

Operating Manual

Full Range Tensiometer

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1. Introduction

The warranty orients itself on the statutory regulations. Specifications can be found under item 7 to 9 in our general business terms and conditions, which you can find in the appendix.

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

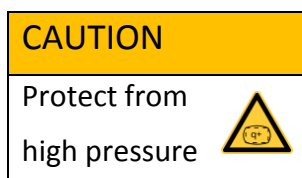
1.1. Safety Instructions

Tensiometers are measurement devices for the determination of soil water tension and should only be used for that purpose. Please note that damage due to improper handling may not be covered by warranty.

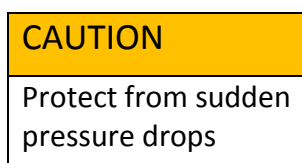
Please attend to the following safety instructions for your own protection and for maintaining the full functionality of the device:



Freezing of water within the tensiometer may result in permanent damage of the tensiometer. Make sure to store the tensiometer in a frost-free environment. At temperatures below 0° C the tensiometer should not be used for measurements.



High pressure may lead to permanent damage of the pressure transducer. Avoid installing the tensiometer with high pressure surges.



Sudden pressure drops inside the tensiometer may result in permanent damage of the pressure transducer.

CAUTION

Protect from
mechanical forces

Mechanical forces may result in damage of the ceramic and/or the pressure transducer. Prevent jolting or hard hitting as well as partial pressure on the ceramic by rocks in the soil.

CAUTION

Protect from
chemical influences

Grease, talc and solvents may influence the properties of the ceramic cup. Aggressive media may affect the whole device and leads to permanent damage. Do not touch the ceramic with bare hands. Use only pure water and no detergent for cleaning.

CAUTION

Use only clockwise
rotations

To remove or insert the tensiometer from or into the protective case turn the tensiometer only to the right.

1.2. Scope of Delivery

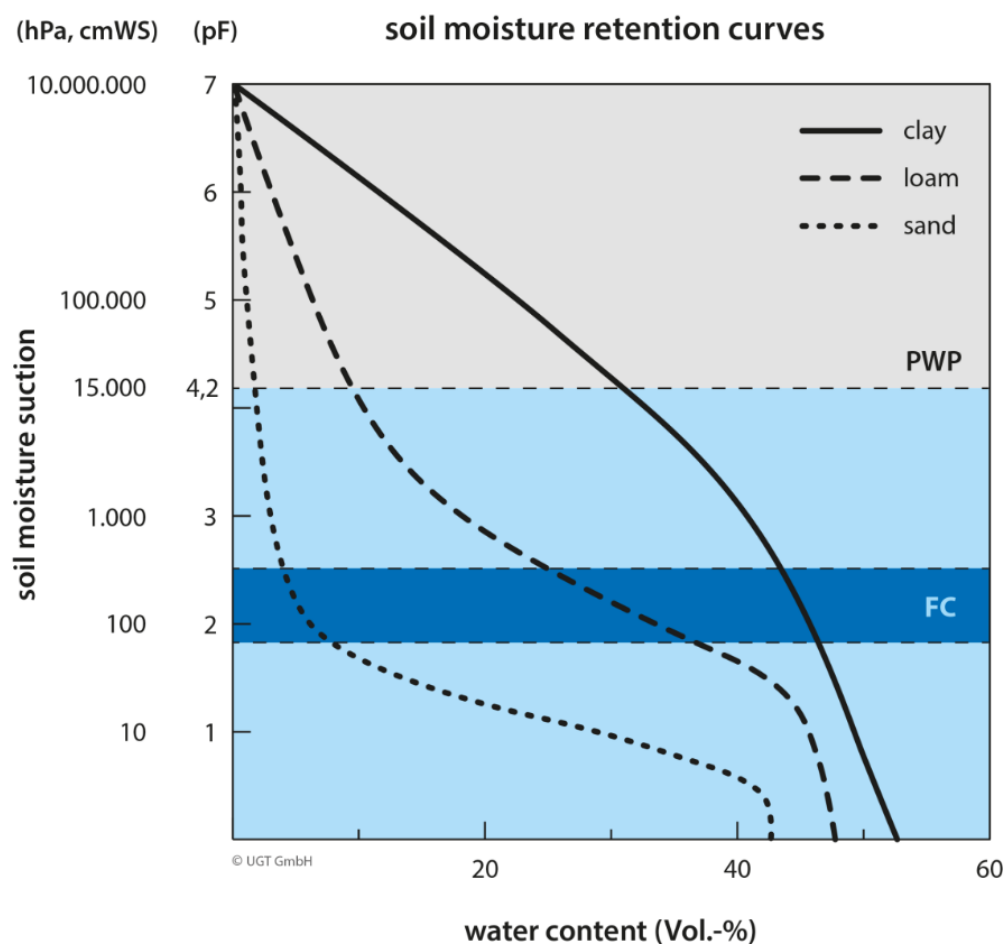
Please note that the tensiometer is delivered together with a protective case. Additional accessories such as connection cables, a data logger, an installation auger or standpipes, etc. can be found and purchased under Accessories.

