Operating Manual

Air Pycnometer

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Content

1. Introduction

The warranty for this product is based on the provisions of sections 7 to 9 of our General Terms and Conditions, which you find in the appendix.

If a defect is found in our product, please notify us immediately by fax or e-mail.

2. General Information

2.1. What is an Air Pycnometer used for?

The air pycnometer is an innovative measuring device for the determination of the air filled pore volume, the solids volume, and the particle density of a substrate sample in the laboratory.

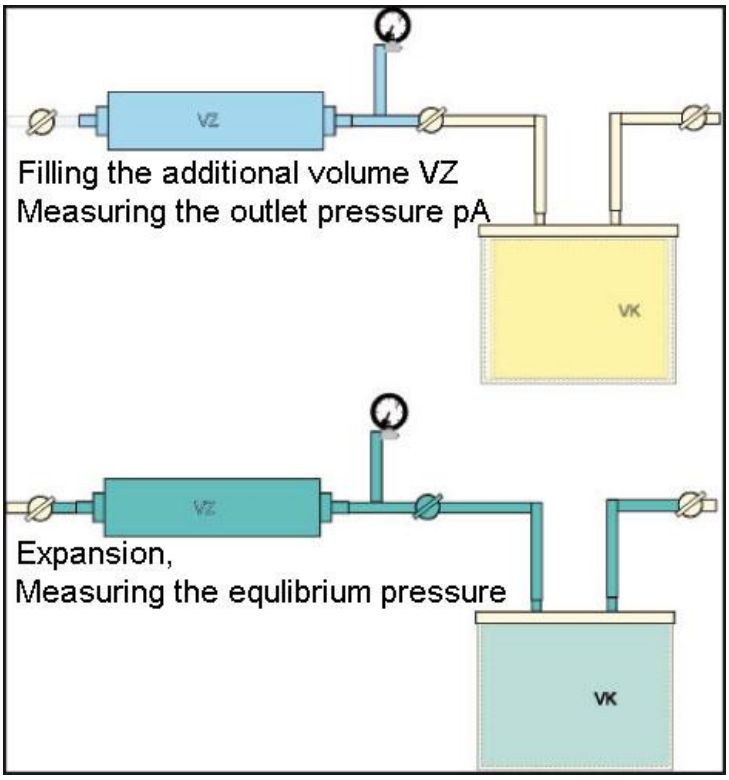
The pore volume is a relevant parameter for soil specification. It provides important information for many questions of water balance studies, cultivation of land or land reclamation. Air- and water conductivity as well as water- and nutrient retention are directly connected to the pore volume.

The air pycnometer is suitable for undisturbed soil samples as well as for bulk solids like sand, gravel or plant pellets. It provides faster and easier measurements compared to glass pycnometers. A high content of fine particles may reduce the applicability of the gas pycnometer.

Due to the big measurement chamber with a volume of 2120 cm^3 it is possible to investigate samples of large volume.

2.2. How Does an Air Pycnometer Work?

The measurement method is based on the fact that only the solids volume displaces gas while pore or cavity volumes are filled with gas. The air pycnometer consists of two connected chambers, a measurement chamber and an additional volume chamber. The additional volume chamber is filled with compressed air and connected via a shut-off valve to the measurement chamber that contains the sample. Opening the shut-off valve leads to pressure equalization between both chambers.



Schematic illustration of the measuring principle

Based on the ideal gas law the solids volume of the sample can be determined from the measured change in pressure. For isothermal conditions the ideal gas law reduces to the ***BOYLE-MARIOTTE*** law.

From the isothermal base equation

$$p \cdot V = const \qquad \textbf{(1)}$$

follows:

$$p_A \cdot V_Z = p_E \cdot (V_K - V_F + V_Z) \qquad \textbf{(2)}$$

With V_F for all incompressible substances in the measurement chamber:

$$V_F = V_{SS} - V_{SW} + V_W \qquad \textbf{(3)}$$

V_Z … Additional volume

V_K … Volume of the measurement chamber

V_{ss} … Volume of the granular structure of the sample (soil solid)

V_{sw} … Volume of the pore water (soil water)

V_W … Volume of the wall of the sample cylinder(wall)

The volumes V_K and V_Z are determined by calibration.

By transposing equation **(2)** one derives:

$$V_F = V_K - \frac{(p_A - p_E)}{p_E} \cdot V_Z \qquad \textbf{(4)}$$

For a dry sample without test cylinder V_F equates the volume of the granular structure (V_{ss})

The evaluation of the air filled pore volume V_L follows from:

$$V_L = V_S - V_F \qquad \textbf{(5)}$$

V_L … volume of air filled pores = Volume of soil air

V_s … Volume of the whole sample

Inserting **(3)** into **(4)** and rearranging to the relevant components on the left side of the equation results in:

