CONDITIONS FOR THE VALIDITY OF THE CONTAINMENT SYSTEM ASSEMBLY VERIFICATION METHODS TO GUARANTEE THE RADIOACTIVITY CONTAINMENT REQUIREMENTS

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ABSTRACT

American and international standards relative to leakage tests on packages for shipment indicate that the leakage rates of the test performed before shipment can be higher than the ones used to demonstrate the activity release regulatory criterion (10^{-6} A_2/h). This practise is based on the hypothesis that the control of a correct closure of the package before shipment allows to have a leaktightness better than measured, and equivalent to the level measured during the package maintenance.

This paper presents the results of a study which demonstrates that defects of intermediate size (scratches, dust, cruds, etc.) may affect the sealing by elastomer O-rings and cause leakages at rates lower than those fixed to detect an incorrect closure but higher than those allowing to directly guarantee the containment conformity to the regulation.

Leaktightness tests have been performed with a mockup of a typical closure system. Different kinds of defects (metallic and organic capillaries, scratches), with various sizes (5 µm to 300 µm) were installed between inner gasket and gasket seat. Some of them are not visible to the naked eye.

The results indicate that the measured leakages uniformly vary with the size of the defect.

We conclude that the control of the correct closure of a package does not provide assurance that the leaktightness necessary to meet the regulatory criterion is reached.

Results of this study have been submitted to an expert group appointed by the French Authority (Nuclear Installations Safety Directorate). It has been concluded that the practise of the unique control of a correct closure of a package to guarantee leaktightness is not acceptable unless specific procedures are implemented to guarantee the absence of defects liable to cause leakage rates higher than those directly derived from the acceptable activity release rates.

EXPERIMENTAL SYSTEM

Leaktightness tests have been performed with a mockup of a typical closure system. This one is constituted with a disk, a lid and a leaktightness system, which allows testing O-rings. The disk is a clamp in stainless steel, and provides the contact surface of seals. An orifice is used to perform the leaktightness measurement. The lid, also constituted with stainless steel, is fixed by bolts at the disk. It is equipped with one leaktight barrier constituted by two concentric elastomer O-ring gaskets (EPDM), separated by an interspace volume. Two tests orifices are provided, in order to inject helium and to connect the helium mass spectrometer.

The mockup dimensions meet all the dimensions of the O-ring groove cross-sections that are specified for the typical package closure system.

A description and dimensions are provided in figures 1 and 2. The torque force applied to the bolts has been quantified to guarantee the metal/metal contact between the disk and the lid.

DIFFERENT KINDS OF DEFECTS

Three types of defects have been tested.
Metallic and organic capillaries are cylindrical, full, and their lenghts are bigger than the width of the gasket seat.
Metallic capillaries are in iron, in order to be representative of steel capillary. Six sizes of capillaries are used from 10 µm to 320 µm.
Organic capillaries are in cotton, wool and polyamide, in order to be representative of sewing cotton or a single hair. Six sizes of capillaries are used from 5 µm to 300 µm.

Five disks are used with one scratch by disk. Scratches are made by electro-erosion, with an equilateral triangular shape and a depth from 10 µm to 150 µm.

TESTS

Leaktightness tests have been performed for one type of gasket (EPDM), taking into account each capillary one by one and with a method of helium quantitative verification. The tested gasket is the inner one.
Six types of tests have been carried out :
Test type 1 : metal/metal contact (without gasket and defect)
Test type 2 : with gaskets and without defect
Test type 3 : wih gaskets and capillary
Test type 4 : repetitive test with gaskets and capillary
Test type 5 : with gaskets and scratched disk
Test type 6 : repetitive test with gaskets and sractched disk.

The sequence A was composed of test types 1 and 2, in order to qualify the experimental system.
The sequence B was composed of test types 2, 3 and 4 performed in this order, with metallic capillaries.
The sequence C was composed of test types 2,3 and 4 performed in this order, with organic capillaries.
The sequence D was composed of test types 2, 5 and 6 performed in this order.

The leakage rate is measured by creation of a vacuum of the inner space and detection of the tracer gas helium, introduced in the interspace volume.

Qualified operators have performed all tests under quality assurance.

RESULTS

The sensitivity of the detector is 2.22 10^{-11} $Pa.m^3.s^{-1}$. The metal/metal contact is insufficient to achieve the leaktightness of the scale. The test of type 2 indicates, with two concentric O-ring and without defect, that the measure is the limit of the test sensitivity (2.0 10^{-11} $Pa.m^3.s^{-1}$).