2. General Information

2.1. What are Tensiometers? / What is Tension?

Tensiometers are measurement devices for determining the soil water tension. The soil water tension describes all influences exerted on the water by the soil matrix and is also called the matrix potential (or simply pressure head). The tension is defined as a negative pressure and therefore is signed positive if the applied pressure is negative. A pressure of -50 kPa in the pore water accords a tension of 50 kPa.

The tension is closely linked to the water content of a soil. The dryer a soil, the higher is the tension. At the groundwater surface, the tension is zero. The relationship between water content and soil tension is soil specific and depends highly on the soil properties.



Exemplary retention curves of different soil types

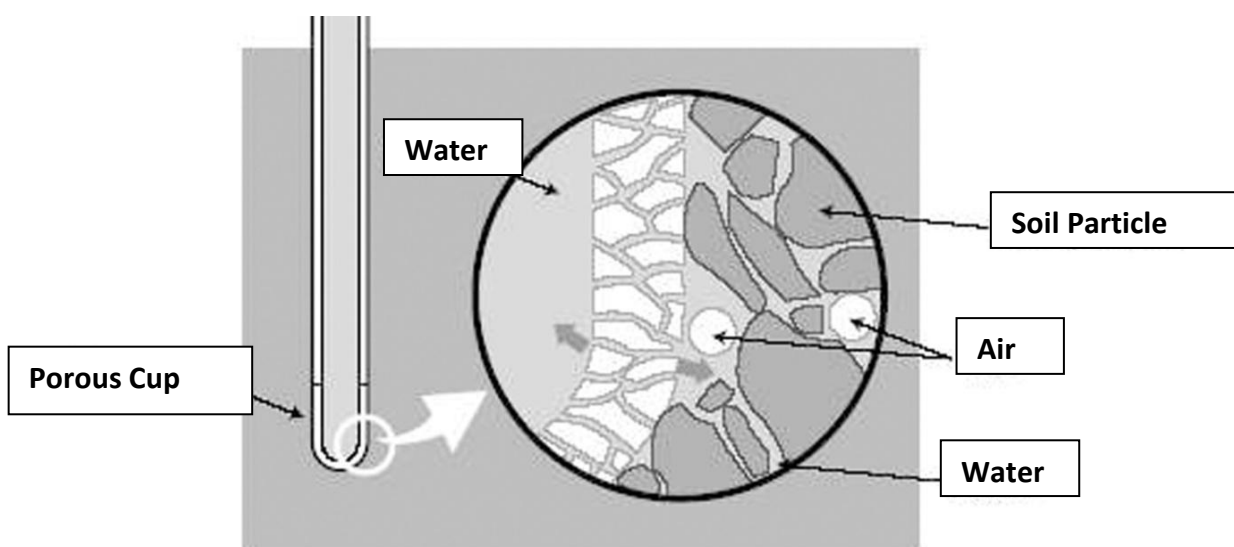
2.2. What are Tensiometers used for?

The tension corresponds to the force which a plant has to apply via the roots to extract water from the soil pores. Among other applications, tensiometers can be used for irrigation control and for evaluations of global warming impacts on ecosystems. The difference between the tensions at two points within the soil acts as the driving force for soil water transport. Determining this gradient by using tensiometers enables the evaluation of water movement in the soil regarding flow direction and velocity. Tensiometer measurements are essential for the comprehensive analysis of the water balance of a region or an ecosystem.

