FVA - Guideline

GUIDELINE FOR THE TESTING OF DIRT CONTAMINATED RSS

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FVA 551 IV	**GUIDELINE FOR THE TESTING OF DIRT CONTAMINATED RSS**	sharing drive innovation

Note: The english translation of the guideline was carried out by DeepL

Contents

1 Introduction and scope of application

Rotary shaft seals (RSS) are used to limit the leakage of lubricants from machines to a technically permissible level and at the same time prevent the inflow of environmental substances such as liquids or dirt particles. The failure of such seals can result in considerable consequential costs due to maintenance work and the downtime of the affected machines, as well as environmental damage caused by leaking lubricants. In heavily contaminated environments, RSS with a protective lip are used to prevent the majority of external substances from reaching the main sealing lip. By greasing the space between the main and protective lip, penetrating substances can be bound and their migration into the sealing contact and into the oil chamber can be slowed down. Depending on the area of application, RSS are often subject to intensive exposure to dirt particles and water, which requires careful design and testing of the seal. The high requirements and the associated risks necessitate the establishment of a standardized guideline.

The methods described here are intended to help manufacturers and applicants compare the performance of their sealing systems in dirt-laden environments using a standardized test environment.

This guideline provides recommendations for the standardized performance of test bench tests to evaluate and classify the operating behavior of rotary shaft seals in contaminated environments. It defines procedures and methods for testing RSS under these conditions. The guideline includes recommendations for carrying out tests, defining test conditions, recording relevant parameters and categorizing them.

All procedures described in this guideline must be carried out carefully by trained specialist personnel and in compliance with the relevant regulations on occupational safety and environmental protection.

2 Limits of the guideline

The statements and information formulated in the further course of this guideline are based on the findings from the FVA 551 I-IV project series [01][02][03][04], which were gathered using the test equipment described below. All test methods used are specified in the course of the guideline. Information marked with an asterisk (*) is specified in more detail at the end of the section. In addition, technical drawings and a list of purchased parts can be found in the appendix to this guideline. The test equipment used in the project series serves as exemplary solutions. Starting points for a transfer of application-specific operating conditions can be found in chapter 7.

3 Cited standards and directives

The standards and directives relevant to this guideline are listed below. The selection does not claim to be complete. The main contents of the individual standards are briefly described in the corresponding chapters where applicable.

DIN 3760:1996, Radial-Wellendichtringe. Berlin: Beuth.

DIN 3761-1:1983, Radial-Wellendichtringe für Kraftfahrzeuge: Begriffe, Maßbuchstaben, zulässige Abweichungen, Radialkraft (zurückgezogen). Berlin: Beuth.

DIN 3761-2:1983, Radial-Wellendichtringe für Kraftfahrzeuge: Anwendungshinweise (zurückgezogen). Berlin: Beuth.

DIN 3761-4:1984, Radial-Wellendichtringe für Kraftfahrzeuge: Sichtbare Unregelmäßigkeiten (zurückgezogen). Berlin: Beuth.

DIN 3761-5:1984, Radial-Wellendichtringe für Kraftfahrzeuge: Prüfung, Messbedingungen und Messmittel (zurückgezogen). Berlin: Beuth.

DIN 3761-9:1984, Radial-Wellendichtringe für Kraftfahrzeuge: Radialkraft-Messgerät-Digital (zurückgezogen). Berlin: Beuth.

DIN 3761-12:1984, Radial-Wellendichtringe für Kraftfahrzeuge; Prüfung; Bestimmung der Kugeldruckhärte von Elastomeren (IRHD); Mikrohärteprüfung (zurückgezogen). Berlin: Beuth.

ISO 7619-1:2012: Elastomere oder thermoplastische Elastomere - Bestimmung der Eindringhärte - Teil 1: Durometer-Verfahren (zurückgezogen). Berlin: Beuth.

ISO 7619-2:2012: Elastomere oder thermoplastische Elastomere - Bestimmung der Eindringhärte - Teil 2: IRHD-Taschengeräteverfahren (zurückgezogen). Berlin: Beuth.

ISO 48-2:2021: Elastomere oder thermoplastische Elastomere - Bestimmung der Härte - Teil 2: Härte zwischen 10 IRHD und 100 IRHD. Berlin: Beuth.

ISO 12103-1:2024, Road vehicles: Test contaminants for filter evaluation. Arizona test dust. Berlin: Beuth.

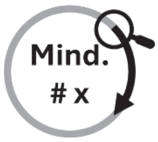
FVA e.V.: FVA 616 I: Entnahme von Ölproben aus Getrieben. Frankfurt: Forschungsvereinigung Antriebstechnik e.V.

4 Legend pictogram

Various procedures and processes are described in this guideline. For better orientation within the document, these descriptions are supplemented by pictograms, the meaning of which is briefly explained below.

General information

Warning notice



Recommended minimum number of measuring points

Temperature specification

Time specification

Mounting / inserting (complemented by time specification)

Pre- and post-measurement required

5 Experimental equipment

This chapter presents the experimental fundamentals for carrying out the test bench experiments. This includes the test equipment as well as the necessary analysis tools and the parameters required for evaluation.

5.1 Experimental materials

This section describes the test equipment in more detail. The test dust recommended for the test is specified in more detail and the design approaches relating to the test stand, the test cells and the dirt water unit are described.

5.1.1 Test dust

The reproducibility of the results is significantly increased when using dirt substances that also contain particles with a size < 5 µm aufweisen deutlich erhöht. In order to minimise the scatter of the test results as far as possible, the use of Arizona-Dust-A2-fine as test dust is recommended. Its particle size distribution is defined in ISO 12103-1 and is shown in Figure 1 below.