For each case of metallic and organic capillaries and scratches, results are indicated in the following table for each size of defect tested.

Diameter of metallic capillary (µm)		8	30	50	80	101	320
Test type 3	Leakage rate **ϕ_1** ($Pa.m^3.s^{-1}$ SHeLR)	5.9 10^{-7}	1.0 10^{-4}	2.5 10^{-4}	6.55 10^{-4}	3.45 10^{-3}	1.66 10^{-2}
Test type 4	Leakage rate **ϕ_2** ($Pa.m^3.s^{-1}$ SHeLR)	9.9 10^{-7}	1.0 10^{-4}	7.0 10^{-4}	3.0 10^{-4}	4.0 10^{-3}	1.0 10^{-2}

Diameter of organic capillary (µm)		4.54	18.9	26	36.55	60	300
	Type of capillary	cotton	wood	Hollow polyester	wood	Trefoil polyamide	cotton
Test type 3	Leakage rate ϕ_1 ($Pa.m^3.s^{-1}$ SHeLR)	3.19 10^{-7}	4.0 10^{-6}	5.0 10^{-5}	2.0 10^{-4}	4.5 10^{-5}	1.0 10^{-3}
Test type 4	Leakage rate ϕ_2 ($Pa.m^3.s^{-1}$ SHeLR)	1.99 10^{-6}	1.0 10^{-5}	4.0 10^{-5}	1.5 10^{-4}	5.0 10^{-5}	1.0 10^{-3}

	Size of scratch : **dxl** (µm)	12x13.9	46x53,1	74x85,5	100x115	150x173
Test type 5	Leakage rate **ϕ_1** ($Pa.m^3.s^{-1}$ SHeLR)	0	7.94 10^{-7}	2.0 10^{-6}	5.0 10^{-5}	1.0 10^{-3}
Test type 6	Leakage rate **ϕ_2** ($Pa.m^3.s^{-1}$ SHeLR)	0	4.8 10^{-7}	2.99 10^{-6}	8.0 10^{-5}	2.0 10^{-3}

These leakage rate results are reported in figure 3 according to the actual initial capillary diameter and in figures 4 and 5 according to the equivalent hydraulic diameter of the leak paths, with leak path profiles estimated as in figure 6.
The variation of leakage rates with defect size is uniform.

INTERPRETATION OF THE RESULTS

The limit of visibility of the defect (capillary or scratch) is a subjective parameter. Its determination depends on the operator, on his position in relation to the defect, on the length of the defect, and on the type of lighting.

Defects of capillary type on a gasket seat could be of differents types. But, whatever the type, during the realization of tests, all defects with a diameter greater than 100 µm were visible to the naked eye. For defects with a lower section diameter, the visibility of defects on the gasket seat was more difficult to determine.

With an adapted lighting, all scratches were visible.

For the capillaries, the limit of visibility to naked eye, in laboratory conditions, was from 10 to 30 µm.

With a rigorous control, realized in good conditions (lighting, eye of the operator, short distance of control, etc.), but taking into account existence of operational methods (for example the limitation of the time of the controls in order to reduce the people exposure), we consider a 50 µm criterion for visibility of the capillaries and a 25 µm one for scratches.

We consider capillaries with a diameter lower than 50 µm are not detectable in usual working conditions, except with specific procedures of control more precise than a visual control.

The leakage rate criteria adopted for the leaktightness test performed before each shipment and for demonstrating conformity to the regulatory activity release limit are in the range 10^{-5} to 10^{-2} $Pa.m^3.s^{-1}$ SLR.

The diameter of the defects that generates these levels is between 8 µm and 135 µm.

A visible 100 µm capillary defect provokes a leakage rate between 10^{-4} and 4.10^{-3} $Pa.m^3.s^{-1}$ SLR.

A generally not visible 50 µm defect provokes a leakage rate between $2,6.10^{-5}$ and 7.10^{-4} $Pa.m^3.s^{-1}$ SLR that may exceed the leakage rate necessary to meet the regulatory criterion.

The results of the study demonstrate that a defect on a gasket seat can increase the leakage rate above the value allowing to demonstrate the conformity to the activity release regulatory limit.

Therefore the control of the correct closure of a package by a slackened leaktightness test is not sufficient to provide assurance that the leaktightness necessary to meet the regulatory criterion is reached.

