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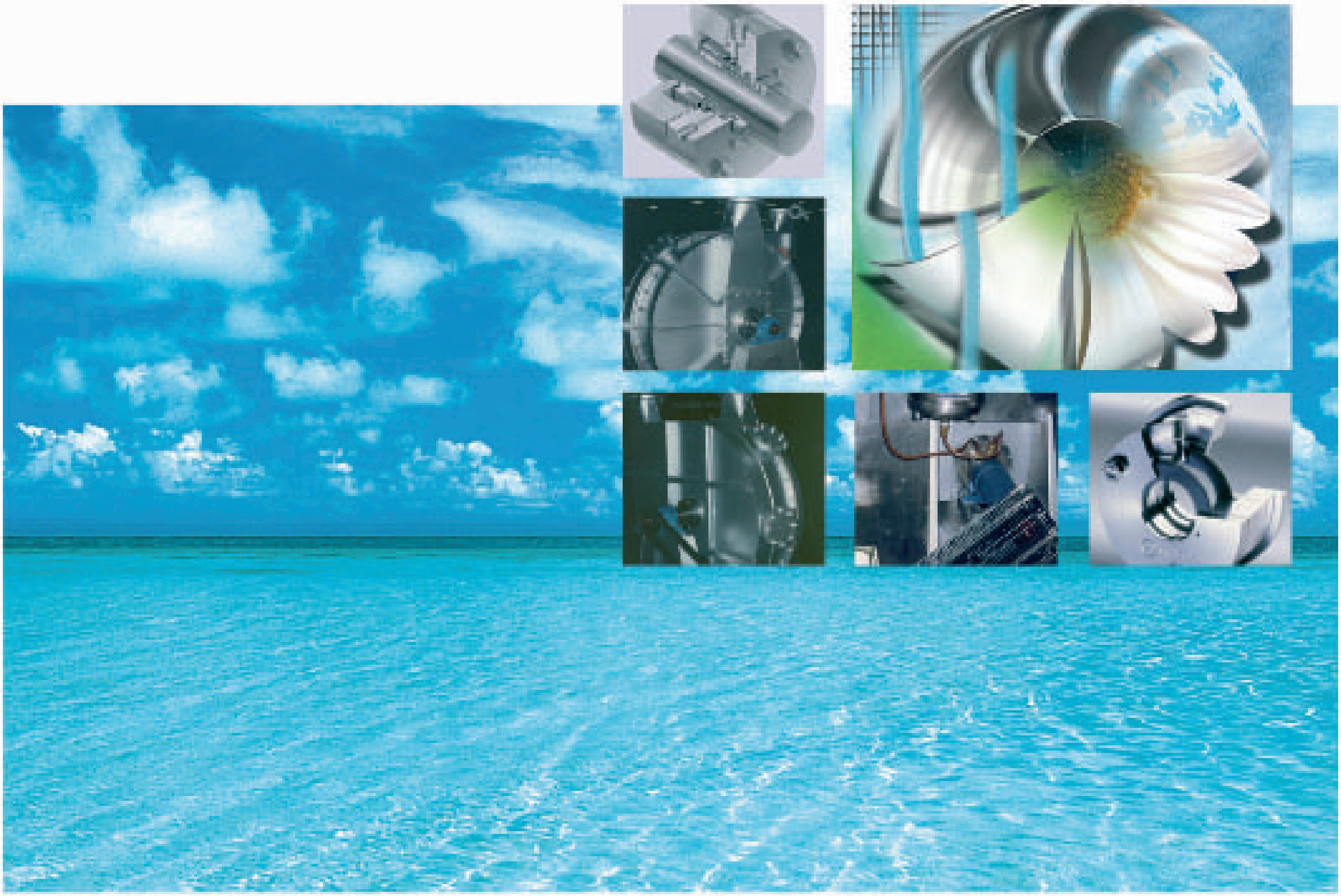


GUIDELINES FOR GAS TIGHT FANS

EUROVENT • CECOMAF

EUROVENT 1/10 - 2005

This document has been prepared by the Eurovent/Cecomaf WG 1 “Fans”, which represents the majority of European manufacturers. It is the result of a collective work – a draft prepared by Alain Godichon (Solyvent - Flakt Woods) has been extensively discussed by all other members.

Although several members of the Group took part in discussions the particularly important contributions have been provided by Bill Cory (Chairman of the WG 1), Prof Hans Witt (Witt and Son) and Dario Brivio (Nicotra).

SUMMARY

1. PURPOSE

The purpose of this document is to provide guidelines for the user, designer and tester of gas tight fans. This document will help users to choose the most suitable class of tightness for their process with the appropriate ways to achieve this and to measure the leakage. The smaller the permissible leakage, the higher is the cost. It must be remembered that perfect tightness is difficult to obtain and especially to maintain for a long time.

