Vacuum pumps in accordance with directive 94/9/EC (ATEX 95)

Guideline

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Busch COBRA TC
with EC-type examination

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1. Introduction

Vacuum pumps are used in the chemical and pharmaceutical industries as well as in industrial applications where there is a risk of explosion. From July 1st, 2003 onwards, new vacuum pumps which are to be used in the pumping of explosive substances or which will be used in an environment that carries a risk of explosion, will have to comply with directive 94/9/EC (ATEX 95). This new directive will then become law in all European member states.

Directive 94/9/EC is also known as ATEX-directive (ATEX = Atmosphères Explosibles), ATEX 100a or ATEX 95. The numbers in the ATEX-denominations originate from the foundation treaty of the European Union. Article 95 of the foundation treaty (known as article 100a before the treaty was amended) established the "harmonisation of legal regulations".

It is the aim of article 95 to achieve free trade of goods in all EU member states through harmonisation of the European laws for equipment to be used in areas with a risk of explosion. The term equipment as mentioned here includes all accessories (such as the motors, measuring accessories, etc.) built around a vacuum pump.

Directive 94/9/EC (ATEX 95) stipulates a lawful reduction of trade barriers in order to open up the European home market. The directive will come into force on the basis of the so-called "new approach". This means that minimum technical standards are laid down to various products and their different markets and applications (such as toys, medical equipment, etc.), details of which will be further delineated with the help of European standards. Member states are required to adapt their national laws in compliance with the agreed time schedule. The CE-marking will identify products as being in conformity with the corresponding directives. Vacuum pumps that will be used in explosive areas will need an additional, special Ex-marking.

Directive 99/92/EC (ATEX 137) deals with the transitional period an appliance can run legally if it was supplied or started up before July 1st, 2003. It can be used legally for up to 3 years thereafter. This means that running a vacuum pump in explosive areas after July 1st, 2006 will only be possible if it meets the standards that have been laid down in directive 94/9/EC (ATEX 95).

2. The interaction of directives 94/9/EC and 99/92/EC

Directive 94/9/EC (ATEX 95) is a so-called "product layout directive" which defines amongst others the minimum explosion- and application-related requirements for the relevant vacuum pumps as well as the testing cycles which will be necessary. Directive 94/9/EC (ATEX 95) also describes the responsibility of all bodies concerned which place any applicable products for use in an explosive environment on the market. These will generally be the product manufacturers, but also the distributors and importers (grouped as manufacturers in picture 1).

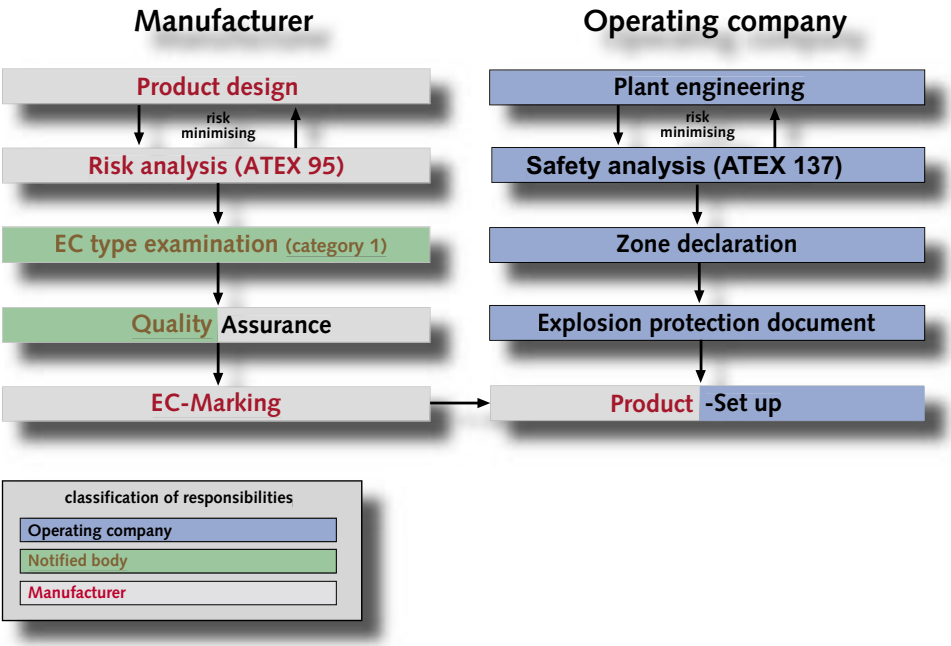
As opposed to directive 94/9/EC (ATEX 95), directive 99/92/EC (ATEX 137, also known as ATEX 118 before the treaty was amended) is a so-called "health and safety directive". This directive describes the minimum requirements needed to improve upon health protection and safety at work for the workers. Directive 99/92/EC (ATEX 137) defines the responsibility of plant operating authorities that work with explosive substances. A plant operating authority must do a risk analysis of their plant and subsequently define the corresponding zones.

