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Ring Shear Tester
RST-XS

Operating Instructions v2.1

Please read thoroughly before you begin setting up or using the tester.

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Important!

Please read the operating instructions and safety instructions thoroughly before setting up or using the Ring Shear Tester!

Keep this manual for future reference.

Assembly instructions: see Section 9.

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2 Preface

These operating instructions are designed to familiarize the user with computer-controlled Ring Shear Tester RST-XS and its designated use.

This manual contains important information on how to operate Ring Shear Tester RST-XS safely, correctly, and efficiently. Following these instructions will help to avoid dangerous situations, will reduce repair costs and downtime, and will increase reliability and longevity of the machine.

This manual is to be supplemented with the respective national rules and regulations regarding safety and environmental protection.

The operating instructions must always be available whenever the machine is in use.

These operating instructions must be read and applied by any person using, maintaining, or transporting the Ring Shear Tester.

In addition to the operating instructions, the mandatory rules and regulations regarding safety and environmental protection in the country and place of use of the tester and the generally recognized technical rules for safe and proper use must also be observed.

Due to technical advances, the Ring Shear Tester is being updated continuously. Thus, small variations between the following instructions and your Ring Shear Tester (e.g. figures) are inevitable.

The information in these operating instructions is given in good faith and belief in its accuracy, but does not imply the acceptance of any legal liability or responsibility whatsoever by the manufacturer for the consequences of its use or misuse.

In case of questions about the operation, assembly, or disassembly of the Ring Shear Tester which are not answered in these operating instructions, please send an e-mail or a fax to the local distributor or to the manufacturer. The manufacturer is:

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4 Fundamental safety instructions and general instructions

4.1 Warnings and symbols

The following points are used in this manual to designate instructions of particular importance.

Important Refers to special information on how to use the machine most efficiently.

Attention Refers to special information directed towards preventing equipment damage.

Danger Refers to information to prevent injury or extensive equipment damage.

4.2 Basic operation and designated use of the Ring Shear Tester

Computer-controlled Ring Shear Tester RST-XS has been built in accordance with state-of-the-art standards and recognized safety rules. Nevertheless, its use may constitute a risk to life and limb of the user or of third parties, or cause damage to the machine and to other material property.

The Ring Shear Tester must be used only in suitable areas in accordance with its designated use and the instructions set out in the operating manual, and then only by safety-conscious persons who are fully aware of the risks involved in operating the Ring Shear Tester.

Ring Shear Tester RST-XS is designed exclusively for the measurement of the flow properties of bulk solids. Using the Ring Shear Tester for purposes other than those mentioned above is considered contrary to its designated use. The manufacturer cannot be held liable for any damage resulting from such use. The risk of such misuse lies entirely with the user.

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Operating the machine within the limits of its designated use also involves observing the instructions set out in the operating manual.

4.3 Organizational measures

The operating instructions must always be at hand when Ring Shear Tester RST-XS is being used.

In addition to the operating instructions, the user must follow all generally applicable legal and other mandatory regulations relevant to safety and environmental protection. These compulsory regulations include, but are not limited to, the handling of hazardous substances and issuing and/or wearing of personal protective equipment.

The operating instructions must be supplemented by instructions covering the duties involved in supervising the personnel operating the machine and notifying them of special organizational features such as job organization, working sequences, etc..

Personnel entrusted with operating the Ring Shear Tester must have read the operating instructions and in particular the chapter on safety before beginning work. This applies especially to persons working only occasionally on the Ring Shear Tester, e. g. during set-up or maintenance.

It is the responsibility of the supervisor to verify, at least from time to time, that the operator is carrying out the work in compliance with the operating instructions and paying attention to all necessary risks and safety factors.

For safety reasons long hair must be tied back or otherwise secured, garments must be close-fitting, and no jewelry (such as rings) may be worn. Injury may result from being caught in the machinery or from rings catching on moving parts.

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In order to avoid injury from falling weights or equipment (e.g. shear cell, calibration weight), safety boots are required when operating the Ring Shear Tester.

Use protective equipment wherever required by the circumstances or by law.

Observe all safety instructions and warnings attached to the Ring Shear Tester.

See to it that safety instructions and warnings attached to the machine are always complete and perfectly legible.

In the event of problems regarding safety with the Ring Shear Tester during operation, stop the Ring Shear Tester immediately (emergency stop button or main power switch at the front side) and report the malfunction to the appropriate authority/person.

Never make any modifications which might affect safety without the supplier's approval.

Spare parts must comply with the technical requirements specified by the manufacturer. Spare parts from original equipment manufacturers should be used.

The operator must be familiar with the location and operation of fire extinguishers.

Observe all fire-warning and fire-fighting procedures.

4.4 Selection and qualification of operators - basic responsibilities

Any work on and with the machine must be performed by reliable personnel only. Statutory minimum age limits must be observed.

Employ only trained staff and set out clearly individual personnel responsibilities for operation, setup, maintenance, and repair.

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Make sure that only authorized personnel work on or with the machine.

Define the machine operator's responsibilities, giving the operator the authority to refuse third-party instructions that are contrary to safety.

All persons to be trained or instructed, or persons taking part in a general training course, may not work on or with the machine without being permanently supervised by an experienced person.

Work on the electrical system of the machine must be carried out by a skilled electrician, or by instructed persons under the supervision and guidance of a skilled electrician, in accordance with electrical engineering rules and regulations.

4.5 Safety instructions governing specific operational phases: standard operation

Take all necessary safety precautions when using the Ring Shear Tester. Operate the Ring Shear Tester only if all protective and safety-oriented devices, such as removable safety devices and exhausts, are in place and fully functional.

Check the machine at least once per working shift for obvious damage and defects. Report any changes (including changes in the machine's working behavior) immediately to the person in charge. If necessary, stop the machine immediately and disconnect it from the power supply.

In the event of malfunction, stop the machine immediately and lock it. Have any defects rectified immediately.

Never leave the Ring Shear Tester unattended when it is running. After completion of the measurements switch off the Ring Shear Tester (main power switch at the front side) and disconnect the power supply from the mains.

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When the Ring Shear Tester is running, parts on the working table of the Ring Shear Tester must not be touched.

4.6 Safety instructions governing specific operational phases: maintenance

When working with the Ring Shear Tester and its safety-oriented devices, always observe the start-up and shut-down procedures set out in the operating instructions.

If the Ring Shear Tester is shut down for maintenance and repair work, it must be secured against starting.

The Ring Shear Tester is to be cleaned dry exclusively using lint-free cleaning rags. Never use harsh detergents. Only the bottom ring and the lid may be washed in warm water (no harsh detergents).

Use the provided handles at all times when transporting the unit.

In general, opening the casing is not necessary since the gears, bearings, etc. are well-dimensioned with respect to the loads occurring with normal, designated use. Thus, opening of the casing should be avoided, especially since during assembly extensive adjustment work is necessary. If, in spite of this, the casing of the Ring Shear Tester must be opened, then it first must be disconnected from the power supply and all other devices (such as the PC).

Always tighten any screw connections that may have been loosened during maintenance and repair.

Any safety devices removed for setup, maintenance, or repair purposes must be refitted and checked immediately upon completion of the work.

Ensure that all consumables and replaced parts are disposed of safely and with minimum environmental impact.

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4.7 Warning of special dangers: electric energy

Use only original fuses with the specified current rating. Switch off the Ring Shear Tester immediately if trouble occurs with the electrical system.

Work on the electrical system or equipment may be carried out only by a skilled electrician in accordance with the applicable electrical engineering rules, or by specially instructed personnel under the control and supervision of such electrician and in accordance with the applicable electrical engineering rules.

The Ring Shear Tester electrical equipment (especially power supply and cables connected to it) is to be inspected and checked at regular intervals. Defects such as loose connections or scorched cables must be rectified immediately.

4.8 Transport

When moving the Ring Shear Tester, use lifting gear and equipment of sufficient capacity.

Lift the Ring Shear Tester only with the handles provided for this according to the operating instructions.

Only use suitable means of transportation with adequate carrying capacity.

Prior to shipping, remove all parts which are lying loosely on the machine (such as shear cell, tie rods etc.: see operating instructions).

Disconnect the external power supply from the machine even if the unit is moved only a short distance. Properly reconnect the machine to the supply mains before recommissioning.

Carefully refit and fasten all parts removed for transportation before recommissioning the machine.

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When recommissioning, proceed only in accordance with the operating instructions.

4.9 Range of application

Ring Shear Tester RST-XS is designed for the measurement of bulk solid properties that are acted upon by low normal stresses. In order to prevent damage, the Ring Shear Tester is to be operated only up to the maximum normal load prescribed in the "Technical data" section.

No guarantee or responsibility is taken for results achieved with the Ring Shear Tester. Likewise, no responsibility is taken for damages resulting from measurements obtained with this Ring Shear Tester. The same applies to faulty measurements and measuring errors that result e.g. from incorrect operation of the unit, faulty evaluation of the measured values, errors in the present instruction, or fundamental errors in the Ring Shear Tester. Likewise, no responsibility is taken for damages resulting from defects in the Ring Shear Tester.

All efforts have been undertaken to ensure operator safety when using the Ring Shear Tester and when evaluating the measurement data. Since errors cannot be avoided completely despite all efforts, the manufacturer will be thankful for any information and criticism relating to such errors.

The Ring Shear Tester is a sensitive measurement device, whose precision can be affected through improper operation. Please keep this point in mind when operating the Ring Shear Tester.

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5 Technical data

Dimensions	width ca. 600 mm (plus handles), height ca. 550 mm, front-to-back-size ca. 480 mm
Weight	approx. 40 kg
Driving mechanism	shear: variable speed digitally controlled DC motor normal load: variable speed digitally controlled DC motor
Electric input	24 Volt DC, 1.9 Ampere
Power consumption	maximal 75 Watt (peak value)
Fuse	2 A, F (quick-acting) dimensions: diameter 5 mm, length 20 mm (installed at the connecting panel at the back side of the tester)
Sound emission	airborne sound < 70 dB(A)
Environmental specifications	temperature: operating: 10°C to 35°C (50°F to 95°F) storage 0°C to 40°C (32°F to 104°F) humidity: operating: 20% to 80% RH, non-condensing storage: 10% to 80% RH, non-condensing
Force measuring system	shear force: 2 paralleled load beams, total range: 4 kg normal load: load beam, range 5 kg
Displacement transducer (lid displacement)	inductive displacement transducer installed within the casing, range 50 mm
Accuracy (digitalization)	normal load: +/- 1/10000 of the range shear force: +/- 1/10000 of the range displacement: 0.01 mm sampling rate: max. 10 Hz
Range of the normal load	maximum adjustable normal load: ca. 5 kg maximum normal stress: ca. 20 kPa (shear cell type XS-M) and ca. 10 kPa (shear cell type XS-L)
Serial communication port	9-channel D-Sub-socket (female), RS-232, 9600 Bit/sec
Shear cell(s)	materials and dimensions: see shear cell data sheets in this manual.
Shear velocity	computer-controlled adjusted from approx. 0.025 mm/min to approx. 15 mm/min (at mean diameter 24 mm of the specimen in the standard shear cell XS-M)
Materials	shear cells: see shear cell data sheets in this manual. working table: stainless steel 1.4301 parts on the working plate: 1.4305, AlMg3 frame: AlMg3

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6 Construction

Information on the function and principles of Ring Shear Tester RST-XS is presented in this section.

6.1 Ring Shear Tester RST-XS

Computer-controlled Ring Shear Tester RST-XS is composed of the following elements (Figure 6.1):

- casing 1,
- horizontal guiding system 2,
- normal load system 3,
- shear force transducer 4,
- driving axle 5 for supporting the shear cell, consisting of bottom ring 6 and lid 7.

Casing 1 is covered by the working plate 20, which is made from stainless steel. Casing 1 contains the electronic equipment (amplifiers, A/D-converters, communication modules, digital motor control). Casing 1 is provided with four adjustable stands 17 (Figure 6.1). The adjustable stands 17 are to be adjusted accurately to ensure that the unit is level.

The driving axle 5 supports the shear cell, consisting of bottom ring 6 and lid 7. The bottom ring 6 contains the bulk solid specimen. For testing, the bottom ring 6 is set on the driving axle 5 (Figure 6.2 to 6.4). Thereby, the driver pins on top of the driving axle 5 must lock in the bores beneath the bottom ring 6 to obtain a close connection between bottom ring and driving axle. The driving axle is driven by an electric motor and can rotate to the right or to the left. In order to shear the bulk solid specimen, the driving axle 5 and the bottom ring 4 both rotate clockwise (as seen from the top).

Lid 7 is placed on top of the bottom ring of the shear cell, which is filled with the bulk solid specimen to be tested (Figures 6.2 and 6.3). In order to prevent slipping of the bulk solid on the lid or bottom of the shear cell,

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the lower side of the lid 7 is provided with vertical bars (Figure 6.4). Additionally, the bottom of the bottom ring is equipped with an annular plate provided with cutouts, or alternatively the bottom has a rough surface (pyramidal pattern).

When performing wall friction tests a specially designed shear cell is used, where the bottom ring contains an annular sample of the wall material (see Section 6.33).

A crossbeam 8 is fixed to each lid 7. The crossbeam 8 has several functions: In the center of the crossbeam 8 is an indentation for receiving the loading rod 9 (Figure 6.2.a). The loading rod 9 transfers the normal load from the normal load system to the lid and the bulk solid specimen, respectively. To adjust the normal load, the normal load system is moved downward by a motor drive until the desired normal load (a normal force) is obtained. For measuring the normal load, a load cell is installed at the normal load system within a cylindrical protective cover. The conical receiver 10 for the loading rod 9 is mounted at the tip of the load cell.

At the ends of the crossbeam 8 cutouts are provided for the fixation of the tie rods 11 (Figure 6.2.a). A similar cutout can be found at the adjustable seating 16 of the shear force transducers 4. Due to the balls at both ends of the tie rods 11, tensile forces can be transferred from the crossbeam 8 through the tie rods 11 to the adjustable seatings 16. The seatings 16 are adjustable to allow the horizontal position of the lid 7 to be varied.

At the right side of casing 1 is a storage tube 19 for storing the tie rods 11 and the loading rod 9 if these parts are not used (Figure 6.2.b).

When shearing the bulk solid, the bottom ring rotates clockwise (viewed from above). The rotation of the lid 7 is prevented by the tie rods 11. The force acting in the tie rods is measured by the shear force transducers 4. The load cells of the shear force transducers are protected from damage by the protecting caps 21 (Figure 6.1).

DANGER!
To avoid overloading the load beams, the indicated maximum normal load (Section 5) must not be exceeded!

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At one end of each crossbeam 8 is a second cutout for guiding bar 13 which connects the crossbeam to the horizontal guiding system 2 (Figures 6.2.a and 6.3). The horizontal guiding system ensures that the movement of the lid 7 perpendicular to the tie rods 11 is limited so that the lid 7 cannot touch the side walls of the bottom ring 6. Thus the centric position of the lid is obtained.

Within casing 1 an inductive displacement transducer is installed. With the displacement transducer the height of the bulk solid specimen (lid displacement Δh) is measured continuously during a test.

The normal load system is an electronically controlled mechanical system. The system simulates the placement of weight pieces on the hanger, as performed in normal, manually operated shear testers. With the normal load system, normal loads of up to nearly 5 kg (approximately 50 N) can be exerted in increments of 0.0005 kg (approximately 0.005 N).

The rear wall 21 of casing 1 (Figure 6.5) contains the following elements:

- Fuse: 2 Ampere, quick-acting (fast-blow)

- Grounding screw "GND" for grounding the Ring Shear Tester. The grounding screw is connected internally to the metal parts of the Ring Shear Tester

- 9-channel D-Sub-socket "RS-232": The serial communication port "COM1" or "COM2" of the PC must be connected to this socket. The included connecting cable with 9-channel D-Sub-plugs at both ends must be used exclusively!

- 3-channel circular input voltage socket "24 V DC" for connection to the power supply.

Panel 22 (Figure 6.1) is located at the front side of casing 1. It contains the following operating elements (from left to right):

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- Main power switch (to switch the Ring Shear Tester on and off, including the internal motor control units). The main power switch separates the electronic system of the Ring Shear Tester from the input voltage. Position "0" means "off", "1" means "on".

- Red signal LED indicating when the tester is switched on.

- Emergency stop: Press the red button to stop the Ring Shear Tester in case of emergency. To switch on the tester subsequently, pull the red button.

- "OK-Button" 23 is located on the right part of the front side of the casing. When the Ring Shear Tester is controlled by RST-CONTROL 95, the OK-Button is used for confirmation of the different steps of operation.