UTILIZATION FOR THE PACKAGES

For packages that are loaded and closed under water, the possibility of the control of the cleanliness of the gasket seat and the gasket is not conceivable because the closure operations are realized under a depth of several meters of water beyond which such small defects are not detectable.

No guarantee of lack of defect can be provided for the loading and the closure of packages under water. For instance, during spent fuel loading in the packaging cavity, at least oxide or metal cruds are present and may contaminate the gasket seat.

Then any slackened leakage rate criterion for the test performed before shipment cannot provide assurance that the leaktightness necessary to meet the regulatory criterion is reached.

For packages that are loaded and closed in dry conditions, the possibility of the control of the cleanliness of the gasket seat and the gasket is conceivable.

For packages for which the allowable leakage rate controlled before shipment would be 5.10^{-4} $Pa.m^3.s^{-1}$ SLR, and the required one to meet the regulatory criterion 10^{-5} $Pa.m^3.s^{-1}$ SLR, the presence of a metallic or organic capillary may remain undetected by a visual control (dimension < 50 µm) and by the preshipment leakage test, but can nonetheless provoke a leakage higher than that one necessary to meet the regulatory criterion.

For packages for which the allowable leakage rate controlled before shipment would be 2.10^{-1} $Pa.m^3.s^{-1}$ SLR, and the required one to meet the regulatory criterion 2.10^{-3} $Pa.m^3.s^{-1}$ SLR, the diameter of the capillaries, which provoke leakage rates above the one necessary to meet the regulatory criterion, are greater than 50 µm and could be detected by a visual control. As a result, if the leakage rate necessary to meet the regulatory criterion is higher than the one equivalent to the lowest visually detectable defect, a preshipment leakage test criterion higher than the one necessary to meet the regulatory criterion is acceptable if the control is doubled by a thorough visual test for absence of any visible defect.

The results of the study demonstrate that intermediate size defects (scratches, dust, cruds, etc.) may affect the sealing by elastomer O-rings and cause leakages at rates lower than those fixed to detect an incorrect closure but higher than those allowing to directly guarantee the containment conformity to the regulation.

These findings are valid for EPDM O-rings with a Shore hardness between 65 and 85. Since the Shore hardness has an influence upon the shape of the seal area that covers the capillary or the scratch and consequently, on the leak path cross section, some modifications of the result values may be expected for different grades.

CONCLUSION

The control of the correct closure of a package may not be sufficient to provide assurance that the leaktightness necessary to meet the regulatory criterion is reached.

To use a leakage rate before shipment higher than the one necessary to meet the regulatory criterion, this one must be greater than 7.10^{-4} $Pa.m^3.s^{-1}$ SLR.

In order to accept the closure test method, the absence and the detectability before closure of the package, of invisible defects with a size between 10 and 50 µm, according to the package, should be guaranteed. Nevertheless, these conditions should require specific control operations which should be qualified, but the industrial feasibility is uncertain.

Results of this study have been submitted to an expert group appointed by the French Authority (Nuclear Installations Safety Directorate). It has been concluded that when it is not feasible to implement a control procedure to guarantee the absence of detrimental defects, the applicant should either check for existing safety margins – for instance on the activity of source available for release – or use more sensitive preshipment leakage test methods.