Various methods can be applied for leakage detection and measurement. Some reference methods will be given for a proper leakage evaluation.

Additionally, as various sealing devices can be used in particular for the design of the shaft seals, some of them only will be indicated as a reference.

2. REFERENCE DOCUMENTS

[1]	Etanchéïté en mécanique – Techniques de l'Ingénieur – B5420 11 1990
[2]	ISO 13349: Industrial Fans – Vocabulary and Definitions of Categories
[3]	AMCA draft #1 Guidelines for leak-resistant fan construction - P990501.97
[4]	API Standard 673: Special-Purpose Centrifugal Fans for General Refinery Service
[5]	API Standard 617: Centrifugal Compressors for General Refinery Services

3. SCOPE

Gas tightness may be a key feature for fans used in industrial applications. The purpose is often to prevent ambient air to enter from the outside or dangerous gases (corrosive, toxic or explosive) to escape into the surrounding atmosphere. The required degree of tightness will of course depend on the application: a very small leakage may have dramatic consequences, while it can be ignored in other cases. A high reliability of the sealing device may be requested in many cases. Seals may have to be effective under different operating conditions of the fan: during start-up, normal running, shut-down, or even during long periods where the fan is switched off. Different tightness classes will be defined as well as the possibility to measure and test sealing properties.

4. DEFINITION OF TIGHTNESS

Tightness of a fan is its ability to retain a medium inside or prevent an outside medium to enter. High degrees of tightness are difficult to obtain, to maintain and to measure.

A leak may be due to:

- permeability of the enclosure material
- structural wall defects
- faulty static assemblies
- imperfect dynamic assemblies i.e. a gap between moving and static parts, especially the shaft seal.

A leak is measured either as a mass flow rate, or more commonly as a volume flow rate. The flow rate is largely dependent on the pressure difference, driving the gas through the enclosure. In this paper, using the volume flow rate, tightness is characterized by the gas flow power P_{vl} through the leakage:

$$P_{vl} = q_{vl} \times p \quad \text{[Watt]} \quad (1)$$

where q_{vl} is the leakage volume flow rate in m^3/s at the constant pressure difference p in Pacausing the flow. The unit is $m^3/s \times Pa$ (Watt).

The pressure difference is a function of the design working pressure of the fan plus, if applicable, the system pressure.

<u>Note</u>

> *This definition gives values independent of the fan size. It does not refer to the casing wetted area i.e. the confinement surface as it is the case in ISO 13349 (§ 5.3.4). The reason is that the wetted area may be difficult to establish and furthermore be irrelevant because of the shaft seal, which in most cases is the largest leakage source by far.*

5. GAS TIGHTNESS CATEGORIES

Gas tightness requirements will vary largely for various applications. Three general categories can be defined.

- A near absolute gas tightness or when no leakage flow can be measured with the best instrumentation and the leakage power is less than $10^{-12} W$.
- A controlled leakage, relatively constant with time is often required in process industry.
- A relative gas tightness is often sufficient. Ventilation fans are normally not required to have a specific gas tightness.

In gas tight fans it is relatively easy to control the permeability of the enclosure material, structural wall defects and faulty static assemblies. Therefore in the matrix below it is assumed that the leakage occurs at the shaft seal exclusively. It will in first approximation be proportional to shaft diameter, a parameter which is easily accessible and which often anyhow will be informed to the user, who may have to renew seals.

The leakage flow depends on gas temperature and molecule size, as well as the pressure and the nature of the seal. The matrix below is based on normal air at 20°C, where most tests will be carried out. With e.g. hydrogen and some other gases or at higher temperatures a larger leakage flow must be expected.

For axial fans with the impeller mounted directly on the motor shaft, there is normally no dynamic assembly and it is relatively easy to obtain a near absolute tightness.

For centrifugal fans and special axial fans with the driving motor outside the casing or in an enclosure ventilated from the outside the seal differential pressure will be defined as the system pressure, plus the nominal pressure increase of the fan. The pressure at the shaft seal of centrifugal fans is normally lower than the nominal fan pressure, especially if scavenger blades are used. For test purposes, this difference is ignored.

Other dynamic assemblies may have to be considered as shafts for control vanes or dampers, which form an integral part of the fan unit.

The approximate maximum leakage volume flow is shown in the matrix for a number of pressure intervals and leakage powers.

Example: for a class "a" fan with $P_{vl} = 1\ W$, the calculation gives at a normal sealing pressure of $p = 1\ kPa$, a leakage flow of:

$$q_{vl} = \frac{P_{vl}}{p} = \frac{1}{1000} = 0{,}001\ m^3/s$$

or 60 litres/minute, an often used unit.

At $3\ kPa$ test pressure the same leakage class would correspond to a smaller leakage flow. This must be considered when the appropriate leakage class is chosen.