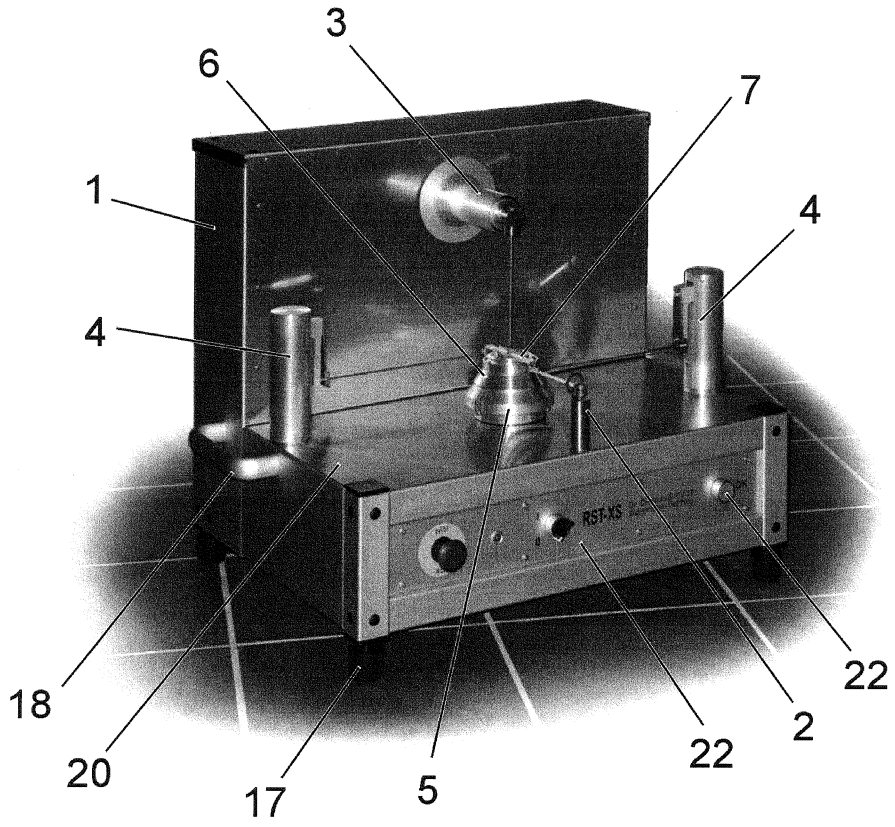


Figure 6.1: Ring Shear Tester RST-01.XS (overall view)

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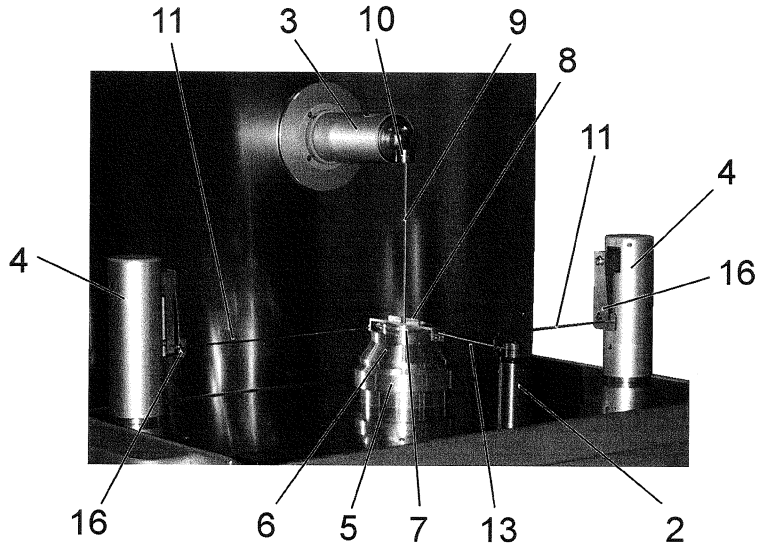


Figure 6.2.a: Working plate with shear cell

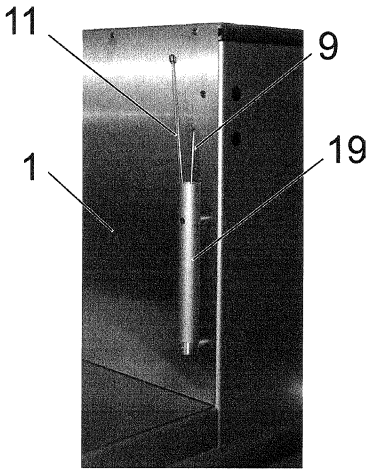


Figure 6.2.b: Storage tube 19

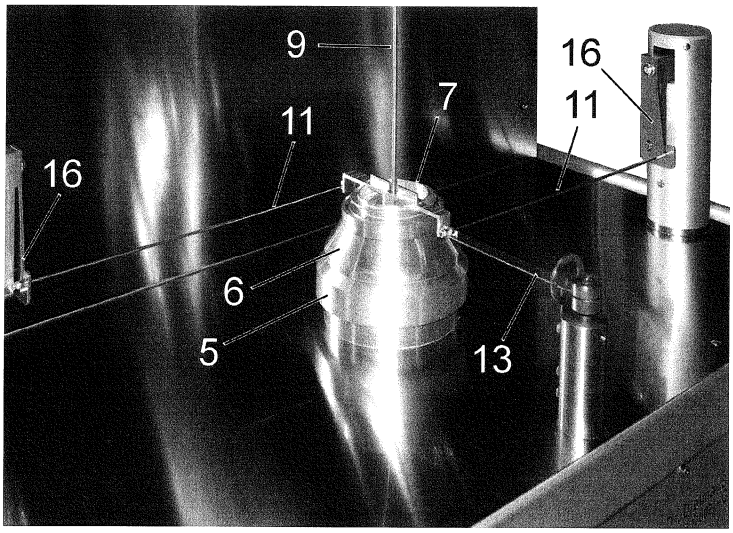


Figure 6.3: Shear cell during testing

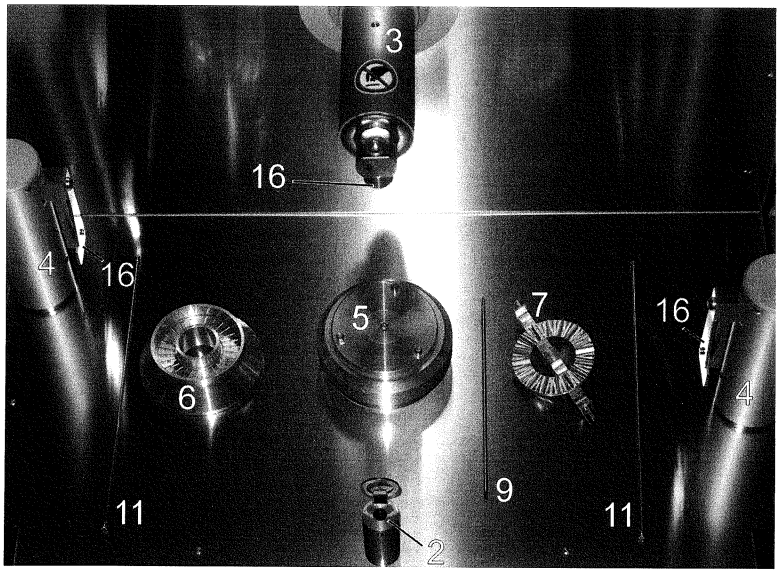


Figure 6.4: View on the working plate; shear cell removed from the driving axle 5

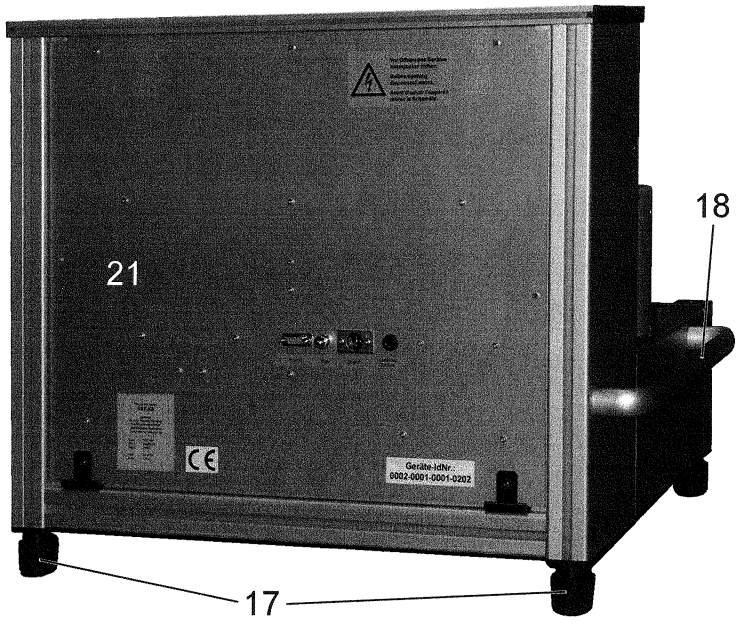


Figure 6.5: Rear wall

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6.2 Shear cells

The general construction of a shear cell is described in Section 6.1. Different shear cells are available for the Ring Shear Tester, with the basic principle shown in Figure 6.6. Their dimensions are given in the shear cell data sheets (Section 14). The "standard shear cell" is the shear cell type XS-Mr. Its cross-sectional area A_{SZ} (cross-section of the annular internal volume for the specimen; see remarks in Section 14) is approximately 24 cm^2, its internal height h_{SZ} is 13 mm, and its specimen volume V_{SZ} is approximately 30 cm^3. The bottom of the shear cell is covered by a bottom plate, which is provided with cutouts and bores. Depending on the type of shear cell, the bottom plate is removable (standard; e.g. shear cell XS-Mr; "r" indicates the removable bottom plate) or fixed. To prevent the bottom plate from rotating, it is provided with bores, which fit on the screw heads at the bottom of bottom ring 6 (Figure 6.7). The orientation of the spokes of the bottom plate does not play a role.

Each lid is delivered with a crossbeam. **Important: Never unscrew the crossbeam from the lid!**

Shear cell type XS-L has larger dimensions than shear cell XS-M: Its cross-sectional area A_{SZ} is approximately 46 cm^2, its internal height h_{SZ} is 16 mm, and its specimen volume V_{SZ} is approximately 73 cm^3. A version with removable bottom is available (type XS-Lr).

The smaller shear cell is type XS-MV4. Its diameters correspond to the diameters of shear cell XS-M, but the specimen height is reduced. Furthermore, the lid and the bottom are provided with a rough surface (pyramidal pattern, consisting of small pyramids). The net volume of this shear cell is only about 9 cm^3.

The dimensions of the shear cells limit the maximum size of particles which can be tested. An accurate value for the maximum particle size cannot be given because of the influence of the particle shape and the particle size distribution. Table 6.1 gives a rough indication on the limits which must be checked in each particular case. Comparative tests with different shear cells have shown that the shear cell geometry can have

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a slight effect on the results. Thus, for comparative tests the same shear cell type should be used for all samples.

Shear cell	maximum particle size x_{max}	
	monodisperse	distribution 0 .. x_{max}
XS-M, XS-Mr	0.5 mm	1.0 mm
XS-MVx	0.25 mm	0.5 mm
XS-L, MX-Mr	0.75 (1.0) mm	1.5 (2) mm

Table 6.1: Maximum particle size
(in brackets: possible with not-too-brittle particles)

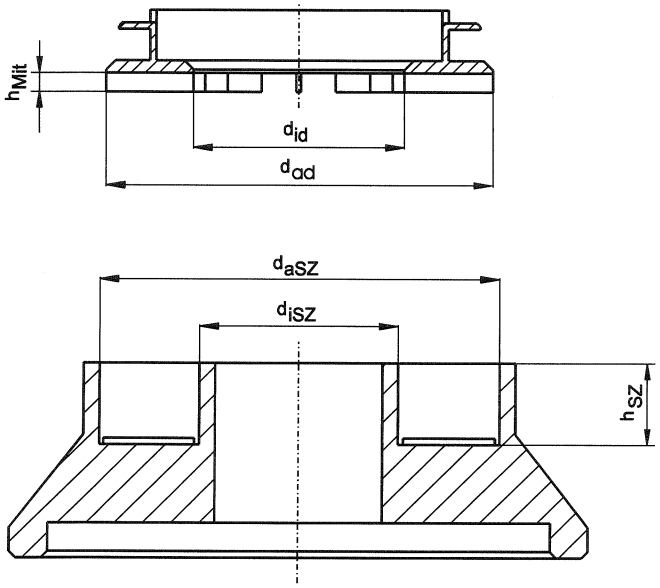


Figure 6.6: Shear cell XS-M, definition of the main dimensions

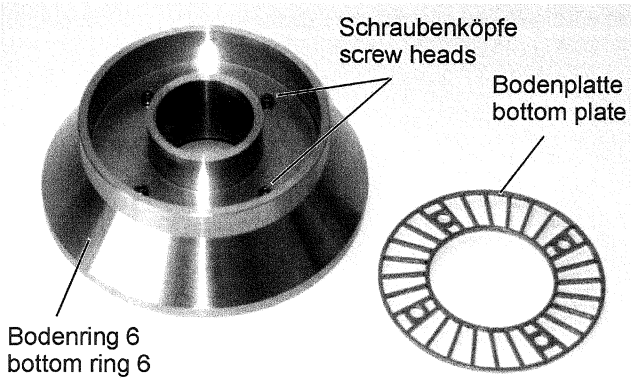


Figure 6.7: Shear cell XS-Mr, bottom plate removed

6.3 Wall friction cells

The optional wall friction cells allow the measurement of the wall friction angle (the friction angle between a bulk solid and a wall material like mild steel, stainless steel, etc.) and the measurement of wall yield loci [3,6].

The construction of a wall friction cell is similar to that of the shear cells described in Sections 6.1 and 6.2. In Figure 6.8 the main dimensions are defined.

The bottom ring 40 of the wall friction cell (see Figure 6.9) contains the wall material sample to be tested. The wall material sample is placed on an appropriate number of spacer rings 43. The thickness of each spacer ring is 1 mm. The upper surface of the wall material sample should be located about 4 mm beneath the upper edge of the bottom ring 40 (see Figure 6.9). Hence, to obtain the required distance, the number of spacer rings 43 must be chosen with respect to the thickness of the wall material sample. To avoid any relative circumferential displacement between the bottom ring 40 and the wall material sample, two driving pins 42 are installed at the outer wall of the bottom ring 40. The annular wall material sample must be provided with notches for these driving pins so that the bottom ring and the wall material sample are interlocked. The required dimensions of the wall material sample are shown in Figure 6.10.

The bottom ring 40 is filled with the bulk solid flush to its upper edge. The bottom ring is placed on the driving axle 5 of the Ring Shear Tester to allow measurements to be taken. The driver pins on the driving axle must lock in the bores beneath the bottom ring 40 to obtain a close connection between bottom ring and driving axle.

The lid 41, which is connected to a crossbeam 45, is then set on the bottom ring 40 and filled with the bulk solid to be tested. The lid has pyramids at its underside to prevent slipping of the bulk solid on the lid of the shear cell.

In order to take measurements, lid 41 is connected to the Ring Shear Tester, as noted in Sections 6.1 and 6.2.

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Due to the dimensions of lid 41 and bottom ring 40, most bulk solids will display a vertical distance of a few millimeters between the lower edge of the lid and the upper surface of the wall material sample. Thereby, the bulk solid beneath the lid is moved relative to the wall material sample during shearing, so that the force measured at the load beams is directly proportional to the shear stress acting at the surface of the wall material sample.

The dimensions of the wall shear cells are listed in the shear cell data sheets in Section 14. The standard wall friction cell is shear cell type XS-WM.