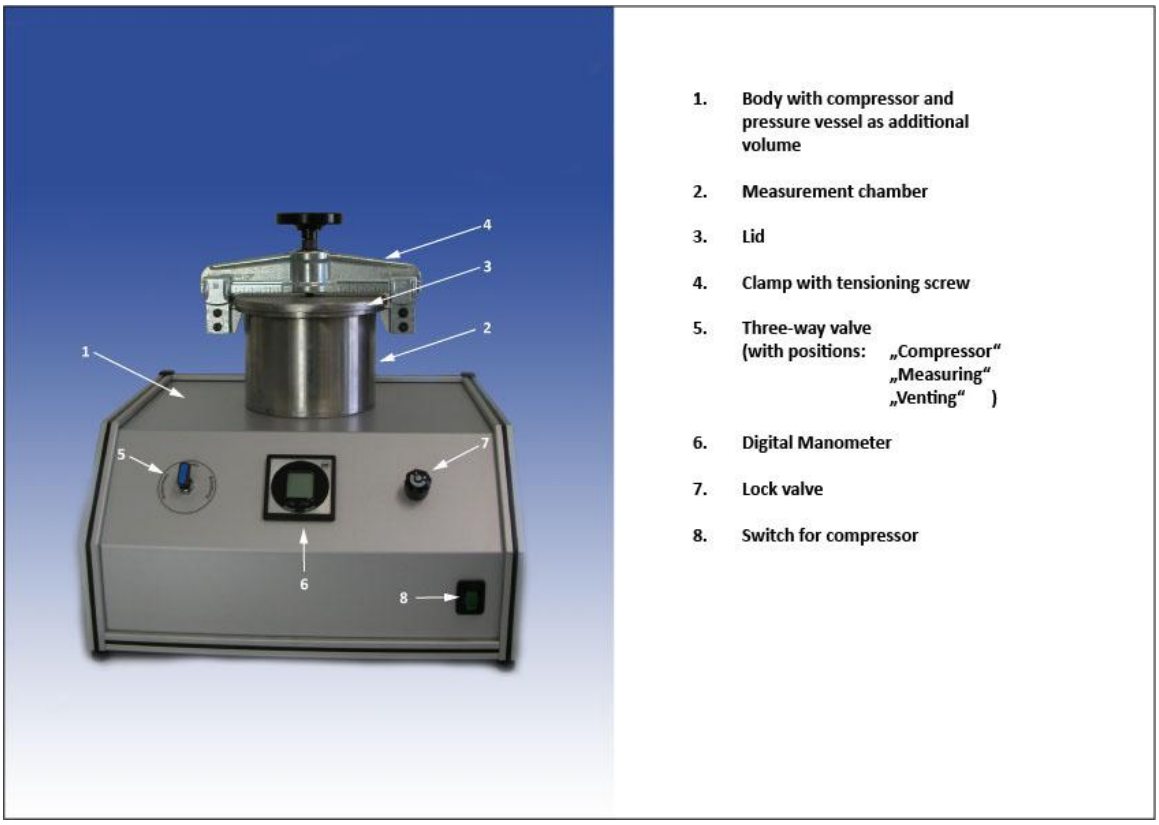
$$V_{SS} + V_{SW} = \left(V_K - \frac{(p_A - p_E)}{p_E} \cdot V_Z\right) - V_W \qquad \textbf{(6)}$$

After inserting **(6)** in **(5)** one gets the air filled pore volume:

$$V_L = V_S - \left(V_K - \frac{(p_A - p_E)}{p_E} \cdot V_Z - V_W\right) \qquad \textbf{(7)}$$

3. Set Up and Technical Parameters

3.1. Set Up



1. Body with compressor and pressure vessel as additional volume
2. Measurement chamber
3. Lid
4. Clamp with tensioning screw
5. Three-way valve (with positions: „Compressor“ „Measuring“ „Venting“)
6. Digital Manometer
7. Lock valve
8. Switch for compressor

By default ambient air is used as measuring gas (air pycnometer). Different measuring gases can be used optional via a separate inlet pipe (gas pycnometer).

The measurement chamber is fixed to the device body and gets shut with a lid that gets pressed on by a clamp with a tensioning screw. Therefore, a sample cylinder or soil sample ring is not necessary to run measurements.

3.2. Technical Parameters

Measurement Chamber:

Height	12 cm
Ø	15 cm
Volume	≈ 2120 cm^3

Pressure vessel (additional volume):

Volume	≈ 1000 cm^3

Digital Manometer:

Manufacturer	Keller
Model	Leo 1
Pressure Range	-1 bis 3 bar
Resolution	1 mbar
Overpressure	10 bar
Accuracy RT (room temperature)	< 0,1 %FS
Total Error Band (0…50°C)	< 0,2 %FS
Storage- / Operating Temperature	-20…70 °C / 0…50 °C
Compensated Temperature Range	0…50 °C
Supply	3 V Battery, CR 2430
Battery Life	•1000 hours continuously in Mano-mode •150 hours continuously in Peak-mode
Pressure Connection	G1/4”
Protection CEI529	IP65

4. Measurement Procedure

4.1. Calibration

The calibration is carried out according to DIN 66137-2:2004-12. The calibration of the volumes of the pressure vessel and the measurement chamber are carried out stepwise using calibration blocks (glass cylinder) of known volume (V_{kal}). Either a single calibration block or a combination of two or three blocks can be used for the calibration.

Note
The scope of supply includes three blocks of known volume. The blocks can also be used to artificially reduce the volume of the measurement chamber when working with small soil samples. This procedure provides more stable results due to a smaller influence of measurement errors.

The pressure in the measurement chamber and in the additional volume chamber has to be equalized to the atmosphere by opening both valves (that means position “venting” at the three-way valve). If a different measuring gas is used (optional) the measurement chamber and the pressure vessel have to be flushed and filled with the measuring gas.

These initial conditions have to be realized before each step of the calibration, i.e. after opening the measurement chamber.

In the first step of the calibration the measuring pressure $p_{A,1}$ is set up in the pressure vessel. The expansion takes place in the empty measurement chamber (equilibrium pressure $p_{E,1}$). The second step is carried out analogous to step one with the calibration block located in the measurement chamber. Again the initial pressure $p_{A,2}$ before the expansion and the equilibrium pressure $p_{E,2}$ after the expansion have to be measured. Following equations apply for the volume of the measurement chamber V_K and the additional volume V_Z:

$$V_K = \frac{\left(p_{E,2} \cdot \left(p_{A,1} - p_{E,1}\right)\right)}{\left(p_{A,1} \cdot p_{E,2} - p_{A,2} \cdot p_{E,1}\right)} \cdot V_{kal} \qquad \textbf{(8)}$$

$$V_z = \frac{\left(p_{E,1}\right)}{\left(p_{A,1} - p_{E,1}\right)} \cdot V_k \qquad \textbf{(9)}$$

Changes in the measuring gas, its pureness or in the measuring pressure compared to the previous calibration necessitate a new calibration. It is recommended to make a calibration before each measuring campaign.