Tabel 1 : Gas Tightness Class with Corresponding Leakage Flow

Gas tightness class	Leakage power (W)	Maximum leakage in m³/s as function of system test pressure and fan pressure (Pa)				
		< 1 000	< 3 000	< 10 000	< 30 000	< 60 000
a	$10^{-1} \leqslant P_{vl} < 1$	1.0×10^{-3}	3.3×10^{-4}	1.0×10^{-4}	3.3×10^{-5}	1.7×10^{-5}
b	$10^{-2} \leqslant P_{vl} < 10^{-1}$	1.0×10^{-4}	3.3×10^{-5}	1.0×10^{-5}	3.3×10^{-6}	1.7×10^{-6}
c	$10^{-3} \leqslant P_{vl} < 10^{-2}$	1.0×10^{-5}	3.3×10^{-6}	1.0×10^{-6}	3.3×10^{-7}	1.7×10^{-7}
d	$10^{-4} \leqslant P_{vl} < 10^{-3}$	1.0×10^{-6}	3.3×10^{-7}	1.0×10^{-7}	3.3×10^{-8}	1.7×10^{-8}
e	$10^{-5} \leqslant P_{vl} < 10^{-4}$	1.0×10^{-7}	3.3×10^{-8}	1.0×10^{-8}	3.3×10^{-9}	1.7×10^{-9}
f	$10^{-10} \leqslant P_{vl} < 10^{-5}$	1.0×10^{-8}	3.3×10^{-9}	1.0×10^{-9}	3.3×10^{-10}	1.7×10^{-10}
g	$P_{vl} < 10^{-10}$	No leakage detected with the best known instrumentation				

Intermediate values may be obtained by interpolation.

High degrees of tightness may require the use of a neutral purging gas as e.g. nitrogen, carbon dioxide or a rare gas. The tightness classes "a" to "f" may also be employed to calculate the consumption of the purging gas.

When a purging gas is employed, the consumption of this gas shall be indicated by the maker. This could be done by stating the gas tightness class for the purging gas.

Often, a higher leakage can be acceptable for the purging gas than for the gas inside the fan.

Note

Some purging gases are expensive and may warrant improved seals to reduce their cost.

6. LEAKAGE RESISTANCE

6.1 Introduction

The leakage resistance of a fan can be measured when the fan is stationary or with the fan running. For measuring purposes, in both cases sealing plates must be fitted to the fan inlet and the fan outlet (end seals). The sealing quality of the plates must be superior to the sealing class for the complete fan.

6.2 Leakage Resistance at Stand Still

The casing tightness can be measured separately without impeller shaft, provided the shaft passage is also sealed with a proper sealing plate. This test is often carried out before the running test. This test may also be carried out without the sealing of the shaft passage to check shaft seal performance at stand still if this is a required performance property. Some shaft seals as e.g. labyrinths have a much larger leakage at stand still than during operation.

6.3 Leakage Resistance during Operation

The leakage resistance of a fan in operation shall preferably be measured without the impeller, but with the end seals as indicated for the measurement of the leakage resistance at stand still. This method is recommended to avoid any temperature increase due to the action of the impeller on the gas inside the fan. On the other hand, the leakage will to some extent differ from the performance we can expect with the impeller installed because of the pressure difference at the shaft seal. When the fan is disassembled and reassembled again after the test with the impeller, a change of leakage may occur. Therefore this running test can not be expected to guarantee the expected performance during future normal service.

If the fan is tested with the impeller installed, it may be difficult to maintain important parameters (pressure and temperature) at a constant value during the time necessary for the measurements. A difference in such a measurement may only serve as a quick check after final assembly.

6.4 Room Ventilation

As leakage flow may increase with time, there should always be an adequate room ventilation, able to cope with a worst case situation.

Especially with noxious gases frequent checks would seem indispensable. Gliding seals are always subject to wear and tear. Some types of seal may take time to be run in, only showing their proper function after that time. This is the case with sectioned carbon ring seals which may require a number of hours running before they become effective.

7. LEAKAGE RESISTANCE MEASUREMENT

This is normally carried out in two steps:

- A qualitative localization method in order to identify a leakage source so it can be taken care of.
- A quantitative method is used to verify leakage class performance.

Among localization methods, the soap-bubble test is the most commonly used. The surface to be controlled is sprayed with a liquid containing a soap solution or other liquids such as Teepol to reduce surface tension properties, the confined system is being pressurized with air or nitrogen. This method can be used to control casing tightness and static assemblies. The test shall be considered satisfactory when no casing or casing assembly leaks are observed.

The use of tracer gases can be considered as a localization method as well as a quantifying method. This method is however restricted to quite special applications.

Among quantity measuring methods, two principles can be used : one is based on the measurement of the volume flow which is necessary to maintain the given pressure inside the fan at a constant value, the other is based on the measurement of pressure decrease.

