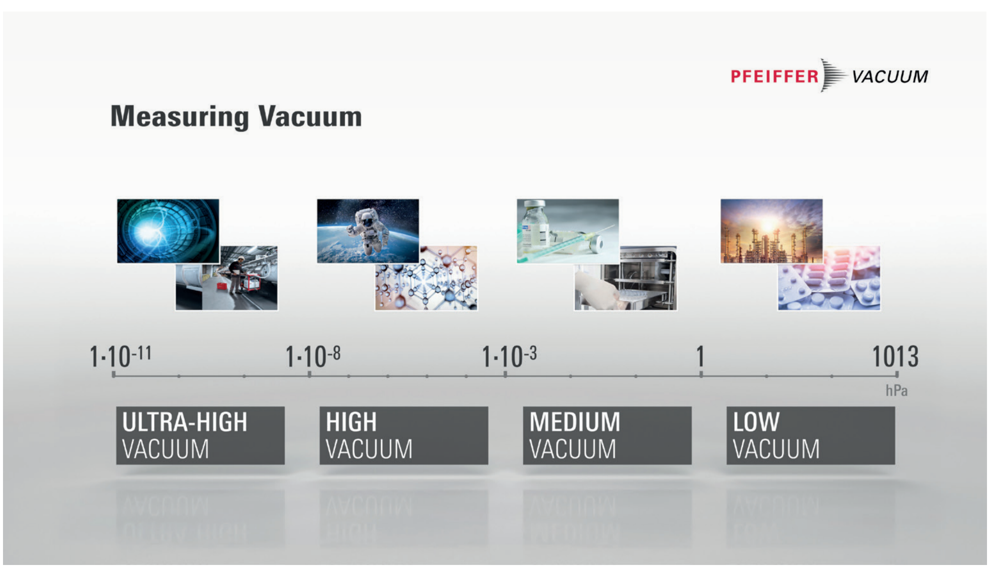
Pressure measurement basics

Many vacuum applications operate only in a specific pressure range. To define and regulate the particular range, analog and digital vacuum gauges are used. All of these gauges measure and control the total pressure in a vacuum system.

Pressure is defined as the force exerted by the gas per unit area – for example, in the unit Newton per square centimeter. It is caused by the collisions of the gas molecules with the vessel wall. At atmospheric pressure – the highest pressure in vacuum technology – the force is 1 kp/cm^2 = 9.81 N/cm^2. Example: To get a feeling for this pressure, imagine placing a 1,000 kilogram hammer carefully on the tip of your little finger.

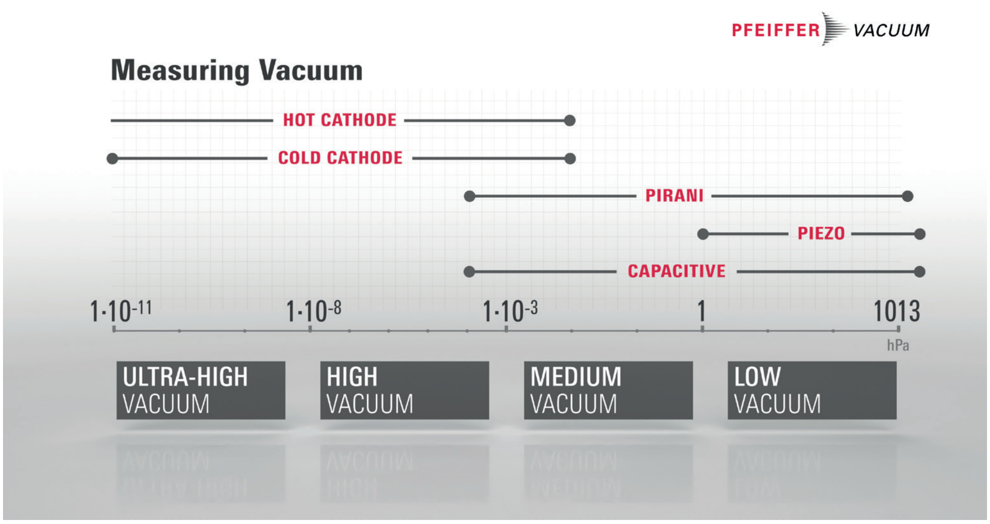
The more the pressure decreases, the smaller the exerted forces get. Therefore, more and more technical effort is required for still being able to measure the pressure. When evacuating a vacuum vessel, the pressure rapidly decreases by several orders of magnitude and, at the same time, the force per unit area decreases to the same extent. If the hammer in the example is replaced by a standard size business card, this change becomes obvious.