Picture 1 shows the assignment of the above-mentioned responsibilities. The combination of the two directives has been highlighted using category 1 equipment.

3. The directives 94/9/EC and 99/92/EC

The directive 94/9/EC (ATEX 95) defines groups and categories of equipment, the area of application and the necessary requirements for assessment in order to attain proof of conformity.

Equipment belonging to equipment group I is used in mining (both in underground and surface mining). Equipment belonging to equipment group II, on the other hand, belongs to all the other applications found in trade and industry.



Picture 1: Responsibilities according to directives 94/9/EC and 99/92/EC

Nearly all applications of vacuum pumps and systems can be found here.

Equipment belonging to equipment group II is subdivided into 3 application categories:

Equipment belonging to category 1 has a very high safety factor when used in explosive atmospheres, whereas equipment belonging to category 2 has a high safety factor and equipment belonging to category 3 has a normal safety factor when used in explosive atmospheres.

Equipment group	**Category**	**Applications**
I	M1 and M2	Applications in **underground and surface mining**
II	1G (highest EX-protection)	**Gases, mists and vapours; Zone 0** (frequent or constant explosive atmosphere; mainly within closed systems)
	2G (high EX-protection)	**Gases, mists and vapours; Zone 1** (temporary explosive atmosphere or normal operation in explosive atmosphere, also in accessible areas)
	3G (normal EX-protection)	**Gases, mists and vapours; Zone 2** (occasional explosive atmosphere, or when system breakdown occurs)

Chart 1: Equipment groups, categories and applications

Equipment group	**Category**	**Procedures in accordance with ATEX 95**
II	1 all equipment (for zone 0)	● QA-certificate of production (extension towards EN ISO 9000) **and** ● Type-approved through a notified body
	2 electrical equipment (for zone 1)	● Type-approved through notified body **and** ● QA-certificate of production (extension towards EN ISO 9000) **or** ● Conformity to Type
	2 all other non-electrical equipment (for zone 1)	● Internal control of production **and** ● Deposition of unchecked documentation with a notified body **or** ● Examination through a notified body
	3 all equipment (for zone 2)	● An internal control of production is sufficient **and** ● Internal archiving of unchecked documentation

Chart 2: Equipment group II, equipment categories and necessary measures for attainment of product qualification in accordance with directive 94/9/EC

Directive 99/92/EC (ATEX 137) defines all technical and organizational measures that need to be undertaken by an employer, depending on the type of his company, to prevent any risk of explosion in the following order of priority.

1. Prevention of explosive atmospheres to occur
2. If 1. is not possible: preventing ignition of explosive atmospheres
3. Limiting harmful effects of explosions in order to safeguard health and safety of employees

The employer is also under the obligation to take all necessary measures to limit any danger to employees through explosive atmospheres. This includes the duty to inform and instruct his employees, the development and updating of explosion protection documentation, as well as an evaluation of explosion risks. The appendix at the end of this directive describes the subdivision into zones and the identification of areas which are at the risk of explosive atmospheres.

Equipment categories for all applications except mining (group II) in accordance with directive 94/9/EC (ATEX 95)						
Zone	**0**	20	**1**	21	2	22
Type of atmosphere	**G Gas**	D Dust	**G Gas**	D Dust	G Gas	D Dust
Equipment category	**1**		**2**		3	
Explosive category	**constant**		**intermittend**		occasional	
Zone definition in accordance with prEN 13237	Constant long term or frequent explosive atmosphere		Explosive atmosphere is to be expected in normal conditions of operation		Explosive atmosphere not or occasionally to be expected in normal conditions of operation	
Certification requirements	EC type examination		EC declaration of conformity		EC declaration of conformity	

Chart 3: Definition of zones and equipment categories

The definition of zones describes areas in which explosive atmospheres can be found. These areas can be either interior areas of process application such as piping, vessels or internal areas in vacuum pumps or external areas around process applications. Zone 0 around external areas is very rare, as there would be otherwise no air to breathe for company personnel.