The leakage flow measurement method can be used, provided sufficiently small flow values can be measured accurately when high leakage classes are required. The pressure decrease method will be described in more details below. The pressure decrease during a given period of time is recorded. The pressure drop will be relatively small for fans having a high gas tightness class. As a variation of the gas temperature is a major source of error, this parameter must be correctly controlled.

7.1 Test Set up

Casing

The casing shall be correctly cleaned and sealed properly at the inlet and at the outlet with appropriate sealing plates, after the impeller is removed.

Test Gas

The gas to be used shall be non flammable and non toxic. Ambient air or nitrogen are commonly used. The relative test pressure need not be much higher than operation pressure to prevent casing failure or distortion. A test pressure equal to 1.1 times the maximum achievable pressure in the fan and system should give a sufficient margin of safety. Prior to the proper test, the pressure must be maintained for a certain time in order to obtain a uniform tempe-rature distribution and to equalize the casing temperature with the gas temperature.

Temperature

The gas, casing and ambient temperatures have to be measured and monitored. The test will normally be carried out at room temperature unless otherwise specified. To carry out a test at other temperatures could involve a very high cost.

Test Repetition

When temperature differences are not negligible, it may be necessary to repeat the test procedure to quantify the leakage.

7.2 Impeller Removal

Shaft seal performance is usually tested at nominal speed. In practically all cases the impeller will have to be removed during the test to prevent excessive heating inside the enclosure and to maintain stable temperature. The shaft rotational speed is recorded during the test.

The inclusion of the fan impeller can be considered case by case for short term tests. In this case, variations of the gas temperature may make a correct interpretation of results difficult. Even shaft gliding seals may cause some increase of gas temperature.

However, with the impeller removed, there maybe a possibility of bearings damaged due to under loading.

7.3 Instrumentation

All instruments must be calibrated. The precision of the instruments will affect the precision of the test results. The instruments shall be selected according to the tightness class.

7.4 Test Procedure and Leakage Calculation

The purpose is to determine the gas flow energy of the leakage using one of the two methods. It will be assumed a perfect gas is used and for simplicity humidity effects will be not considered.

7.4.1 Flow Measurement at Constant Pressure

The pressure can be maintained in the casing by flow adjustment thanks to an auxiliary variable supply gas system. ΔV represents the volume of gas being supplied by the auxiliary system at the pressure p_0 during the duration of test from t_0 to t_1.
Referring to the definition of the gas flow energy of the leak :

$P_{vl} = q_{vl} \times p_0$

where $q_{vl} = \dfrac{\Delta V}{t_1 - t_0}$ *(2)*

Note

The volume may have to be corrected with the pressure according to the perfect gas law.

7.4.2 Pressure Decrease Method

This is an indirect method requiring some calculation:

V represents the gas volume inside the casing. p_0 and p_1 represent the 2 pressures measured at time t_0 and t_1 at time respectively, ΔV represents the leakage volume of gas at the mean pressure. $\dfrac{p_0 + p_1}{2}$

Per definition (1) the gas flow energy is then:

$$P_{vl} = \frac{\Delta V}{(t_1 - t_0)} = \frac{(p_0 + p_1)}{2} \quad \text{[Watt]} \quad (3)$$

Note

Provided $p_0 - p_1$ is small, and that p_0 and p_1 are almost equal amount above and below the nominal test pressure, this measuring method gives the same result as the method described in § 7.3.1 within the accuracy limits.

We can demonstrate (see annex A):

$$P_{vl} = \frac{V \times \Delta p}{(t_1 - t_0) p_{test}} \times \frac{p_0 + p_1}{2} \quad (4)$$

where:

$\Delta p = p_0 - p_1$,

- p_{test} is the absolute mean pressure during the test: $p_{test} \; \dfrac{p_0 + p_1}{2} + p_{atm}$,

- p_0 and p_1 are relative pressures.

The gas flow power can be calculated with pressure decrease only. It is dependent of the initial pressure p_0.

The atmospheric pressure p_{atm} is measured at the beginning and the end of the test. Temperature difference shall be negligible.

At time t_0, the relative pressure p_0 is measured inside the casing together with the casing temperature T_0 and the gas temperature T_{0g}. These temperatures must be practically equal.

At time t_1, the relative pressure p_1 is measured inside the casing together with the casing temperature T_1 and the gas temperature T_{1g}.

7.5 Leakage Measurement with the Impeller Running

With an impeller running in a perfectly sealed enclosure, the gas temperature may increase very fast because of the energy transferred to the gas. This temperature increase ΔT is only limited by the energy transferred to the outside through the enclosure walls. Due to the difficulties to calculate the actual leakage in such conditions, this type of measurement is not recommended.