For an exact calibration measurements should be taken redundant and analyzed statistically (see Excel-file „Evaluation Air Pycnometer”).

4.2. Measuring Process

Debris at the sealing ring may confine its functionality. To keep the air pycnometer work correctly always use the plastic ring to cover the sealing ring while the measurement chamber is open.

At the beginning of a measuring sequence the three-way valve [5] has to be in the “venting”-position, the lock valve [7] is completely opened and the lid is removed from the measurement chamber, that the complete system is under current atmospheric pressure. Pushing the “Enter”-button switches on the digital manometer [6], the pressure has to be logged as current air-pressure.

The sample container/sample (V_F) is put in the measurement chamber (V_K), which is hermetically sealed by putting on the lid and hand-tight screwing of the tensioning screw. Thereby the displayed pressure should not change. Otherwise it is to check, that the three-way valve is in the “venting”-position.

The inserted samples have to be dry. External drying to constant mass is advisable. Using a specific measuring gas, the sample has to be flushed with that measuring gas. The dried sample has to be weighed; thereby it does not matter if the weighing is done before or after the measurement. Closing the lid attention should be paid to its absolute cleanliness (it has to dry completely after cleaning it with water) and that the sealing ring is in its designated slot. The pike of the tensioning screw should rest in the cavity in the middle of the lid.

The following procedure is shown schematically in the following figure:

1.Initial State:

The lock valve [7] is closed and the three-way valve [5] is switched to the “compressor”-position. Both volumes are under atmospheric pressure.

2. Filling the additional volume:

By switching on the compressor the integrated pressure vessel (additional volume V_Z) is filled with compressed air. As control variable a pressure of 3 bar is specified. Reaching this pressure the compressor switches off automatically. After reaching this pressure the three-way valve [5] has to be switched to the “Measuring”-position **immediately** to separate the compressor from the system and hence to avoid a loss of pressure through the compressor. When the pressure in the additional volume is leveled out to a constant value (ca. 2 min.) the pressure has to be logged as initial pressure p_A. The value can be taken over to the second line of the display as maximum value by pressing the “Select”-button and then the “Enter”-button.

3. Pressure Compensation:

Now the lock valve [7] has to be opened **slowly**. The measuring gas (compressed air) flows from the additional volume into the measurement chamber. A fast expansion would lead to a cooling of the gas and breach the test condition of an isothermal change of state (p*V=const.). The reading of the equilibrium pressure p_E is done after reaching the equilibrium, thus by constancy of pressure.

Important for step 2 and 3: The criterion for constancy of pressure (maximum pressure variation per time step) has to be defined before the analysis.

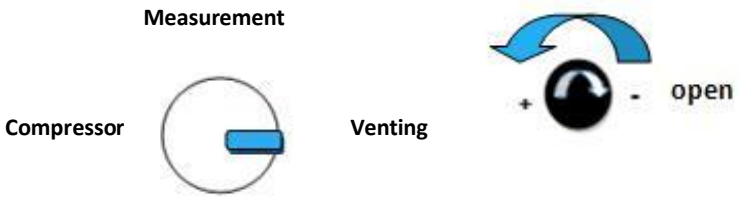
4. Venting:

Before opening the measurement chamber after logging the equilibrium pressure it has to be vented. For venting the three-way valve [5] has to be switched to the “Venting”-position while the lock valve [7] is still open. The measurement chamber and the additional volume chamber are now under atmospheric pressure.

The air in the pipe from the compressor to the three-way valve [5] has not been expanded since finishing step “2. Filling the additional volume”. The compressor is ready for further fillings. After finishing all measurements the compressor has to be vented by switching the three-way valve from “Compressor” to “Venting” several times.

Operation Sequence for the air pycnometer

1. Initial State

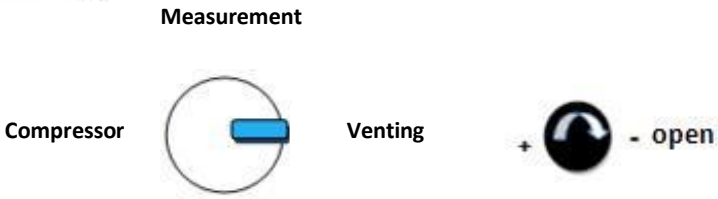


2. Filling the additional volume

3. Pressure Compensation

Immediately! After the compressor switched off

4. Venting



5. Handling of the Digital Manometer

The digital manometer “Leo1” by Keller is able to measure the pressure in different units and to show minimum and maximum values of a measuring period. It is operated with the two buttons “Select” and “Enter”

2 modes are available for the measurement:

- **Mano-Mode:**
  The pressure is measured and displayed twice per second. The upper value is the current pressure, the lower line displays the maximum (MAX) or minimum (MIN) pressure since the last “RESET”.
- **Peak-Mode:**
  The pressure is measured 5000 times and displayed twice per second. The upper value again is the current pressure, the lower line displays alternatively the maximum (MAX) or minimum (MIN) pressure.