Explosive atmospheres occur all the time or very often in zone 0 (e.g. in the piping systems, reaction vessels and containers

of the distillery shown in picture 2).
Zone 1, on the other hand, is an area in which explosive atmospheres occasionally occur (in picture 2, the entire area of the surrounding building was declared as being zone 1).
Explosive atmospheres should not occur at all or only for a brief period of time in normal conditions of operating in zone 2.

Zone 20, 21 and 22 have been set up for explosive atmospheres which consist of air and combustible dust. These, however, are of little significance to vacuum technology.

The category of equipment dictates the various procedures that are imposed by the directive in order to safeguard the conformity of the product (see picture 3). It should be noted that the examination procedures for non-electrical equipment differ from those for electrical equipment. As opposed to non-electrical equipment, which include vacuum pumps, category 2 electrical equipment must be submitted to a notified body for EC type examination.

Picture 3 shows that a special individual testing (for type approval) of a vacuum system that was only built once through a notified body is possible.
However, this option is rather uneconomical and therefore rarely used.

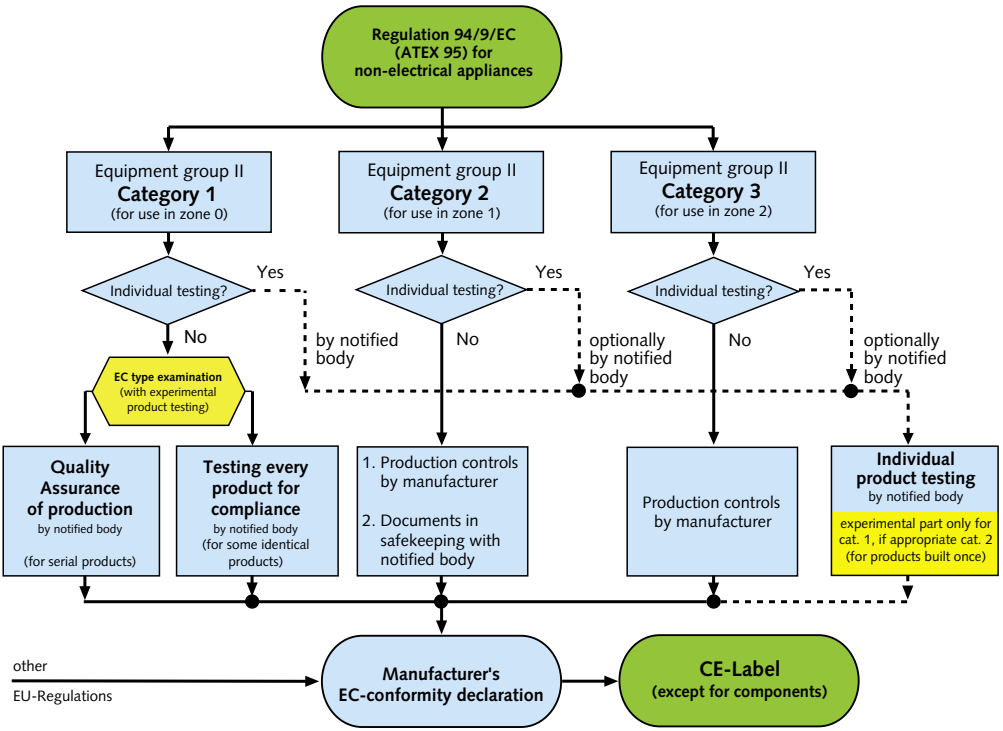
The higher the necessary safety parameters for an appliance, the more complex

Picture 2: Distillery with zone 0 within the system and zone 1 in the surrounding building

the assessment procedures of conformity will be. For example, a category 1 appliance needs to be submitted to a notified body for thorough assessment, before said institution issues an EC type examination certificate. The above assessment also includes proof of safety, in line with the latest developments in technology, against flame penetration and safety against auto-ignition as a consequence of thermal or electrostatic ignition sources.

