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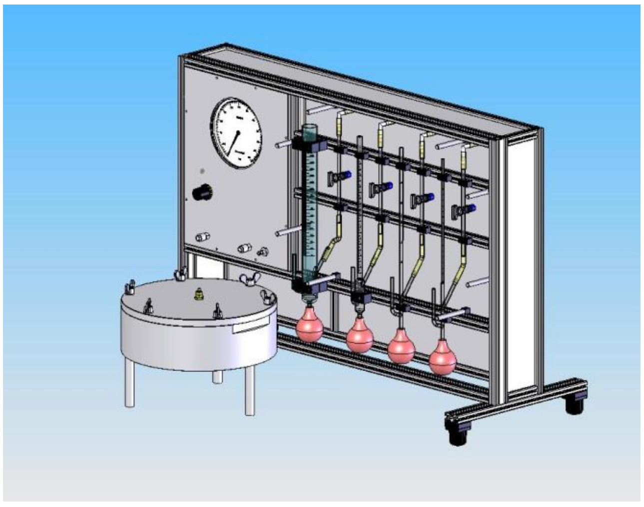
Operating Manual

Testing System for Measurement of Air Permeability
(Bubble Counter)



Importance of this Operating Manual:
Caution: The operator must read and understand this entire Operating Manual before putting the system into operation.

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1. General instructions

1.1 Purpose for which this system was designed

This testing system has been designed exclusively for determination of air permeability. It may not be used for any other purpose.

1.2 Use of this system for purposes for which it was not intended

Any use of this system, application of pressure, or filling of the system that is not in accordance with the instructions provided by the manufacturer must be considered as “use of this system for purposes for which it was not intended.” Any such use of the system can endanger the health and safety of the user or operator, and can damage or destroy the testing system.

1.3 Guarantee and liability

Our **General Terms of Sale and Trade** shall basically apply. The manufacturer guarantees that this Operating Manual has been prepared in accordance with the technical and functional parameters of the testing system as delivered.

The manufacturer reserves the right to add supplementary information to this Operating Manual.

The manufacturer grants the legally stipulated guarantee. This guarantee does not cover wear parts. The manufacturer guarantees trouble-free operation of this testing system only if the user observes all the instructions in this Operating Manual, and only if the user employs this testing system for the purposes for which it was intended.

The manufacturer shall not be liable for any damages that result from using this testing system for purposes for which it was not intended, or from any use not in accordance with the instructions and rules of operation provided in this Operating Manual.

The manufacturer shall likewise not be liable for any guarantee claims if any structural characteristics or any functional properties of this testing system have been modified without the prior and express written consent of the manufacturer.

1.4 Items delivered with the system

- 1 ea. control unit
- 1 ea. measuring cell
- 1 ea. stopwatch
- 1 ea. collar made of PU
- 1 ea. pressure hose
- 2 ea. air-distribution plates (1 top and 1 bottom)
- 1 ea. compressed-air gauge
- 3 ea. connection hoses with quick-connect fittings
- 1 ea. spray bottle

2. Basic safety instructions

2.1 Instructions that must be observed by the operator

Only the following persons may operate this testing system without supervision:

- Persons at least 18 years old
- Persons who have received sufficient instruction in the operation of the system, and who are familiar with the valid German Accident-Prevention Regulations (*UVV*)
- Persons who have been authorized by their company to operate the system.

The operator of this system must take sufficient care to ensure that he/she does not endanger himself/herself or any other persons in the operation of this equipment.

2.2 Safety instructions

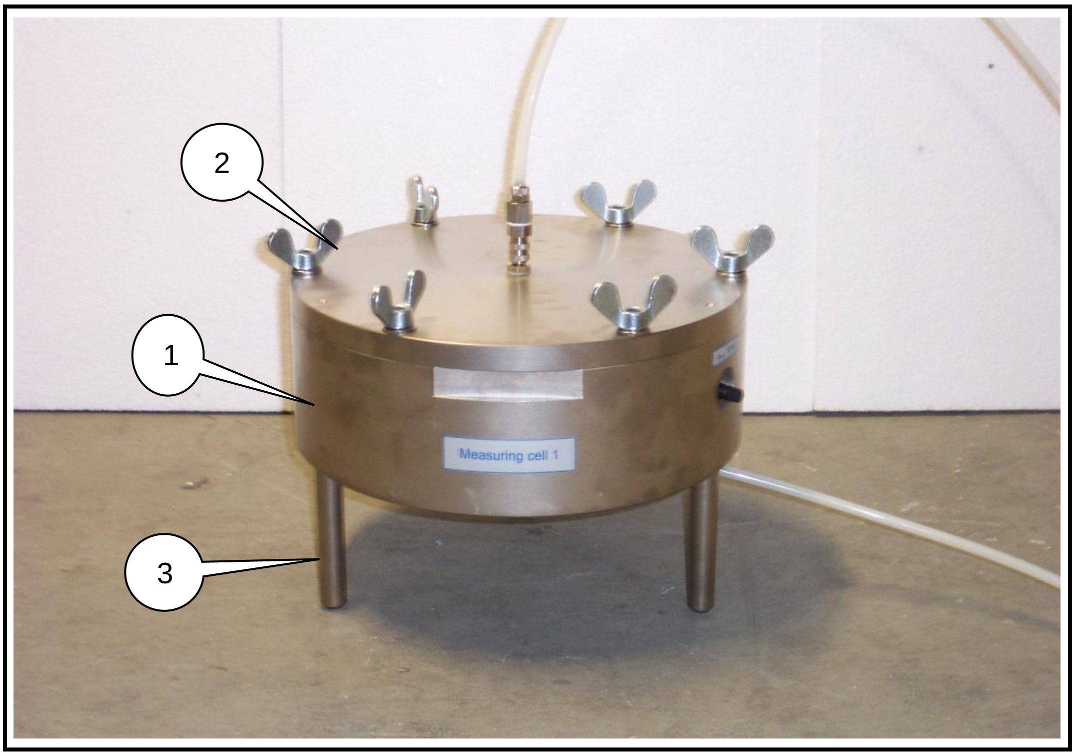
The application of pressure to the test specimen, and the resulting increased air pressure in the hoses and at their fittings, mean that a relative potential for danger exists.