When evacuating a vacuum vessel, the pressure as well as the force per area decreases



If the pressure continues to drop, it requires delicate mechanics and possibly electrical amplification, to measure the minute forces. To continue the example from above: These minute forces can be felt with the tiny hairs of our skin.

Figure 1: Pressure measurement ranges and measuring principles



Direct pressure measurement through determining the force acting on a known area is no longer viable once you get to high vacuum. The reason for this is that the minute forces are no longer detectable. Pressure-dependent gas properties are used as an alternative to indirectly deduce the pressure in the vacuum system:

In high vacuum, pressure-dependent gas properties are used to indirectly determine the pressure in the vacuum system

- Heat conduction in thermal vacuum gauges, e.g. Pirani vacuum gauge
- Gas friction, e.g. spinning rotor gauge
- Ionization, e.g. cold and hot cathode vacuum gauge

These indirect measurement methods require very delicate measurement systems to capture the small effects as signals and, with electrical amplification, to make them show up on a display.

What should be observed when cleaning vacuum gauges?

It is crucial to consider these connections completely before starting to clean the measuring equipment. Vacuum gauges are sensitive instruments; their task is naturally incompatible with rough or abrasive cleaning procedures. Vacuum gauges are usually in operation for a very long time before the operator has the urge to clean them. These periods can be measured in weeks, but usually in months, or even years.

Every driver can imagine the difference between a car wash after:

(a) a 5 kilometer drive on a dusty dirt track and

(b) a six-week vacation of 5,000 kilometer through Scandinavia.

Cleaning a vacuum gauge is almost always like case (b). This means, it is not about loose dust which can be rinsed off quickly. It is more a matter of "accumulated" deposits that have built up over long periods of time and are firmly attached.

Grown, firmly adhering deposits must be removed carefully

To return to the car example: These deposits can be compared to insects that you have collected on the front of your car during a long vacation.

The high temperatures encountered at times and the formation of reactive particles, in some vacuum gauges, cause chemical reactions by gases and vapors on the surfaces of the sensor elements. This often causes thermally and electrically insulating layers to form, which adhere firmly and impair the function of the indirect measurement principles. Cleaning a vacuum gauge means removing these layers.

Guidelines for cleaning vacuum measuring equipment

When cleaning the highly sensitive measurement gauges, the strict rule applies that surfaces which are exposed to the vacuum should not be touched with bare hands. This applies in particular to high and ultra-high vacuum systems.

With vacuum gauges, there is also a risk that at high temperatures and under ion bombardment, fingerprints can burn into the surfaces and impact its function. Therefore, when working on vacuum measuring equipment, suitable gloves should be worn, especially when assembling the cleaned parts.

Fingerprints can burn into the surface and impair the function of the measuring devices

Important utensils for the cleaning of vacuum gauges are also lint-free paper towels, cotton swabs, and isopropyl alcohol (also called isopropanol or 2-propanol). Furthermore, a clean, tidy workplace is recommended with good lighting where solvent vapors can easily be removed.

Cleaning of different gauge types

1. Cleaning diaphragm vacuum gauges

Vacuum gauges that measure the force on a known diaphragm surface, are used for the gross vacuum range down to 1 hPa. The active measuring element is generally a diaphragm whose deflection is converted into an electrical signal by various methods. The geometry exposed to the vacuum is relatively simple. There is neither an intricate mechanism that requires special care nor are the conditions extreme during operating, for example, high temperatures, which would bake the dirt on (except for capacitive vacuum gauges, see point 2). These measurement instruments are robust and any attempt at cleaning is promising.

The type of contamination determines the cleaning procedure. In industrial applications, the dirt usually consists of oily dusts, which can be removed with organic solvents. Isopropanol, for instance, is an alcohol that has proven to successfully eliminate such contamination without impacting elastomers, for example. Put a few drops of solvent into the tube, shake the whole unit slightly and pour the solvent out. This procedure is repeated until the cleaning agent no longer removes any more dirt.

