Leak Test of Test Parts with Pressure Compensation Elements using the Test Medium Compressed Air

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Abstract. Many products which are used outdoors are exposed to a variety of environmental influences. By temperature-induced pressure fluctuations as well as the cooling of the heated system during operation, a vacuum can occur inside the product. If the welding, the seals or the contacts are not leak-tight moisture and liquid can be drawn into the interior of the system. Penetration of moisture can lead to serious disturbances in electronic components and can impair the function. In addition, the cyclical heating and cooling stresses the seals.

Therefore often pressure compensation elements (like membranes) are used for ventilation. These allow pressure equalization while protecting against oil, water and particles. As part of the quality control in the production line leak testing of the housing is of particular importance.

Hereby very often compressed air is used as test medium. The leak test with compressed air is an objective test method that can be automated quite well. For the leak test the test part must be filled through the pressure compensation element to the test pressure.

In addition to checking the tightness of the housing, membrane defects and assembly errors of the membrane have to be detected reliably. The test process consists of two steps: 1) After mounting the pressure compensation element it has to be checked if it is still intact. Sometimes the pressure compensation element is integrated into the cover, which is later mounted to the housing. But mostly the pressure compensation element is inserted into the completely assembled housing. 2) The tightness of the housing must be checked. Hereby the test part has to be filled through the pressure compensation element.

The specific characteristics of the leak testing of systems with pressure compensation elements are treated in practice.

1. The danger of low pressure in a product

Many products which are used outdoors or in harsh environments are exposed to a variety of influences. Temperature-induced pressure fluctuations can create an overpressure but also a negative pressure inside the system. Thereby, the housing seals, welding and adhesive seams are heavily stressed and can leak. If the inside of a product is on a low pressure level and the product is not vented, there is a risk that moisture and liquid are drawn into the system. This can cause severe malfunction of electronic components.
### 2. Ventilation through pressure compensation elements (PCE)

For the ventilation pressure compensation elements (PCE) are often used. Typical examples are shown in Fig. 1. These allow the pressure equalization while protecting against oil, water and particles. With regard to the mounting position of the component, there are often requirements. The pressure compensation element should not be positioned horizontally. Often the pressure compensation element is mounted behind a mesh to protect it against dirt and mechanical damage. By leak testing the product it has to be filled through the pressure compensation element.

![Examples of pressure compensation elements](image)

**Fig. 1.** Examples of pressure compensation elements [1]

### 3. Properties of membranes

Widely used are membranes made of expanded polytetrafluoroethylene (ePTFE). The hydrophobic and oleophobic material is produced in thin layers and the flow is adjusted by a stretching process which creates microholes. These membranes can be mounted by welding or gluing. Typical products with membranes are shown in Fig. 2.

A fundamental problem of this type is that often only the minimum flow is specified in the data sheet. Flow measurements of these types of membranes have shown that the flow is typically 2 to 3 times greater than the minimum flow. And the flow rates of different batches may vary. This complicates the detection of defects of the membrane and its mounting process. This means the flow variation can cover defects. And in the leak test, the batch to batch variation of the flow affects the filling process. The fill and test pressure can only be controlled and measured in front of the membrane, but not inside the product. It has to be ensured that the test pressure is reached in the test part. This can be proofed with a special prepared test part.
4. Volume dependent duration for venting

The function of the membrane is to equalize pressure differences. The time needed to vent a product depends on the volume, the flow active area and specific membrane data. For effective venting of the test part volume a suitable membrane and active flow area have to be chosen. The following example demonstrates the venting effect.

Different volumes (10 ml, 50 ml, 100 ml) pressurized at 100 mbar are vented using a membrane with a specific air flow of 17 l/(min*cm²*bar) and 5 mm flow active area. The times $t_{50\%}$ and $t_{1\%}$ are measured ($t_{50\%}$ and $t_{1\%}$ = time until the residual pressure is 50% and 1% of the starting pressure is reached). The results are shown in Table 1. The related venting curves are displayed in Fig. 4.
Table 1: Volume depended duration for venting (t_{50\%} and t_{1\%}) [4]

<table>
<thead>
<tr>
<th>Volume</th>
<th>t_{50%}</th>
<th>t_{1%}</th>
</tr>
</thead>
<tbody>
<tr>
<td>10 ml</td>
<td>0,1 s</td>
<td>0,7 s</td>
</tr>
<tr>
<td>50 ml</td>
<td>0,6 s</td>
<td>4,1 s</td>
</tr>
<tr>
<td>100 ml</td>
<td>1,3 s</td>
<td>8,3 s</td>
</tr>
</tbody>
</table>

During the venting through the membrane the pressure decreases exponentially.