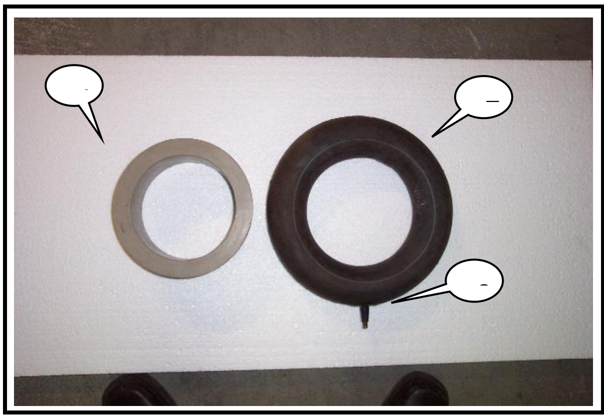
For safe and accident-free operation of this testing system, the operator must always perform a visual inspection of all the individual components of the system before he/she puts it into operation. If the operator discovers damaged or leaking components, he/she must immediately shut down the testing equipment. After-sales service must be informed of the circumstances before the equipment can be placed back into operation.

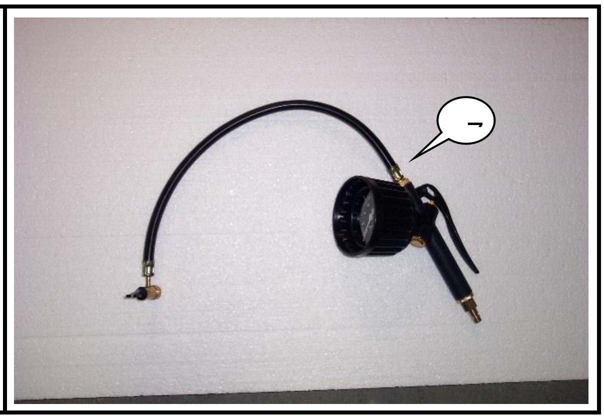
3. Description and connections

3.1 Description of the measuring cell

The basic enclosure of the cell [1], its cover [2], and the supporting legs [3] are made of aluminium. These aluminium components have been plated by a chemical-nickel process to ensure better resistance against mechanical damage and environmental influences. These bolts, which are not made of stainless steel, must be treated at regular intervals with silicone grease or spray.



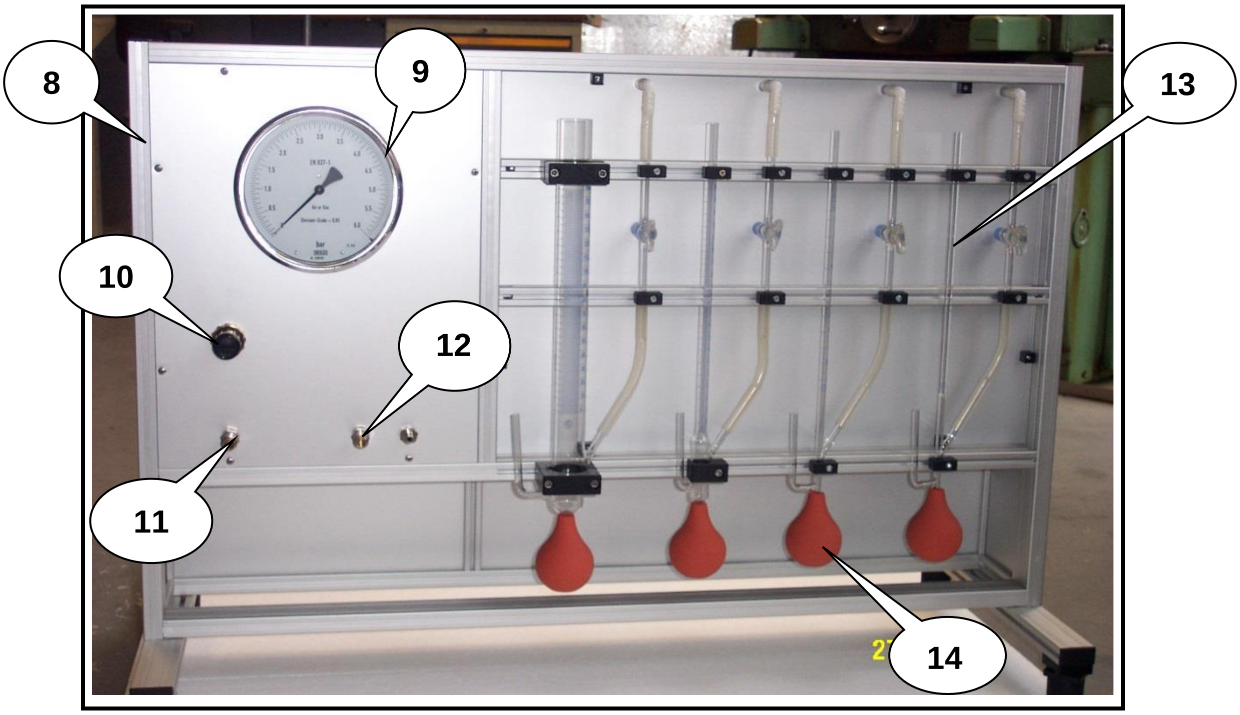




The above picture shows the polyurethane collar [4] for sealing the surface of the test specimen. The compressed-air ring [5] is filled through the hose valve [6], with the aid of the compressed-air gauge [7].