2.3. How Does a Tensiometer Work?

The operating principle of the Full Range Tensiometer differs slightly from water filled tensiometers. Both kinds of tensiometers consist of an air-tight sealed, liquid-filled measurement chamber, a unit where the pressure transducer is located, and a porous cup, usually made out of ceramic. The pores of the ceramic cup are filled with water and connect the liquid of the measurement chamber inside the tensiometer with the water in the soil outside the tensiometer. By connecting the two liquid bodies the pressure conditions inside the tensiometer are always adjusted to the pressure conditions of the water in the surrounding soil. If the soil dries, water will flow through the pores of the porous tensiometer cup from the measurement chamber into the soil. In case of water filled tensiometers the measurement volume is filled with water. Water that leaves the measurement volume via the pores of the ceramic creates a negative pressure inside the tensiometer. If the surrounding soil is wetted again, for example by a precipitation event or irrigation, the negative pressure decreases in the surrounding soil and water flows from the soil into the measurement volume, whereby the negative pressure in the measurement volume is reduced again.

In case of the Full Range Tensiometer the measurement volume is filled with water that is bonded to a polymer.



Schematic representation of the functional principle of a tensiometer

The measurement principle of the Full Range Tensiometer is based on a known pressure in the measurement volume that is reduced by the soil tension.

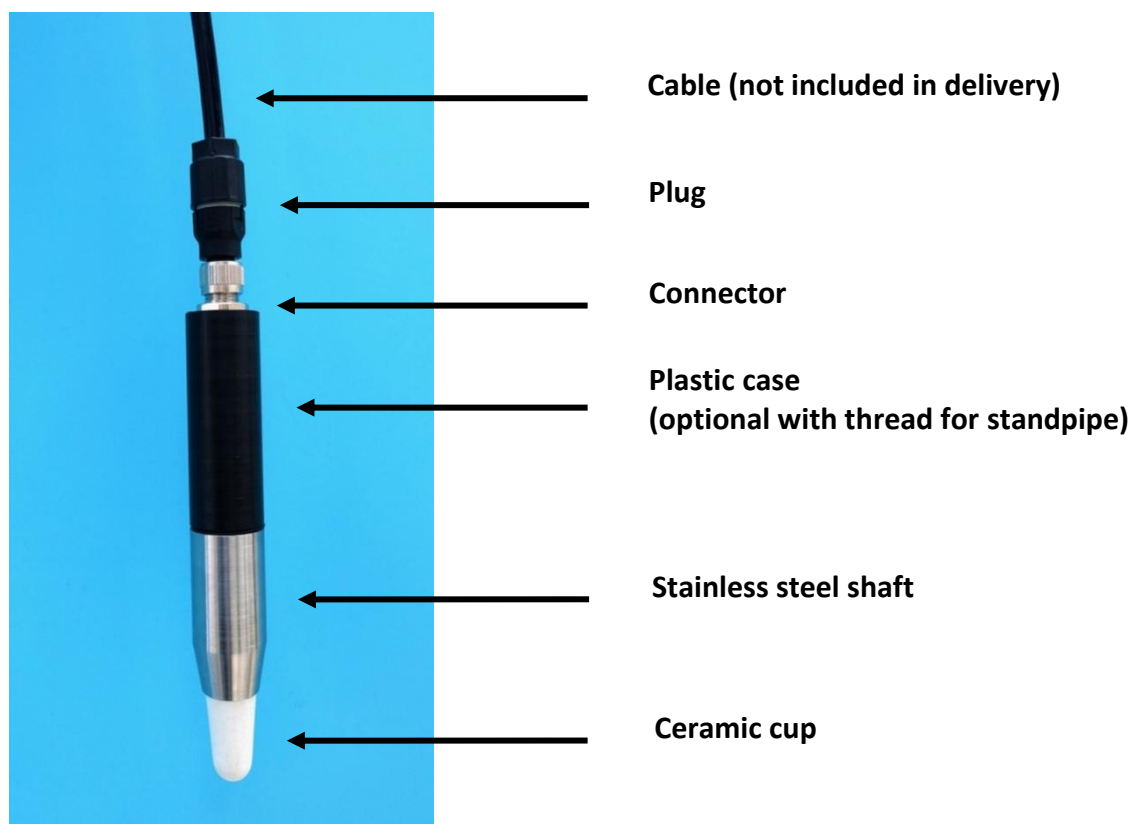
The measurement range of **conventional, water-filled tensiometers** is physically limited by the boiling point of water, which is pressure- and temperature-dependent. The boiling point inside the tensiometer and thus the upper limit of the measurement range depends on the ambient atmospheric pressure and ambient temperature. At 20 °C and 950 hPa barometric pressure the water starts boiling at approx. -926.6 hPa.