A cleaning attempt is promising, as diaphragm vacuum gauges are robust

Once the dirt has been removed, the diaphragm gauge is "vacuum-dried" by connecting it to a vacuum pump or a vacuum system.

Generally, the contamination cannot be completely removed by merely rinsing it with a solvent. A mechanical cleaning method, which would promise a better result, is not an option because of the sensitivity of the diaphragm to mechanical impact. It is a good idea to find out the price of a new vacuum gauge before starting a cleaning test, since the cost of cleaning may exceed the value of the gauge. After a certain period, the vacuum gauge should be replaced anyways.

In industrial applications, the dirt usually consists of oily dusts.

2. Cleaning capacitive diaphragm vacuum gauges

Like diaphragm vacuum gauges, capacitive diaphragm vacuum gauges use pressure definition to measure the force which the gas exerts on a known surface – the diaphragm. To clean it, it would be imaginable to just rinse the diaphragm, as described earlier. However, it is important to note that there are significant differences to the previously described diaphragm vacuum gauge:

- Capacitive vacuum gauges are usually highly accurate precision instruments that must be handled with the utmost care.
- These measurement instruments are available from atmospheric pressure to a near-high vacuum range. However, the lower the pressures to be measured, the more delicate the diaphragm and the better it may be shielded from any cleaning efforts by the user.
- The forces down to the µN range are electrically detected and amplified. Cleaning must therefore not affect the mostly integrated electronics.
- Capacitive diaphragm gauges are often used in processes that cause insoluble deposits. They are operated at elevated temperatures, which prevent the deposition of some substances, but bind others particularly tightly to surfaces.
- These measurement instruments usually have fittings to protect the diaphragm. But they make it difficult to clean. Contamination in a capacitive diaphragm vacuum gauge may become noticeable through pressure measurement errors or by a drift in the zero point. In practice, the former is usually not detected, since it requires comparison with a reference gauge to detect any deviation at all.

Unstable zero point behavior is easier to recognize but it can have different causes. First of all, correct zero point adjustment must be carried out according to the procedure specified in the operating instructions. If, after that, it still appears that contamination is leading to a drift in the zero point, then the vacuum gauge must be visually inspected. It must be removed from the vacuum system, and the connecting flange, the inside of the tube and, if necessary, the built-in filter element, must be inspected, too. If dirt is detected on surfaces, a cotton swab moistened with isopropyl alcohol can be used to test whether a cleaning attempt has any chance of success. Only if the coating comes off the tube wall easily onto the swab if wiped off with light pressure, it can be assumed that cleaning will be successful. The procedure is similar to that described in point 1: Fill up with solvent, allow it to take effect, gently swirl, and let it drain. Repeat the procedure several times until no more dirt is flushed out. Allow it to dry at least overnight in a vacuum system. After that, adjust the zero point according to the instructions. Long term observation will then show whether the zero point stability has improved. If this is not the case, the measurement instrument must be replaced.

The contamination of a capacitive diaphragm vacuum meter can become noticeable through faulty pressure measurement or through drift of the zero point

3. Cleaning Pirani vacuum gauges

Thermal transfer vacuum gauges according to the Pirani principle are often used as inexpensive vacuum gauges in the low and medium vacuum range. This is an indirect measurement method which allows the pressure in the vacuum system to be inferred from the heat which is dissipated by the gas from a thin metal filament. If the heating filament is dirty, it can impair the heat dissipation and falsify the pressure measurement.

Assess the cost-benefit ratio of the cleaning process, since Pirani vacuum gauges are comparatively inexpensive

The heating filament of a Pirani vacuum gauge generally consists of a coiled tungsten wire with a diameter of about 1 µm. The operating temperature of the wire is typically about 100 °C higher than room temperature, with the result that oily dirt is baked on. In view of the thin wire size, it is not possible, of course, to clean it by scrubbing the dirt off. Therefore, as with capacitive diaphragm vacuum gauges, gentle rinsing with alcohol is the only option left.