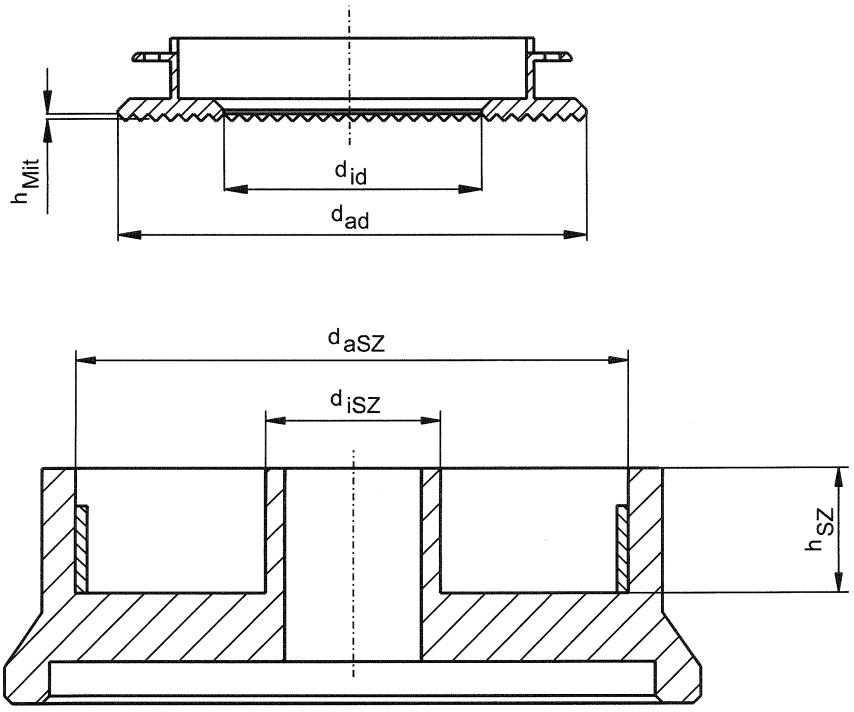


Figure 6.8: Wall friction shear cell type XS-WM, definition of the main dimensions

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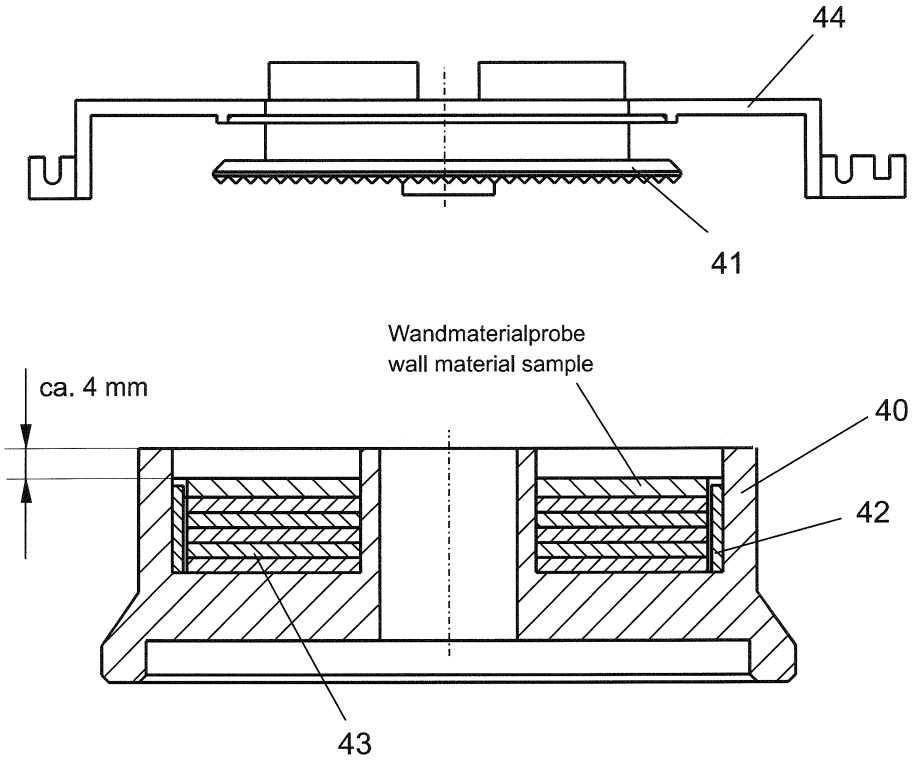


Figure 6.9: Wall friction cell with wall material sample

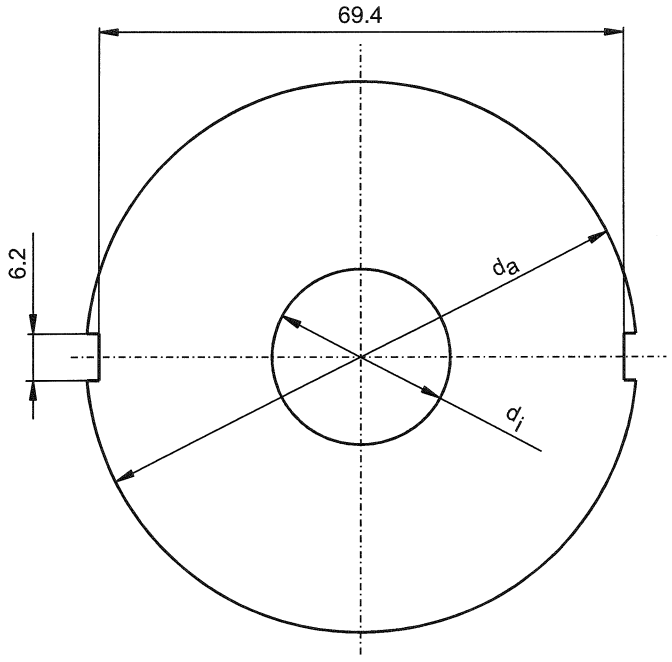


Figure 6.10: Dimensions of the wall material samples,
tolerances: +/- 0.2 mm
Wall friction cell XS-WM: d_i = 23.3 mm, d_a = 72.7 mm

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6.4 Time consolidation benches

The time consolidation benches serve as a storage and loading device for a shear cell filled with a bulk solid specimen. This simulates loading conditions during periods of storage at rest, which may exist for example in a silo.

For Ring Shear Tester RST-XS two types of time consolidation benches are available: Type XS1-C with cover and type XS1-O without cover.

6.4.1 Time consolidation bench XS1-C

Time consolidation bench XS1-C (Figure 6.11) is composed of a frame Z1, on which a protective wall Z2 and a supporting plate Z3 are fastened. During a test, a shear cell is placed on the supporting plate Z3, which serves to centrally position the shear cell.

The protective cover Z4 is joined to the lower end of the loading rod Z8, which can be locked in the upper position (as shown in Figure 6.11) with the locking screw Z7. The underside of the protective cover Z4 is provided with an annular channel which fits to the upper edge of the protective wall Z2. The protective cover Z4, when lying on the protective wall Z2, serves to protect the specimens from the surrounding atmosphere (e.g. to reduce moisture changes of the bulk solids).

Furthermore, the disk Z6 is joined to the loading rod Z8. Weight pieces are added on this disk to set the appropriate time consolidation vertical load.

The locking screw Z7 serves as a fixation point for the loading rod Z8 in the upper position (Figure 6.11). When moving the loading rod upward or downward, the locking screw must be unscrewed somewhat. In the loading position the locking screw **must remain unscrewed**.

The operation of the time consolidation bench is described in Section 8.2 (time consolidation tests).

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Time consolidation bench XS1-C must not be subjected to temperatures higher than 100°C (212°F).

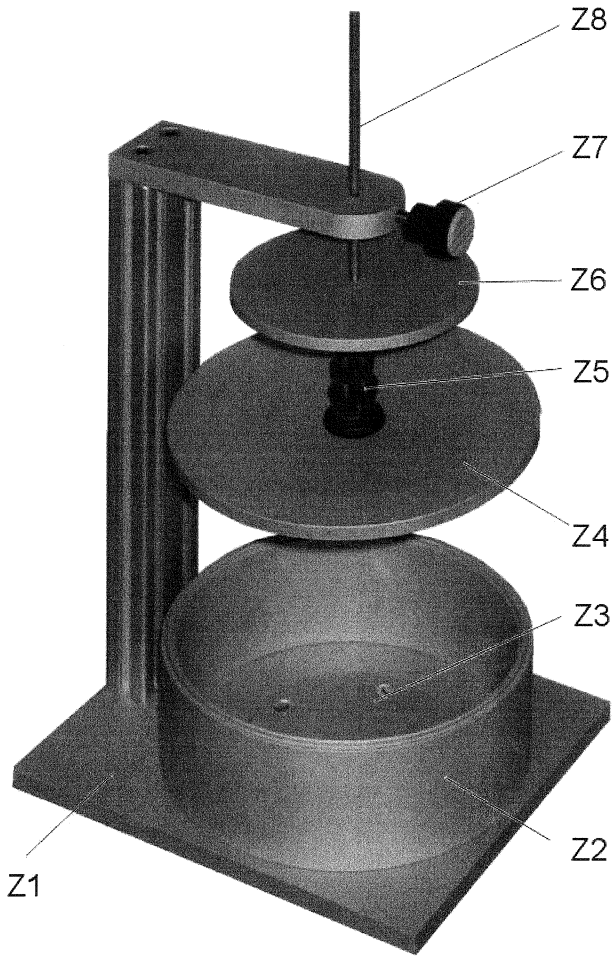


Figure 6.11: Time consolidation bench XS1-C

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6.4.2 Time consolidation bench XS1-O

Time consolidation bench XS1-O (Figure 6.12) is composed of a frame Z10, on which a supporting plate Z15 is fastened. During a test, a shear cell is placed on the supporting plate Z15, which serves to centrally position the shear cell.

At frame Z10 a parallel guide Z11 is attached, which supports the disk Z12. The disk Z12 is provided with a thread Z13 at its lower side. At the rear end of the parallel guide is a counterweight Z16, which compensates the weights of the disk Z10 with thread Z13, and the front part of the parallel guide.

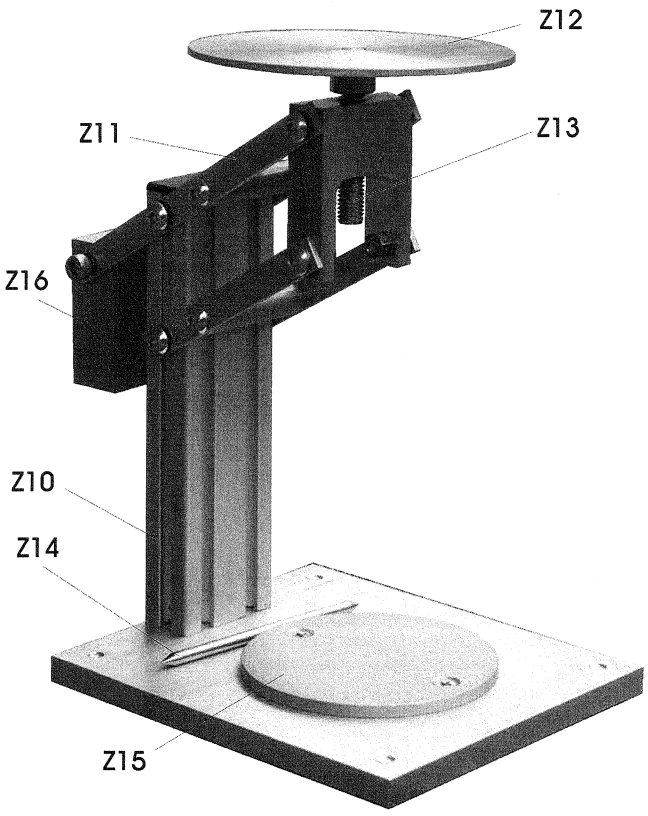


Figure 6.12: Time consolidation bench XS1-O (without shear cell)

Figure 6.13 shows the time consolidation bench XS1-O with a shear cell XS-M and weights for the adjustment of the consolidation load. The loading rod Z14 is constrained between thread Z13 and crossbeam 8 at

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lid 7 of the shear cell. The loading rod Z14 transfers the normal load from the disk Z12 with the weights to the lid 7 and the bulk solid specimen, respectively. In the center of the crossbeam 8 and at the lower end of the thread Z13 is an indentation for receiving the loading rod Z14.

Time consolidation bench XS1-O must not be subjected to temperatures higher than 100°C (212°F).

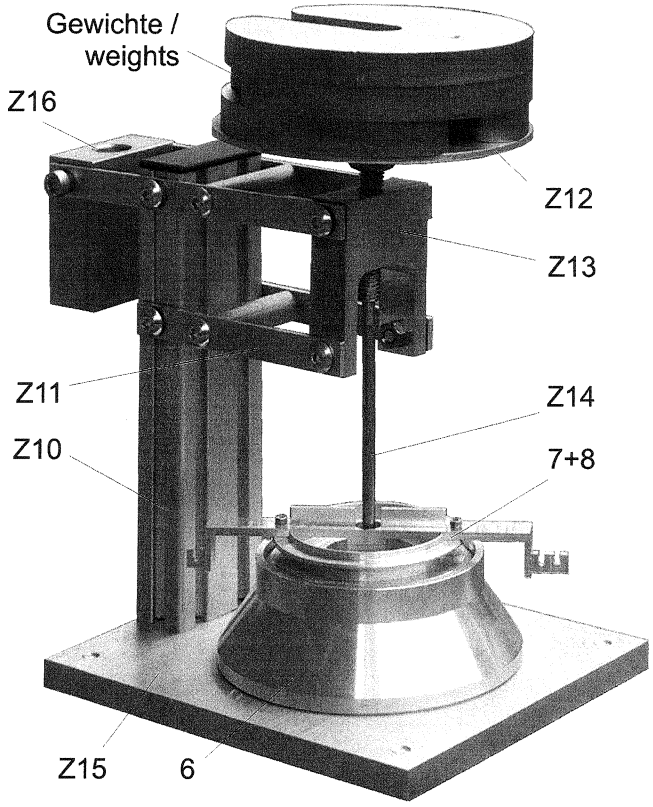


Figure 6.13: Time consolidation bench XS1-O (with shear cell XS-M)

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7 Set-up

This section describes how to connect Ring Shear Tester RST-XS to a power supply and a PC, and how to set up and adjust the tester.

7.1 Connection to a power supply

Connect the Ring Shear Tester to an appropriate power supply:

ATTENTION:
Exclusively use the power supply supplied with Ring Shear Tester

A cable for connection to the Ring Shear Tester is already installed with the power supply delivered with the Ring Shear Tester. This cable is provided with a 3-channel plug at one end, which fits into the 3-channel circular socket ("24 VDC") at the rear wall 21 of casing 1. The pin assignment of the socket is shown in Figure 7.1.

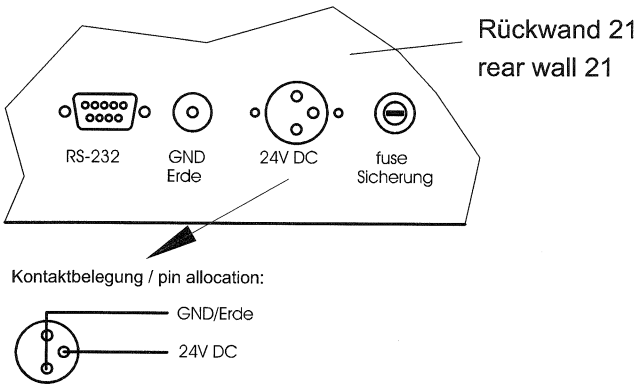


Figure 7.1: Pin assignment of the power input socket 24 VDC

The power supply is provided with an IEC-socket (according to IEC320, CEE 22), which must be connected to the mains (socket-outlet with ground) using an IEC-cable with ground. If the cable supplied with the tester does not fit into the mains socket-outlet, you must procure an ap-

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propriate cable (specifications: ampacity 6 A, according to local safety rules).

Important!
The Ring Shear Tester should be grounded by connecting the grounding screw to ground (according to the local safety regulations). The grounding screw, marked "GND", is located on the rear wall 21 (see Figure 7.1).

DANGER!
Under no circumstances should a power supply with an output voltage greater than 24 Volt, or with an alternating output voltage (AC), be connected to the Ring Shear Tester!

7.2 Connection to a personal computer

The Ring Shear Tester must be connected to the PC's serial communication port COM1 or COM2 (For details concerning system requirements please refer to the RST-CONTROL 95 manual.). For this a 9-channel D-Sub-socket (female) is provided at the rear wall 21 of casing 1. The pin numeration is shown in Figure 7.2, the pin assignment in Table 7.1.

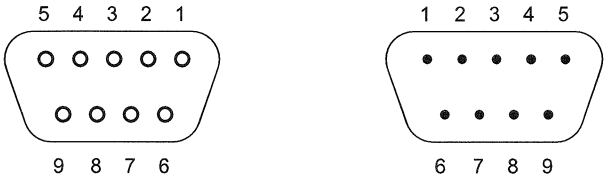
Connection	9-channel D-socket serial communication port (at rear wall 21); 9-channel D-connectors (male/female) at serial communication cable
TXD	3
RXD	2
RTS	7
GND	5

Table 7.1: Allocation of contacts (pin assignment) of 9-channel D-socket "RS-232" at rear wall 21 and connectors of serial communication cable

The serial communication cable (for pin assignment see Table 7.1) supplied with the Ring Shear Tester has a 9-channel D-connector at both ends (one male, one female). One plug fits into the "RS-232" socket at the rear wall 21, with the other plug connected to the PC. If

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the PC is equipped with a 25-channel D-Sub socket, an appropriate adapter must be used. For pin assignment of the PC's D-Sub socket, please refer to the PC's operating manual.



socket (female)
Buchse (weiblich)

plug (male)
Stecker (männlich)

Figure 7.2: 9-channel D-Sub-connectors (male and female), pin numeration (view from outside)

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7.3 Ring Shear Tester adjustments

ATTENTION: Improper adjustment of the tester can cause severe measurement errors.

Before you start working with the Ring Shear Tester, the following adjustments are required:

1. The Ring Shear Tester must be assembled completely. The Ring Shear Tester must stand firmly on a solid table where it must be **level**. The stands 17 can be adjusted to level the tester.

2. Adjust the horizontal position of the lid (**very important!**). During testing, the lid must be concentric with the bottom ring. It must not touch the walls of the bottom ring.

   Note: The horizontal position is adjusted before the ring shear tester is shipped. Therefore, while you should check the adjustment, usually there is no need to change the horizontal position.

   Place bottom ring 6 of a standard shear cell XS-M or XS-Mr on driving axle 5 (Figure 7.5). Then place lid 7 (with the crossbeam 8) on bottom ring 6 so that the end of the crossbeam with two cutouts is directed toward the front side of the tester. Connect tie rods 11 to crossbeam 8 and the adjustable seatings 16 at the shear force transducers 4, and connect the crossbeam with the guiding bar 13 of the horizontal guiding system 2. Then turn lid 7 clockwise (from above) with your hands around its vertical axis until tie rods 11 are slightly in tension; see Figure 7.6. (Pay attention to the position of the lid. Its lower surface must be level.) In this situation lid 7 must be concentric with bottom ring 6. (This can be confirmed by noting a constant width of the inner and outer circumferential slit between bottom ring 6 and lid 7; at points C and D shown in Figure 7.6 the width of the slit must be about 1 mm.) Additionally, the longitudinal axis of the crossbeam 8 should be perpendicular to the front edge of the Ring Shear Tester (Figure 7.6).