The second physical limit is defined by the air entry point of the ceramic. This point is reached when the negative pressure is high enough to suck air through the biggest pore of the ceramic. The upper limit of the measurement range of a tensiometer is defined by which point is reached first. If this tension is exceeded the tensiometer stops working.

Due to the bonding of water to the polymer the physical measurement limit of approximately 1 bar does not account for the **Full Range Tensiometer**. The Full Range Tensiometer cannot run dry like water filled tensiometers and is able to measure soil tensions up to 5 or 15 bar, respectively. For soil tensions out of the measurement range the Full Range Tensiometer simply does not function properly. When the soil tension is back in the measurement range, the Full Range Tensiometer simply starts to work properly again. No refilling of the tensiometer is needed. Additionally, the Full Range Tensiometer also measures the ambient temperature.

3. Set Up and Technical Parameters

3.1. Set Up



3.2. Technical Parameters and Available Accessories

| Technical Parameters | |
|---|--|
| Measurement range Tension | -100 ... 500 kPa -100 ... 1500 kPa (model-specific) |
| Accuracy | 1% of the measurement range |
| Operating temperature | +1... +39 °C (surrounding soil temperature) |
| Operating pH-value | pH 2 ... pH 10 |
| Power supply / Supply voltage | 20 mA / 5 ... 20 V |
| Interface output signal | RS485 / Analog output signal available on request |
| Dimensions | Ø25 mm, Length 150 mm |
| Optional equipment | |
| <ul style="list-style-type: none"> • Cable (standard length: 1.5 m, customizable) • Installation auger • Standpipe (length customizable) • Data logger / Software | |

4. How to Use the Full Range Tensiometer?

The tensiometer is delivered in a wet state and thus ready to use. If the tensiometer has dried during the delivery or subsequent storage it has to be saturated prior to the installation. Therefore, place the ceramic cup of the tensiometer in distilled water for at least 24 hours. Keep the ceramic cup wet during transportation by using the protective case until installation. If the tensiometers are not installed store them in a dry state with the ceramic cup exposed to the open air at temperatures between +1°C and +39°C to ensure lasting functionality.

Caution!

Freezing of the tensiometers may cause irreparable damage of the ceramic, the pressure transducer or the polymer. Temperatures over 40°C may change the polymer and cause faulty measurement readings.

Note:

If you expect a high ion concentration in the surroundings (e.g. soil or irrigation water) while operating the Full Range Tensiometer a calibration under the expected site conditions is highly recommended. The calibration can be carried out by following the instruction in section 5 or by our trained UGT staff.

4.1. Installation of the Full Range Tensiometer

Be careful to not touch the ceramic cup with bare fingers during installation. In general it is recommended to install the tensiometers in wet soil. Dry soil complicates the installation significantly and can lead to damage of the tensiometer. If you are unconfident about the installation, contact us for advice or support from our trained staff.

Note:

To operate the Full Range Tensiometer a connection cable is needed, which is not included in the scope of delivery. Suitable cables of different lengths can be found under Accessories.

Connect the tensiometer cable to the connector of the tensiometer and screw the cap hand tight. Check that the cable reaches from the installation site of the tensiometer to the data logger.

Caution!

Inside the cable is a capillary for pressure equalization. Buckling or squeezing the cable may cause irreversible damage to the cable. Coiling the cable too tight may cause insufficient pressure equalization which results in incorrect measurements.

The tensiometer can be installed horizontally or vertically. In both cases make sure that the whole plastic case (including plug) is buried to prevent temperature conduction via the case which may influence the measurement.

For the vertical installation use an installation auger to prepare the installation hole in the desired depth. The auger, which can be found under Accessories, are designed in a way that the surrounding soil is influenced as little as possible and the ceramic cup can be installed providing good connection with the surrounding soil. In dry conditions it is recommended to wet the soil by

filling water into the borehole until the soil in the area of the ceramic cup is well soaked. Now, press the tensiometer carefully with the ceramic cup first into the borehole.

Caution!

