12 Integrity Testing

12.1 General Overview

Integrity testing can be an effective means of checking the intactness of the membrane fibers and the modules. Two types of tests are available for PES-UF modules as standard: fully automatic pressure hold test and semi-automatic bubble test with visual inspection.

Both tests are based on the phenomenon seen in wetted ultrafiltration membranes whereby water can pass through the pores, but air is prevented from passing through until a certain pressure has been exceeded (the minimum pressure at which air begins to flow is referred to as the “bubble point”). The bubble point pressure depends on the membrane's pore size and on the surface tension at the air-liquid interface. The bubble point pressure of the pores of PES-UF membranes is much higher than the applied test pressure (approx. 1 bar) that is required to detect non-intact fibers.

As a general rule, integrity testing can be performed on both the feed and filtrate sides. If air is used to displace all the water on one of the two sides of the membrane (feed or filtrate side), the pressure on this side will then continue to increase since the air cannot pass through the wetted pores (this side is referred to in this context as the "high-pressure side"). Once the test pressure has been reached, all the valves are closed on the pressure side. This means that the air can now only escape through defective fibers or epoxy sealing or faulty valves/devices/pipes. A slight pressure drop may be observed due to the natural air diffusion process through the water-filled pores of the membranes. If the pressure differential from the high-pressure side to the low-pressure side is higher than the tolerance limit stipulated by DuPont™ this may indicate a defective fiber or epoxy sealing (or a leakage in the pressurized equipment parts).

In the bubble test, air escaping on the low-pressure side due to defects in the fibers or epoxy sealing is visually confirmed by bubbles appearing in the transparent pipes on the feed or filtrate side (depends on the specific product Series; see Figure 12.4-3). In principle, the bubble test can therefore be performed in conjunction with every pressure hold test.

NOTE	
	**ATTENTION!** Observe the following guidelines!

- In conventional rack systems with PES-UF Modules for Open Platform the test is carried out on the filtrate side, i.e. the high-pressure side in this case is the filtrate side and the transparent pipe is located on the feed side of the module. In T-Rack™ systems the test is carried out on the feed side, i.e. the high-pressure side in this case is the feed side and the transparent pipe is located on the filtrate side of the module.
- Higher test pressures than those recommended by DuPont™ are to be discussed and approved in writing by DuPont™.
- The air used for air integrity testing must comply with at least the air quality specified in 12.2.Compressed Air Specification.
  Using air with lower quality can cause irreversible fouling and is not permitted.

The vertical installation of the modules and the ergonomic configuration of the T-Rack™ system enable pressure hold testing to be carried out automatically, making it easy to detect any affected modules using the bubble test. Integrity testing is carried out on installed modules (i.e. it is not necessary to remove any of the modules from the rack/system).

12.2 Compressed Air Specification

PES-UF Modules for Open Platform and T-Rack™

Integrity-Testing & Valve-Cluster

Application	Class* [solid.water.oil]	Pressure [barg] / [psi]
Cabinet / Valve Cluster	1.4.2	6.0 / 90
Integrity test	1.4.1	1.0 / 15

Class	ISO 8573-1 (2010)*					
	solid (particle size and max. concentration [mg/m³])				water	oil
	0.1<d≤0.5µm	0.5<d≤1.0µm	1.0<d≤5.0µm	ppm	max. pressure dew point (DTP)	mg/m³ / ppm
1	≤ 20 000	≤ 400	≤ 10	0.08	- 70°C / -94°F	0.01 / 0.008
2	≤ 400 000	≤ 6 000	≤ 100	0.8	- 40°C / -40°F	0.1 / 0.8
3		≤ 90 000	≤ 1 000	4.2	- 20°C / -4°F	1 / 0.83
4			≤ 10 000	6.7	+3°C / +37°F	5 / 4.2
5			≤ 100 000	8.3	+7°C / +45°F	25 / 21

* according to ISO 8573-1: 2010

Classification of purity for the particles, water and oil

Total air flow rate** @ 1bar	=	Hold-up volume Module Rack***	+	Hold-up volume connecting pipework****	/	Time (recommended)
T-Rack™	=	feed side	+	Feed header / manifold	/	10 minutes
PES-UF Modules for Open Platform	=	filtrate side	+	Filtrate header / manifold	/	10 minutes

** For compressor sizing

*** Find hold-up volume in the DuPont™ IntegraTec™ P Series | PES In-Out product data sheet

**** To be calculated

12.3 Testing Frequency

Both integrity tests (pressure hold and bubble test) should be performed at the end of the commissioning phase, after maintenance work, and in the event of any suspicion that the membrane system may be malfunctioning (e.g. increased bacteria counts on the filtrate side). Integrity testing can also be regularly carried out on an automated basis (for example once a day, once a week or once a month) and seamlessly integrated in standard filtration operations. There are no restrictions on the frequency of integrity testing for PES-UF modules. The frequency can therefore be flexibly tailored to match the regional or operator's specific requirements and preferences.