<u>The device comes with following functions:</u>

Reset	The reset-function sets the MAX or MIN value to the current value.
Zero	The zero-function assigns the current pressure as zero value. Hence barometric pressure gradients can be compensated. The factory setting of the zero value for the ranges -1…3 bar and -1…30 bar is 0 bar absolute. To measure the reference pressure press „ZERO SET” at current atmospheric pressure.
Cont	15 minutes after the last actuation of a button the digital manometer switches off automatically. Enabling “Cont” (continuous) deactivates this automatic switch off.
Units	The device is set in bar. The pressure can be displayed in the following units: bar, mbar/hPa, kPa, MPa, PSI, kp/cm^2

Display segments of the digital manometer Leo 1 and the manometer at the air pycnometer

Move through the menu by pressing the “Select”-button several times, access the function and change it, respectively confirm it with the “Enter”-button.

6. Evaluation

6.1. Using the Excel-file “Evaluation Air Pycnometer”

For a fast and easy evaluation of the calibration and measurement an Excel-file is already available on the enclosed USB flash drive. Based on entered measurement values the file calculates the pore volume, the solids volume, the particle density, and the bulk density of the soil sample.

Use the worksheet “measurement protocol” to insert calibration and measurement data as well as further metadata of the experiment. The worksheets “evaluation calibration” and “evaluation measurement” automatically evaluate the calibration and measurement, respectively.

In the worksheet “measurement protocol” the values of $p_{A,1}$ and $p_{E,1}$ as well as $p_{A,2}$ and $p_{E,2}$ have to be inserted into the columns B and C; and E and F, respectively. The ambient air pressure has to be inserted into the second line. The relevant units have to be taken into account.

The relation between $p_{A,1}$ and $p_{E,1}$ as well as $p_{A,2}$ and $p_{E,2}$ is automatically displayed in diagrams. The diagrams allow identifying incorrect values. The relation between p_A and p_E should be linear. Values that are off from this relation should not be considered within the evaluation process and thus should be removed.

The values of p_A and p_E of the measurement with the soil sample in the measurement chamber have to be inserted into the columns H and I. An additional diagram allows identifying incorrect values. The ambient air pressure during the measurement has to be inserted into the second line. The metadata table requires the entry of further information. The volume V_K which was used during calibration has to be inserted.

In case small soil samples are investigated it is sometimes useful to reduce the volume of the measurement chamber by inserting an additional solid volume. This solid volume has to stay in the measurement chamber throughout the measurements. For evaluation of the measurement this volume has to be inserted into the metadata-table. In case no extra volume is used the value has to be set to 0. Sometimes it is useful to reduce the volume of the measurement chamber right from the beginning of the calibration (when small sample sizes are analyzed). Then the additional solid volume stays in the measurement chamber throughout the whole measurement procedure, calibration and measurement. In this case the value of the solid volume is **not to** insert into the table.

Further the dimensions of the soil sample have to be inserted. In case a sample ring is used the outer diameter and the inner diameter of the soil sample have to be inserted. In case the sample is hand filled into the measurement chamber the diameter of the hand filled sample has to be inserted instead of the outer diameter. In that case the inner diameter has to be set to 0. In both cases the height of the sample has to be inserted. At last the value of the dry mass has to be inserted.

The worksheet “evaluation calibration” calculates the volumes V_Z and V_K based on the entries in the measurement protocol and calculates the corresponding mean value. The worksheet “evaluation measurement” automatically evaluates the solids volume, the pore volume, and the particle density for each entry in the measurement protocol as well as the bulk density of the sample.

6.2. Errors and Advices for effective Measurements

- If the sample contains enclosed pores, the gas pycnometric density value is smaller than the real density. In this case it is advisable to break up the sample to a fineness where all pores are destroyed

- Gases or vapors (e.g. water vapor) discharged during the measurement can affect the equilibrium pressure. Indications are long setting-times and a steadily sinking pressure.

- To assure constant temperatures the measurements should take place in a constant-temperature room.

- If the lock valve was not closed at the beginning of step “2. Filling the Additional Volume” the measurement chamber has to be vented, before the measurement can be accomplished.

- If the pressure does not get to a constant value shortly at step “3 Pressure Compensation” the system is not airtight anymore. Check the sealing ring for damages or debris. Even a single grain of sand might lead to that problem. Hence, make sure to always cover the sealing ring if the measurement chamber is open.

General Terms and Conditions of Sale and Delivery of Umwelt-Geräte-Technik GmbH, Eberswalder Straße 58, 15374 Müncheberg ("Supplier")

1.1 With the exception of contracts with consumers within the meaning of Section 13 BGB *[Bürgerliches Gesetzbuch - German Civil Code]*, the following terms and conditions apply on an exclusive basis for all - including future - offers, orders, contracts, deliveries and other performances, except in so far as any deviations are to be made from the same or they are to be modified or excluded with the express written consent of the Supplier; in this case, express reference is to be made to the relevant clause of these terms and conditions. Any other ancillary agreements shall only be binding if they have been made in writing.
1.2 In regard to offers, orders, contracts, deliveries and other performances made in tendering procedures under the Vergabeordnung für Leistungen (VOL) *[Regulations Governing the Award of Contracts for the Provision of Supplies and Services]*, the mandatory provisions of the same shall take precedence over these terms and conditions in the case of any deviations from the latter.
1.3 Any deviating terms and conditions of the Customer which are not expressly recognised by the Supplier in writing shall not be binding on the Supplier, even where the order is placed on the basis of the same and the Supplier does not expressly contradict them once more.
1.4 Where, pursuant to these terms and conditions or any contract concluded on the basis of these terms and conditions, a declaration is to be given in writing, this declaration must be signed personally with his own signature by the authorised signatory properly empowered to represent the respective contract partner or by means of a notarially certified sign made by hand, or must be notarised, and is to be delivered to the other contract partner as an original or by fax. The written form described in sentence 1 may not be substituted by electronic form or text form.
1.5 Should either party to the contract fail to comply with one or more provisions of these terms and conditions or of any contract concluded on the basis of these terms and conditions, and should the other party to the contract fail to draw any consequences as a result thereof, no waiver of the duty of compliance with these provisions may be derived herefrom, even in the case of repetition.
1.6 Should any provisions of these terms and conditions or of any further agreements made be or become ineffective, the validity of the remainder of the contract shall not be affected thereby. However, this shall not apply where adherence to the contract in this case would represent undue hardship for either party to the contract. The parties to the contract shall replace the ineffective provision with a provision which as closely as possible achieves the same economic effect.