Rocks or obstacles in the soil may damage the ceramic cup if the force exerted on the tensiometer is too high.

For installation depths over 20 cm use a standpipe (can be found under Accessories) for secure positioning of the tensiometer and for being able to retrieve it later. Lead the tensiometer cable through the standpipe and screw the standpipe onto the thread on the upper end of the plastic case. The standpipe remains in the soil with the tensiometer.

For measurements close to the surface it is recommended to install the tensiometer horizontally and with the whole casing buried in the ground. Therefore, dig up the soil up to the designated measurement depth that the sensor can be placed horizontally in the hole. Check that there are no rocks at the designated penetration spot of the tensiometer. Place the tensiometer horizontally in the hole and push the ceramic cup into the side wall of the hole. If the soil is too hard to push the tensiometer into it, prepare an according cavity on the side wall of the hole. Make sure that the tensiometer rests stable before refilling the hole. Otherwise subsidence may cause shear forces that lead to fracture of the ceramic cup.

The installed tensiometer has to be connected to the data logger via a tensiometer cable. The cable may also be buried in the ground. It is recommended to always protect the cable against damage caused by animals. If possible, always use a cable with a suitable length for the designated measurement site. Unnecessarily long cables can limit the function of the tensiometer. To prevent the intrusion of moisture through the pressure equalization capillaries at the end of the cable, it is recommended to place a suitable desiccant at the cable connector (inside the data logger).

4.2. How to Operate the Full Range Tensiometer?

The Full Range Tensiometer starts measurements with an initial overpressure (P_{ref}) inside the measurement chamber, which is then reduced by the soil tension. The soil tension is thus calculated based on the difference between P_{ref} and the currently measured pressure inside the measurement chamber:

$$\Psi = p_{ref} - p_{current} \quad (1)$$

The overpressure in the measurement chamber is temperature dependent. In consequence P_{ref} , which was determined during the calibration process under specified temperature conditions, has to be adjusted to the current measurement temperature. The estimation of P_{ref} in equation 1 by using the measured temperature is done via the following equation:

$$p_{ref} = T \cdot C_T + P_0 \quad (2)$$

Ψ ... Tension [kPa]

p_{ref} ... Reference pressure, temperature compensated [kPa]

$p_{current}$... Measurement value: pressure [kPa]

T ... Measurement value: temperature [°C]

C_T ... Temperature coefficient [kPa/K]

P_0 ... Reference pressure at 0 °C [kPa]

The parameters C_T and P_0 are determined and preset by UGT prior to delivery. Due to aging of the polymer P_0 might be subjected to drift and should be calibrated regularly (see chapter 5). In individual cases it might be also necessary to re-calibrate the temperature coefficient C_T .

This can be done by using the provided excel-file "Full Range Tensiometer" (see explanations in chapter 5) or by trained UGT staff.

4.3. How to Use the Full Range Tensiometer with a UGT Data Logger

A RS485-Interface is required to connect the Full Range Tensiometer to the UGT Data logger or any other device with a digital interface. The following chapters describe the communication between the Full Range Tensiometer and the data logger.

4.3.1. Interface and power supply

| Mechanical Properties | | Electrical Properties |
|--|--|--|
| Full Range Tensiometers are connected via a ventilated 4-pol connector | | The power supply of the connected sensor is carried out via two pins |
| | | The supply voltage must be in the range of 5 to 20 V DC |
| | | The remaining two pins are the differential lines of the RS485 interface |
| Pin Assignment | | (For color assignments of the pins, see calibration certificate!) |
| Pin 1 | | VCC |
| Pin 2 | | RS485 (A) |
| Pin 3 | | RS485 (B) |
| Pin 4 | | GND |

Transmission Parameters:

- Parameters for the serial interface (UART) are 9600 8N1 (9600 baud, 8 data bits, no parity, 1 stop bit)
- The RS485-Interface enables the operation in half duplex mode

4.3.2. Protocol

The logger communication protocol is based on the fact that the data logger acts as the only master on the RS485-Bus and the sensors act as slaves. In consequence, requests are only committed by the master and answered by the addressed slave (Response).

The data are transmitted in the form of ASCII - coded characters. The control character 0x0D (or CR, \r) shows the end of the line.

Every physical value (pressure, temperature ...) recorded by the Full Range Tensiometer is readable via an own address.

Caution!