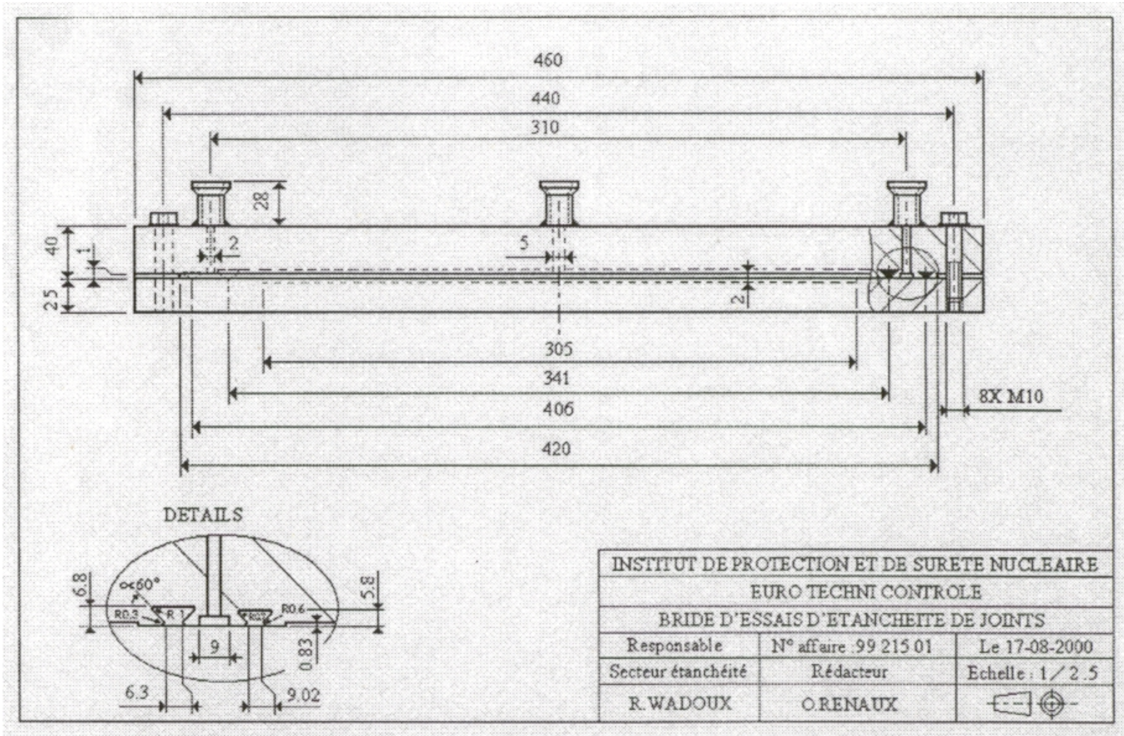

Fig. 1 : Mockup

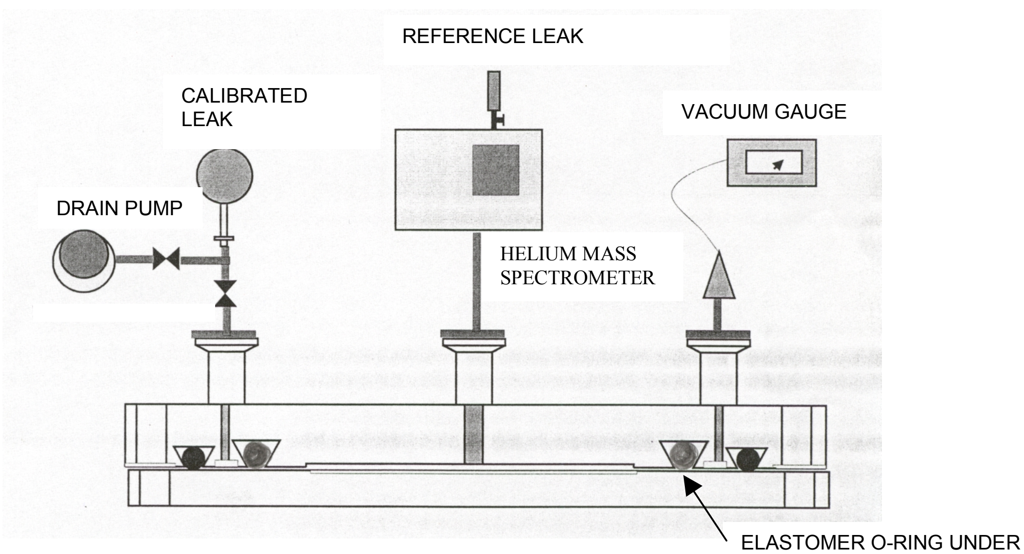

Fig. 2 : Experimental system

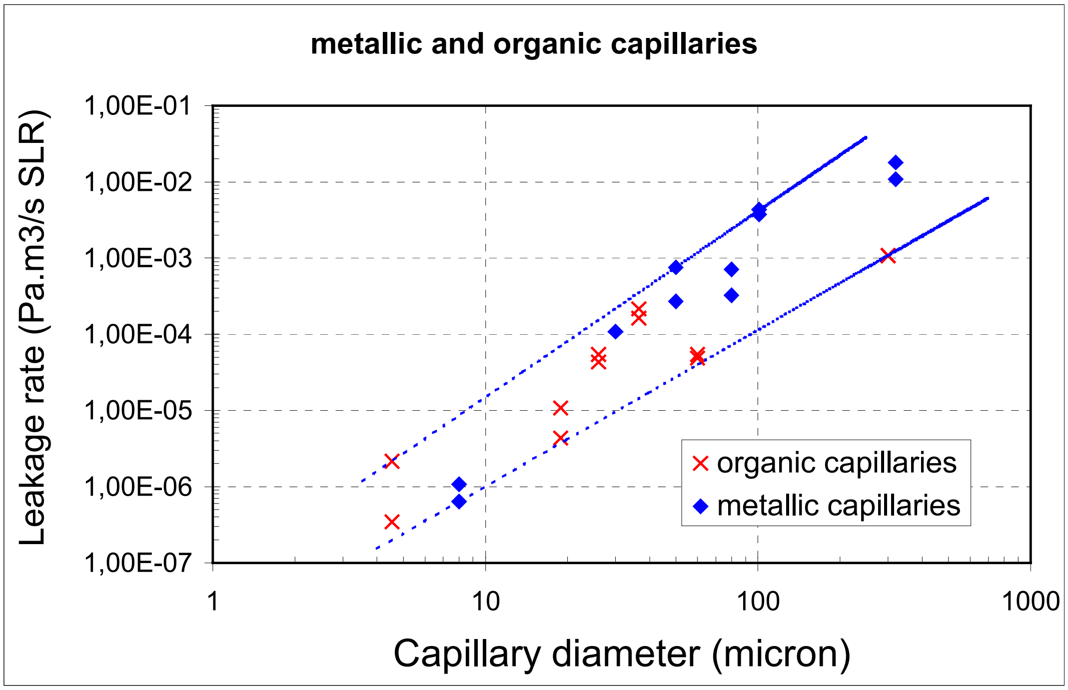