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![Venting curves for different volumes](image.png)

**Fig 4.** Venting curves for different volumes (10 ml, 50 ml, 100 ml) by using a membrane (5 mm diameter of the flow active area) with a specific air flow of 17 l/\text{min*cm}^2*\text{bar} at starting at a pressure of 100 mbar [5].

5. Production integrated routine test

In the production process an in-line leak testing is often integrated. In addition to checking the tightness of the housing, also defects of the membrane itself and membrane defects caused by the assembly process have to be detected reliably.

5.1 Membrane test

Due to the handling of the pressure compensation element and its mounting it must be checked whether the membrane is intact. Sometimes the pressure compensation element is integrated into the cover which is later mounted to the housing. Mostly the pressure compensation element is inserted into the completely assembled module.

For the membrane test an internal volume of the leak test device (so-called reservoir volume) is pressurized to a defined pressure. When flooding the pressurized air from the reservoir volume through the pressure compensation element into the test part, the pressure decrease is delayed due to the limited flow through the membrane. The temporal pressure decrease depends on the state of the membrane (intact, not completely welded or glued, damaged, missing membrane). If the pressure is measured shortly after the start of flooding process, the membrane state can be qualified. A pressure-time diagram for this test is displayed in Fig. 5.

The batch-dependent variation of the membrane flow is critical. This should be considered by the interpretation of measurement results.
5.2 Leak test

If the test of the membrane shows that the membrane is intact, the leak test follows. Hereby the test part must be filled through the pressure compensation element which has been mounted over the vent opening. The fill time needed to reach the test pressure in the test part depends on the permeability of the membrane, the flow active area, the test pressure and the volume to be filled. The filling time is significantly longer than for a test part of the same volume which can be filled directly.

The overall leak test consists of the consecutive phases: filling, stabilizing, testing and dumping (see Fig. 6 and 7). In the filling phase the test part has to be filled to reach the test pressure. The stabilizing phase is necessary so that air disturbances (caused by the filling process and generated by the switching of the internal valves of the test device) can subside. In case of a positive relative test pressure, the air is compressed adiabatically during the filling process which heats up the air. So, the temperature of the compressed air has to adjust to the temperature of the test part. In the testing phase, the rate of pressure loss is measured and compared with the permitted tolerances. The testing phase must be long enough to generate a significant measurement value. In the testing phase a very sensitive differential pressure sensor is activated to measure the pressure decay with high resolution. A stable measurement phase is characterized by the effect that the leakage-induced pressure loss is proportional to time. Finally, the dumping phase follows.
The two tests (membrane test and tightness test) can be realized with a leak tester with appropriate equipment.

6. Practical Comments

- Consideration of the instructions for the installation of the PCE
- A modification of the mounting conditions should be discussed with the manufacturer of the PCE if this has an influence upon the flow of the PCE.
- Use of the prefill functionality with a higher initial pressure for faster filling up of the test part. It has to be ensured that the PCE is not irreversibly damaged. And it has to be taken care that the test part is not overfilled.
- If the opening in the cover resp. housing is punched, the dimension of the opening may change slowly through tool wear. This effects the flow through the membrane.
- PCE’s from different batches should be used by setting up the test process. The case of the PCE with minimum flow rate should also be considered.
- Realistic PCE defects - that really occur in the production process - have to be prepared to determine the test parameters.
- Consideration of the flow direction of the PCE (if necessary)
- The mounting direction of glued PCE’s should correspond to the effective direction of the pressure, so that the bond is not redeemed by the pressure load.
- Vent clips have advantages regarding the handling. And the test of the correct mounting is quite easy. If the sealing o-ring is missing, the pressure drops nearly instantly.
- The pressure can be measured and controlled in the leak test process only in front of the PCE. It has to be ensured that the test pressure is really reached inside the test part. To this purpose a sample has to be prepared with an additional tap for controlling the pressure with a manometer. This is of particular importance when checking the feasibility, for the finding of test parameters and during putting into operation.

References