When distributing addresses, please make sure not to use the same address twice!

4.3.3. Data Polling

The table below shows the procedure of data polling (exemplary for channel 1). To get the specific value the master first has to send a request: OP1\r (OP 1\r or hexadecimal 4F 50 20 31 0D). The sensor confirms this with OK\r and responds to the following GN\r request with the measurement value.

| Master | Sensor |
|--------|----------|
| OP 1\r | OK\r |
| GN\r | 009000\r |

The number within the OP 1\r command stands for the channel. The channel assignment of the sensor is listed below.

4.3.3.1. Analog Version

The analog versions of the Full Range Tensiometer provide an analog output signal. The pressure and temperature readings are exported in form of a voltage, for example between 0 and 1 V (customizable). The voltage has to be transformed into a temperature and pressure signal. The equations to transform the sensor signal into a measurement value (pressure and temperature readings) can be found on the enclosed calibration certificate.

The conversion into the tension has to be done by using equations 1 and 2. This can also be done by using the provided excel file "Full Range Tensiometer" (see chapter 5). The temperature data can be requested on channel 2 and the pressure data on channel 3.

4.3.3.2. Digital Version

The digital versions of the Full Range Tensiometers provide a digital output signal for the temperature and pressure readings. The transformation of the digital signal in a measurement value is shown below.

The conversion into the measured soil tension has to be done by using equations 1 and 2, which can be also carried out by using the provided excel file (see chapter 5). The temperature data can be requested on channel 2 and the pressure data on channel 3, respectively.

Conversion of the digital output into a measurement signal:

The Full Range Tensiometer sends a six-digit number in the range of 000000 to 065536. Those are converted as follows:

Temperature:

The measurement range of the temperature sensor installed in the Full Range Tensiometer is limited to -40 °C to +60 °C. However, the digital version of the Full Range Tensiometer is able to display temperature values between - 327.68 °C and +327.67 °C with a step size of 0.01 °C. The temperature value is obtained from the digital number by the following equation:

$$T = \frac{\text{dig. output value} - 32768}{100}$$

Note, that the measurement range of the temperature sensor limits the measurement range of the Full Range Tensiometer.

Pressure:

The digital version of the Full Range Tensiometer is able to display pressure values between - 100.0kPa to +3176.8 kPa with a step size of 0.05 kPa. However, the measurement range of the pressure transducer is limited to -100 kPa and the customizable upper limit, e.g. 500 or 1500 kPa. For specifications see the included calibration certificate. The pressure value is obtained from the digital output by the following equation:

$$P_{\text{current}} = \left(\frac{(\text{dig. output value} - 16384) \cdot 31}{32768} - 1 \right) \cdot 100$$

Note, that the measurement range of the pressure sensor limits the measurement range of the Full Range Tensiometer.

4.3.4. Channel Configuration

The Full Range Tensiometer has four channels for data polling. Channel 1 and 4 are used only for UGT services/calibration. The calculation of the tension is done via the values from channel 2 (corr. temperature) and 3 (pressure), which are the channels of main interest for the user.

To set the address for a specific channel you have to use the command „SAD”. For example the command „SAD2 100\r” changes the address of the temperature to 100.

| Master | Sensor |
|------------|--------|
| OP 1\r | OK\r |
| SAD2 100\r | OK\r |

Now it is possible to get the temperature value with the command „OP100\r”. The address for a specific value can be obtained with the command „GAD”.

| Master | Sensor |
|--------|--------|
| OP 1\r | OK\r |
| GAD2\r | 100\r |

For the case that no address is known, you can switch the command „OP 1\r” in the example above with the command „OP+Serialnumber\r” (e.g. OP201500101\r).

5. Maintenance

The Full Range Tensiometer is basically maintenance free and can remain in the field even for longer periods. In case of malfunctioning, the manufacturer should be contacted in any case.

Caution!

The case of the tensiometer must not be opened under any circumstances. The single parts are not separable. An open case causes irreparable damage of the tensiometer and forfeits all guarantee claims.

Note:

Under site conditions with a high ion concentration ion exchange between the surroundings and the polymer inside the Full Range Tensiometer can lead to changes of the polymer. If you expect a high ion concentration in the surroundings (e.g. soil or irrigation water) while operating the Full Range Tensiometer a calibration under the expected site conditions is highly recommended. For soils with a high ion concentration we recommend to carry out the following calibration steps by using a saturated soil sample of the soil of interest.