ANNEX A: LEAKAGE CALCULATION FOR THE PRESSURE DECREASE METHOD

V represents the gas volume inside the casing. p_0 and p_1 represent the relative pressures measured at time t_0 and at time t_1 respectively, ΔV represents the leakage volume of gas at the mean pressure.

Referring to the definition of the gas flow energy of the leak and considering an average value for the pressure:

$$P_{vl} = \frac{\Delta V}{(t_1 - t_0)} = \frac{(p_0 + p_1)}{2} \qquad (1)$$

We assume here the gas temperature T_0 to be constant during the test period.

N_0 and N_1 represent the number of moles contained in this volume at time t_0 and at time t_1 respectively.

Applying the perfect gas law :

at time t_0 : $(p_0 + P_{atm})\, V = N_0 R T_0$

at time t_1 : $(p_1 + P_{atm})\, V = N_1 R T_0 \qquad (2)$

If ΔN represents the number of moles contained in the leakage volume ΔV at the average pressure :

$$\left(\frac{p_0 + p_1}{2} + P_{atm}\right) \Delta V = \Delta N \times RT_0 \text{ and } \Delta N = N_0 - N_1 \qquad (3)$$

The following relation can be obtained :

$$\left(\frac{p_0 + p_1}{2} + P_{atm}\right) \Delta V = (p_0 - p_1) V = \Delta p V = P_{test}\, \Delta V \qquad (4)$$

where $\Delta p = p_0 - p_1$

and $P_{test} = \dfrac{p_0 - p_1}{2} + P_{atm}$

Therefore:

$$P_{vl} = \frac{V \times \Delta p}{(t_1 - t_0)\ p_{test}} = \frac{p_0 + p_1}{2} \qquad (5)$$

p_{test} is the absolute mean pressure during the test,

p_0 and p_1 are relative pressures.

The gas flow power can be calculated with pressure decrease only. It is dependent on the initial pressure p_0.

The atmospheric pressure p_{atm} is measured at the beginning and the end of the test. Temperature difference shall be negligible.

At time t_0, the relative pressure p_0 is measured inside the casing together with the casing temperature T_0 and the gas temperature T_{0g}. These temperatures must be practically equal.

At time t_1, the relative pressure p_1 is measured inside the casing together with the casing temperature T_1 and the gas temperature T_{1g}.

ANNEX B: GAS FLOW ENERGY CALCULATION (for comparison with iso 13349)

Referring to ISO 13349 regarding the categorization of gas-tight fans, we can evaluate the corresponding gas flow energy due to the leakage:

The gas flow energy for one square meter wetted surface varies only by a factor of 4 over the whole range.

Leakage as a function of test pressure – Gas flow energy

Leakage category	Maximum test pressure p in KPa	Time at maximum pressure minutes	Acceptance criteria/ maximum leakage rate litres/(s.m^2)	Gas flow energy per square meter of casing wetterd area W/m^2
A	0.5	15	0,027 $p^{0,65}$	0,8
B	1.0	15	0,009 $p^{0,65}$	0,8
C	2.0	15	0,003 $p^{0,65}$	0,8
D	2.5	15	0,001 $p^{0,65}$	0,4
E	2.5	15	0,0005 $p^{0,65}$	0,2
F	3.0	60	Fall in $p<500\ Pa$	
G	10.5	15	No detectable leaks	

ISO 13349: Table 4 - Categorization of gas-tight fans – Leakage as a function of test pressure

As the leakage power of classes A to E only differs by a factor of 4, it was found that a better differentiation may be needed. For this reason this new categorization is introduced. Furthermore, unlike ISO 13349, purging gas losses are treated separately in this new document.

ANNEX C: GAS TIGHTNESS CATEGORIES WITH TENTATIVE DESIGN FEATURES (REFER TO ANNEX D)

Gas tightness class	Leakage power (W)	Casing (Figure reference)	Shaft seal	Revision period
A	$10^{-1} \leqslant P_{vl} < 1$	Non continuous welding or Pittsburgh assembly or continuous welding assemblies (Fig 1)	Coverplate or Floating bushing with 1 ring (Fig 5)	6 months
B	$10^{-2} \leqslant P_{vl} < 10^{-1}$	- Continuous welding - Near absolute tightnes for static assemblies (Fig 2, 3)	Floating bushing with 2 rings (Fig 5)	3 months
C	$10^{-3} \leqslant P_{vl} < 10^{-2}$	- Continuous welding - Near absolute tightness for static assemblies (Fig 2, 3)	Floating bushing 2 or 3 rings with purging gas (Fig 5)	6 months
D	$10^{-4} \leqslant P_{vl} < 10^{-2}$	- Continuous welding - Near absolute tightness for static assemblies (Fig 2, 3)	Floating bushing with 4 rings and purging gas (Fig 5)	6 months
E **F**	$10^{-5} \leqslant P_{vl} < 10^{-4}$ and $10^{-10} \leqslant P_{vl} < 10$	- Continuous welding - Sealing gaskets in grooves for static assemblies ("O" rings)	Labyrinth seal with purging gas (Fig 4) or floating bushing with 6 rings and purging gas (Fig 5) or ferrofluid sealing (Fig 8)	6 months
G	$P_{vl} < 10^{-10}$	Continuous welding Sealing gaskets in grooves for static assemblies	Motor included in fan casing (Fig 9). Cooling through air stream or hermetic external system	6 months

It is to be considered that the leakage will vary during seal life and the shaft seals suggested are tentative only.