12.4 How to Perform a Pressure Hold Test

A pressure hold test is carried out for each rack in turn, i.e. the modules of a single rack are tested in parallel. The following figure shows an example using the feed side as the high-pressure side.

1. Dewater the respective high-pressure side (feed side for T-Rack™; filtrate side for PES-UF Modules for Open Platform) and build up the pressure:

   Fill the entire high-pressure side with dry, oil-free compressed air at a pressure of 1 bar (14.5 psi). The low pressure side of the modules must be left open to drain towards atmospheric pressure. The applied air pressure forces the water through the membrane from the high-pressure side to the low-pressure side (dewatering phase). In principal air cannot pass integral membranes due to the surface tension of the water in the membrane pores (diffusion processes not considered). The duration of emptying a rack depends on total rack size and volume of connected pipework and compressor capacity. Based on experience the dewatering phase takes up to 20 minutes to complete.

2. Once the high-pressure side has been completely emptied of water and a stable pressure of 1 bar (14.5 psi) has been reached (and maintained for at least 1 minute), close the air supply to the high-pressure side.

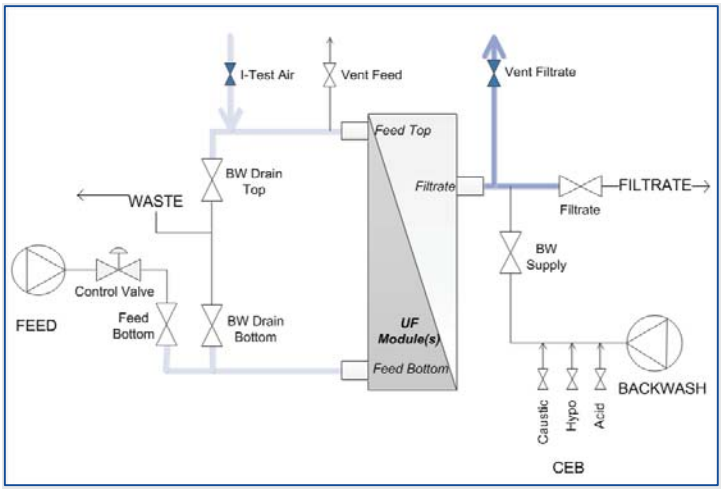

Figure 12.4-1 - Dewatering phase for integrity test from feed side

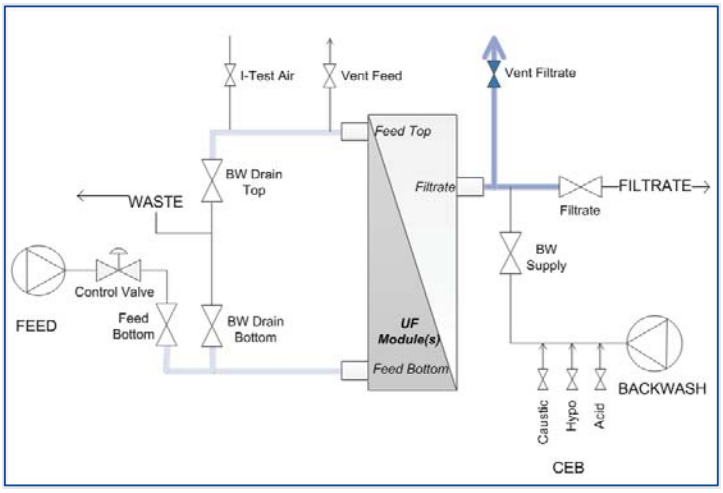

Figure 12.4-2 - Pressure hold phase and pressure measurement for integrity test from feed side

3. Measure the pressure drop:

   Measure the pressure drop on the high-pressure side for at least 3 minutes. Due to the air diffusion process through the water-filled pores of the membranes, a slight pressure drop may be observed. This should be taken as a base value and should not be regarded as a membrane leakage due to defective fibers. This diffusion effect may also result in a minor degree of bubble formation becoming visible in the transparent pipe. The base value is dictated by various factors, including the hold-up volume, the tightness of all valves and fittings and the diffusion component of the modules. In the event that the base value is exceeded, we recommend conducting a detailed examination to establish the cause.

NOTE	
	**ATTENTION!** Observe the following guidelines!

- Determination of the base value must be performed using new modules (during system commissioning) in the fully assembled rack. This base value then serves as a reference value. At a test pressure of 1 bar (14.5 psi), this value is expected to be lower than 10 mbar/min for all rack sizes.
- It is important to ensure that the low-pressure side is open, unpressurized and completely filled with water when measuring this value.

4. Bubble test:

   Any leakage in an individual module can be detected on the low-pressure side using a built-in transparent pipe (see Figure 11-3). In the event of a leak, a continuous stream of air bubbles of a steady intensity will be visible during the integrity test.