   At the front and rear of the shear cell (points A and B in Figure 7.6)

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the slit is variable according to the play provided by the horizontal guiding system 2. Move the lid 7 horizontally to A and B. The minimum width of the slit at A and B should be the same. The lid must not touch the wall of the bottom ring!

If the lid is not concentric with the bottom ring, you must correct its position. Start with the position in direction C-D. The adjustable seatings 16 at the shear force transducers are provided with adjusting screws 29 (Figure 7.7). First loosen the counternuts, then turn the screws stepwise until the lid is in the right position (check as described above). Afterwards fasten the counternuts.

Next correct, if necessary, the position of the lid in the A-B direction. The position of the adjustable bracket 14 is fixed by the adjusting screws 30 and 31 (Figure 7.8). To move the bracket toward the shear cell, loosen adjusting screw 30 (cylinder head screw) and fasten adjusting screw 30 (grub screw). To move the bracket in the opposite direction, loosen screw 30 and fasten screw 31. At the end, both adjusting screws must be fastened.

3. Before starting the first test, the device dependent parameters must be determined (initial set-up). These parameters are the offset and factor of the lid displacement measurement, and the offsets of the shear force and normal load measurement. The RST-CONTROL 95 manual describes when and how these parameters must be determined. The RST-CONTROL 95 program will also prompt the user when appropriate (i.e., when first starting the RST-CONTROL 95 program, an automatic procedure will be performed to check and adjust all the parameters).

4. Check position of the normal load system:

   Note: The normal load system is adjusted before the ring shear tester is shipped. Therefore, you should check the adjustment, but usually there is no need to change it.

   Note: This procedure must be performed after step 3.

   Place a standard shear cell type XS-M with lid 7, but without bulk solid, on the driving axle 5 (Figure 7.3). Insert the loading rod be-

tween the crossbeam 8 at lid 7 and the conical receiver 10 at the normal load system 3. Now the lid is in its lowest position. In this situation the loading rod must neither be vertically compressed by the normal load system nor fall away from its roughly vertical position. If this is not the case, adjust the position of the normal load system by turning the adjusting screw 12 located at the left side wall of casing 1 (Figure 7.3). Turn the adjusting screw clockwise to raise the normal load system, or counterclockwise to lower it.

For the next step you need the spacer blocks 25 (see Figure 7.14 in Section 7.4.3.1). Place the spacer blocks 25 (height 8 mm) between bottom ring 6 and crossbeam 8 (Figure 7.4); the bores in the spacer blocks must be oriented vertically. Thereby the lid is in its uppermost position. Even in this situation, the loading rod must not be vertically compressed by the normal load system, but must have some vertical play so that no force is exerted on the shear cell lid by the normal load system. If the loading rod has no vertical play, turn the adjusting screw 12 clockwise to raise the normal load system.

IMPORTANT! If you have changed the position of the normal load system by turning the adjusting screw 12, you must repeat the initial set-up (step 3; see above). Start the initial set-up procedure in RST-CONTROL 95 ("Ring shear tester" menu, "Tester adjustments and checks" command; see RST-CONTROL 95 manual).

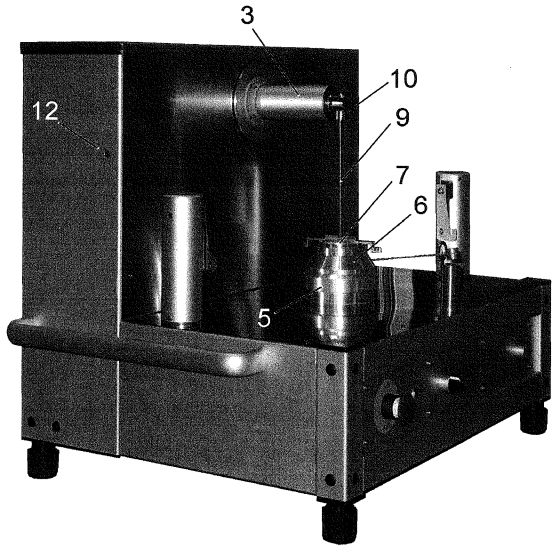


Figure 7.3: Adjustment of the normal load system

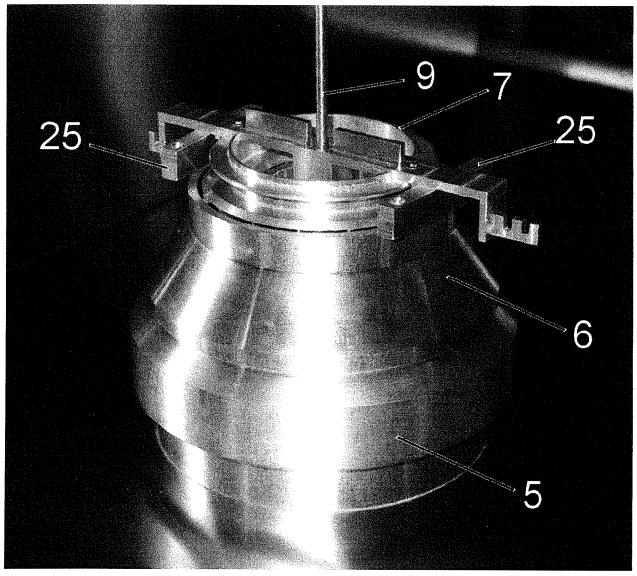


Figure 7.4: Shear cell with spacer blocks 25 (8 mm). Please note the orientation of the bores.

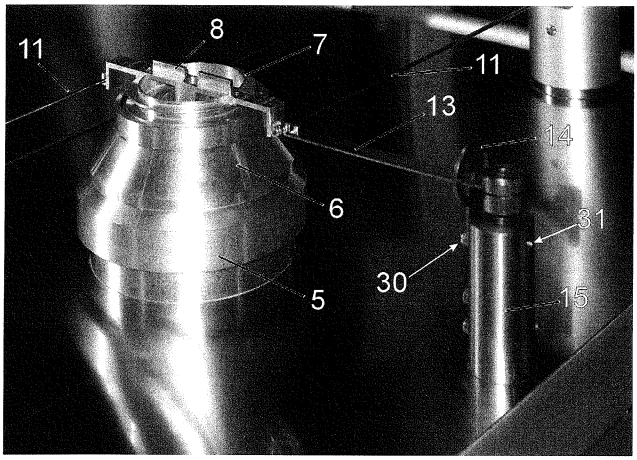


Figure 7.5: Set-up for checking the concentric position of the lid 7

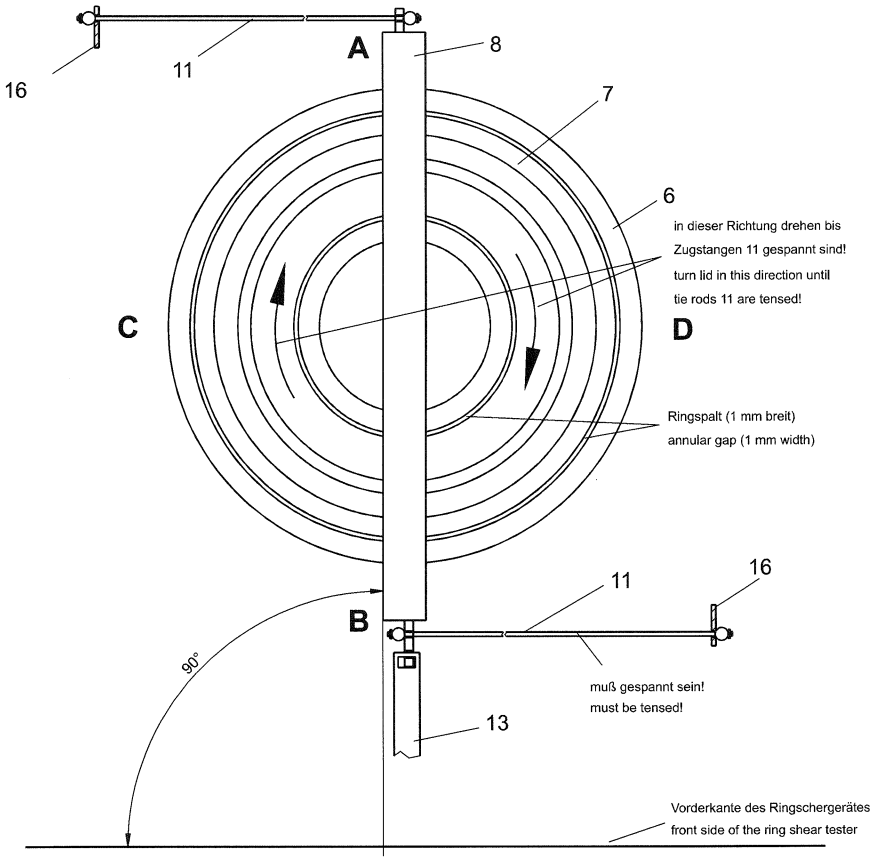


Figure 7.6: How to adjust the concentric position of the lid

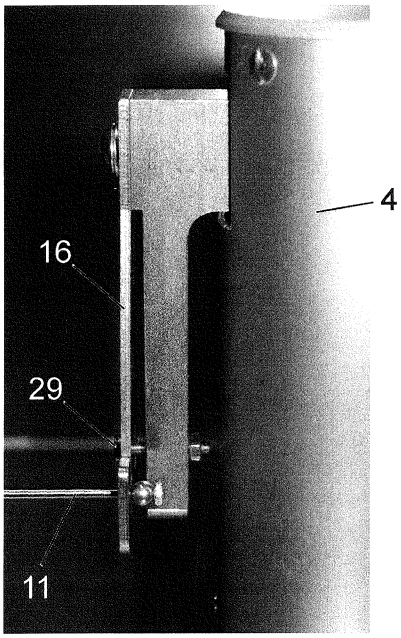


Figure 7.7: Adjustable seating 16 at shear force transducer 4

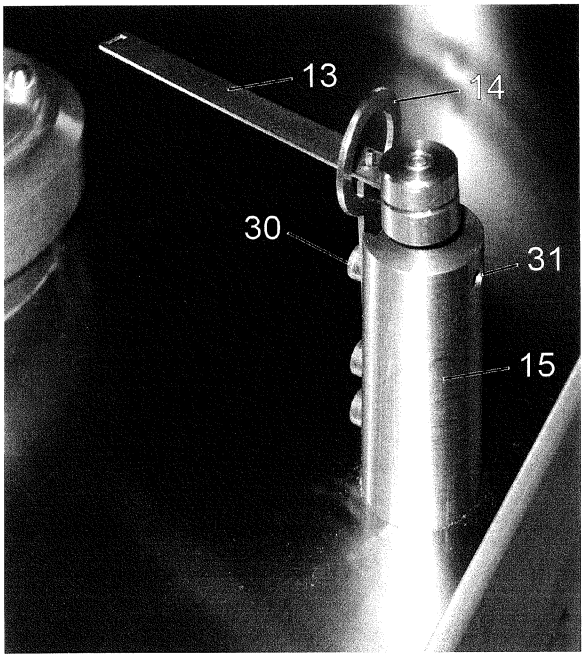


Figure 7.8: Adjustable bracket 14 at the bearer 15 of the horizontal guiding system

CHECK WEIGHT OF TIE RODS (2) : 15.083 g
LOAD ROD (1) : 9.523 g

7.4 Calibration

MANUF: METTLER TOLEDO MODEL: PL303
SCALE #: 118889 SERIAL #: 1229150196
7/23/08 TJB (JHJ)

The Ring Shear Tester is tested and calibrated before it is shipped. Before testing, the calibration of the displacement transducer should be checked using RST-CONTROL 95 (see Section 7.4.3). The calibration of shear force and normal load can also be checked and adjusted with RST-CONTROL 95. This can be done, for example, after long-term use of the tester (e.g. once a year).

MANUF.: SARTORIUS
MODEL: CP 34001P
CALIBRATION WEIGHT CHECKED = 925.39 g
SCALE # 118859
SERIAL # 22750017 7/23/08 TJB (JHJ)

7.4.1 Normal load system

The normal load system sensitivity calibration must be performed using control software RST-CONTROL 95. In the "Ring Shear Tester" pull-down menu, select the "Tester adjustments and checks" command, then "Normal load calibration". The program will guide the user through the procedure. An overview of the procedure follows.

The calibration hanger 26 is placed on top of the conical receiver 10 at the normal load system 3 (Figure 7.9). Take care to ensure that the calibration hanger 26 is at rest; i.e. it must not swing or turn.

RST-CONTROL 95 will then measure the normal force.

After the above has been completed, the calibration weight 27 should be attached to the calibration hanger 26 (Figure 7.10).

After the calibration weight has been attached, take care to ensure that the calibration weight is at rest; i.e. it must not swing or turn. RST-CONTROL 95 will then measure the normal force.

If prompted by RST-CONTROL 95, a portion of the procedure outlined above may need to be repeated.

With the mass of the large calibration weight known, RST-CONTROL 95 will calculate the sensitivity of the normal load system.

The offset (zero) value of the normal load system, i.e., the signal measured when the normal load system is not in contact with the loading rod, will be checked each time after starting the RST-CONTROL 95, and before each test. When RST-CONTROL checks the offset value, it tells the operator to ensure that the normal load system is not in contact with the loading rod or any other part. This is the only way the correct offset value can be determined Please follow the instructions on the computer screen.

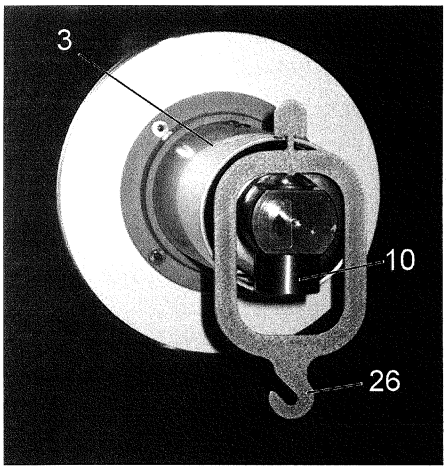


Figure 7.9: Calibration hanger 26 with normal load system 3

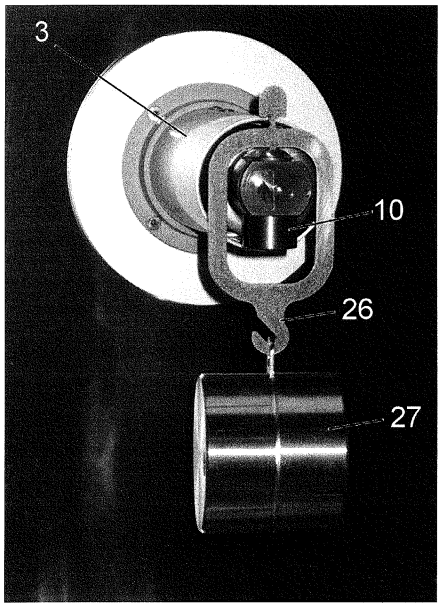


Figure 7.10: Calibration weight 27 attached to calibration hanger 26

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7.4.2 Shear force

The shear force measuring system sensitivity calibration must be performed using control software RST-CONTROL 95. In the "Ring Shear Tester" pulldown menu, select the "Tester adjustments and checks" command, then "Shear force calibration". The program will guide the user through the procedure. An overview of the procedure follows:

First the right shear force transducer 4 is checked, then the left one. For calibration, the Ring Shear Tester must be turned carefully and placed on its left side, and then on its right side. This procedure ensures that the calibration process can be performed without the negative influence of friction forces.

DANGER!
For turning the Ring Shear Tester a second person is required, and safety boots must be worn!

RST-CONTROL 95 will first ask that the Ring Shear Tester be turned, with the help of a second person, onto its left side (Figure 7.11). The tester then rests on the left handle 18 and the adjustable calibration support 28. The calibration support 28 must be located between the table and the tester (around 10 cm from the upper edge of casing 1). Adjust the calibration support so that the right side wall of the tester, which is now on top, is level.

When prompted by RST-CONTROL 95, append the calibration hanger 26 to the adjustable seating 16 of the right shear force transducer. The position of the calibration hanger 26 relative to the adjustable seating 16 must be the same as the position of the tie rods 11 during testing (Figure 7.12). Take care to ensure that the calibration hanger is at rest; i.e. it must not swing or turn. RST-CONTROL 95 will then measure the shear force.

After the above has been completed, the calibration weight 27 should be attached to the calibration hanger 26 (Figure 7.13).

After the large calibration weight has been attached, take care to ensure that the calibration weight is at rest; i.e., it must not swing or turn,

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and must not touch any part of the Ring Shear Tester. RST-CONTROL 95 will then measure the shear force.

A portion of the procedure outlined above may need to be repeated if prompted by RST-CONTROL 95.

The entire procedure is then repeated with the other load beam. For this, the Ring Shear Tester must be turned and placed on its right side. This also must be done with the help of a second person.

Finally, RST-CONTROL 95 will calculate the sensitivity of the shear force measurement from the known calibration weight and the measured calibration signals.

The offset (zero) value of the shear force will be checked each time after starting RST-CONTROL 95, and at the beginning of each test. RST-CONTROL 95 will tell the user to ensure that the tie rods 11 are not attached to the load beams, so that no force can act on the load beams. The shear force measured in this case is taken as the offset value. Please follow the instructions on the computer screen.