3.2 Description of the control unit

The primary component of the control unit consists of an aluminium frame [8]. A precision gas-pressure gauge [9] enables precision measurement of the air pressure. The operator uses the pressure regulator [10] to set the required test pressure. The maximum pressure that can be set is 6 bar. The control unit is supplied with air or some other gas through the quick-connect fitting [11] . The measuring cell is connected to the testing system (measurement system) by quick-connect fittings [12]. The rise of the bubbles can be observed at the capillary measuring tubes [13]. The bubbles required for measurement are produced by rubber bulbs [14].



3.3 Connection of the measuring cell

1. Place the control unit and the measuring cell on a dry and level surface.
2. Use a spirit level to make sure that the control unit is straight and level.
3. Connect the nylon hoses (part of the equipment supplied) by using the quick-connect fittings to connect the following pairs of points:

	Connection from:		Connection to:
●	Pressure generator (German: *Druckerzeuger*)	⇒	Test-pressure input (German: *Prüfdruck Eingang)*
●	Output to the measuring cell (German: *Ausgang zu den Messzellen*)	⇒	Measuring cell, lower connection (German: *Messzelle, unterer Anschluss*)
●	Measuring cell, upper connection (German: *Messzelle, oberer Anschluss*)	⇒	Input to the capillary measuring tubes (German: *Eingang zu den Messkapillaren*)

3.4 Test specimens

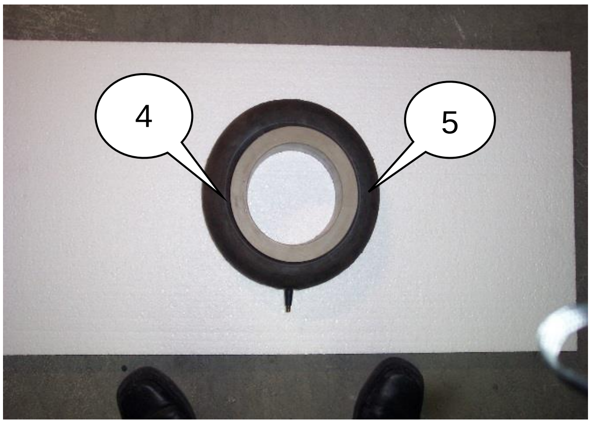
Cylindrical test specimens have proven to be most effective form, since they are especially easy to seal. They can be produced especially for these test purposes, or they can be taken as core specimens by drilling them out of existing structures. We recommend cylindrical specimens with a diameter of 100 or 150 mm, and a height of 50 mm. The use of specimens with these diameters means that there will be only a small spread (dispersion) of measured values as a result of the unavoidable inhomogeneity of the concrete.

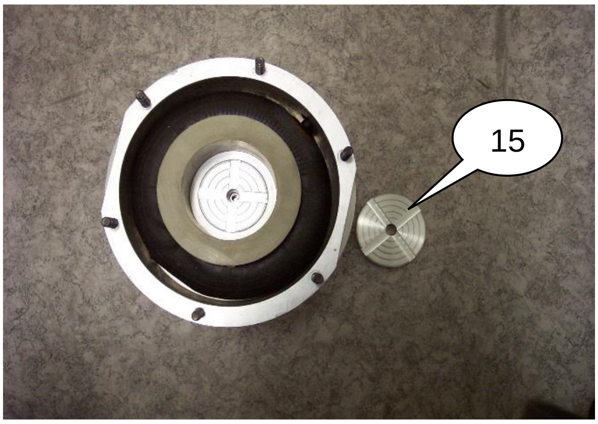
Comparable and reproducible results can be achieved on various test specimens only if they have been stored under identical ambient conditions. This is because the gas permeability of the open pores will rise greatly as the water content of a test specimen decreases. To achieve these necessary identical storage conditions, we recommend that the specimens be stored for approx. six (6) weeks in a climate-controlled room, under standard conditions: 20°C and 65% relative humidity. For test specimens that are only slightly permeable, it can be expected that the permeability will increase after the specimens are dried for longer periods in a climate-controlled room. In order to assure identical conditions over the entire surface to be tested, the cylindrical surface area of the specimens must be enclosed by a tightly fitting collar made of polyurethane [4]. Two (2) identical test specimens should be tested for each type of concrete.

3.5 Insertion of the test specimen

1. Place the polyurethane collar [4] inside the compressed-air ring [5].
2. Partially fill the compressed-air ring [5] with compressed air.
3. Push the compressed-air ring [5], together with the polyurethane collar [4], into the round side hole of the measuring cell. The valve of the compressed-air ring must point to the front.
4. Place the polyurethane collar [4], together with the compressed-air ring [5], into the lower clearance space, inside the measuring cell. The polyurethane collar must now be flush (level with) the upper surface of the measuring cell.
5. Now the test specimen can be placed into the polyurethane collar.
6. As final step, the slotted air-distribution disk [15] must be placed onto the test specimen. Place this disk onto the specimen in such a way that the milled contour faces toward the inside, onto the test specimen, and the smooth top side is flush (level) with the polyurethane collar and the upper edge of the measuring cell.

Important	The test specimen may not be taller than 50.0 mm. Otherwise, the cover [2] cannot be smoothly closed.