Fig. 3 : Capillary leakage rates versus initial diameter

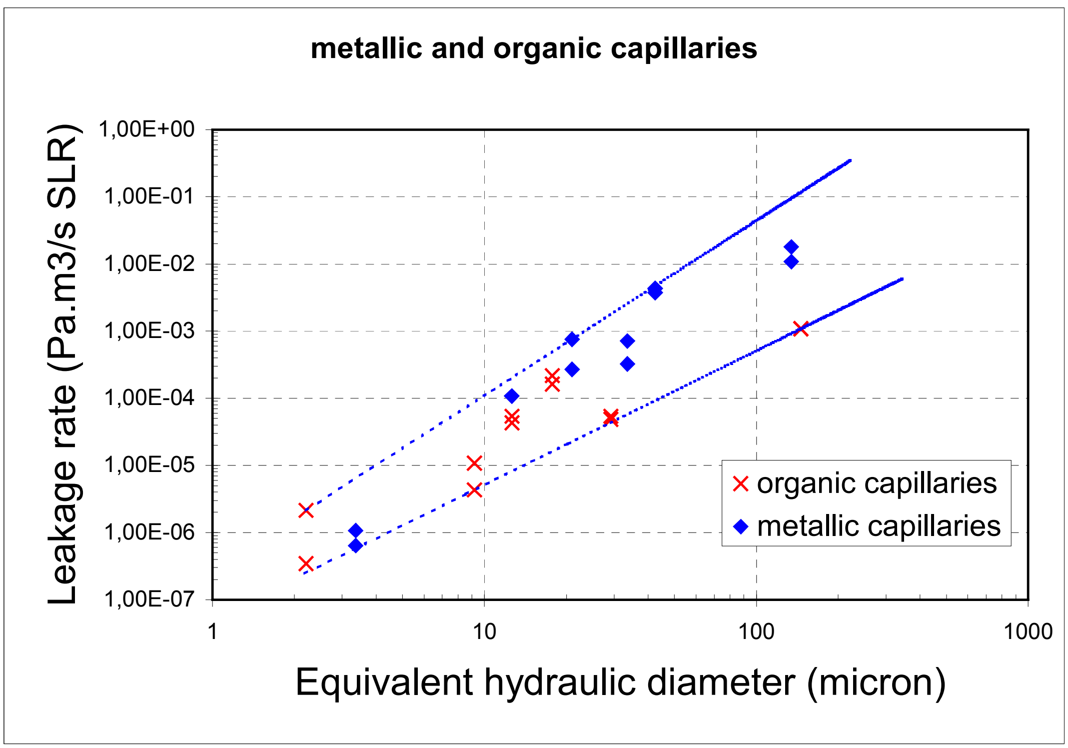

Fig. 4 : Capillary leakage rates versus estimated half leak path hydraulic diameter