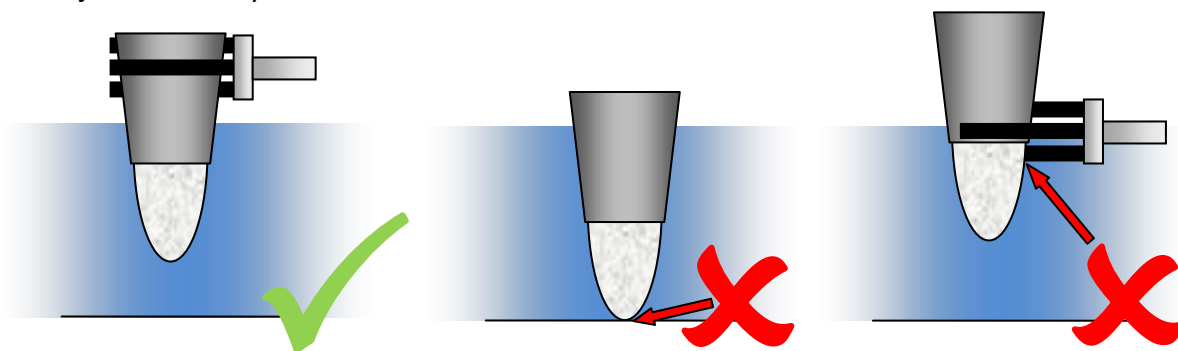
Alternatively, the calibration can also be carried out by our trained staff when providing us with a soil sample of your soil of investigation.

5.1. Calibration of the Full Range Tensiometer

The Full Range Tensiometer is factory calibrated that the measured tension equals 0 kPa at a water temperature of 20 °C when the ceramic cup is saturated and placed on the free water surface.

Aging of the polymer can lead to a slow decrease of the maximum measurable pressure value (initial pressure in the measurement volume) resulting in a shift of P_0 . This can be recognized as a drift in the data. In this case the tensiometer has an offset and no longer displays 0 kPa for a saturated ceramic on the free water surface at 20° C.

A drift in the measurement readings for long measurement periods can be corrected by determining the maximum pressure before and after the measurement campaign. To determine the maximum pressure value put the tensiometer at least for 3 hours in water with a free surface (e.g. water filled beaker) and a constant temperature of 20 °C. Note that the ceramic is not allowed to touch the bottom of the water tank and that the ceramic cup should not be touched by any holding device. Comparing both values, the offset can be determined and the data set can be adjusted linearly.



Correct (left) and incorrect (middle and right) positioning of the Full Range Tensiometer for the determination of the maximum pressure in a temperature controlled water bath

Under the assumption that C_T did not change, the estimation of P_0 is done as follows:

$$p_0 = P_{ref20^\circ C} - 20^\circ C \cdot C_T$$

$P_{ref,20^\circ C}$... measured initial pressure at 20 °C [kPa]

C_T ... temperature coefficient [kPa/K]

Use the new P_0 value for all further readings. Further, a simplified calibration with a parallel conventional tensiometer at the measurement site is possible. For this the offset between the Full Range Tensiometer and the conventional tensiometer is determined and subtracted from the reference pressure.

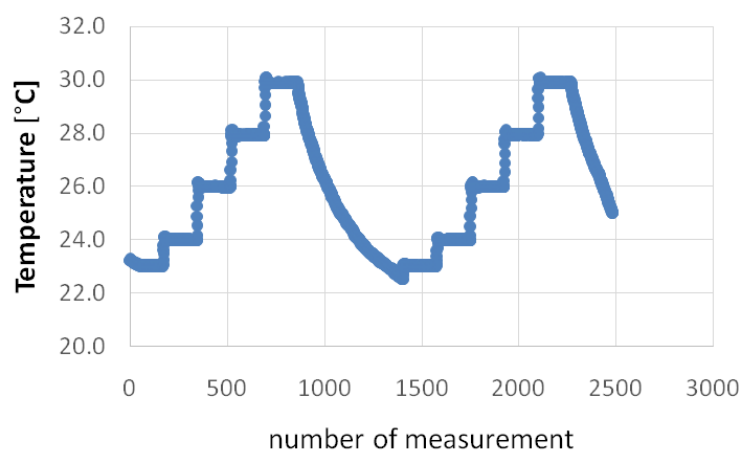
To ensure the correct function of the tensiometer a complete check-up and maintenance through UGT GmbH in a yearly interval is recommended.