3.6 Filling the compressed-air ring with air

1. Make sure that the polyurethane sleeve [4], the compressed-air ring [5], the test specimen, and the slotted air-distribution disk [15] are all properly in place as described above.
2. Place the cover [2] on top of the other items. Tighten down the cover with the wing nuts. Make sure that these wing nuts are all screwed down with the same tightness. **Do not forget the washers.**
3. Connect the compressed-air gauge [7] to a supply of compressed air.
4. Connect the compressed-air gauge [7] to the valve [6] by using the clamp connector.
5. Now fill the compressed-air ring [5] with compressed air. Be sure that the pressure in the compressed-air ring [5] is always approx. 2 bar greater than the test pressure. Also make sure, however, that the pressure in the compressed-air ring [5] is never greater than 12 bar.

4. Applying the test pressure to the test specimen

Important: Make sure that you have completed all actions described in steps 3.1 to 3.6 above.

4.1 Providing the compressed gas

1. Provide the compressed gas from a compressor or from an oxygen bottle.
2. Now apply the pressure to the test specimen by turning the pressure regulator [10] in a clockwise direction.

4.2 Setting the testing pressure

1. We recommend a test pressure of 1.5 … 3.5 bar as most effective for many concrete test specimens.
2. Read off the momentary pressure at the gas-pressure gauge [9].
3. Use the pressure regulator [10] to increase or decrease the gas pressure. If you reduce the pressure, the extra gas will be released through the pressure regulator.

5. The testing procedure

5.1 Description of the testing procedure

Apply the testing gas (oxygen or compressed air) to the installed test specimen. The gas is applied from one side, from the bottom. The gas should be at a pressure of 1.5 to 3.5 bar (absolute pressure). On the secondary side, atmospheric pressure of approx. 1 bar (absolute pressure) will prevail.

Always select at least three pressure levels, with a difference of approx. 0.5 bar between these levels. For permeable test specimens, these pressures could be, for example: 1.5, 2.0, and 2.5 bar (absolute pressure). For test specimens that are not so permeable, we recommend pressure levels of 2.5, 3.0, and 3.5 bar (absolute pressure). The volume of gas flowing through is determined per unit of time. It has proved effective to use a bubble counter with a combination of capillary measurement tubes with various measurement volumes: 1.5, 5, 20, and 160 cm^3.

For each of the measurements, choose the particular capillary measurement tube that allows the measurement volume to be reached in approx. 20 … 60 s. This time is long enough so that only minor errors will result when you measure the time with a stopwatch. For each pressure level, wait until uniform gas flow becomes established. This adjustment period will be approx. 5 … 30 minutes, depending on the permeability of the test specimen. You can consider that this period is finished when the flow rate does not appreciably change between two measurements taken at intervals of 3 minutes. This period can be considered to be finished when the flow time (measured by a stopwatch) necessary to allow the chosen constant measuring volume to pass through does not vary by more than 0.5 s for these two measurements.

With experienced laboratory staff, it will suffice to measure once, with 3 pressure levels and with increasing pressure. We recommend, additionally, to verify these results by also measuring with decreasing pressure levels. Each flow time is measured 3 times for each pressure level. To calculate the flow rate Q, use the average flow time per pressure level.

The flow rate is calculated by dividing the measured volume by the flow period. The unit is m^3/s.

5.2 General

The rubber bulbs and the lower part of the capillary measurement tubes must be filled with an especially prepared soap wash liquor (soapy water). This solution should consist of one-third detergent, two-thirds water, and small amounts of glycerine. Fill the system with the soapy water up high enough so that the lateral opening of the test-gas feed line for the capillary measurement tubes is almost filled up to the top edge with the soapy water (see Fig. 1 below). Do not fill the soapy water higher than the upper edge shown below; otherwise, there will not be a continuous flow of gas for the rise of the bubbles produced.

Use the same soapy solution to fill (from the top) the measuring chamber of the capillary measuring tube. This will ensure that the bubbles will rise with a minimum of friction. For this purpose, use the spray bottle that is delivered with the equipment.

Make sure that testing gas is available for the tests. Then assure that all hose connections have been made.

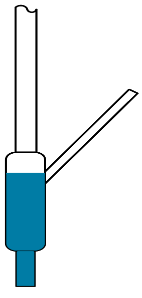


Fig. 1

5.3 Testing sequence

1. Place the test specimen in the measuring cell, and place the cover over the cell.
2. Blow up the compressed-air ring [5] to 12 bar. This is necessary to seal off the test specimen to the side, and to press the lips of the polyurethane collar against the cover and the base plate.
3. Before beginning the measurement, at least one of the glass valves of the capillary measuring tubes must be opened. This is required to prevent excess pressure in the system.
4. It is recommended to begin the test with the 20 cm³ capillary tube, and to open the glass valve belonging to this tube. All other glass valves must be closed at this time.
5. Use the pressure regulator [10] to set the test pressure, as described in Section 5.1 Check the pressure by the precision gas-pressure gauge [9]. Also see Section 5.1 for instructions on how to select the best capillary measuring tube for the test.
6. To produce a soap bubble, carefully squeeze the rubber bulb of the capillary measuring tube until the rising soapy water has slightly climbed above the opening of the lateral test-gas feed line. Do not release the rubber bulb. The volume of test gas now flowing will produce one or more bubbles. Now carefully release the rubber bulb: but make sure that the bubbles that have been produced continue to rise. The bubbles must rise continuously at a uniform rate (without stopping and starting again, and without jerking), in order to ensure conclusive test results.
7. Use a stopwatch to measure the time that a selected bubble needs to pass through the respective maximum volume of the capillary measuring tube.

The selected capillary measuring tube (i.e., the volume) is correct when the measured time for a soap bubble to flow through the entire volume is $\geq$ 30 s. If the measured time is shorter than 30 s, then you must select a larger capillary measuring tube (i.e., greater volume). If the measured time is longer, you must use a smaller capillary measuring tube (i.e., smaller volume).
When changing to another capillaring measuring tube, first open the valve of the newly selected capillary tube, and then close the used until now.
In order to confirm that the flow through the test specimen is consistently uniform, measure the coefficient of permeability for at least three different pressures.