2. Offer and scope of delivery

2.1 Offers of the Supplier are in each case non-binding and without obligation.
2.2 Orders placed by the Customer shall only bind the Supplier after the latter has confirmed the same. Silence shall not constitute confirmation.
2.3 In regard to the scope of delivery, exclusively the order confirmation of the Supplier shall be decisive.
2.4 The details contained in printed material (for example price lists, brochures), in cost estimates, on electronic data carriers or on Internet pages of the Supplier and in the documentation accompanying its offer, such as illustrations, descriptions, drawings, details of dimensions and weights, other technical data and also DIN, VDE or other company or industry-wide norms and samples quoted or referred to are only approximations unless they are expressly specified as being binding.
2.5 The Supplier reserves the right to supply surplus or short weights and deliveries within the limits customary in the branch. They do not entitle the Customer to raise any objections.
2.6 The Supplier reserves proprietary rights and copyright in cost estimates, drawings, plans and other documentation and information of both a tangible and intangible nature, including those contained in electronic form; they may only be made accessible to third parties with the prior written consent of the Supplier.
2.7 The Customer assumes full responsibility for the details to be provided and the documentation to be delivered by it, such as drawings, models, samples, measurement protocols, expert opinions and such like.

3. Price and terms and conditions of payment

3.1 Unless agreed to the contrary, all prices are quoted in Euro. They apply for delivery ex-works without packaging, freight, postage and insurance or customs. Value added tax in the respective statutory amount is to be added to the prices.
3.2 Unless agreed to the contrary, payments are to be made without any deduction by bank transfer free of charges at the paying agent of the Supplier within 30 calendar days from the date of the invoice.
3.3 The Supplier may set off all claims to which it is entitled as against the Customer against all claims which the Customer has against the Supplier.
3.4 The Supplier may furthermore set off all claims to which it is entitled against companies affiliated with the Customer within the meaning of Section 15 Aktiengesetz of *[Stock Corporations Act]*.
3.5 Part deliveries will be invoiced immediately.
3.6 Bills of exchange and cheques are only accepted by way of provisional performance. They shall only be deemed to have been paid when they are honoured. Discount and bill charges shall be borne by the Customer and are payable by it immediately. The Supplier expressly reserves the right to reject bills of exchange. The Supplier shall not be liable for the timely presentation, protest, notification and return of a bill of exchange where it has been dishonoured.
3.7 Without prejudice to any right to assert further claims, the statutory default interest will be charged, without the necessity of any extra formal demand, where the agreed periods of payment or the period of payment specified under Clause 3.2 of these terms and conditions are exceeded.
3.8 The Customer shall only be entitled to withhold payments or to set off the same against counterclaims in so far as its counterclaims are undisputed or have been judicially decided and are final and legally binding,
3.9 If payment is delayed or any claims of the Supplier are at risk through a deterioration in the creditworthiness of the Customer, the Supplier shall be entitled immediately to call in all existing claims in favour of the Supplier arising from the business relationship - irrespective of the term of any bills of exchange - or to demand security. In these cases, the Supplier shall be entitled only to make any deliveries still outstanding against advance payment or the provision of security.

4. Delivery period

4.1 Delivery periods and dates are only binding where they have been expressly agreed in writing.
4.2 A pre-requisite for compliance with the delivery period by the Supplier is that all commercial and technical questions between the contract parties have been clarified, and the Customer has fulfilled its respective obligations, such as procurement of the necessary official certificates or approvals or the making of a down-payment. Where it has failed to do so, the delivery period shall be extended accordingly. This shall not apply where the Supplier is responsible for the delay.
4.3 The delivery period shall be deemed to have been met if the item to be delivered has left the works of the Supplier or its readiness for shipment has been notified by the expiration of the period. If the item is subject to an acceptance procedure, the date of acceptance shall - except in the case of justified refusal of acceptance - be the relevant date; alternatively, the date of notification that the item is ready for acceptance.
4.4 In case of delivery in accordance with Incoterms® 2010, EXW [ex works], Eberswalder Straße 58, 15374 Müncheberg, Germany, the delivery period shall be deemed to have been met if the Supplier has given notice of the readiness for shipment or has called upon the Customer to collect the item or to have the same collected.
4.5 The delivery period will be extended by an appropriate length of time in the case of any measures taken within the scope of industrial disputes, in particular in the case of strikes or lockouts, and also in the event of unforeseen obstacles for which the Supplier is not responsible, for instance cases of force majeure, official measures, delay in the production of parts from suppliers for which the Supplier is not responsible, operational disruptions, failure of subcontractors to perform their obligations in so far as such obstacles can be shown to have a significant effect on the production or delivery of the item to be supplied. This also applies where the foregoing circumstances arise at subcontractors. The Supplier shall also be deemed not to be responsible for circumstances of this kind where they arise during a delay already existing. The Supplier will notify the Customer as soon as possible of the commencement and end of any such circumstances.
4.6 Where unforeseeable occurrences within the meaning of Clause 4.5 considerably change the commercial importance or the contents of the delivery or have significant effects on the operations of the Supplier, the contract is to be adapted appropriately in observance of the principles of good faith. Where this is not commercially conscionable for the Supplier, the Supplier shall have the right to rescind the contract. In this case, notification is to be given to the Customer without delay after the Supplier has gained knowledge of the full implications of the occurrence, even where an extension of the delivery period has initially been agreed with the Customer.
4.7 The Customer may rescind the contract without setting a deadline if the entire performance becomes definitively impossible for the Supplier before the risk has passed. The Customer may furthermore rescind the contract if in relation to any order the performance of a part of the delivery becomes impossible and it has a legitimate interest in rejecting the part delivery. Where this is not the case, the Customer shall pay the contract price attributable to the part delivery. The same applies in the case of the inability of the Supplier to make performance. In all other respects, except in cases of strict liability, Clause 8.2 applies, subject to limitation of the claim of the Customer for damages to 10 % of the value of that part of the delivery which, on account of the impossibility, cannot be taken into operation for its intended purpose.
Should the impossibility or inability arise during any delay in acceptance, or should the Customer be solely or predominantly responsible for these circumstances, it shall remain liable to make payment.
4.8 Any subsequent changes requested by the Customer shall entitle the Supplier to suspend the delivery until the requested changes have been examined in regard to their feasibility and effects, in particular in regard to the situation concerning costs and delivery dates. The changes shall only become binding upon express confirmation by the Supplier. The Supplier may then extend the delivery period commensurately in order to implement the changes.
4.9 If the Supplier is in default of delivery, *the Customer is to be informed immediately of the reason for the delay and notified of a new delivery period*.
If the Customer sets the Supplier a reasonable period for performance following the due date - taking into account the statutory exceptions -, and this deadline is not met, the Customer shall be entitled to rescind the contract within the scope of the statutory provisions.
4.10 Upon the demand of the Supplier, the Customer shall be obliged to declare within a reasonable period whether it wishes to rescind the contract on account of the delay in delivery and/or to demand damages in lieu of performance, or whether it insists upon delivery.
Further claims arising from delay in delivery shall be governed exclusively by the terms of Clause 8.2.
4.11 If the shipment or the acceptance of the item to be delivered is delayed for reasons for which the Customer is responsible, it will be charged for the costs arising through the delay, beginning one month following notification of the readiness for shipment or acceptance.