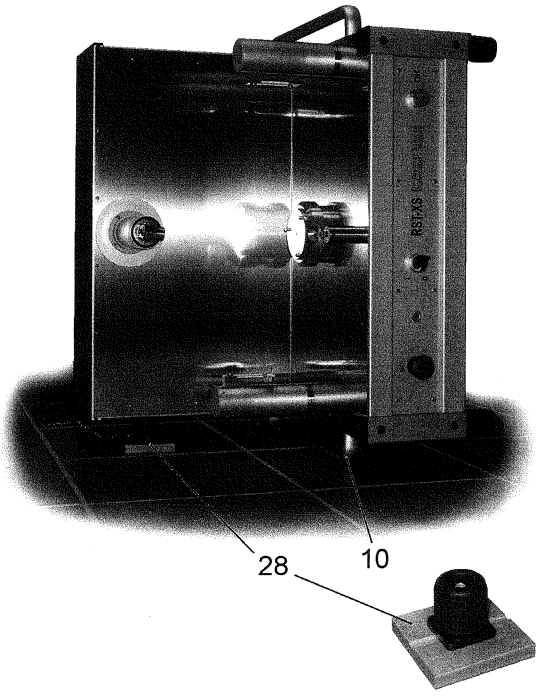


Figure 7.11: Ring Shear Tester, resting on its left side; calibration support 28

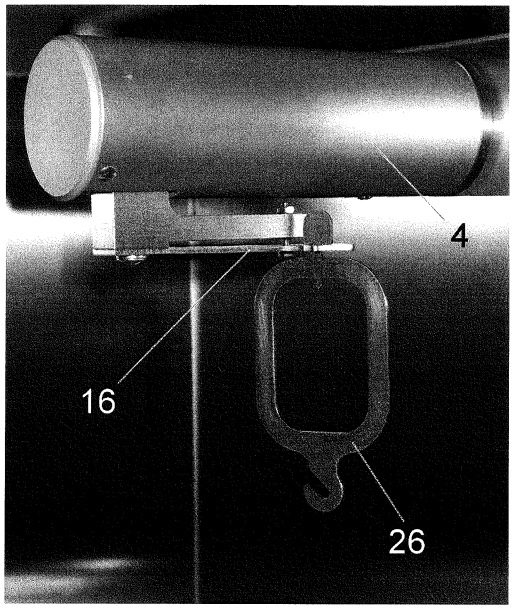


Figure 7.12:Calibration hanger 26 attached to adjustable seating 16 of the right shear force transducer 4

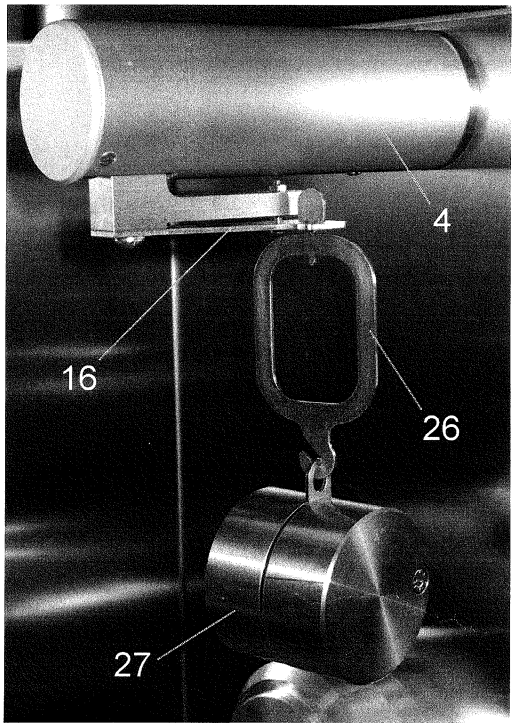


Figure 7.13: Calibration weight 27 attached to calibration hanger 26

7.4.3 Calibration of the displacement transducer

The system for measurement of the lid displacement and, thus, the height of the bulk solid specimen, is found within casing 1. It is connected mechanically to the normal load system 3.

The lid displacement 0 mm (Δh = 0 mm) is defined at this position, where the horizontal underside of the lid 7 is in the same plane as the upper edge of the bottom ring 6. In this position the bars beneath the lid (or the pyramids in case of a lid with pyramidal pattern) are below the upper edge of the bottom ring 6.

The maximum vertical displacement of the lid of a standard shear cell type XS-M is about Δh = 8 mm, as measured from the starting position (lower side of the lid in the same plane as the upper edge of the bottom ring, i.e., Δh = 0 mm).

7.4.3.1 Sensitivity (span calibration)

The displacement transducer sensitivity calibration must be performed using the RST-CONTROL 95 control software. In the "Ring Shear Tester" pulldown menu, select the "Tester adjustments and checks" command, then "Lid displacement calibration". The program will guide the user through the procedure. An overview of the procedure follows:

The bottom ring 6 of a shear cell (only a standard cell type XS-M or XS-Mr; if not available use a shear cell type XS-L or XS-Lr) is placed on driving axle 5 of the Ring Shear Tester. Lid 7 is then placed on the bottom ring, and the loading rod 9 is inserted between crossbeam 8 and the conical receiver 10 of the normal load system.

The spacer blocks 24 and 25 (Figure 7.14) have a height of 2 mm (spacer block 24) and 8 mm (spacer block 25), measured parallel to the axis of their bore. Two spacer blocks of the same dimensions are placed at two opposite points on the upper edge of the bottom ring 6, just below the crossbeam 8 (Figure 7.15). If shear cell type XS-L is

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used, the spacer blocks must be placed on the inner wall of the bottom ring. Depending on the height of the spacer blocks, the distance between the lower edge of crossbeam 8 and the upper edge of the bottom ring 6 is then 2 mm or 8 mm.

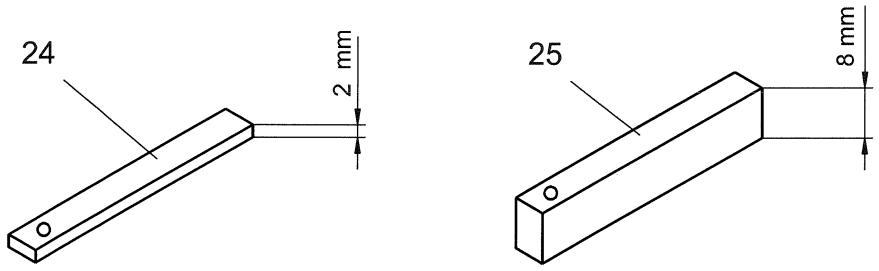


Figure 7.14: Spacer blocks 24 and 25 with bores

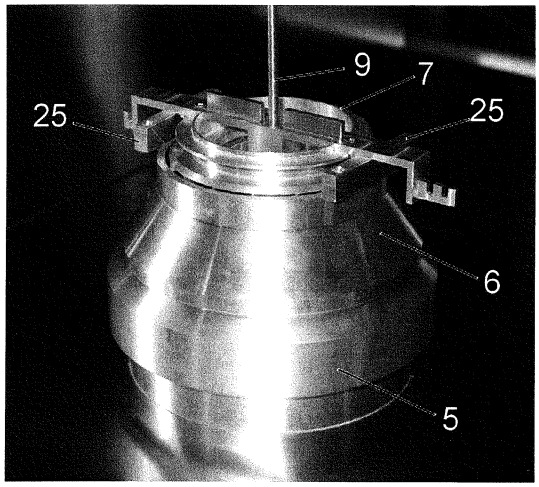


Figure 7.15: Shear cell with spacer blocks 25 (8 mm); bores oriented vertically

First, RST-CONTROL will ask you to place the spacer blocks 25 (8 mm) between bottom ring and crossbeam. Throughout this procedure, lid 7 has the same vertical position as at maximum specimen height; i.e., the bottom ring is filled up to the upper edge with bulk solid, but the specimen is not compressed by the lid (only the bars beneath the lid or the pyramids in case of a lid with pyramidal pattern are below the upper edge of the bottom ring). With the unit in this position, RST-CONTROL 95 will measure the vertical position of the lid.

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When the above has been completed, lid 7 must be lifted somewhat. Spacer blocks 25 are removed and spacer blocks 24 (2 mm) are placed between bottom ring and crossbeam.

Note: Do not place the spacer blocks below the local projection at the underside of the crossbeam (Figure 7.17)!

By utilizing the spacer blocks 24, the vertical distance between the lower edge of crossbeam 8 and the upper edge of bottom ring 4 is reduced to 2 mm.

RST-CONTROL 95 again will measure the vertical position of the lid. With this information, RST-CONTROL 95 knows the sensitivity of the displacement transducer for measuring the vertical position of the lid.

The **sensitivity** of the displacement transducer will essentially not change with time as long as the construction of the Ring Shear Tester remains unchanged and the adjustments of the electronic system are not changed. It is advisable, however, to check the calibration value at certain time intervals, after transport, and after long periods without use.

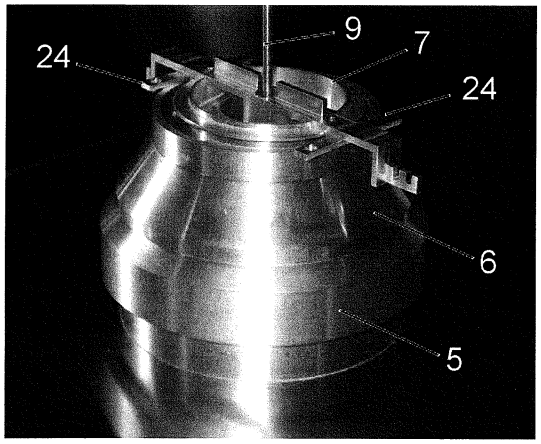


Figure 7.16: Shear cell with spacer blocks 26 (2 mm); bores oriented vertically

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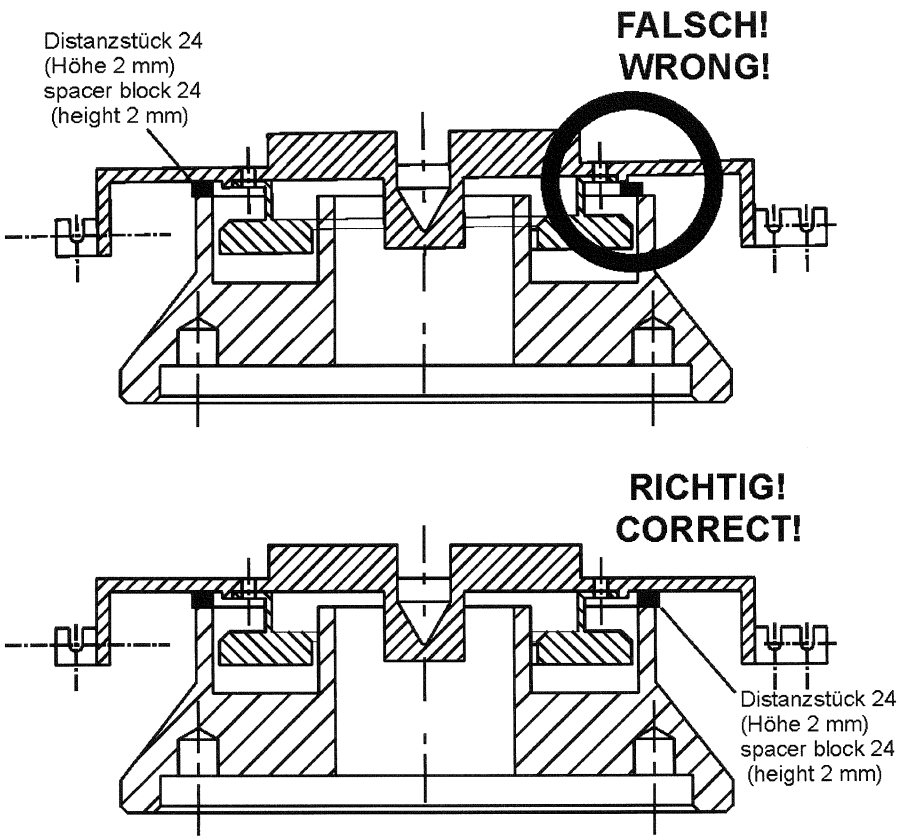


Figure 7.17: Correct and wrong placement of spacer blocks 24:
IMPORTANT: Spacer block must not be located below the local projection at the underside of the crossbeam!

7.4.3.2 Offset calibration

The displacement transducer offset calibration must be performed with each shear cell, using the RST-CONTROL 95 control software. In the "Ring Shear Tester" pulldown menu, select the "Tester adjustments and checks" command, then "Lid displacement - offset". The program will guide the user through the procedure. An overview of the procedure follows:

The bottom ring 6 of the shear cell (for which the offset position of the lid must be determined) is placed on driving axle 5 of the Ring Shear Tester. Then lid 7 must be put on the bottom ring, and loading rod 9 must be inserted between the crossbeam 8 and the conical receiver 10 of the normal load system 3.

First, RST-CONTROL will ask you to place the spacer blocks 25 (height 8 mm, Figure 7.14) between bottom ring 6 and crossbeam 8. Throughout this procedure, lid 7 has the same vertical position as at maximum specimen height; i.e., the bottom ring is filled up to the upper edge with bulk solid, but the specimen is not compressed by the lid (only the bars beneath the lid or the pyramids in case of a lid with pyramidal pattern are below the upper edge of the bottom ring). This position of the lid is the position at vertical displacement $\Delta h = 0$. After this position has been established, RST-CONTROL 95 will measure the vertical position of the lid and store it as the offset, or zero, value for the shear cell used.

When the above has been completed, the spacer blocks 25 must be removed from the shear cell so that the lid can move to its lowest possible position; i.e., depending on the type of shear cell, the crossbeam 8 will lie directly on the bottom ring, or the lid will touch the bottom of the bottom ring. RST-CONTROL 95 again will measure the vertical position of the lid and store it as the lowest possible position.

With this information RST-CONTROL 95 knows the offset (zero) value of the lid displacement as well as the maximum displacement for the shear cell used.

The **offset values** of the lid displacement will essentially not change with time as long as the construction of the Ring Shear Tester remains

unchanged and if the adjustments of the electronic system are not changed. It is advisable, however, to check the offset values at certain time intervals, after transport, and after periods without use.

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7.5 Maintenance

Consider the safety instructions, particularly Section 4.5, prior to conducting maintenance.

To ensure the required function of the Ring Shear Tester, the following measures of maintenance and precaution are necessary:

- Keep the working table 20 of the Ring Shear Tester and all elements on it clean, particularly the shear force transducers 4, the horizontal guiding system 2, and the normal load system 3.

- Do not use the Ring Shear Tester in dusty environments as well as in condensing atmospheres (see Section 5, Technical data). Use appropriate de-dusting equipment.

- Always remove bottom ring 6 from the Ring Shear Tester for filling. Under no circumstances should the bottom ring be filled while it is resting on the driving axle 5.

- Lid 7 must be placed carefully on the filled bottom ring 6. If this is not done, the bulk solid inside the shear call might become compressed so fast that some of the bulk solid will escape with the air through the gap between the bottom ring and the lid. This might yield pollution of the tester and other instruments.

- After completion of a measurement, remove bottom ring 6 with lid 7 from the Ring Shear Tester. Never remove lid 7 from bottom ring 6 while it is still resting on the driving axle 5.

- Clean the Ring Shear Tester working table 20 and the elements on it regularly.

- Clean the Ring Shear Tester only with dry media. Do not use harsh detergents. Use lint-free cleaning rags. Only the bottom ring and the lid may be washed in warm water, and only without any harsh detergents.

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- Clean handles 18 regularly to keep them free from dirt (e.g. bulk solid) and oil.

- It is not generally necessary to open casing 1, since the used gears, bearings, etc. are well designed with respect to applied loads at normal and designated use. If the Ring Shear Tester must be opened, it must first be disconnected from the power supply and the PC.

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8 Testing

Assumption: The user of the Ring Shear Tester is familiar with the principles of measuring flow properties with shear testers [3].

8.1 Flow properties (yield loci)

The measurement procedure must be performed with the aid of the RST-CONTROL 95 control program [5]. Although RST-CONTROL 95 may be used in semi-automatic or automatic mode, preparation of the tester is independent of the mode used.

Before each test, the Ring Shear Tester must be in the "start position" (use the "Adjust start position" command of RST-CONTROL 95; usually this position is adjusted automatically at startup of RST-CONTROL 95 and after each test).

Prepare the shear cell as follows when starting a test:

1. Fill the shear cell bottom ring 6 uniformly in small portions with a spoon or spatula (Figure 8.1.a) without applying force to the surface of the material until the material is somewhat above the top of the bottom ring wall. Filling should be conducted so as to ensure that there are no voids within the bottom ring and the specimen is largely homogeneous. With very fine bulk solids it can be advantageous to fill in the bulk solid with the help of a sieve. In this case, do not press the sieve on the bulk solid filling.
   Note: The more homogeneously the shear cell is filled, the better the reproducibility and accuracy of the measurements.

2. Remove excess material from the cell by scraping off with a rigid, sharp, straight blade or spatula until the bulk solid is flush with the top of the bottom ring 6 (Figure 8.1.b). A spatula having a rigid, sharp, straight blade at least 50% longer than the width of the annulus of the bottom ring is recommended. The blade should first be scraped counterclockwise across the ring once or twice in a zigzag motion. Then the blade should be scraped around the annulus

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counterclockwise, as shown in Figure 8.2.a, where the blade should be inclined at an angle α = 15 to 30° to the radial direction. The blade should be held vertically or tilted by a few degrees to the vertical (angle β =0° to 10°) as shown in Figure 8.2.b. Do not exert a downward force on the material with the blade.
Note: If coarse particles are present, scraping may tear them from the surface and alter the structure. In such cases it is better to attempt to fill the cell so that the material surface is flush with the annulus after filling.