6. Shutting down the test system

1. Reduce the test pressure by turning the pressure regulator [10] in the anti-clockwise (counter clockwise) direction, until the pressure gauge [9] has reached the final value of “0”.
2. Use the valve to let all the air out of the compressed-air ring [5]. Use the compressed-air gauge [7] here. Remove the compressed-air gauge [7] and use a pointed object to press on the stem of the valve to let the rest of the air out of the compressed-air ring [5].
3. Remove the six wing nuts and the washers from the cover.
4. Take off the cover, and remove the slotted air-distribution disk [15].
5. Now take out the test specimen.
6. The measuring cell is now ready for a new test.

7. Analysis of test results

Use the following equation to calculate the coefficient of permeability for uniform (laminar) flow:

$$K = \eta \frac{2 * Q * p_0 * h}{A * (p^2 - p_a^2)} \quad (m^2)$$

Where:

K = the specific coefficient of permeability, (in m^2)

A = the cross-sectional area of the test specimen (in m^2)

Q = the flow rate of the test gas (in m^3 / s)

H = the height of the test specimen in the direction of flow (in m)

η = the dynamic viscosity of the test gas Oxygen at 20°C:
η = $2.02 * 10^{-5}$ (in N s / m^2) Air at 20°C:
η = 1.82 * 10-5 (in N s / m2)

p = inlet pressure (absolute) (in N / m^2)

p_a = outlet pressure (for this test, this corresponds to atmospheric pressure (in N / m^2)

p_0 = pressure at which the flow rate is measured (here, this equals atmospheric pressure, p_a) (in N / m^2)

The coefficient of permeability K must be separately calculated for each pressure level. Because of the increasing deviation of flow conditions from conditions of perfect uniform (laminar) flow, increasing pressure will cause the coefficient of permeability to slightly fall. These deviations, however, are small in comparison to the differences that are observed, for example, for concrete types with various compositions or different curing conditions. It has proved effective to give the average value calculated from at least 3 K values (which are measured for the various pressure levels).

8. Cleaning and service

The entire testing system requires practically no maintenance.
Occasionally apply oil or grease to protect the 6 vertical bolts on the body of the system from rusting.
Keep the system clean from dust and other soiling.

9. References

- Deutscher Ausschuss für Stahlbeton: “Prüfung von Beton Empfehlungen und Hinweise als Ergänzung zu DIN 1048”published by Beuth Verlag GmbH

- Gräf, H., Grube, H.: “Verfahren zur Prüfung der Durchlässigkeit von Mörtel und Beton gegenüber Gasen und Wasser”

- Zagar, L.: “Die Grundlagen zur Ermittlung der Gasdurchlässigkeit von feuerfesten Baustoffen,” *Arch. f.d. Eisenhüttenwesen*

- J. J. Kollek : “The determination of the permeability of concrete to oxygen by the Cembureau method – a recommendation”

10. After-sales service and ordering spare parts

A great deal of care has been taken to ensure that this Operational Manual is correct. We cannot, however, guarantee that it is without mistakes or errors, or that all information contained herein will continue to remain valid in the event of technical changes.

10.1 Version of this Operating Manual

2st edition
June 2005

10.2 Copyright

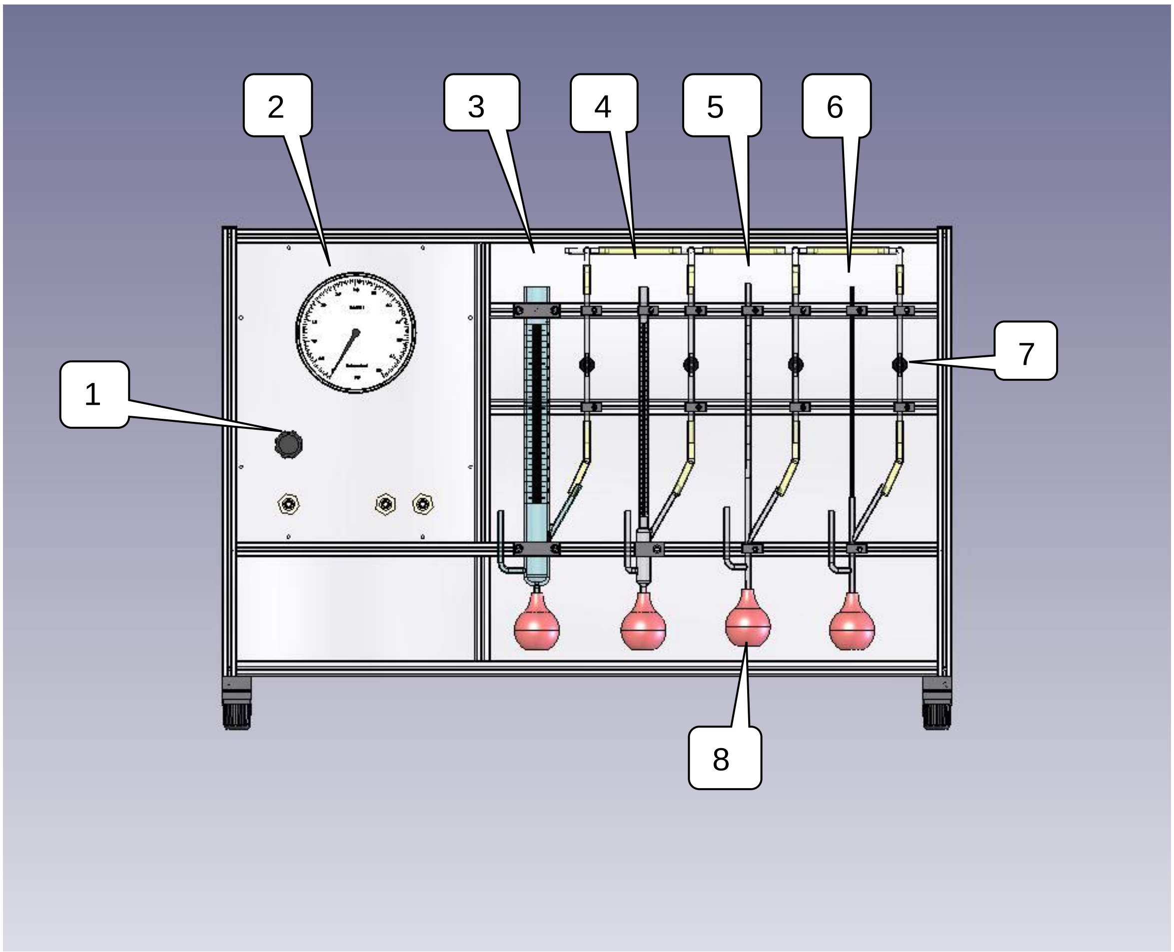
10.3 Address of the manufacturer:

If you have any questions, or if you need to order spare parts, please get in touch directly with TESTING at the following address:

TESTING Bluhm & Feuerherdt GmbH
Motzener Str. 26b
DE – 12277 Berlin
Germany
Tel. + 49 / 30 / 710 96 45-0
Fax: + 49 / 30 / 710 96 45-98
E-mail: info@testing.de

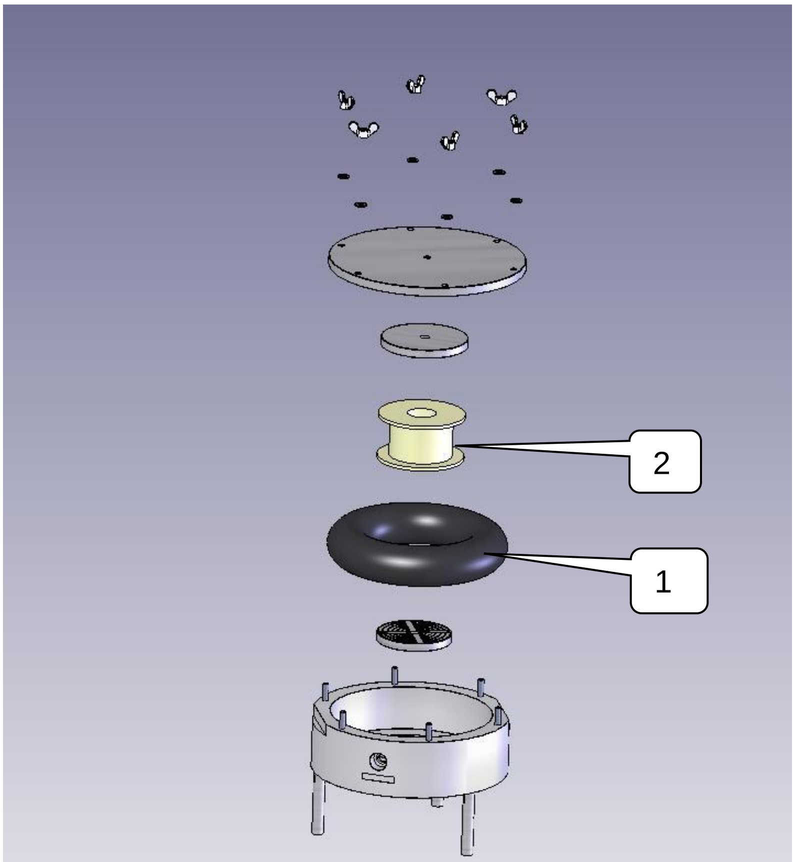
11. Spare parts list

11.1 testing system with capillary measuring tube



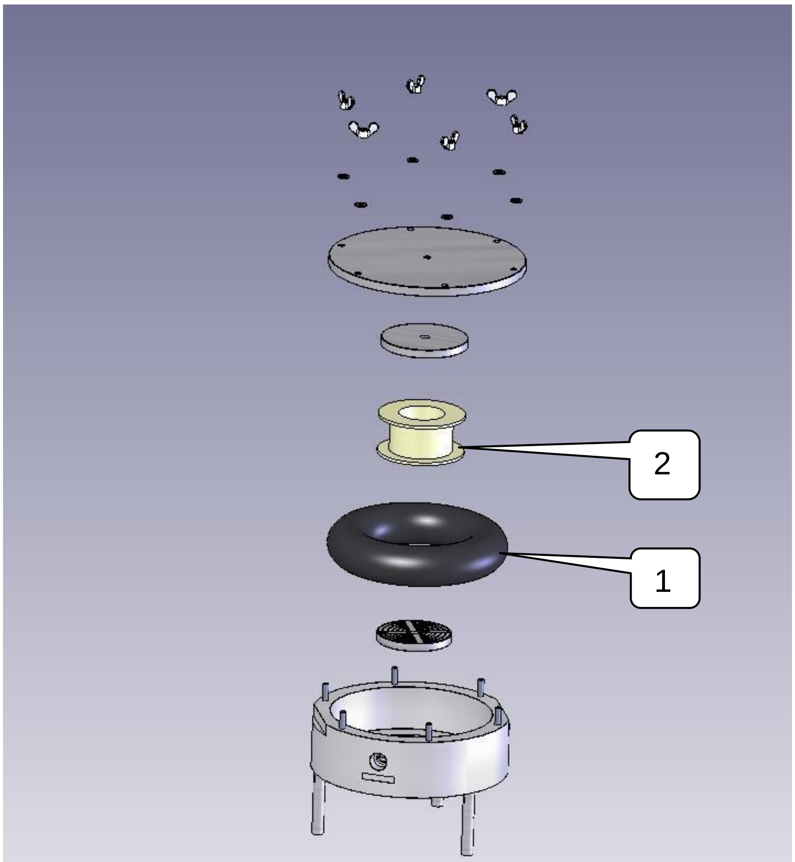
Pos..	Articel number	Designation	Dimensions	Weight
1	2.0331-42	Pressure regulator	40x40x80mm	0,150kg
2	2.0331.00.19	precision gas-pressure gauge	Ø160x50mm	1,200kg
3	2.0331-33	capillary measuring tube 1,5ml	80x420mm	0,048kg
4	2.0331-34	capillary measuring tube 5,0ml	80x420mm	0,045kg
5	2.0331-35	capillary measuring tube 20ml	76x420mm	0,050kg
6	2.0331-37	capillary measuring tube 160ml	113x420mm	0,187kg
7	2.0331-38	Einwegkugelhahn	63x210mm	0,036kg
8	2.0331-39	Rubber bulb	Ø60x76mm	0,042kg