If, in the addition to the above, the required quality management system for production has been set up, and the full documentation of the equipment has been assessed at the notified body, series production of the equipment can be started.

Only liquid ring vacuum pumps which are tested as category 1 equipment are exempted from having to provide proof of safety against flame penetration, as they have proved in countless tests and after many years of use in applications that they carry a very low risk.



Picture 3: Assessment procedures of conformity

4. Explosion groups and temperature classes

A sudden oxidation or disintegration phenomenon, together with a rise in temperature, pressure or both together, is generally called an explosion (EN 1127-1 and EN 12874).
Explosions are generally subdivided into deflagrations and detonations. The propagation speed of deflagration lies below the speed of sound. Detonations, on the other hand, expand above the speed of sound, i.e. they spread in shockwaves.

A detonation that spreads at a constant speed and pressure within an enclosed system is called a stable detonation.
The transitional state between a deflagration and a stable detonation is called an unstable detonation.

Gases and vapours have very different explosion behaviours. When looking at the danger potential of an explosion, the possibility of such an explosive mix escaping out of an enclosed system such as a dry running vacuum pump is of prime importance. Any expansion of an explosive mix into either inlet or discharge side of a process application, or, for that matter, into the system environment through gaps in the housing is to be avoided. Any risk of danger caused by outbursts of casting materials must be prevented through design measures.

Gases and vapours are classed into explosion groups according to their explosion behaviour. They are classed into groups of substances with the same flame penetration capacity through a pre-defined, standardized gap.

The maximum experimental safe gap (MESG) of a gaseous mix is the largest possible gap between two enclosed systems of an examination order (IEC 60079-1 A) that will, under pre-defined test conditions, prevent the ignition of the gaseous mix outside through a 25 mm gap (EN 12874).

Substances of the same explosion group need not have any chemical common ground.

Chart 4 shows explosion groups according to EN 12874. After classification into equipment groups I or II, the explosion groups themselves are classified. The smaller the MESG, the more complex the explosion protection methods.

It ought to be noted that losses of pressure at the inlet flame arrester of a vacuum pump increase dramatically when the inlet pressure drops below 80 mbar. At that pressure or below, suction capacity can drop below 50%. For safety reasons, the sieve inserts in the flame arresters must always have smaller gaps than the gaps in chart 4.

The cells in chart 4 concerning explosion group IIB3 have been highlighted. They cover more than 90% of all applications in the chemical and pharmaceutical industries.

Another important characteristic of explosion protection concerns the temperature classes of gases and vapours.

Equipment group	Explosion group	MESG (mm) maximun experimental safe gap	Reference gases
Equipment for mines	I	MESG = 1.14	Methane
Equipment for surface industries	II A	MESG > 0.9	Propane
	II B1	MESG ≥ 0.85	Ethylene
	II B2	MESG ≥ 0.75	
	II B3	MESG ≥ 0.65	
	II B	MESG ≥ 0.5	
	II C	MESG < 0.5	Hydrogen

Chart 4: Explosion groups and maximum experimental safe gap (MESG)

They give the maximum, non-explosive surface temperatures that come into contact with an explosive, gaseous mix. Auto-ignition temperatures of gases and vapours belonging to temperature class T4, for instance, range between 135°C and 200°C.

Temperature classes						
Class	T1	T2	T3	T4	T5	T6
Maximum surface temperature	450 °C	300 °C	200 °C	135 °C	100 °C	85 °C

Chart 5: Temperature classes with corresponding max. surface temperatures that do not yet auto-ignite

5. Explosion protection of dry running vacuum pumps

The risk of a vacuum pump to become a source of ignition on the inside can be classified as follows:

1. All non-touching, dry running vacuum pumps for coarse or fine vacuum such as screw vacuum pumps, claw vacuum pumps and Roots vacuum pumps have comparable clearances for the separation of process chambers and generate more or less compression heat. The above pumps have to be classified as potential sources of ignition due to the remaining risk of too high a temperature of the process medium, as well as the possibility of sparking or a high rise in temperature caused by friction or contact of the rotors with the cylinder or with each other.