The revision period suggested is also tentative only. In case the noxious gases or if the entrance of ambient gas into the fan may be considered dangerous, more frequent revision shall be carried out.

In case of gliding seals the wear and tear surfaces might need to be renewed. In many cases cleaning and re-greasing might be required. If the fan has been dismantled a new tightness measurement can be required.

ANNEX D: TIGHTNESS DESIGN FEATURES (informative only)

We have distinguished between:

- The casing tightness.
- The tightness of static assemblies (with or without sealing joints)
- The tightness of dynamic rotating interfaces (shaft seals)

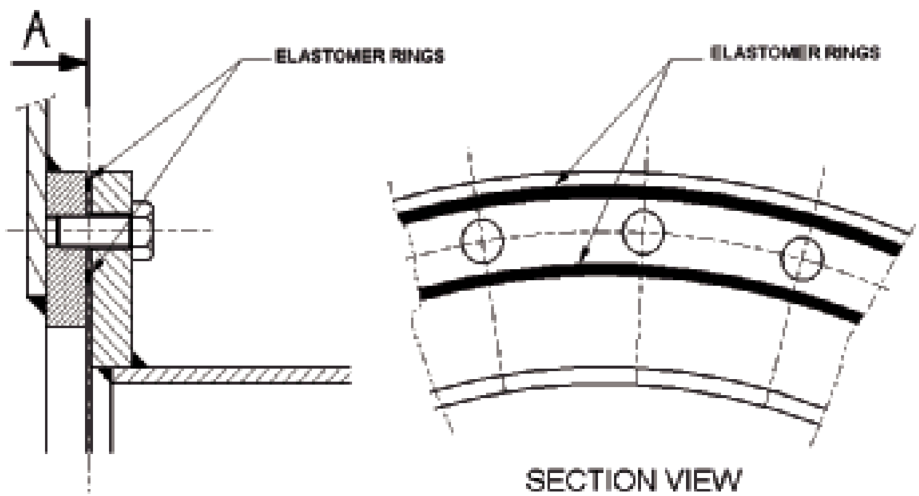
A.1 Tightness of Casing

A near absolute casing tightness can normally only be obtained between metallic materials through a correct welding of the components. The control of the casing tightness is normally carried out simultaneously with the control of the static assemblies. The main problems occur at inspection openings and casing divisions.

A.2 Static Assemblies

This type of junction shall allow it to be dismantled, at least from time to time. The most common seal used for fans consists of an elastic ring or putty inserted between plane surfaces as two flanges, Fig 1.Throughholes should be avoided.

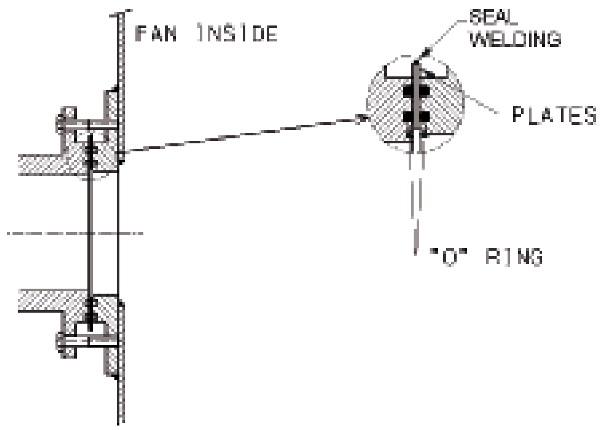
Fig. 1: Common tightening method for static assemblies



Near Absolute Tightness

In practice, a near absolute tightness can only be obtained through welding which cannot be easily dismantled. In order to facilitate the dismantling, it may be possible to insert additional thin plates welded at their periphery (see fig 2.)

Fig. 2: Welded flange with added plates



Relative Tightness

The assembly of two surfaces pressed against each other is providing a relative tightness only, even when a high pressure is used for the assembly.

With Sealing Gaskets

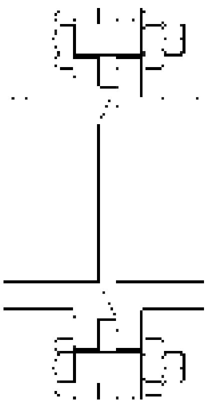
With a sealing gasket or elastic putty a high tightness can be obtained (10^{-10} Pa x m^3/s) on larger areas with a non perfect surface quality. The sealing gasket must have good properties regarding elasticity, plasticity, impermeability ; it must be compatible with the fluid properties during all operating conditions.