5. Shipment and passing of risk

5.1 Risk shall pass to the Customer upon shipment of the items of delivery ex works (EXW, Incoterms® 2010, **Eberswalder Straße 58, 15374 Müncheberg**, Germany), even where part deliveries are made or the Supplier, in exceptional cases, has also undertaken to perform additional services, for instance freight-free delivery, installation or assembly. In so far as an acceptance procedure is to be carried out, this is the relevant date for the purpose of passing of risk. It must be carried out without delay on the agreed acceptance date or, alternatively, following notification by the Supplier of the readiness for acceptance. The Customer may not refuse acceptance on grounds of an immaterial defect.
5.2 The Incoterms in the version valid on the date of confirmation of the order, currently the Incoterms® 2010, shall apply for the interpretation of the delivery clauses used.
5.3 Packaging and shipment will be made in accordance with the best judgment of the Supplier but without any further-reaching obligation of the Supplier.
5.4 At the request of the Customer, the consignment will be insured by the Supplier at the expense of the Customer against the risks stipulated by the Customer - in so far as insurable.
5.5 Should the shipment or acceptance be delayed or not be performed due to circumstances not attributable to the Supplier, risk shall pass to the Customer as from the date of notification of the readiness for shipment or acceptance. Following the setting and fruitless expiration of a reasonable period, the Supplier shall be entitled to make alternative dispositions over the items of delivery and to make delivery to the Customer with an appropriately extended delivery period. Further claims of the Supplier e.g. for payment or on account of delay in acceptance remain unaffected hereby.
5.6 Discrepancies in the consignment are to be notified to the Supplier in writing without delay following receipt of the goods.
5.7 Part deliveries are admissible in so far as conscionable for the Customer.

6. Reservation of title

6.1 The Supplier reserves ownership of all goods/items of delivery supplied by it until payment has been made in full - in the case of payment by cheque or bill of exchange, until the same has been honoured - of all its claims against the Customer arising from the business relationship (reserved goods); in this connection, all deliveries are deemed to constitute a single delivery transaction. In the case of a running account, the reserved ownership serves as security for the balance outstanding.
6.2 The Customer may neither pledge nor assign the reserved goods by way of security. In the case of any attachment or seizure or other dispositions over the same by third parties, it shall notify the Supplier hereof without delay. The Customer shall only be entitled to resell or otherwise utilise the reserved goods within the scope of its normal course of business.
6.3 Any processing or re-working of the reserved goods shall be carried out on behalf of the Supplier as manufacturer within the meaning of Section 950 BGB, without any obligations thereby arising for the Supplier. The goods processed or re-worked are deemed to be reserved goods.
6.4 If the reserved goods are combined by the Customer with other objects into a single new item, the parties agree that the Customer transfers proportionate joint ownership to the Supplier within the meaning of Section 947 (1) BGB and holds the item in safe keeping on its behalf. If the other object is to be regarded as the main object, the parties agree that the Customer will transfer proportionate co-ownership to the Supplier in so far as it is the owner of the main object. The rights of the Supplier in items delivered by it which do not become an essential integral part of a new item are not affected by this provision.
6.5 Where, in accordance with the intended purpose, the Customer resells the goods delivered, it hereby assigns to the Supplier, already now, the claims against its purchasers or against third parties arising from the resale, together with all ancillary rights, up until full payment has been made of all claims of the Supplier. Even following the assignment, the Customer remains empowered to collect these claims.
6.6 On justified grounds, for instance delay in payment, cessation of payments, significant deterioration in the financial situation of the Customer, the Supplier shall be entitled to revoke the authority to collect the claims, and the Customer shall be obliged, at the demand of the Supplier, to notify the third party purchasers of the assignment and to provide the Supplier with the information and documents necessary to enable it to enforce its rights.
6.7 In the event of any conduct by the Customer in breach of contract, in the case of delay in payment, any unauthorised dispositions over the reserved goods, in the event of a significant deterioration in the financial situation of the Customer, protested bills of exchange or cheques and also where application has been made, either by the Customer itself or by third parties, for the opening of insolvency proceedings over the assets of the Customer, or the opening of any such proceedings has been refused on account of lack of assets, the Supplier shall be entitled to prohibit the processing or re-working and also the resale of the reserved goods. In these cases, the Supplier shall further be entitled to take possession of the reserved goods and for this purpose to enter the business premises of the Customer, to demand pertinent information and also to carry out any necessary inspection of its records.
6.8 The claim for return, but not the repossession or seizure, of the reserved goods constitutes rescission of the contract.
6.9 The Supplier will, at the demand of the Customer, release the security retained by it to the extent that its value exceeds the amount of the claims secured by more than 20 % in total.
6.10 Should the Customer or any third party make application for the opening of insolvency proceedings over the assets of the Customer, or should insolvency proceedings against the Customer be opened by the court, or the opening of any such proceedings be refused on account of lack of assets, the Supplier shall be entitled to rescind the contract and to demand the immediate return of the reserved goods.