2. Oil lubricated rotary vane vacuum pumps, and in particular through-flow rotary vane vacuum pumps, can have an internal source of ignition. However, they have proved their worth in many applications with explosive process media and have not caused any explosion-related accidents for many years. The risk of igniting through sparks is therefore smaller.

3. Compared with the above-mentioned previous two groups of vacuum pumps, the liquid ring vacuum pumps are the pumps which have had the greatest wealth of experience with explosive process material gathered so far. A number of studies on the subject have shown that the risk of sparking is almost negligible due to liquid sealing and a comparatively large gap between the rotor and the housing. In addition to this, a liquid ring vacuum pump in use can work as a flame arrester. Any heat caused by compression is taken away by the process fluids. As a conclusion, it can be said at present that the risk of sparking in a liquid ring vacuum pump can be considered as low.

In non-touching, dry running screw vacuum pumps, the following possible sources of ignition ought to be considered:

1. **Ignition through sparking or friction heat** induced by touching, especially between the rotors and the cylinder, or after ingress of foreign matter.
2. **Ignition caused by gas temperatures** that are too high, or as a consequence of gas compression, i.e. exceeding ignition temperatures of a process medium.
3. **Ignition caused by the vacuum pump surface temperature** being too high. Both external and internal surfaces of the vacuum pump become a source of ignition.
4. **Ignition caused by sparks** caused by electrostatic charging.

The following measures can help reduce the risk of sparking or auto-ignition due to too high a temperature (preventative explosion protection).

- Cooling through direct internal rotor cooling. This also helps to minimise the differences in clearances between a cold and a hot pump, which would otherwise run the risk of clearances closing up as a consequence of hot rotors and cooled housing.
- Cooling through injection of cold gases into the process chamber, either using fresh gases or returned, cooled gases. The latter, however, will always carry additional costs as a heat exchanger and extra piping will be needed.
- Intensive liquid cooling of the housing jacket using a very cold cooling medium. This solution, however, carries the risk of condensation and corrosion in the vacuum pump in many applications.
- Cooling through the use of a frequency converter which reduces the speed of the rotors in the pump. This will lead to performance losses especially with non-touching, dry running screw vacuum pumps
- Use of electroconductive material
- Potential balancing and earthing of all machine components.

In addition to the above measures, the following measurements can be used to control and supervise:
The above measurements are the most

- Supervision of the gas temperatures at both inlet and discharge of the vacuum pump and shut off or speed reduction when a specific temperature has been exceeded.
- Supervision of the housing temperatures and shut off when a specific temperature has been exceeded.
- Supervision of the discharge pressure and shut off when a specific max. value has been exceeded in order to prevent any over-compression with corresponding rise in temperature.

important ones. Other parameters, however, can be monitored as well, in order to increase machine safety, such as motor temperatures, cooling water flow, oil temperature, oil pressure, barrier gas pressure and barrier gas flow.

Sources of ignition can never be totally ruled out with screw vacuum pumps. Therefore, the consequences of an explosion should be kept to a minimum, as far as it is technically possible ("Means of explosion protection relating to equipment"). Technically this is carried out in the following way:

- Explosion-resistant construction of the vacuum pump. The pump will withstand an explosion without damage, no parts will break off the pump, no gas, no flames will escape from the pump.
- Flame arresters (also: detonation protection) at both inlet and discharge sides of the vacuum pump will prevent an explosion spreading onto neighbouring systems.

6. Equipment marking

Equipment which is in agreement with CE regulations for the specific use in potentially explosive areas must carry a specific identification in the name plate on which it will be possible to see the equipment group, the equipment category, the explosion group and the temperature class (picture 4).