3. If necessary, clean the outside of the bottom ring 6. Weigh the bottom ring with contents. Note the total mass m_{tot}.

4. When prompted by RST-CONTROL 95, put the filled bottom ring 6 on the driving axle 5 (Figure 8.3). Ensure that the bolts on top of the driving axle 5 engage the bores beneath the bottom ring 6.

5. When prompted by RST-CONTROL 95, place the lid on the powder specimen as follows: Hold the lid 7 somewhat above the bottom ring, whereby the side of the crossbeam 8 with two cutouts must be directed to the front side of the tester. Connect the guiding bar 13 to the outer cutout of crossbeam 8 as shown in Figures 8.4 and 8.5. Then **carefully** position the lid concentrically on the bottom ring in a position rotated about 1 degree counterclockwise to its shear position (Figure 8.5). (Note: Shear position means that the longitudinal axis of the crossbeam is perpendicular to the front edge of the casing 1. The shear position is the position shown in Figure 7.6.)
Insert the loading rod 89 between the crossbeam 8 and the conical receiver 10 at the normal load system 3 **without** exerting force on the crossbeam 8 or the lid 7 (Figure 8.6.a). First push the loading rod 9 into the conical receiver 10 from below, thereby raising the normal load system until you can move the lower tip of the loading rod above the central notch of the crossbeam 8. Then carefully lower the loading rod until the normal load system comes to resting position.

6. When prompted by RST-CONTROL 95 (**not before**), place tie rods 11 in the cutouts of the crossbeam 8 (on the side with two cutouts use the inner one) and the cutouts of the adjustable seatings 16 of the shear force transducers 4 (Figure 8.6.b). This should be possi-

ble due to the slightly rotated position of the lid (as described in step 5). Tie rods 11 should have some clearance in the seatings 16; i.e., the tie rods **must not be stressed.** The set-up should now look like that shown in Figure 8.7.
Attention! If it is not possible to connect the tie rods as described above, do not rotate the lid while it is resting on the bulk solid specimen because this will lead to incorrect test results. Use only the motor drive to rotate the shear cell to an appropriate position. The active window of RST-CONTROL 95 displays "forward", "backward", and "stop" buttons, which can be used to rotate the shear cell to an appropriate position. Alternatively, the load beams for shear force measurement can be used (please refer to the RST-CONTROL 95 manual).

Please follow further program instructions.

After the test is finished, the shear cell must be removed from the tester. Please proceed as follows:

7. Remove tie rods 11.

8. Remove loading rod 9: First push the loading rod upwards, raising the normal load system until you can move the lower tip of the loading rod horizontally without touching crossbeam 8.

9. Take off the bottom ring 6 along with the lid 7.

10. Empty the shear cell; if necessary, clean the bottom ring, the lid, and the driving axle.

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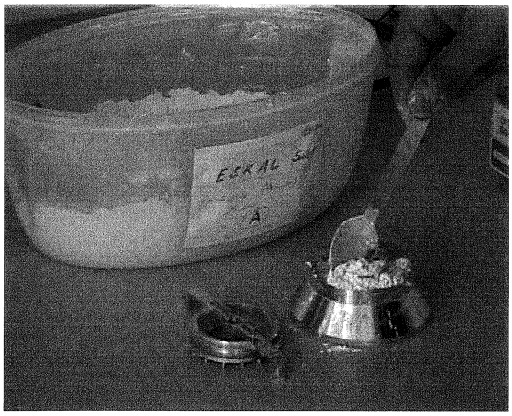


Figure 8.1.a: Filling

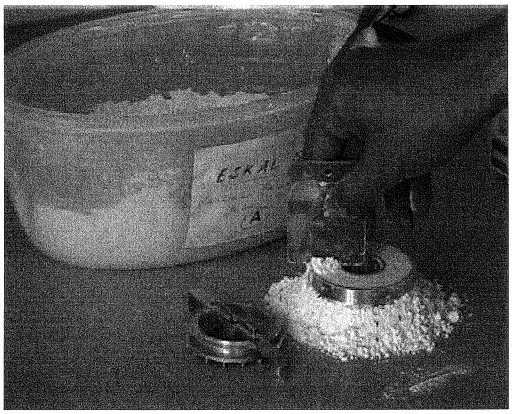


Figure 8.1.b: Scraping off excess powder

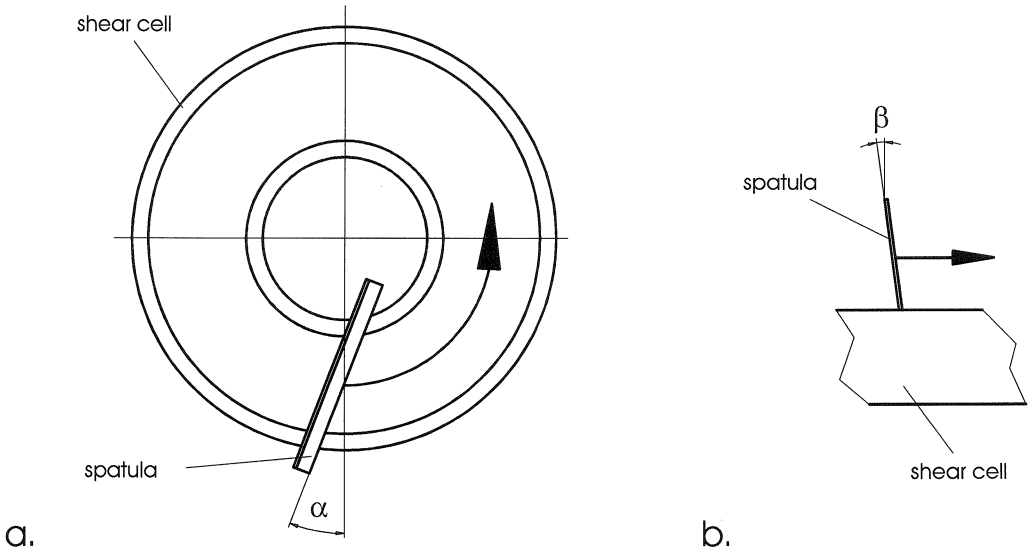
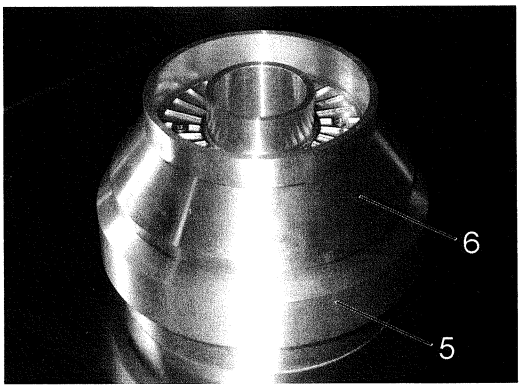


Figure 8.2: Scraping off excess powder



a.



b.

Figure 8.3: a. Placing the bottom ring 6 on the driving axle 5
b. Bottom ring on driving axle (here: bottom ring not filled)

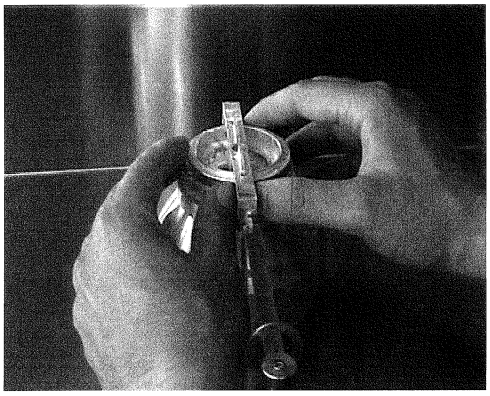


Figure 8.4: Placing the lid (connected to the guiding bar 13) on the powder specimen

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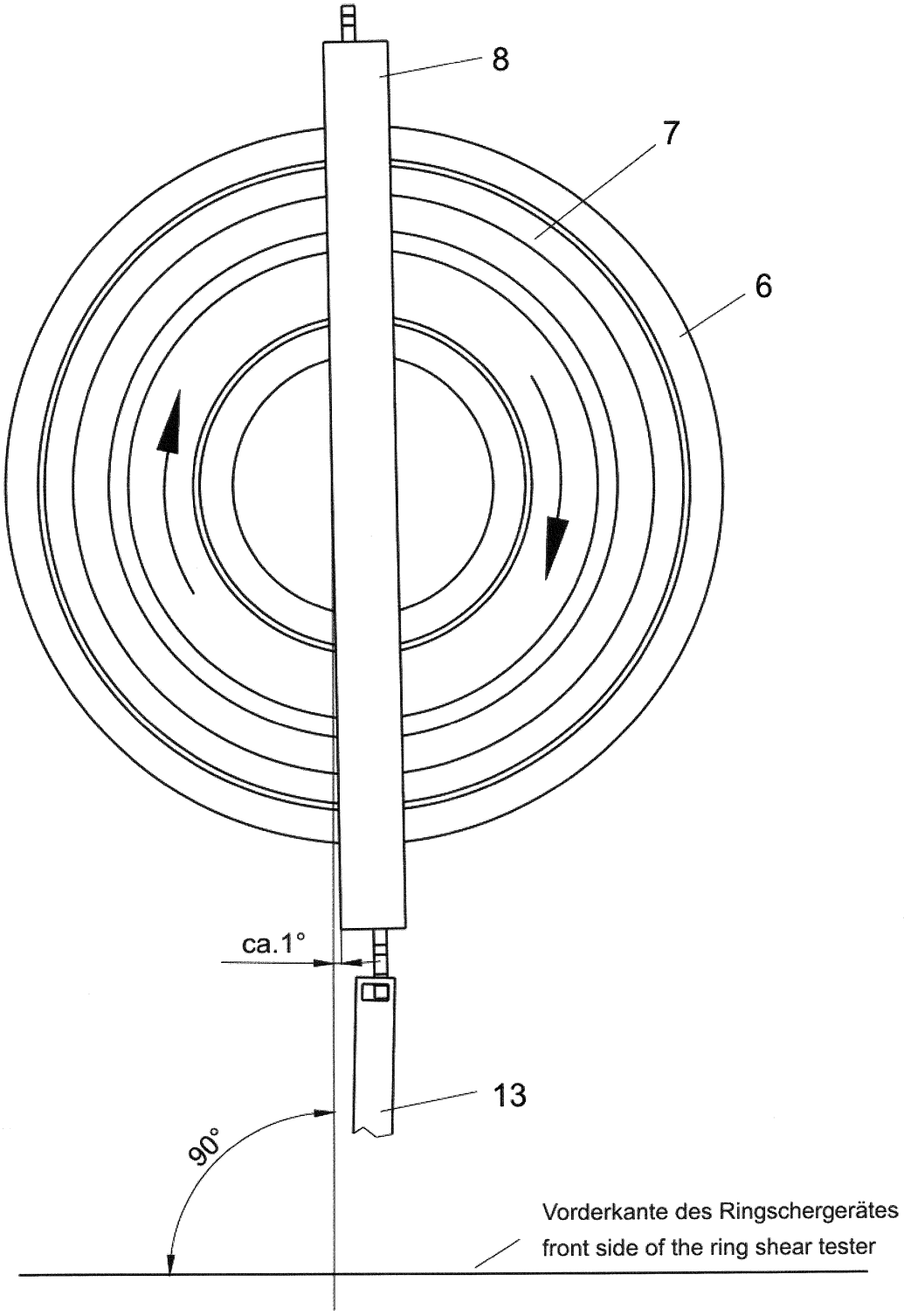
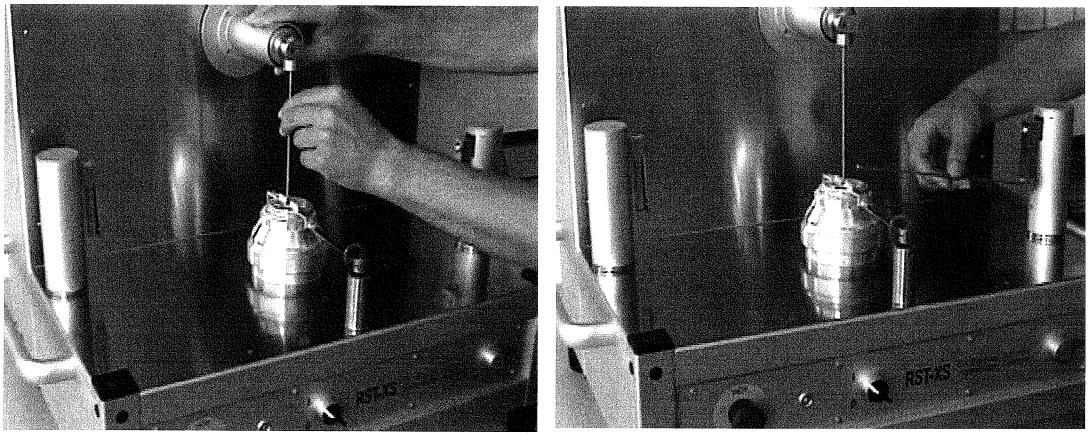


Figure 8.5: Position of the lid 7 when placed on the bottom ring 6



a. b.

Figure 8.6: a. Inserting the loading rod 9
b. Inserting the tie rods 11 (here: right tie rod)

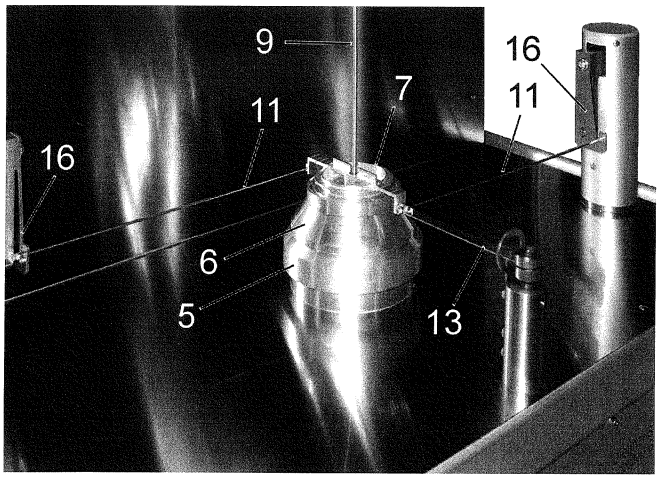


Figure 8.7: Bottom ring 6 and lid 7 connected to loading rod 9, tie rods 11 and guiding bar 13

8.2 Time consolidation tests

RST-CONTROL 95 can perform a complete time consolidation test where the bulk solid specimen is stored on the Ring Shear Tester during time consolidation. In this case, the shear cell must not be removed from the tester until the test is finished. To perform a time consolidation test where the specimen is stored on the tester, choose the "Complete" option in RST-CONTROL 95. Complete steps 1 to 6 as described in Section 8.1. RST-CONTROL 95 will then perform the entire test procedure, including storage. After termination of the test, complete steps 7 to 10 of Section 8.1.

It is also possible to store the filled shear cell separately from the Ring Shear Tester, e.g. in a time consolidation bench. After preshear, which is performed by RST-CONTROL 95, the shear cell with bulk material is removed from the Ring Shear Tester and placed in the time consolidation bench. The time consolidation bench allows the specimen to be stored at rest under load for the required consolidation period. Then the shear cell is set on the Ring Shear Tester again and sheared. If the bulk solid tested shows a time consolidation effect, the measured shear force will be larger.

The individual steps in performing a time consolidation test using the Ring Shear Tester are:

1. Prepare the test corresponding to steps 1 to 6 in Section 8.1. The bulk solid specimen must be presheared by RST-CONTROL 95 ("Preshear" program option). Wait until RST-CONTROL 95 has finished preshear and the tie rods 11 are relieved.

2. Carefully remove the already relieved tie rods 11.

3. Carefully remove loading rod 9: First push the loading rod upwards, raising the normal load system until you can move the lower tip of the loading rod horizontally **without** touching crossbeam 8.

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If you are using time consolidation bench type XS1-C, please proceed as follows:

4. Preparation of the time consolidation bench: Loading rod Z8 must be locked in the upper position with fixed screw Z7 (Figure 8.8).

5. Remove the bottom ring 6 along with the lid 7 from the driving axle 5 carefully and without vibrations. Place the shear cell on the supporting plate Z3 of the time consolidation bench (Figure 8.9).

6. Hold loading rod Z8 with one hand and loosen locking screw Z7. Then carefully lower the loading rod Z8 until the protective lid Z4 rests on the protective wall Z2. Take care that the upper edge of the protective wall Z2 engages with the annular channel beneath the protective cover Z4 (Figure 8.10).

7. Carefully lower the loading rod Z8 further, until the tip at the lower end of the loading rod rests in the central depression of the crossbeam 8.
   Attention! The loading rod Z8 must not be locked in this position with the locking screw Z7.

8. Select the weight m_{Wt} such that the stress state in the specimen during time consolidation is the same as during preshear (i.e., same principal stress as at steady-state flow) [3]. The calculation of the weight m_{Wt} is described in the RST-CONTROL 95 manual, and RST-CONTROL 95 can help to calculate the weight.
   Carefully put the appropriate weights Z9 on disk Z6 of the time consolidation bench.

