PFEIFFER VACUUM

ATEX CERTIFICATION: OPERATE ROOTS PUMPS SAFELY IN EX ZONES

Many vacuum applications in the chemical, pharmaceutical and technical gas industries take place in explosive atmospheres. In the EU, the ATEX directives were put into place in order to minimize the risks that these applications may represent for personnel and plants. The word ATEX is an acronym of the French title of Directive 2014/34/EU: **AT**mosphères **EX**plosibles.

Since 2003, there are two ATEX directives, Directive 2014/34/EU (also known as ATEX 95) and Directive 1999/92/EC (or ATEX 137). ATEX 95 defines the general health and safety requirements for equipment used in potentially explosive atmospheres. ATEX 137 specifies the „Minimum requirements for improving the health and safety protection of workers potentially at risk from explosive atmospheres“ (Directive 1999/92/EC, p. 1). The connections between these two directives are shown in Figure 1. Accordingly, ATEX 95 is relevant for manufacturers of vacuum pumps, whereas ATEX 137 applies to operators who use the equipment in their systems or processes.

Vacuum pumps for use in potentially explosive atmospheres must be certified according to 2014/34/EU. To achieve this, the measures outlined in Figure 1 must be taken. The first step is to analyze potential ignition sources. In accordance with the CE label category, potential ignition sources relating to the conditions of normal operation (category 3), expected failures (category 2) and rare failures (category 1) must be considered. The next step is to prevent these ignition sources from taking effect.

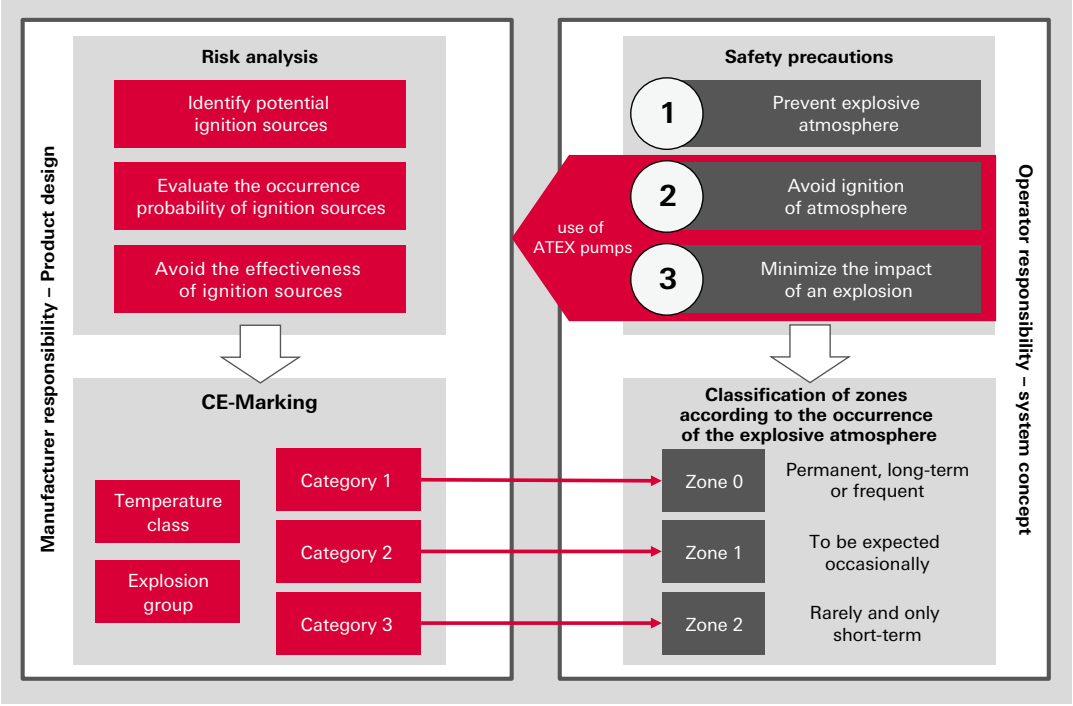

Figure 1: Responsibilities in accordance with Directives 2014/34/EU and 99/92/EC

The operator is, according to directive 1999/92/EG, obliged to check whether an explosive atmosphere can be avoided. Such atmospheres occur when a critical amount of combustible material, in the form of gas, mist, steam or dust, and sufficient oxygen are present at the same time. If this cannot be avoided, the ignition of the atmosphere must be prevented. The European standard EN 1127-1 names the following possible ignition sources, which are analyzed within the framework of the ignition hazard assessment for products according to ATEX 95:

- Hot surfaces
- Flames and hot gases
- Mechanically generated sparks
- Electrically generated sparks
- Electrical compensating currents
- Static electricity
- Electromagnetic waves
- Ionizing radiation
- Ultrasound
- Adiabatic compression
- Exothermic chemical reactions

Functional principle of Roots pumps

Figure 2 illustrates the design of a Roots pump. Inside the pump, two Roots pistons (4) rotate in opposite directions. With them, the gas in the housing is conveyed from the intake connection (3) to the pressure connection (11). A motor (1) drives the main piston. The pair of gear wheels (6) in the gear chamber synchronizes the auxiliary piston. Lubricants are used only in the bearing and gear chambers. These chambers are separated from the suction chamber (5) by a labyrinth seal (8).

A narrow gap between the pistons and the casing ensures contact-free running. This enables high speed operation (1,500 to 3,600 rpm).