5.2. How to Use the Excel-File for Calibration and Data Transformation?

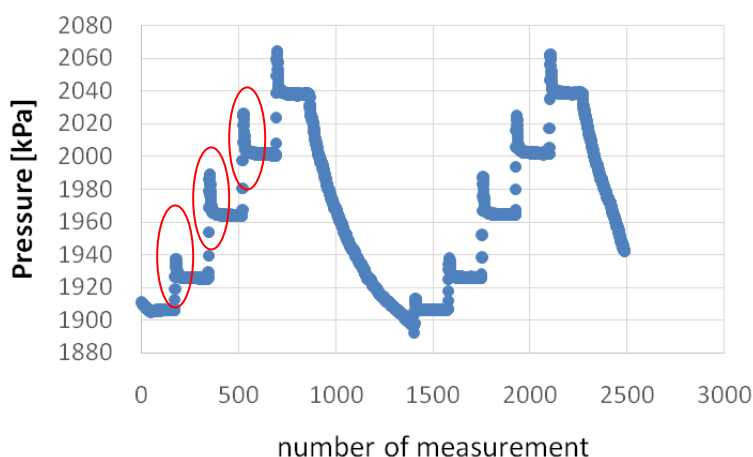
In some cases it is necessary to re-calibrate the value of P_0 and C_T . For that purpose the provided excel-file "Full Range Tensiometer" can be used.

To recalibrate all parameters in equation 2 the Full Range Tensiometer has to be put in a water bath for several hours and at different temperature stages as described above. Make sure to hold each temperature stage for at least 3 hours. Suitable temperature stages of the water bath are for example 20 °C, 21 °C,..., 28 °C. For each temperature stage average the measured temperature and pressure readings and insert the results into column B and C in the worksheet "FRT Calibration" in the "Full Range Tensiometer" excel-file. Make sure not to include pressure values that were recorded while changing the temperature stage. Due to a fast change in temperature the signal of the Full Range Tensiometer tends to overshoot. An overshoot can be recognized by peaks in the graphical display of the pressure readings.

The occurrence of overshoots during abrupt temperature changes is displayed in the two figures below. The first three overshoots in the pressure readings are indicated by red circles. These peaks should not be included within the evaluation of the calibration.



Temperature stages measured with the Full Range Tensiometer during the calibration process.



Pressure readings with the Full Range Tensiometer at different temperature stages.

Once all mean values of the pressure and temperature readings at all temperature stages are inserted into the excel-file, the pressure values are displayed over the temperature values in the given diagram. The displayed equation of the linear compensation line provides the values for P_0 and C_T . P_0 equals the intercept with the y-axis, whereas C_T equals the slope of the linear equation.

In Column M and N the measured pressure and temperature values, respectively can be inserted to calculate the tension by using the new calibrated parameters. The worksheet "FRT Data Transformation" can be used to calculate the tension from a measurement campaign by automatically using the new calibrated parameters from the calibration worksheet. The user only has to insert the pressure and temperature readings in column F and G.

5.3. PH-Value Tolerance

The Full Range Tensiometer can be used for pH values between 2 and 10. Extreme acid or alkaline conditions lead to a damage of the tensiometer. If the tensiometer was used within the range limits (pH 2 – 3 or 9 – 10), the tensiometer should be cleaned afterwards. Flush the tensiometer and especially the ceramic with distilled water. Then saturate the ceramic in distilled water. Repeat this procedure several times to thoroughly flush the ceramic and the polymer.

6. General Terms and Conditions

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 notariately 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 of the 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 or the payment of any such bills.

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 be decisive. The date 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 failure has a significant effect on the production or 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 obstacles 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 conceivable 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 should 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 by 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 conceivable 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 utilize 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 obligation 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, including the right of retention, or the opening of any such proceedings has been followed up by 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 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 be opened over the assets of the Customer 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 a defect. 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 costs of the return of the parts without 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 The costs of the rectification arising through the rectification measures, the Supplier, 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 correct or improve or, in respect of the rectification measures, 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 item, or to correct or improve or, in respect of the rectification measures, 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.

7.1.10 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.

7.2.3 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.