9. Store the specimen under load for the given time interval.
   Note: The time consolidation bench should not be subjected to shocks or vibrations during this time. Also pay attention to temperature effects.

10. Carefully remove the weight pieces Z9 from the time consolidation bench.

11. Carefully pull loading rod Z8 upward until rubber bellow Z5 is strained somewhat. Lift protective cover Z4 with your hand, then

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pull the loading rod Z8 further upward. Lock loading rod Z8 in its upper position with locking screw Z7. Then proceed with step 12.

If you are using time consolidation bench type XS1-O, please proceed as follows:

4. Preparation of the time consolidation bench: Pull disk Z12 upward (Figure 8.12).

5. Remove the bottom ring 6 along with the lid 7 from the driving axle 5 carefully and without vibrations. Put the shear cell on the supporting plate Z15 of the time consolidation bench (Figure 8.13).

6. Carefully push the loading rod Z14 into the centric deepening of crossbeam 8. Then move disk Z12 and thread Z13 downward until the loading rod is constrained between crossbeam and thread (Figure 8.13).

7. Turn disk Z12 until the lateral bars of the parallel guide are directed approximately horizontally (as in Figure 8.13).

8. Select the weight m_{Wt} such that the stress state in the specimen during time consolidation is the same as during preshear (i.e., same principal stress as at steady-state flow) [3]. The calculation of the weight m_{Wt} is described in the RST-CONTROL 95 manual, and RST-CONTROL 95 can help to calculate the weight.
   Carefully put the appropriate weights on disk Z12 of the time consolidation bench.

9. Store the specimen under load for the given time interval.
   Note: The time consolidation bench should not be subjected to shocks or vibrations during this time. Also pay attention to temperature effects.

10. Carefully remove the weight pieces from the time consolidation bench.

11. Carefully pull disk Z12 upward and remove loading rod Z14.

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The next steps are for both types of time consolidation benches:

12. Remove the shear cell (bottom ring 6 along with the lid 7) from the time consolidation bench carefully and without vibrations. Put the shear cell on driving axle 5 of the Ring Shear Tester.

13. Carefully insert loading rod without disturbing the specimen (for details see Section 8.1, step 5).

14. Place tie rods 11 on both the cutouts at the ends of the crossbeam 8 and the adjustable seating 16. The tie rods 11 should have some clearance in the seatings 16; i.e., the tie rods **must not be stressed**.
    If it is not possible to connect the tie rods as described above, use the motor drive to rotate the shear cell to an appropriate position. The active window of RST-CONTROL 95 displays "forward", "backward", and "stop" buttons, which can be used to rotate the shear cell to an appropriate position; alternatively, the load beams for shear force measurement can be used as "buttons" (please refer to the RST-CONTROL 95 manual).

15. The bulk solid specimen must be sheared to failure by RST-CONTROL 95 ("Shear" program option).

16. Complete the test by following steps 7 to 10 in Section 8.1.

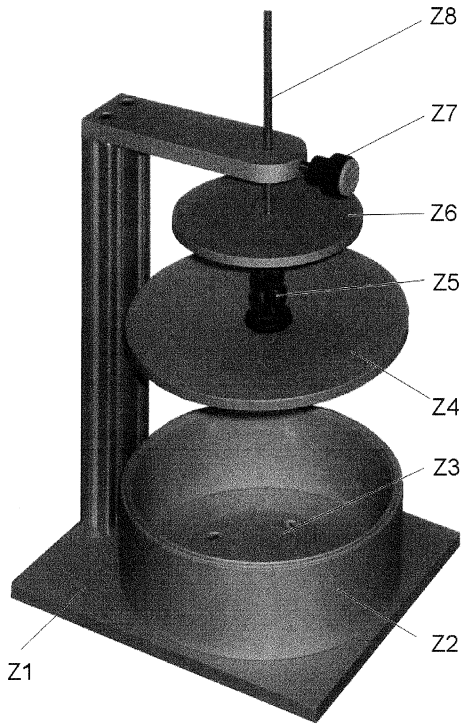


Figure 8.8: Time consolidation bench XS1-C for one shear cell

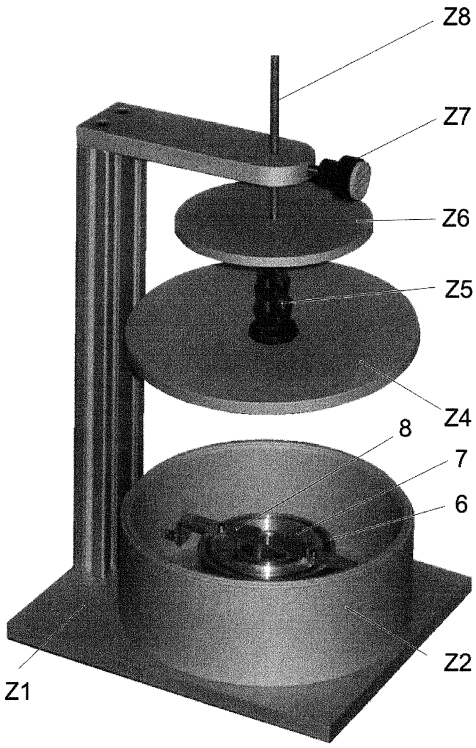


Figure 8.9: Time consolidation bench XS1-C with shear cell XS-Mr, loading rod Z8 locked in upper position

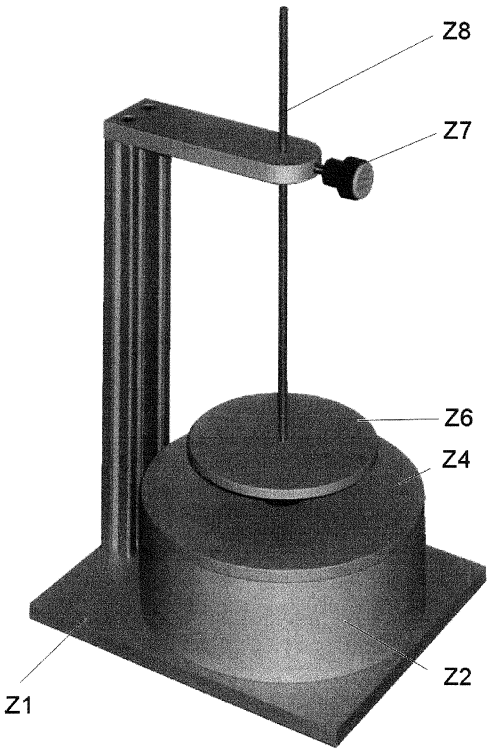


Figure 8.10: Time consolidation bench XS1-C, loading rod Z8 in loading position

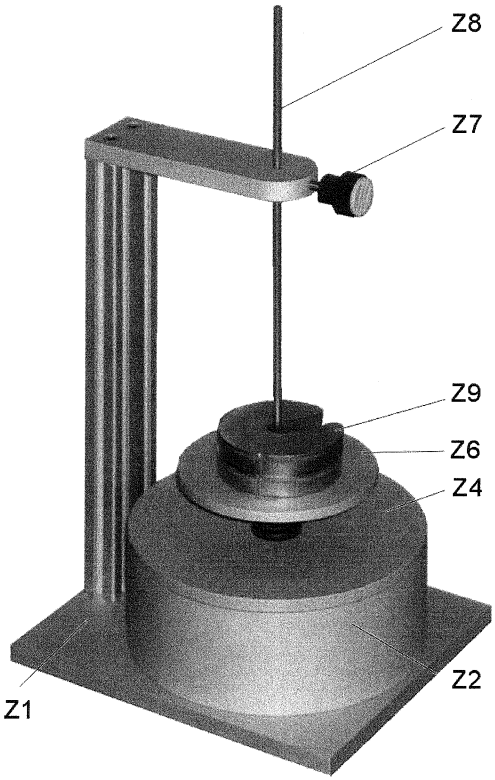


Figure 8.11: Time consolidation bench XS1-C with weights Z9

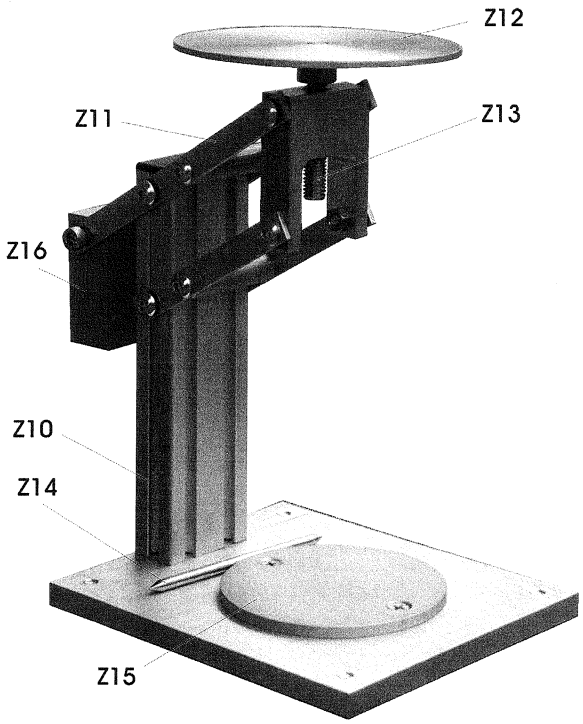


Figure 8.12: Time consolidation bench XS1-O

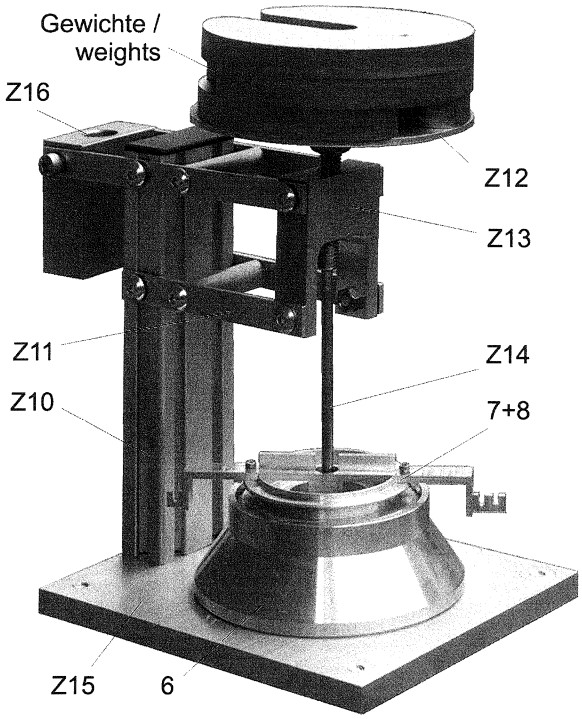


Figure 8.13: Time consolidation bench XS1-C with shear cell and weights

8.3 Wall friction tests

To measure a wall yield locus, follow the same steps as outlined in Section 8.1, with the exception that the bottom ring of the wall shear cell must be prepared and weighed before filling. Hence, perform the following steps:

1. Set up the wall friction cell (see Figure 6.8): Insert the spacer rings 43 and the wall material sample in the bottom ring 40. The distance between the upper edge of the bottom ring 40 and upper surface of the wall material sample should total about 4 mm.

2. Weigh the bottom ring 40 with contents. Note the total mass m_W.

3. Go to step 1 in Section 8.1 and follow the RST-CONTROL 95 instructions.

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8.4 Time wall friction tests

A time wall friction test is conducted to measure a point of a time wall yield locus.

RST-CONTROL 95 (version 2 or higher) can perform a complete measurement of a point of a time wall yield locus where the bulk solid specimen is stored on the Ring Shear Tester for time consolidation. In this case, the shear cell must not be removed from the tester until the test is finished. To perform a time wall friction test where the specimen is stored on the tester, choose the "Complete" option in RST-CONTROL 95. Follow the steps described in Section 8.3 (wall friction test). RST-CONTROL 95 will perform the entire test procedure, including storage.

It is also possible to store the filled shear cell separately from the Ring Shear Tester, e.g. in a time consolidation bench. After preshear, which is performed by RST-CONTROL 95, the shear cell with bulk material is removed from the Ring Shear Tester and placed in the time consolidation bench. The time consolidation bench allows the specimen to be stored at rest under load for the required consolidation period. Then the shear cell is set on the Ring Shear Tester again and sheared.

The individual steps in performing a time wall friction test using the Ring Shear Tester are:

1. Prepare the test corresponding to steps 1 and 2 in Section 8.3 (wall friction test) and following steps 1 to 6 in Section 8.1 (flow properties).

2. The bulk solid specimen must be prepared by shearing, and then presheared by RST-CONTROL 95 ("Preshear" program option). Wait until RST-CONTROL 95 has finished preshear and the tie rods 11 are relieved.

3. Perform steps 2 to 16 in Section 8.2 (time consolidation tests) and follow the RST-CONTROL 95 instructions.

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8.5 Compressibility tests

Perform the steps outlined in Section 8.1 and follow the instructions of RST-CONTROL 95.

The compressibility test option is available in RST-CONTROL 95 version 2.1 or higher-

8.6 Attrition tests

Perform the steps outlined in Section 8.1 and follow the instructions of RST-CONTROL 95.

The attrition test option is available in RST-CONTROL 95 version 2.1 or higher-

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9 Assembly after delivery

Assemble the Ring Shear Tester in the below-mentioned sequence. Please note that some figures mentioned in this section can be found in these operating instructions.

Danger!
Before you start, please read the safety instructions.
Consider the safety instructions while assembling the Ring Shear Tester.

Danger!
Carry the Ring Shear Tester only by the handles. Never carry the Ring Shear Tester by the shear force transducers 4, the normal load system 3, or the horizontal guiding system 2.

Attention!
Pay close attention to ensure that no part becomes damaged by bending. Bent components in the Ring Shear Tester can result in erroneous measurements.

Directions for assembly:

1. Read Section 6, Construction.

2. Remove all adhesive tape used for securing during transport.

3. Carefully unpack all parts.

4. Set the guiding bar 13 on the adjustable bracket 14 of the horizontal guiding system 2 (Figure 9.1). The smaller part of the counterweight at the adjustable bracket must be on top. If the system is equipped with a protective sheath (from 2008), insert the guiding bar as shown in Figure 9.2.

5. Place the tie rods 11, the loading rod 9, and the shear cell(s) on the table close to the tester.

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6. Check the EMERGENCY-STOP button: It must not be in the push position.

   The tester is now set up mechanically (Figure 9.3). Before connecting any of the cables, read the sections referred to in the next steps.

7. Connect the power supply to the Ring Shear Tester: see Section 7.1.

8. Connect the PC to the Ring Shear Tester: see Section 7.2.

9. Tester adjustments: see Section 7.3.

10. Handling of the shear cell (bottom ring 6, lid 7 with crossbeam 8, tie rods 11): see Section 8.

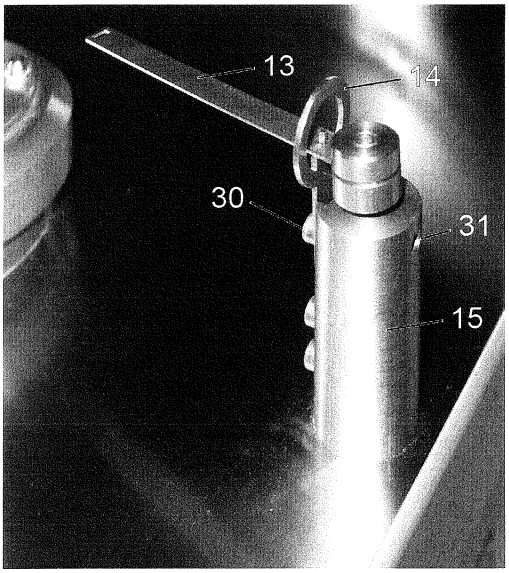


Figure. 9.1: Horizontal guiding system (complete; design without protective sheath)

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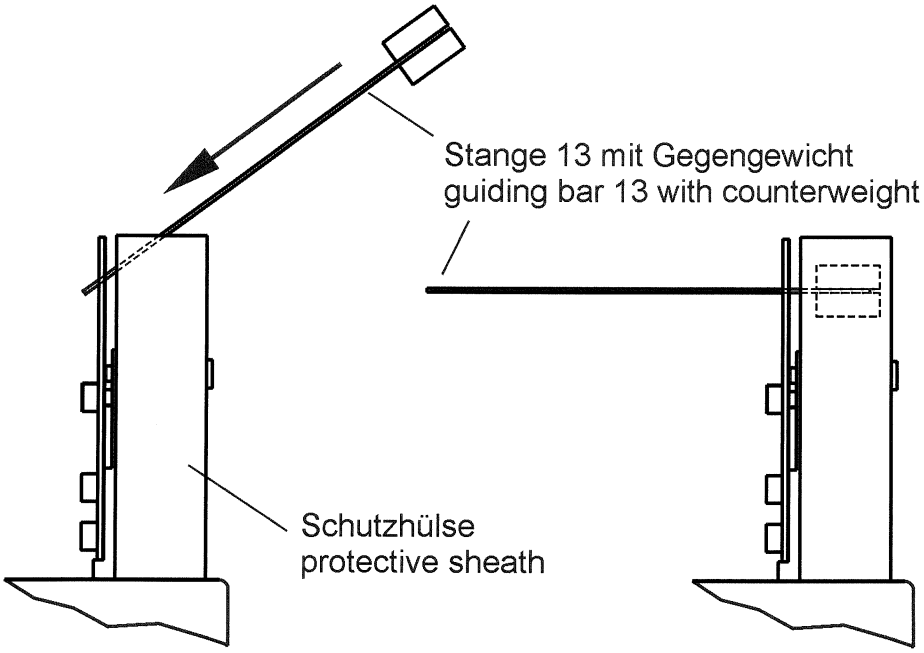


Figure. 9.2:Insertion of guiding bar 13 (new design of 2008 with protective sheath)

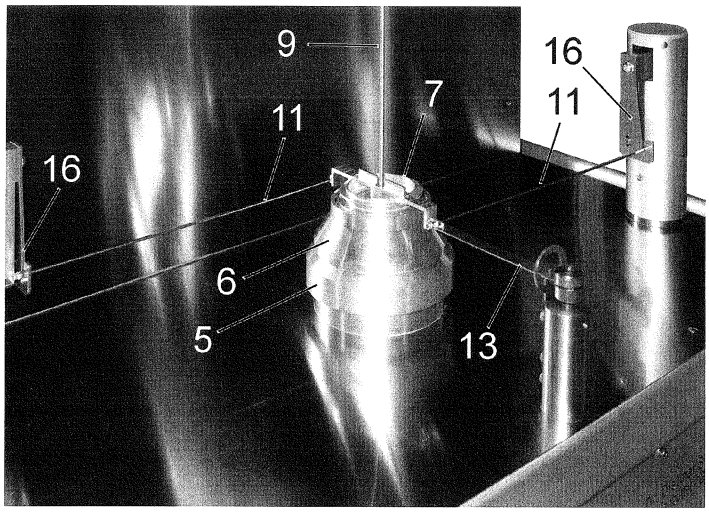


Figure 9.3: Ring shear tester RST-XS, set up completely

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10 Transport

To avoid damage to the unit, the Ring Shear Tester must be prepared for transport.