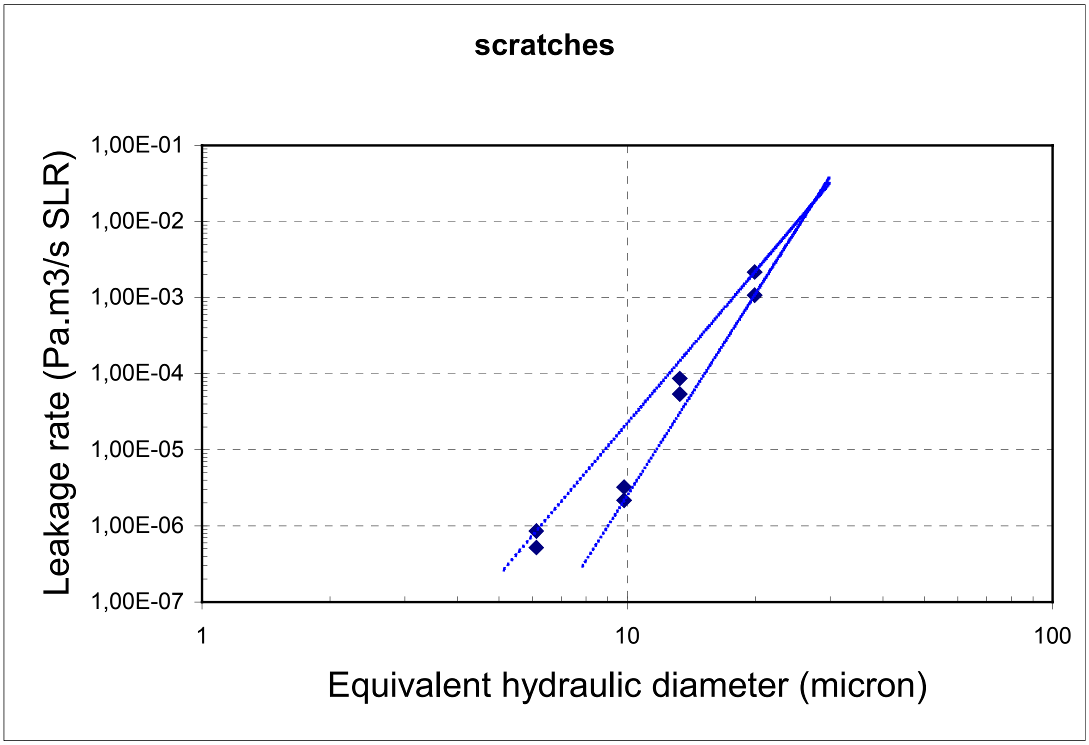

Fig. 5 : Scratches leakage rates versus estimated leak path hydraulic diameter

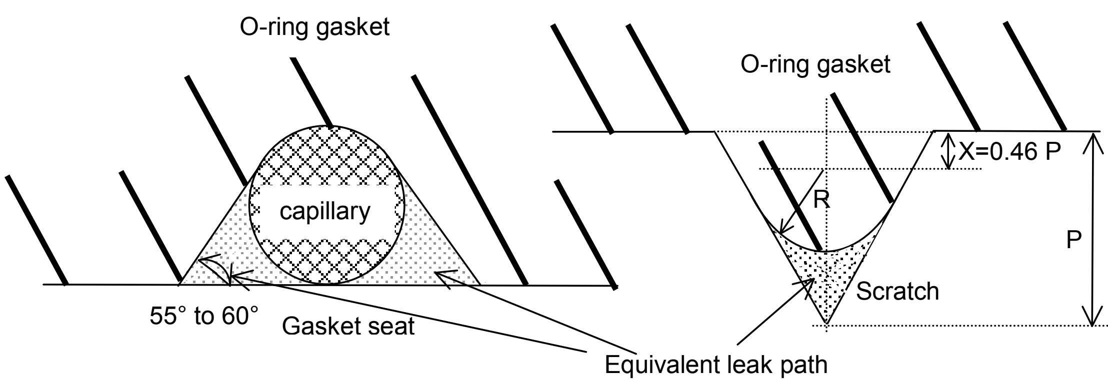

Fig. 6 : Estimated leak path profiles