7. Warranty claims

In regard to any material defects and flaws in legal title in relation to the delivery, the Supplier, to the exclusion of any further claims - subject to the provisions of Clause 8 -, gives the following warranties:
7.1 Material defects
7.1.1 All parts which prove to be defective as a result of a circumstance occurring prior to the passing of risk are, at the choice of the Supplier, to be repaired or replaced with parts free from defects at no charge (repair or replacement/substitute delivery; hereinafter collectively: rectification measures).
7.1.2 The Supplier is to be notified without delay by fax or e-mail following the discovery of any such defects. The provisions of Section 377 HGB *[Handelsgesetzbuch - German Commercial Code]* apply subject to the proviso that the Customer shall be entitled to notify any defects which are not evident within a period of 3 working days following the possibility of their discovery (e.g. upon further processing). The Customer shall bear the burden of demonstration and proof in regard to this later possibility. An initial sensory general examination is always to be performed without delay.
7.1.3 Parts which are the subject of complaint are only to be returned to the Supplier upon its request. The costs for the return of the parts which are the subject of complaint shall be borne by the Supplier unless no defect exists.
7.1.4 The Supplier may demand the surrender and transfer of ownership of any parts replaced.
7.1.5 In the case of complaints, payments by the Customer may only be withheld to an extent in reasonable proportion to the material defects which have arisen. The Customer may only withhold payments where no doubt exists as to the justification of the complaint lodged. If a complaint proves to be unjustified, the Supplier shall be entitled to demand reimbursement from the Customer of the expenses thereby incurred.
7.1.6 The Customer shall, following consultation with the Supplier, grant the latter the necessary time and opportunity to carry out all rectification measures deemed necessary by the Supplier; otherwise the Supplier shall be released from any liability for the consequences arising therefrom. Only in urgent cases where the operational safety is endangered or in order to avert disproportionately extensive damage shall the Customer have the right to remedy the defect itself or have the same remedied by third parties and to demand reimbursement of the necessary expense from the Supplier; in such cases, the Supplier is to be informed immediately.
7.1.7 Of the direct costs arising through the rectification measures, the Supplier shall, in so far as the complaint proves to be justified, bear the cost of the replacement part, including shipment costs.
Where the Customer demands reimbursement of the expenses incurred by itself or of those refunded by it to its own customer pursuant to statutory provisions, the reimbursement to be made by the Supplier shall be determined in accordance with the following provisions:
a) Reimbursement need only be made for the installation, dismantling and transport costs necessary for the purpose of the rectification measures. In determining the amount of this reimbursement, appropriate consideration is to be given in favour of the Supplier to the economic circumstances of the Supplier, the nature, scope and duration of the business relationship and also the degree of causation and any fault on the part of the Supplier as well as to the installation situation of the relevant item of delivery. In particular, the reimbursement to be made by the Supplier must be in reasonable proportion to the value of the item of delivery concerned, and also to the annual sales of these items of delivery between the Supplier and the Customer.
b) The obligation to make reimbursement is excluded where the Customer, for its part, has validly limited its liability as towards its own customer. In this connection, the Customer shall also endeavour to agree limitations on liability in favour of the Supplier in the legally admissible scope.
7.1.8 Within the scope of the statutory provisions, the Customer has a right to rescind the contract where the Supplier - taking into account the statutory exceptions - fails to meet a reasonable period set it for the performance of the rectification measures to be carried out on account of any material defect. If the defect is only of a minor nature, the Customer shall simply be entitled to a right of reduction of the contract price. The right to reduce the contract price is otherwise precluded.
Any further claims shall be governed by the provisions of Clause 8.2.
7.1.9 In particular in the following cases, no warranty is given:
Only insignificant deviations from the agreed features, only insignificant impairments of the usability, incorrect or improper use, incorrect assembly or commissioning by the Customer or third parties, natural wear and tear, incorrect or negligent handling, inadequate maintenance, unsuitable operating materials, special external influences not contemplated under the contract in so far as these do not lie within the sphere of responsibility of the Supplier.
7.1.10 Guarantee commitments by the Supplier, in particular guarantees in relation to features and durability, for example in delivery specifications, product specifications, functional specifications, performance specifications, performance schedules or other documentation are, subject to the provisions of Clause 1.1, expressly excluded even if they are designated as such.
7.1.11 Should the Customer or any third party carry out any improper repairs, the Supplier shall not be liable for the consequences resulting therefrom. The same shall apply for any changes made to the item delivered without the consent of the Supplier.
7.1.12 In regard to the function and properties of the items delivered, the results obtained on the test bench/test rig of the Supplier are decisive. The Supplier assumes no liability for any failures arising through the installation conditions or through improper operation or maintenance unless the Supplier has also contractually undertaken to carry out the installation and the failure results from this installation. In each case, the Customer bears the risk in connection with the subsoil.
7.1.13 In no case does any rectification measure, irrespective in which form, represent an acknowledgement of any claim of the Customer.
7.2 Flaws in legal title
7.2.1 Should the use of the item delivered lead to any infringement of industrial property rights or copyrights of third parties existing in the Federal Republic of Germany at the point in time of the passing of ownership, the Supplier shall, as a basic principle and at its own expense, procure the right for the Customer to continue to use the item delivered, or shall modify the item delivered in a manner acceptable to the Customer to the intent that no infringement of industrial property rights exists any longer.
Should this not be possible upon commercially feasible conditions or within a reasonable period of time, the Customer shall be entitled to rescind the contract. In the circumstances described above, the Supplier shall also have the right to rescind the contract.
The Supplier shall furthermore indemnify the Customer from any claims by the relevant holders of industrial property rights which are undisputed or which have been judicially decided and are final and legally binding.
7.2.2 Subject to the provisions of Clause 8.2, the obligations of the Supplier set out in Clause 7.2.1 are exhaustive in the case of any infringement of industrial property rights or copyrights. They only apply where:
a) the Customer notifies the Supplier without delay of any alleged infringements of industrial property rights or copyrights,
b) the Customer supports the Supplier in adequate scope in averting the claims asserted and/or enables the Supplier to carry out the modification measures in accordance with Clause 7.2.1,
c) all defence measures, including any settlements out of court, remain reserved to the Supplier,
d) the flaw in legal title is not attributable to any instructions issued by the Customer and
e) the infringement of rights was not caused by the fact that the Customer made unauthorised modifications to the item delivered or used the item in a manner not compliant with the contract or is otherwise responsible for the infringement of the industrial property right.
7.3 All warranty claims shall lapse by limitation after 12 months.
7.4 In deviation herefrom, the statutory limitation periods apply for defects in a building or for objects of delivery which, in accordance with their usual purpose, were used for a building and caused its defectiveness. Unless agreed to the contrary for parts of mechanical or electro-technical/electronic systems where maintenance has an influence on safety and functionality, the limitation period for warranty claims in regard to these system components, shall, in deviation from the limitation period stipulated in Clause 7.4, sentence 1, amount to 2 years if the Customer has chosen not to entrust the Supplier with the maintenance for the duration of the limitation period; this shall also apply where a different limitation period has been agreed for further deliveries and services. The provisions of Clause 9.2 remain unaffected.