The sensitive filament must be treated with particular care during the process. The solvent must only be allowed to run cautiously down the inner wall of the tube into the tube interior. Shaking is strictly forbidden and the same care should be exercised during pouring out as during filling.

At the end of the cleaning procedure, drying must take place in a vacuum system, followed by adjustment of the atmospheric pressure and zero point according to the operating instructions. It will now be seen whether the cleaning efforts have been successful. Experience has shown that the success rate is about 50 %. Given the modest price of a replacement sensor, it is a good idea to find out beforehand whether the expense of cleaning is justified.

4. Cleaning of hot cathode vacuum gauges

Hot cathode vacuum gauges are high-vacuum gauges, which can be used in the medium vacuum up to the ultrahigh vacuum range. They use the ionization of gases for pressure measurement by ionizing the gases and taking the ion current as a measure of the pressure.

This measurement principle requires a sensor made of delicate wire elements (hot cathode, grid, anode) that cannot be cleaned.

With this measuring principle, contamination usually occurs due to the chemical reaction of (small) amounts of trace gases in the sensor itself. The reason for this is the high prevailing temperature here and the bombardment of the gas molecules with electrons and ions. Insulating layers can form on the surfaces during this process and make it difficult for the vacuum gauges to work or prevent them from working entirely.

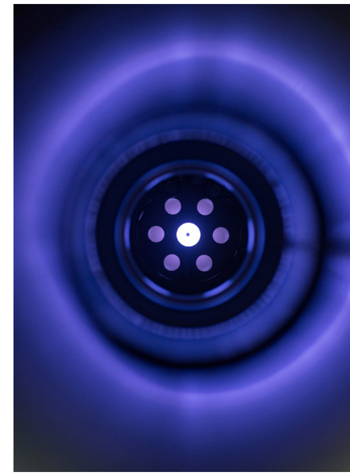
Insulating layers on the surfaces impair or prevent the function of the gauge

Hot cathode vacuum gauges usually have an outgassing function, which heats up the electrodes by an increased emission current, in order to desorb adhering gases. However, this function is not able to remove any visible deposits caused by the chemical reaction of organic compounds (carbon chemistry) or silicon-containing compounds.

Low molecular mass vapors from O-rings, pump oils or vacuum grease are converted in the measurement system to cross-linked thermosetting materials, siloxanes or silicon dioxide that cannot be removed with conventional solvents. Since mechanical cleaning of the sensor is not possible due to its delicate structure, the gauge head must be replaced, if necessary, when dirty.

5. Cleaning of cold cathode vacuum gauges

Cold cathode gauges are available in various designs (penning, inverted magnetron) as single or combination vacuum gauges, usually combined with a Pirani sensor.



Their application range extends from medium to ultra-high vacuum, just as with hot cathode gauges, although the main application range is in high vacuum. The accuracy of these vacuum gauges is clearly lower than that of hot cathodes. Since the measuring system is of a simple mechanical design and does not include intricate elements, it is accessible for cleaning and is usually sealed with O-rings precisely for this purpose. So it can easily be disassembled. Disassembly, cleaning, and reassembly are generally described in the operating instructions.

Before dismantling, it is essential that the protective grid or inlet filter is removed. This allows for the degree of contamination to be assessed. During inspection, rainbow-colored to brown-black deposits can generally be seen on the tube wall. After the sensor has been detached from its electronics, if necessary, and broken down into its individual parts, these firmly adhering deposits must be removed. Fine-grained finishing web (e.g., Scotch-Brite™ 400 grit or 1000) is best suited for this purpose, to scour the surfaces. It is important that the sealing surfaces for O-rings are only worked on in concentric circles so that no scratches occur across the sealing line.

Important:
Perform this work only with protective gloves!

This not only protects you from the resulting grinding dust of unknown composition but also protects the surfaces from grease and traces of acid from the skin. Small parts that are difficult to clean, such as starting aids must be replaced, and the same applies for deformed or brittle elastomers. Once the deposits are completely removed, the sand dust must be thoroughly cleaned from the surfaces using isopropanol. The dry individual components must be assembled according to the operating instructions, if necessary using a maintenance kit. After the sensor has been assembled, the vacuum gauge is initially inspected (without electronics) for leaks with a helium leak tester. When helium is sprayed on sealing joints and electrical feedthroughs, no increase in the background signal should be detected (leak rate $< 10^{-10}$ Pa m^3/s). Before the vacuum gauge is restarted, it should outgas in a vacuum system for at least one to two hours.