11.2 Pressure cell ø50x50mm



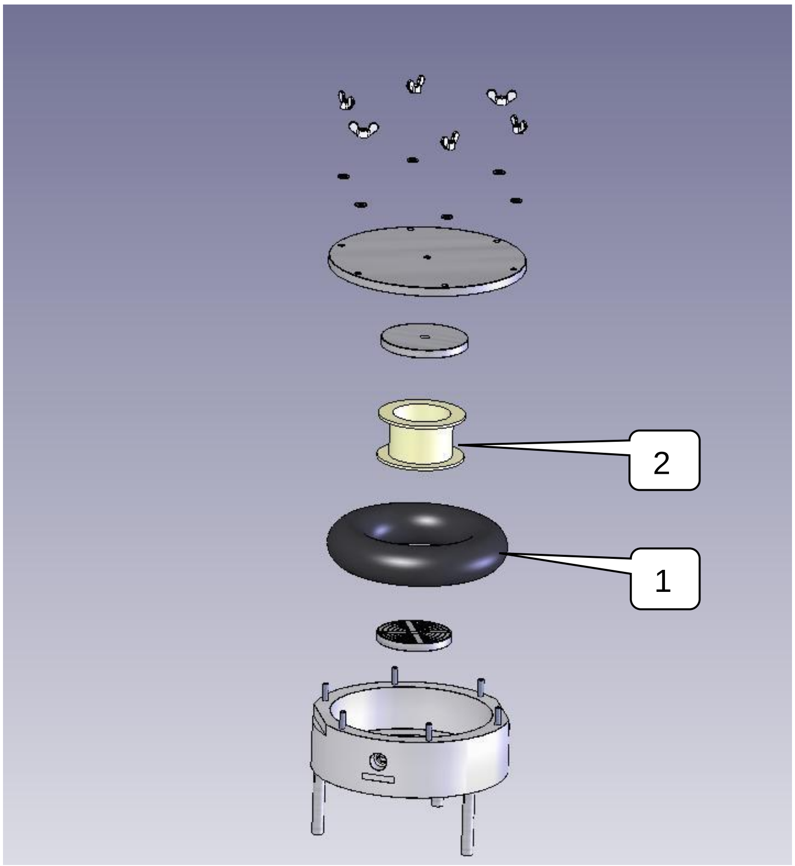
Druckzelle ø50x50mm 2.0331.01				
Pos..	Articel number	Designation	Dimensions	Weight
1	2.0331.01-07	compressed-air ring	Ø270Xø130mm	0,100kg
2	2.0331.01-06	polyurethane sleeve ø50x50mm	Ø50x81mm	0,956kg

11.3 Pressure cell ø80x50mm



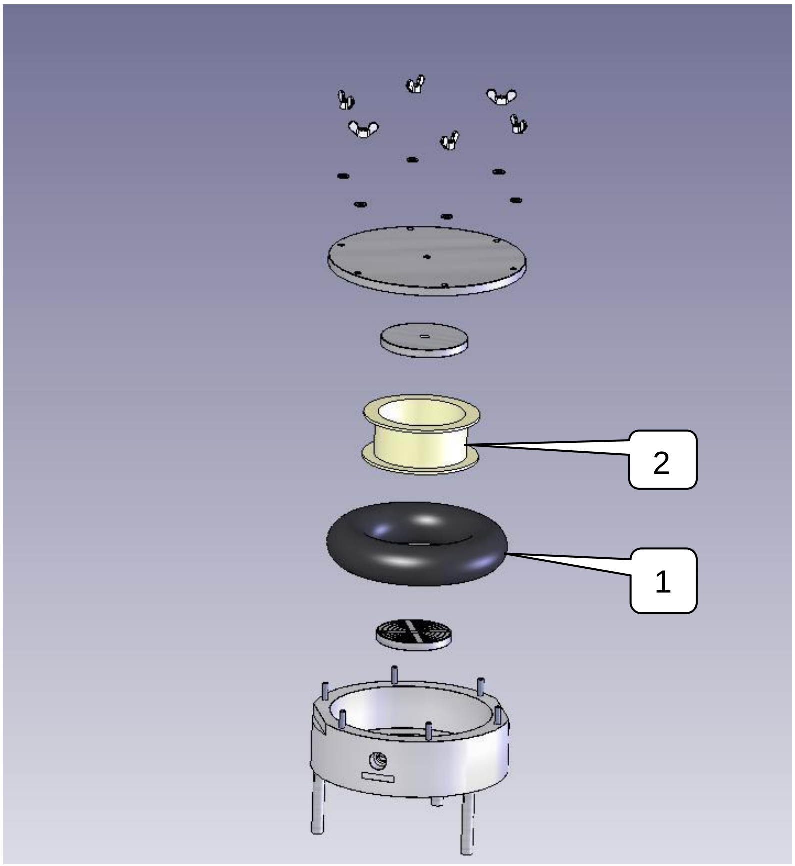
Druckzelle ø80x50mm 2.0331.02				
Pos..	Articel number	Designation	Dimensions	Weight
1	2.0331.01-07	compressed-air ring	Ø270Xø130mm	0,100kg
2	2.0331.02-06	polyurethane sleeve ø80x50mm	Ø150x71mm	0,675kg