The sealing gasket can be mounted in a groove between the two pieces which are assembled by pressure, or without grooves between the two flanges. Many shapes and materials can be used in different applications. Reference 1 can provide more detailed guidelines.

Sealing without Joints

It is not always possible to use soft joints. In some conditions, e.g. high temperature, it is possible to obtain a pretty good tightness (10^{-6} Pa x m^3/s) using the design shown below. The geometry of the surfaces in contact must be very good, the surface roughness very small. A high contact pressure can be obtained by restricting the area of contact. One possibility is to have a knife edge to plane contact (Fig 3). It is also useful to use a material that is more ductile for one of the two parts to be assembled. This type of assembly should in practice be limited to small dimensions, mainly for ducting assemblies (below 100 mm diameter).

Fig. 3: Knife-edge plane contact



A.3 Shaft Seals

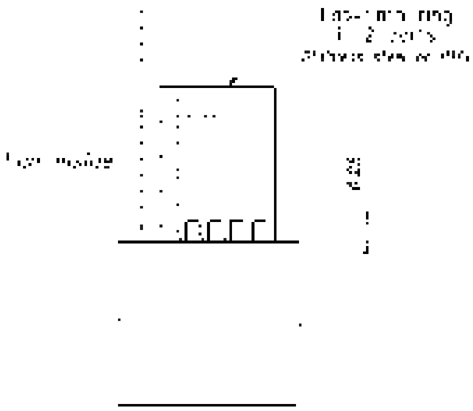
In general, shaft seals may be of one single type or a combination of the following types:

Controlled Tightness (minimum clearance)

The simplest and most common design, but this has a limited efficiency, consists of one single coverplate with a small clearance, generally a brass plate.

For higher demands, labyrinth seals are the most commonly used systems to provide a controlled tightness (Fig 4). The shaft has a polished surface.

Fig 4: Labyrinth seal



The boundary between controlled and relative tightness is indeterminate.

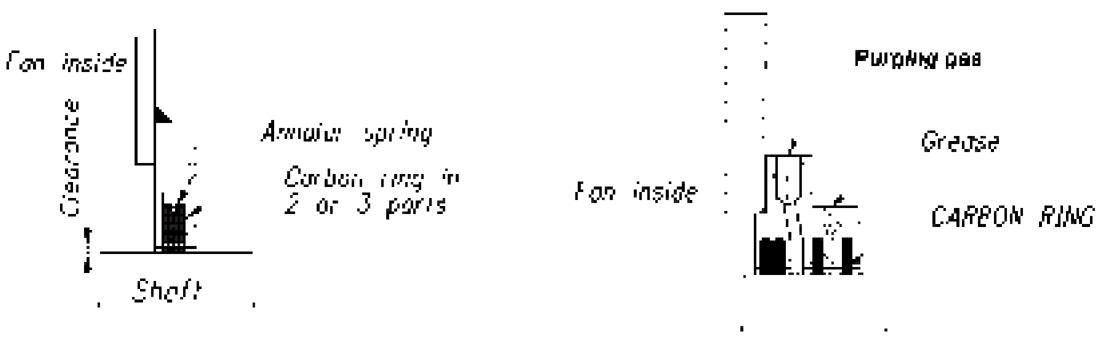
Many variants of seals using these principles are available. To reduce wear between the seal and the shaft, the seal rings can be realised with spring loaded mobile segments (with carbon rings for example).

Relative Tightness (initial contact)

A better relative tightness can be obtained with various principles:

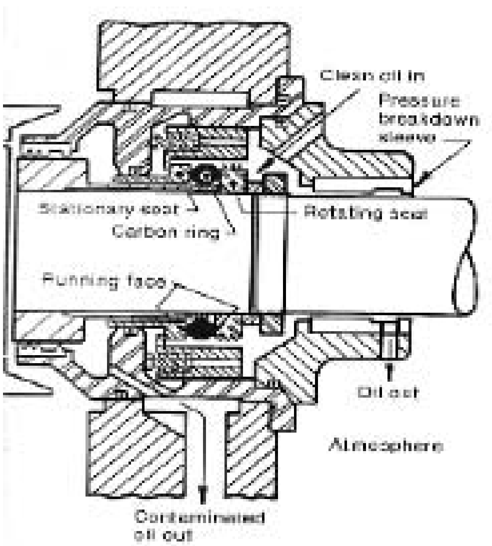
- with a floating bushing (carbon ring): carbon rings made in 2 or 3 parts are maintained closely to the shaft with annular springs (Fig 5.). When the seal is specified to be used for toxic, high pressure or flammable service, one variant is to use a gas injection into a chamber located in the sealing to minimize leakage.