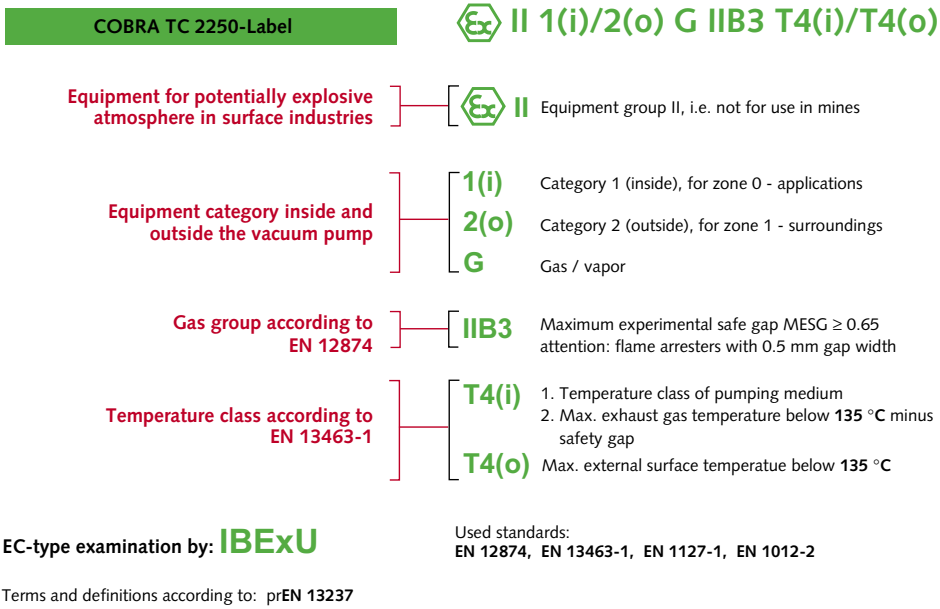
The following information can be found on the name plate which is on the vacuum pump:

- name of the manufacturer
- full type denomination of the pump
- the serial number
- the number of the named notified body
- the permitted ambient temperatures
- the Ex-marking
- other operating data

To decipher the Ex-marking, see picture 5.

Picture 4: Name plate COBRA TC 2250 with Ex-Identification as category 1 equipment in accordance with directive 94/9/EC (ATEX 95);
not in the name plate picture: Ultimate pressure and pump serial number.

The accompanying EC type examination certification or the EC declaration of conformity shows the various specifications that have been used. This data, too, can be used to make comparisons between vacuum pumps or between the execution of the testing.



Picture 5: Example and explanation of Ex-marking in accordance with directive 94/9/EC

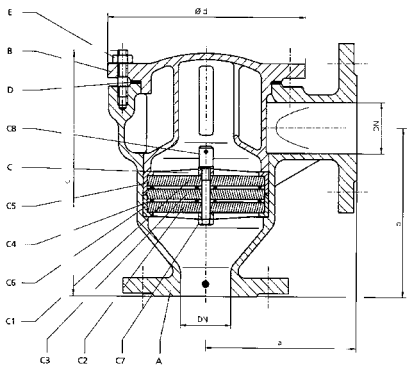
The accompanying EC type examination certification or the EC declaration of conformity shows the various specifications that have been used. This data, too, can be used to make comparisons between vacuum pumps or between the execution of the testing.

7. Flame arresters

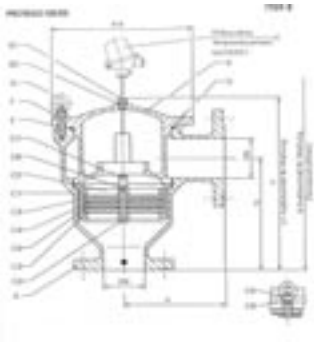
Before directive 94/9/EC became relevant for the industry, it was the accepted standard to fit flame arresters, which had only been tested for pre-determined pipe sizes, directly to dry running vacuum pumps. Explosion tests carried out on pump systems built that way revealed the occasional full flame penetration.

This was the reason why dry running vacuum pumps are now being tested by experiment as a system, together with the flame arresters within the framework of the EC type examination certification. Vacuum pumps, which are approved as category 1 equipment, must therefore be equipped with the relevant tested flame arresters.