11.4 Pressure cell ø100x50mm

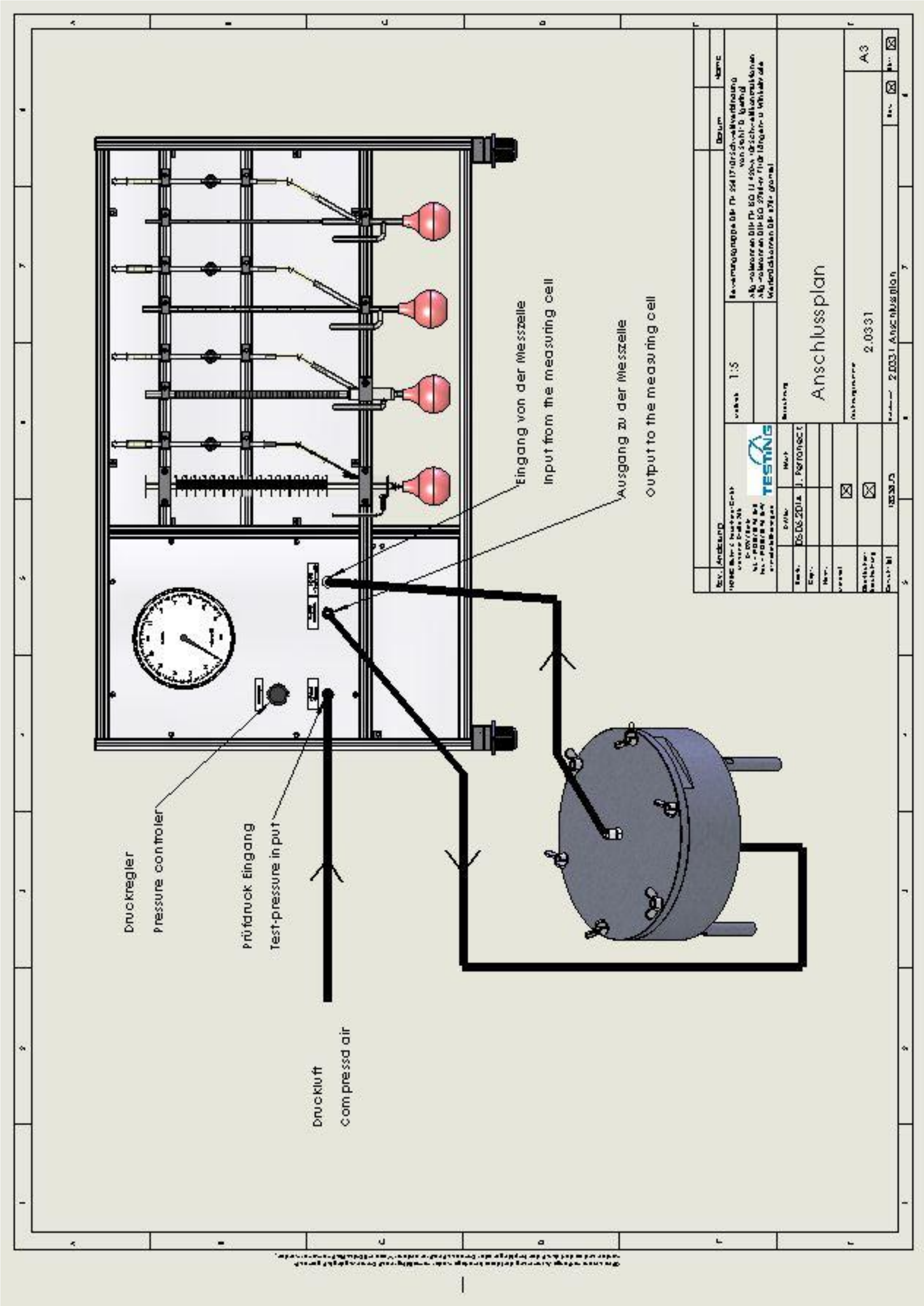


Druckzelle ø100x50mm 2.0331.03				
Pos..	Articel number	Designation	Dimensions	Weight
1	2.0331.01-07	compressed-air ring	Ø270Xø130mm	0,100kg
2	2.0331.03-2	polyurethane sleeve ø100x50mm	Ø150x81mm	0,388kg

11.5 Pressure cell ø150x50mm



Druckzelle ø150x50mm 2.0331.04				
Pos..	Articel number	Designation	Dimensions	Weight
1	2.0331.04-07	compressed-air ring	Ø310x170mm	0,200kg
2	2.0331.04-2	polyurethane sleeve ø150x50mm	Ø200x81mm	0,523kg


Eingang von der Messzelle
Input from the measuring cell
Ausgang zu der Messzelle
Output to the measuring cell
Druckregler
Pressure controler
Prüfdruck Eingang
Test-pressure input
Druckluft
Compressd air
Anschlussplan
2.0331
2.0331 Anschlussplan
A3
1:5
TESTING