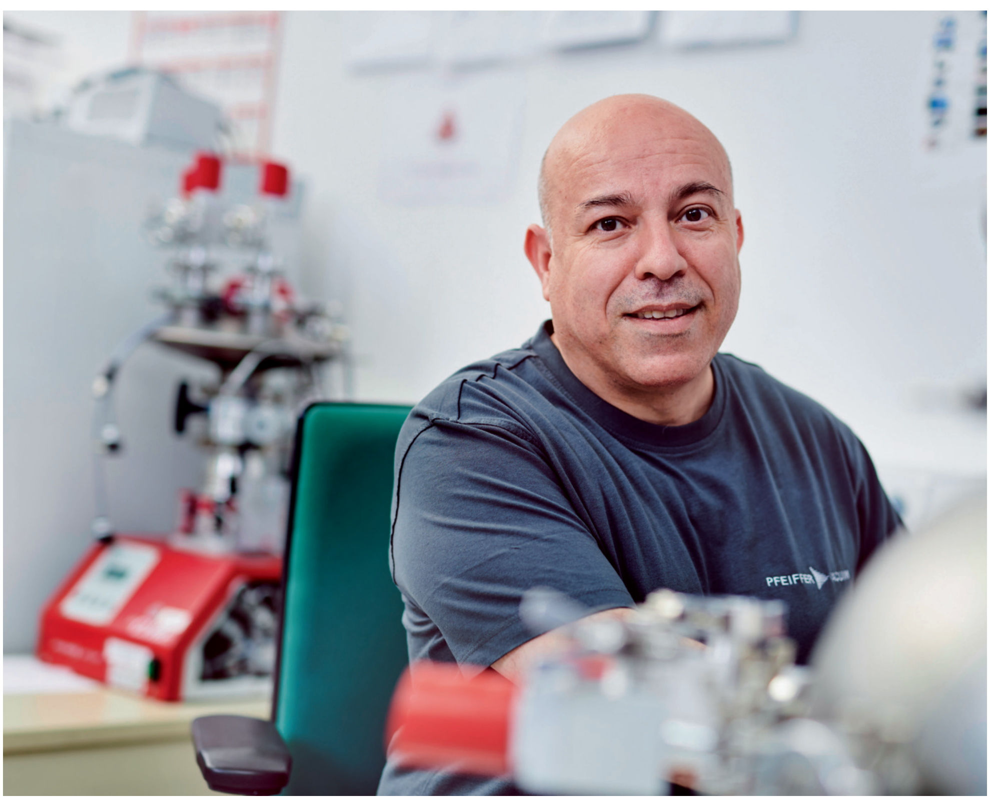
Calibration of vacuum gauges

Your quality management requires the regular calibration of your vacuum gauges? Then we have just the right solution for you:
Our calibration laboratory at the Asslar location offers you both factory calibration according to DIN ISO 3567 as well as the higher-quality DAkkS calibration.

Simply send us your vacuum measuring equipment and we will first check the proper functioning of your product and then perform the calibration in compliance with DIN ISO 3567. You will then receive a calibration certificate documenting the test conditions and any deviations found.

We would be happy to support you in the application-specific optimization of your vacuum solution – contact us!

Please note that a fully completed "Declaration of Contamination" about your measuring equipment must also be submitted.



Checklist

- [ ] Wear clean gloves
- [ ] Provide essential utensils: lint-free paper towels, cotton swabs, and isopropyl alcohol
- [ ] Clean, tidy work area with good lighting and easy exhaust of solvent vapors
- [ ] If necessary, procure and have ready replacement or spare parts.
- [ ] Visual inspection to determine if contamination is present
- [ ] Careful cleaning with solvents
- [ ] If necessary, exchange contaminated parts
- [ ] Drying for several hours on a vacuum system
- [ ] Zero point adjustment according to operating instructions
- [ ] If necessary: Factory or DAkkS calibration in calibration laboratory

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