1. Adjust the transport mode with the RST-CONTROL 95 software ("Ring shear tester" menu).

2. Switch off the Ring Shear Tester and the PC. Disconnect the power supply from the mains. Disconnect all cables from casing 1 of the Ring Shear Tester.

3. Remove all parts that are connected loosely to the Ring Shear Tester: shear cell (bottom ring 6, lid 7), tie rods 11, loading rod 9, guiding bar 13.

Danger!
Consider the applicable safety regulations when disassembling, assembling, or transporting the Ring Shear Tester.

Attention!
Pay close attention to ensure that no part becomes damaged by bending during transportation.

Danger!
Carry the Ring Shear Tester only by the handles.

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11 Parts

casing 1
horizontal guiding system 2
normal load system 3
shear force transducer 4
driving axle 5
bottom ring of shear cell 6
lid of shear cell 7
crossbeam at the lid of the shear cell 8
loading rod 9
conical receiver for loading rod (at normal load system) 10
tie rod 11
adjusting screw for normal load system 12
guiding bar with counterweight 13
adjustable bracket (at horizontal guiding system) 14
bearer (horizontal guiding system) 15
adjustable seating at shear force transducer 16
adjustable stand 17
handle 18
storage tube 19
working plate 20
rear wall 21
front panel 22
OK-button 23
spacer block 2 mm 24
spacer block 8 mm 25
calibration hanger 26
calibration weight 27
calibration support 28
adjusting screw at shear force transducer 4 29
adjusting screw (cylinder head screw) at horizontal guiding system 2 30
adjusting screw (grub screw) at horizontal guiding system 2 31

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Wall friction cell (option):

bottom ring of wall friction cell	40
lid of wall friction cell	41
driving pin for fixation of the wall material sample	42
spacer ring for wall friction cell	43
crossbeam at the lid of the wall friction cell	44

Time consolidation bench XS1-C (option):

frame	Z1
protective wall	Z2
supporting plate	Z3
protective cover	Z4
rubber bellow	Z5
disk for weights	Z6
locking screw	Z7
loading rod	Z8
weight	Z9

Time consolidation bench XS1-O (option):

frame	Z10
parallel guide	Z11
disk for weights	Z12
thread (at disk Z12)	Z13
loading rod	Z14
supporting plate	Z15
counterweight	Z16

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12 Literature

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14 Shear Cell Data Sheets

The shear cell data sheets contain information about the dimensions of the shear cells. There should be a data sheet for each shear cell.

Each shear cell must have a number (1 to 100), which must be noted on the shear cell data sheet. Additionally, the weight of the lid with crossbeam (m_D) and the bottom ring (m_{SZ}) must be determined before a shear cell is used for the first time.

After numbering and weighing the shear cells, some of the shear cell data must be entered in RST-CONTROL 95 and RSV 95. This is described in the program manuals.

Please note:

- The term "internal volume" V_{SZ} in the shear cell data sheets means the annular volume inside the bottom ring up to the upper edge of the shear cell. To get the net volume, the volume of the bars at the lid and the bars or bottom plate at the bottom of the bottom ring (volume V_{Mit}) must be subtracted from the internal volume V_{SZ}. Both values are listed in the shear cell data sheets.

- The volume of the bulk solid specimen (specimen volume) is dependent on the vertical position of the lid. Thus, the volume is calculated using the net volume (V_{SZ} - V_{Mit}), but additionally the vertical displacement of the lid is taken into account. The net volume (V_{SZ} - V_{Mit}) is equal to the specimen volume at a lid displacement Dh = 0 ($\Delta h = 0$).

- The "mean radius" for the specimen is the mean value of the inner and outer radius, i.e. $(r_{iSZ}+r_{aSZ})/2$. The RST-CONTROL 95 control program uses the mean radius as a representative radius for the calculation of shear displacement and shear velocity.

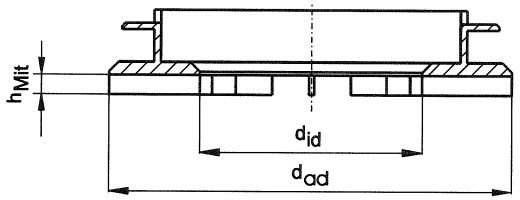
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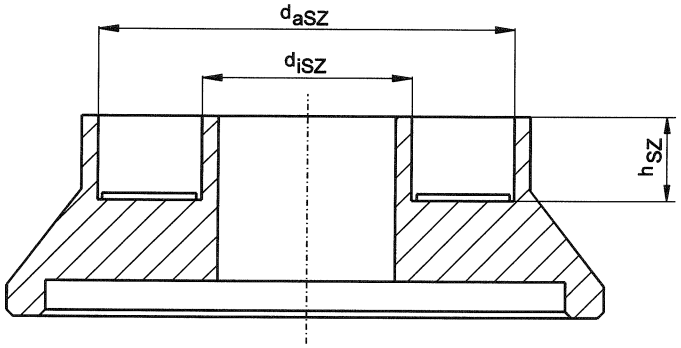
Shear cell data sheet

No. 1	
Type	XS-Mr (standard)
Material	AlMgCuPb, bottom plate 1.4301 (removable)
Shear cell:	
r_{iSZ} (inner radius of the annular internal volume)	16 mm = 1.6 cm
r_{aSZ} (outer radius of ...)	32 mm = 3.2 cm
d_{iSZ} (inner diameter of ...)	32 mm = 3.2 cm
d_{aSZ} (outer diameter of ...)	64 mm = 6.4 cm
h_{SZ} (height of ...)	13 mm = 1.3 cm
A_{SZ} (cross-sectional area ...)	24.13 cm^2
V_{SZ} (internal volume, internal bars and bottom plate not taken into account; $V_{SZ} = h_{SZ} \times A_{SZ}$))	31.37 cm^3
V_{Mit} (volume of the bottom ring + bars at the lid)	1.90 cm^3
h_{Mit} (height of bars)	3 mm = 0.3 cm
m_{SZ} (mass of the bottom ring with bottom plate)	~~318.8845~~ 318.776
Lid (annular):	
r_{iD} (inner radius of the annular lid)	15 mm = 1.5 cm
r_{aD} (outer radius of ...)	31 mm = 3.1 cm
d_{iD} (inner diameter of ...)	34 mm = 3.4 cm
d_{aD} (outer diameter of ...)	62 mm = 6.2 cm
A_D (cross-sectional area of the annular lid)	21.11 cm^2
m_D (mass of the annular lid with crossbeam)	~~30.785~~ 30.773

MANUF: METTLER TOLEDO
MODEL: PL303
Scale # 1188899
Serial # 1229150196
7/23/8 DP (5*5)

Please note: 1 m = 100 cm = 1000 mm = 39.37 in; 1 kg = 1000 g = 2.205 lb.



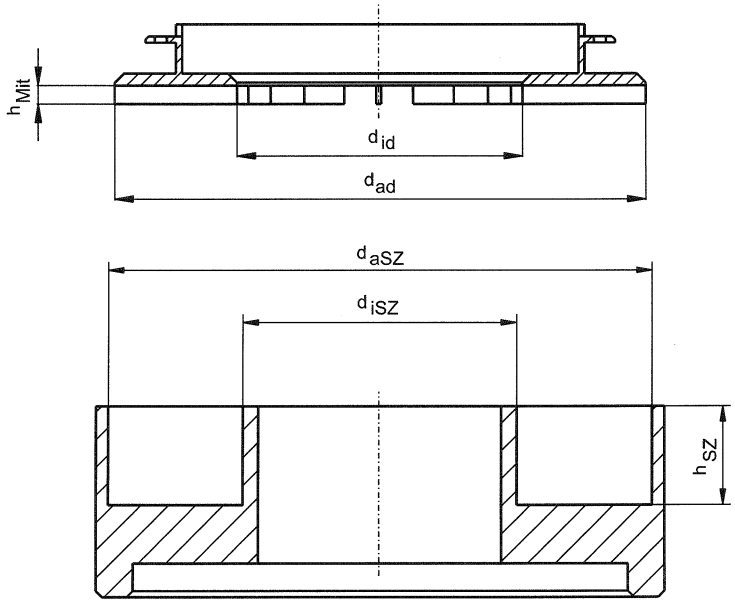


Shear cell data sheet

No. 2	
Type	XS-Lr (large)
Material	AlMgCuPb, bottom plate 1.4301 (removable)
Shear cell:	
r_{iSZ} (inner radius of the annular internal volume)	22 mm = 2.2 cm
r_{aSZ} (outer radius of ...)	44 mm = 4.4 cm
d_{iSZ} (inner diameter of ...)	44 mm = 4.4 cm
d_{aSZ} (outer diameter of ...)	88 mm = 8.8 cm
h_{SZ} (height of ...)	16 mm = 1.6 cm
A_{SZ} (cross-sectional area ...)	45.62 cm^2
V_{SZ} (internal volume, internal bars and bottom plate not taken into account; $V_{SZ} = h_{SZ} \times A_{SZ}$))	72.99 cm^3
V_{Mit} (volume of the bottom plate + bars at the lid)	3.00 cm^3
h_{Mit} (height of bars)	3 mm = 0.3 cm
m_{SZ} (mass of the bottom ring)	215.291
Lid (annular):	
r_{iD} (inner radius of the annular lid)	23 mm = 2.3 cm
r_{aD} (outer radius of ...)	43 mm = 4.3 cm
d_{iD} (inner diameter of ...)	46 mm = 4.6 cm
d_{aD} (outer diameter of ...)	86 mm = 8.6 cm
A_D (cross-sectional area of the annular lid)	41.47 cm^2
m_D (mass of the annular lid with crossbeam)	48.369

MANUF: METTLER TOLEDO
MODEL: PL303
Scale # 118889
Serial # 1229150196
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DP
(5+5)

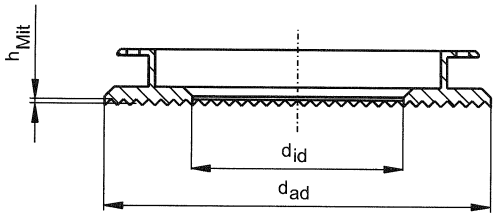
Please note: 1 m = 100 cm = 1000 mm = 39.37 in; 1 kg = 1000 g = 2.205 lb.

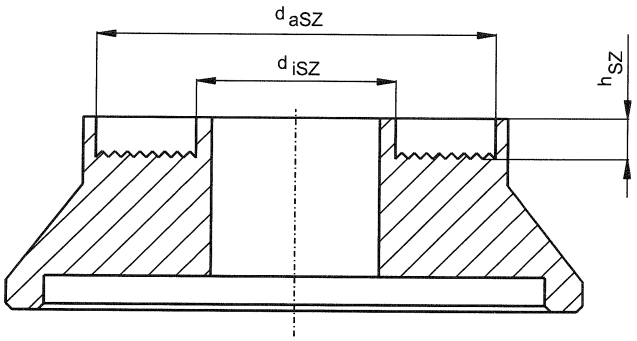


Shear cell data sheet

No.	
Type	XS-MV4 (as XS-Mr, but pyramidal pattern at bottom and lid; reduced internal height 4 mm)
Material	AlMgCuPb
Shear cell:	
r_{iSZ} (inner radius of the annular internal volume)	16 mm = 1.6 cm
r_{aSZ} (outer radius of ...)	32 mm = 3.2 cm
d_{iSZ} (inner diameter of ...)	32 mm = 3.2 cm
d_{aSZ} (outer diameter of ...)	64 mm = 6.4 cm
h_{SZ} (nominal height of internal volume)	4 mm = 0.4 cm
A_{SZ} (cross-sectional area ...)	24.13 cm^2
V_{SZ} (internal volume, pyramids at bottom and lid not taken into account; $V_{SZ} = h_{SZ} \times A_{SZ}$))	9.65 cm^3
V_{Mit} (volume of the pyramids at bottom and lid)	0.70 cm^3
h_{Mit} (effective height of pyramids at the lid)	0.33 mm = 0.033 cm
m_{SZ} (mass of the bottom ring)	
Lid (annular):	
r_{iD} (inner radius of the annular lid)	15 mm = 1.5 cm
r_{aD} (outer radius of ...)	31 mm = 3.1 cm
d_{iD} (inner diameter of ...)	34 mm = 3.4 cm
d_{aD} (outer diameter of ...)	62 mm = 6.2 cm
A_D (cross-sectional area of the annular lid)	21.11 cm^2
m_D (mass of the annular lid with crossbeam)	

Please note: 1 m = 100 cm = 1000 mm = 39.37 in; 1 kg = 1000 g = 2.205 lb.



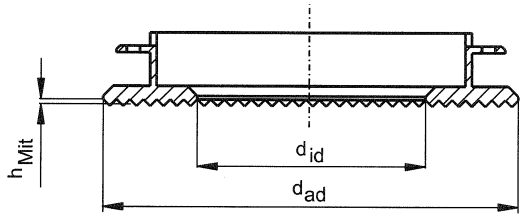


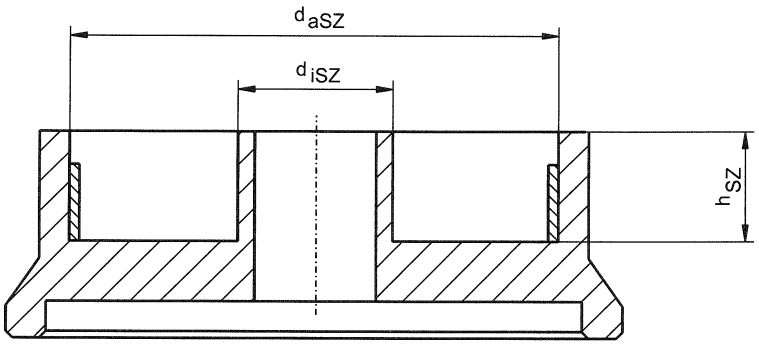
Shear cell data sheet "wall friction cell"

No. 3	
Type	XS-WM (standard)
Material	AlMgCuPb, driving pins 1.4301
Shear cell:	
r_{iSZ} (inner radius of the annular internal volume)	11.5 mm = 1.15 cm
r_{aSZ} (outer radius of ...)	36.5 mm = 3.65 cm
d_{iSZ} (inner diameter of ...)	23 mm = 2.3 cm
d_{aSZ} (outer diameter of ...)	73 mm = 7.3 cm
h_{SZ} (height of the annular internal volume; wall sample and spacer rings removed)	16.5 mm = 1.65 cm
A_{SZ} (cross-sectional area ...)	37.70 cm^2
V_{SZ} (internal volume; wall sample and spacer rings removed; pyramids at the lid and driving pins taken into account)	61.28 cm^3
V_{Mit} (taken into account in V_{SZ})	0 cm^3
h_{Mit} (height of bars)	0.66 mm = 0.066 cm
m_{SZ} (mass of the bottom ring, without lid)	210.544
Lid (annular):	
r_{iD} (inner radius of the annular lid)	15 mm = 1.5 cm
r_{aD} (outer radius of the annular lid)	31 mm = 3.1 cm
d_{iD} (inner diameter of the annular lid)	34 mm = 3.4 cm
d_{aD} (outer diameter of the annular lid)	62 mm = 6.2 cm
A_D (cross-sectional area of the annular lid)	21.11 cm^2
m_D (mass of the annular lid with crossbeam)	30.067

MANUF: METTLER TOLEDO
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