Fig 5: Floating bushing



- with a rotating joint : specific materials are employed to realize a rotating seal joint. The shaft surface quality is of a great importance for the lifetime of such a seal; a specific surface treatment may be required (nickel or tungsten coating, nitriding, or ceramic coating. The joint itself is carefully selected: a toroïdal joint or a lip joint may be used for low speeds (up to 2 m/s), but a packing tow in a stuffing box, or a mechanical (contact) shaft seal can be used at higher speeds (up to 20 m/s) (Fig 6).

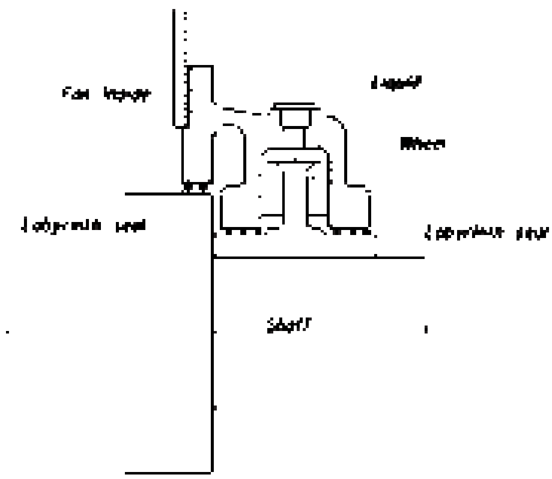
Fig 6: Mechanical (contact) shaft seal
(extract from API Standard 617: Centrifugal Compressors for Refinery Service)



- by centrifugal effect: a liquid can be centrifuged to create a barrier against gas leakage (Fig 7).

Fig 7: Liquid annulus seal

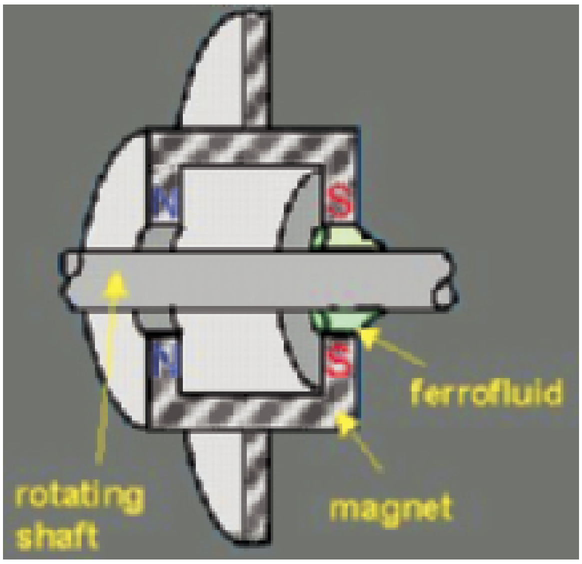
This type of seal must be combined with an additional one to operate the fan at low speed or during the fan standstill.



- by a ferrofluid sealing:

A relatively new shaft seal is being applied now for low pressure fans and blowers. In principle, it relies on the ability to position and control a ferrofluid with magnetic fields and with the field to create liquid « O » rings around the shaft to prevent the passage of vapors across the seal. This principle is illustrated on Figure 8.

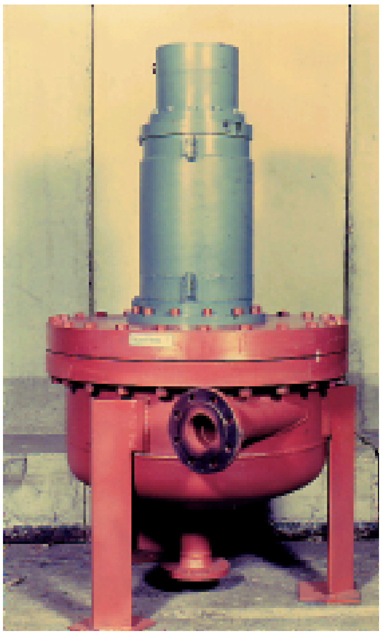
Fig 8: The principle of ferrofluid sealing



Near Absolute Tightness

It is possible to obtain a near absolute tightness even between rotating and static parts. But this is seldom applied in fans. The most common method used for fans, when a near absolute tightness is required, consists to include the motor itself into the confined system which can be realised more easily (fig. 9).

Fig 9: Fan construction for a near absolute tightness (pressurized centrifugal booster)



By courtesy of Fläkt Solyvent - Ventec

Motor cooling may require a liquid cooler inside the enclosure or cooling by external air stream. In axial fans, with the impeller directly mounted on motor shaft, the gaskets at both ends of the fan determine the degree of tightness.

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