Pump characteristics and heating

The pumped medium is neither compressed inside the Roots nor does an outlet valve at the pressure port prevent the emergence of a flow against the conveying direction. This means that the gas flows back from the outlet into the suction chamber as soon as the position of the pistons allows for it. As a consequence, this reverse flow must also be pumped against the outlet pressure.

This effect results in high energy consumption, which causes the pump to heat up significantly. This is especially the case if the difference in pressure between the inlet and outlet is large. A built-in overflow valve prevents such an unallowed heating by limiting the maximum differential pressure. This overflow valve opens and closes a bypass which connects the suction and pressure sides of the housing. If the maximum differential pressure is exceeded, the valve body rises. Depending on the counterpressure level, some of the gas throughput then flows back to the inlet.

Standard Roots pumps cannot operate against atmospheric pressure, as their differential pressure is limited for the reasons given above. With the aid of backing pumps, the pressure at the outlet is kept sufficiently low. Thanks to the overflow valve, the Roots pump can be switched on at the same time as the backing pump even at atmospheric pressure. This enables faster evacuation and makes the pump much easier to use.

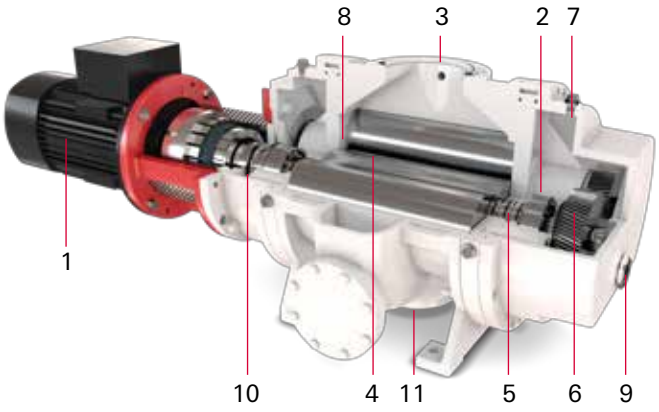

Figure 2: Illustration of a Roots pump design

1 Motor
2 Loose bearing
3 Intake connection
4 Roots piston
5 Labyrinth seal
6 Gear
7 Oil filling screw
8 Suction chamber
9 Oil level glass
10 Labyrinth seal
11 Pressure connection

Roots pumps with ATEX certification

ATEX vs. standard pumps

With ATEX-certified pumps, the overflow valve described above is blocked. This is necessary since the valve hits the housing with high acceleration when the Roots pumps are operated. Both parts are made of metal, which means that mechanically generated sparks can occur. This makes the overflow valve a potential source of ignition which must be prevented from taking effect.

With the valve blocked, the gas is prevented from flowing back. In this case, the Roots pump must be operated with a frequency converter. This ensures that the pump is started up slowly. Alternatively, the pressure at the outlet can also be monitored so that the pump is only switched on when the counter-pressure is sufficiently low.

Prior to the market launch of the ATEX pumps, the use of a frequency converter was considered to be an adequate replacement for the overflow valve. However, through close contact with customers and continuous exchange with them, Pfeiffer Vacuum's experts quickly realized that retrofitting a frequency converter was not possible in some cases – especially in all applications where the ATEX Roots pump was to replace a previously used standard version. And if there are no additional pressure gauges, then starting the pump at a defined counter-pressure is not possible either. Based on these cases, the development experts identified the need of some customers for ATEX-certified Roots pumps with an unblocked overflow valve to make pump replacement and operation as easy as possible.

Development of the ATEX-certified overflow valve

Against this backdrop, developers at Pfeiffer Vacuum were clear that a new version of the relief valve would have to be developed. The greatest challenge here was to find a combination of materials that would not produce any sparks and thus any ignition sources during normal operation or in the event of expected valve failures. The solution is an ATEX valve made of PTFE and stainless steel, where no sparks can occur in contact with the housing (material GGG-40).

In addition to the material pairing, the kinetic energy during opening and closing also influences spark formation. Tests have shown that the kinetic energy of standard Roots pumps during opening of the valve is sufficiently high to ignite a combustible mixture.

For the ATEX version, therefore, a way had to be found to dampen the impact of the valve.

The effectiveness of the measures was checked in various tests. Therefore, the developers at Pfeiffer Vacuum carried out the opening and closing process more than 20,000 times. This made it possible to simulate longer-term loading of the valve. The test results showed that, thanks to the changes in the valve design, no sparks are formed when the valve is opened or closed. The ATEX overflow valve thus enables safe operation in areas with explosive atmospheres and no longer constitutes an effective ignition source.

Standard pumps can easily be replaced by the new ATEX pump with its unblocked overflow valve. Neither frequency converters nor pressure monitoring devices need to be installed. Once again, the Roots pump can be started at the same time as the backing pump, so that the new overflow valve ensures not only safe operation but also shorter evacuation times. If the ATEX overflow valve is used in addition to a frequency converter, it ensures faultless operation even if a failure in the frequency converter occurs.

Even though it is now easier to simply replace older units, Pfeiffer Vacuum recommends that the previous design and dimensioning of the vacuum system should always be checked. Experience shows that already small process flow changes conducted over time can make a new examination necessary. One option is here to optimize the gradation of the Roots pump and the backing pump, which allows for a better distribution of the loads and temperatures.

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