   If a significant, uniform stream of air bubbles is visible in the transparent pipe, and if the pressure drop is greater than the base value, it can be assumed that the rack/system has a capillary or epoxy defect, assuming that all other sources of error have been ruled out during the integrity test.

Figure 12.4-3 - Monitoring and ensuring error-free operation of the assembled rack with the help of an integrated transparent pipe on the feed side (in the PES-UF Modules for Open Platform - left) and on the filtrate side (in the T-Rack™ Series - right)

5. Pressure relief:

   After performing the pressure hold test, the pressure is released on the high-pressure side. For feed-side tests, this is achieved by opening a valve on the feed/rinse water side, while for filtrate-side tests the pressure is released by opening a valve on the filtrate side.

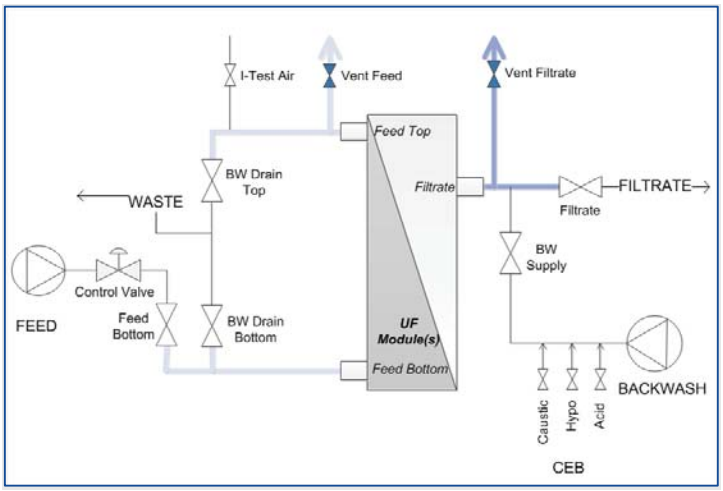

Figure 12.4-4 - Process Flow I-Test Pressure Relief

NOTE	
	**ATTENTION!** Observe the following guidelines!

- Make sure to carefully control the pressure release, among other reasons to prevent any water/air hammers and any risk to people who may be in the surrounding area.

6. Venting the system:

   After completing the integrity test, the rack/system must be vented. Confirm that no valves are closed on the filtrate side.

   Run system in forward flush bottom (FFB) mode at a volume flow rate corresponding to a flux rate of approximately 80 L/(m²h) (47 GFD) for 5 - 10 minutes.

   Regular filtration operation can then resume, starting with a filtration bottom (FB). During the first approx. 5 – 10 minutes, filtration must be performed at a reduced flux rate of approximately 40 L/(m²h) (23.5 GFD) to ensure the system is completely vented.

Figure 12.4-5 shows a clear overview of all the steps involved in a pressure hold test on the feed side.

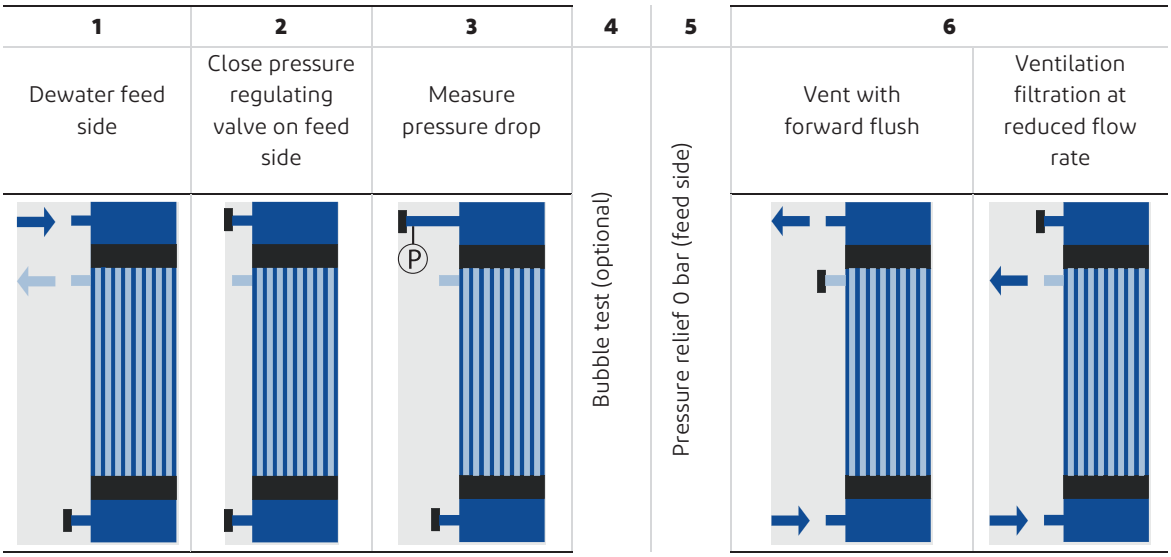

Figure 12.4-5 - Procedure for a feed-side pressure hold test