Typ DR/U

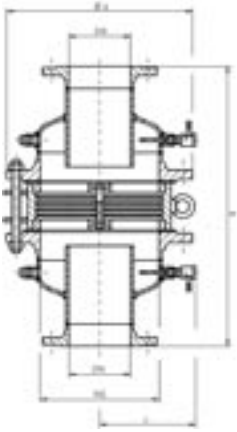


Typ DR/ES

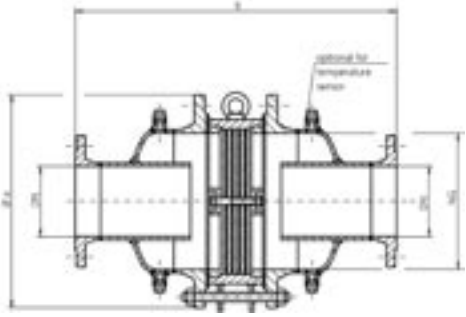


• Anschluss an die zu schützende Zone

Typ DA/SB



Typ FA-I



Picture 6: Various flame arresters for the COBRA

What remains to be discussed is the question concerning the necessity to use flame arresters on dry running vacuum pumps which are going to be used as category 2 equipment. In accordance with directive 94/9/EC, these vacuum pumps need not be tested by a notified body. Any risk analysis and therefore the necessity to use flame arresters in that specific application remains the responsibility of the manufacturer. In such applications, the user ought to seek advice with the supplier of dry running vacuum pumps.

Picture 6 shows the usual type of flame arresters. COBRA screw vacuum pumps that have been approved for use in explosive areas use these types of flame arresters, too, for explosion group IIB3 (DR/U and DR/ES) as well as IIC (DA-SB and FA-I).

In order to ensure that any flame penetration is prevented, the flame arresters must be serviced in accordance with the manufacturer's instructions. The service instructions and recommendations for an exchange of the sieves can be found in the machine documentation.

The inlet and discharge flame arresters have been tested in combination. Only tested combinations are permissible.

The respective combinations can be checked in the EC type examination certification, as well as in the parts list and the checklists for proof of conformity.
This also means that no changes to the configuration of the filter inserts or intermediary layers in the flame arresters are to be done when doing servicing work.

8. Final comments and recommendations for the user

The directives 94/9/EC and 99/92/EC do not forward clear terms of definition and actions in every case. For instance, directive 94/9/EC does not define atmospheric conditions. The ATEX-guideline, in its first issue dated May 2000, which can be downloaded from the Internet, just like the directives, under:

http://europa.eu.int/comm/

reads as follows:

A temperature bracket of between -20°C and +60°C as well as a pressure bracket of 0.8 bar to 1.1 bar seem appropriate as a basis for the pre-determined use of the products.

Although there is normally environment pressure on the discharge side of many dry running vacuum pumps, only the inlet pressure was used as an argument. This would consequently only concern vacuum pumps upon the start-up, i.e. when going through the start-up procedure. However, the entire inlet and discharge pressure area normally is being tested on dry running vacuum pumps within the framework of EC type examination.

A similar topic for discussion is the necessity of flame arresters on dry running vacuum pumps, which are being put into operation as category 2 equipment. There would be 3 reasons to do without the flame arresters:

- a loss of pressure that rises rapidly at low inlet pressures,
- the danger of limited use as a consequence of dirt in the flame arrester and
- the additional costs of having to purchase the flame arresters.

However, in contrast to the above is the knowledge that a dry running vacuum pump carries the risk of being a potential source of ignition. As zone 1 can have per definitionem an explosive atmosphere in normal operation, the duration of such a condition will be of little legal relevance in the event of an accident.

Another unsolved matter concerns the servicing and maintenance of vacuum pumps which have been defined for use in explosive atmospheres in accordance with directive 94/9/EC. Although this subject will increase in importance in years to come, the manufacturers should

already be asked now for the general concept on this. For instance, will the manufacturer's own service personnel be trained regularly and is that training provable? Is there the possibility to train the user to do his own servicing and maintenance? What support can a manufacturer give concerning the handling of explosive process media?

Directive 94/9/EC neither exonerates the users nor the manufacturer from the responsibility to thing about possible risks and act accordingly.

With directive 94/9/EC and the corresponding proceeding therein with regards to the documentation and its depositing, the assignment remains with the responsible people for a period of 10 years.

It is therefore recommended to act accordingly in order to prevent any scenario in which negligence could be brought forward as an argument in the undesired event on an accident. Particularly in technical areas of safety which are not yet clear, this worst case scenario should be evaluated in time, and when arguing the case, one should be able to withstand legal crossfire.

Screw vacuum pumps, category 1(i) devices in accordance with directive 94/9/EC for the pharmaceutical industry

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