8. Liability

8.1 If the item of delivery cannot be used by the Customer as contemplated under the contract due to the fault of the Supplier as a result of the non-implementation or incorrect implementation of recommendations or advice given prior to or following the conclusion of the contract or through the breach of any other ancillary contractual obligations - in particular instructions on the proper operation and maintenance of the item delivered - the provisions of Clauses 7 and 8.2 shall apply accordingly to the exclusion of all further claims of the Customer.
8.2 In respect of damage which has not occurred to the item of delivery itself, the Supplier, irrespective on which legal grounds, shall only be liable
8.2.1 in the case of deliberate intent,
8.2.2 in the case of gross negligence of the proprietor/the organs or senior executives of the Supplier,
8.2.3 in the case of culpable injury to life, limb or health,
8.2.4 in the case of defects which it fraudulently concealed or the absence of which it has guaranteed,
8.2.5 in the case of defects in the item of delivery, in so far as liability applies under the Produkthaftungsgesetz *[Product Liability Act]* for personal injury or material damage to privately used objects.
In the case of culpable breach of fundamental contractual obligations, the Supplier shall also be liable for the gross negligence of non-managerial staff and for ordinary negligence, in the latter case limited to the reasonably foreseeable damage typical for the type of contract.
In all other respects, all claims of the Customer for damages and for reimbursement of expenses, irrespective on which legal ground, in particular on account of breach of duties arising from the contractual relationship and in tort, are excluded.

9. Miscellaneous

9.1 To the extent that the scope of delivery includes software, the Customer is granted a non-exclusive right to use the software supplied, including its documentation. It is provided for use on the item of delivery intended for this purpose. The use of the software on more than one system is prohibited.
The Customer may only copy, revise, translate or change the software from the object code to the source code within the legally admissible scope (Sections 69a et seq. UrhG – *Urheberrechtsgesetz – Copyright Act*). The Customer undertakes not to remove the manufacturer's details - in particular copyright notices - or to change the same without the express prior consent of the Supplier.
All other rights to the software and documentation, including copies of the same, remain with the Supplier or with the software supplier. The grant of sublicenses is not permitted.
9.2 Without prejudice to the provisions of Section 479 (1) BGB, in so far as these are applicable, all claims of the Customer – irrespective on which legal grounds - shall lapse by limitation after 12 months. In deviation herefrom, the statutory limitation periods shall apply for claims for damages under Clauses 8.2.1 to 8.2.5 and also for defects in a building or for items of delivery which, in accordance with their usual purpose, were used for a building and caused its defectiveness.

10. Place of performance; Competent court; Applicable law

10.1 The place of performance for both parties is the registered office of the Supplier.
10.2 The court of competent jurisdiction shall be the court competent at the registered office of the Supplier. The Supplier shall, however, be entitled to bring proceedings at the principal office of the Customer.
10.3 All legal relationships between the Supplier and the Customer shall be governed exclusively by the relevant law of the Federal Republic of Germany applicable for the legal relationships of domestic parties as between each other, to the exclusion of the UN Convention on Contracts for the International Sale of Goods.