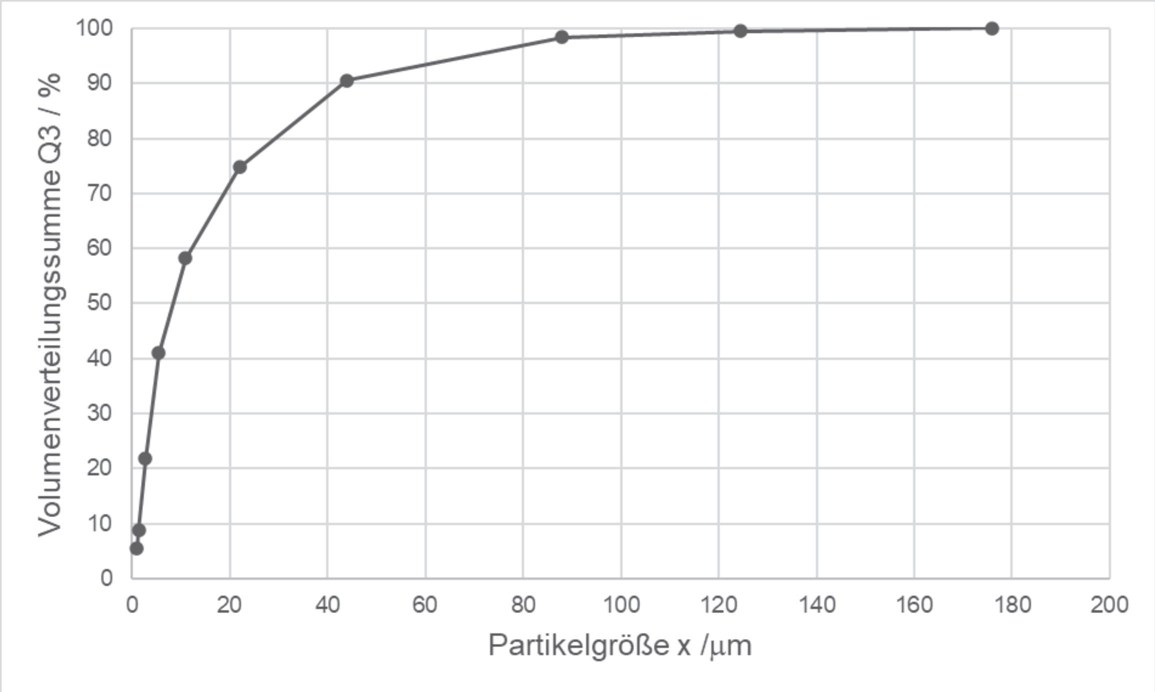


Figure 1: Particle size distribution Q3(x) of the test dust Arizona Dust A2 Fine according to ISO 12103-1

The composition of Arizona-Dust-A2-fine is shown in Table 1 below.

Table 1: Composition Arizona-Dust-A2-fine

Silicon	69,0 bis 77,0
Aluminium	8,0 bis 14,0
Iron	4,0 bis 7,0
Sodium	1,0 bis 4,0
Calcium	2,5 bis 5,5
Magnesium	1,0 bis 2,0
Titanium	0,0 bis 1,0
Potassium	2,5 bis 5,0

The influence of the dirt substance (particle size, particle size distribution, particle hardness, particle shape) on the resulting wear can be seen in Figure 21 in Chapter 7.

5.1.2 Greasing device

Greasing of the RSS cavity must be carried out using a device* that allows the space between the main lip and the protective lip to be greased evenly and in a repeatable manner.

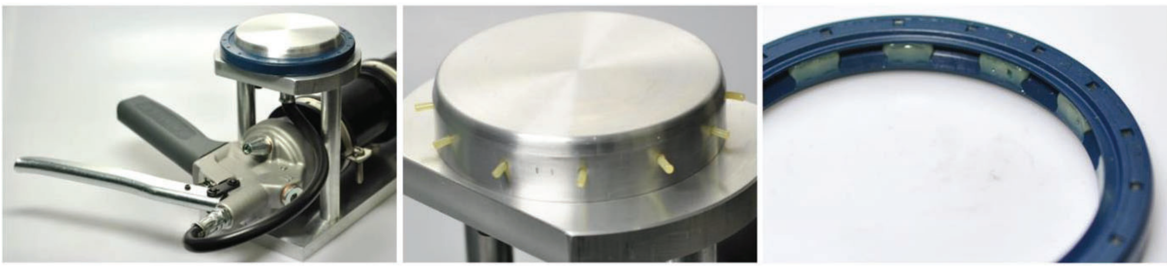


Figure 2: Greasing device RSS

When designing the RSS mount, the specifications for the design of the shaft from DIN 3760 must be followed. It is recommended to provide 12 greasing points around the circumference of the RSS.

Make sure that the channels for the distribution of the grease at the RSS-side outlets are appropriately deburred. When greasing, ensure that the surface of the samples and the RSS mount are clean.

When fitting the RSS onto the RSS mount, ensure that it is positioned vertically and centred.

* *One-hand press Wanner-Abnox (0,5 cm³ / Hub)*

5.1.3 Test-units

This chapter describes the test-units required for carrying out experimental tests on contaminated RSS. These are essentially:

- Test-bench
- Test-cell
- Dirt water unit

Figure 3 below shows a schematic representation of the test-units, which is described in more detail below. It is recommended that a mixture of dirt water is used for the application (see section 6.1 and chapter 7)

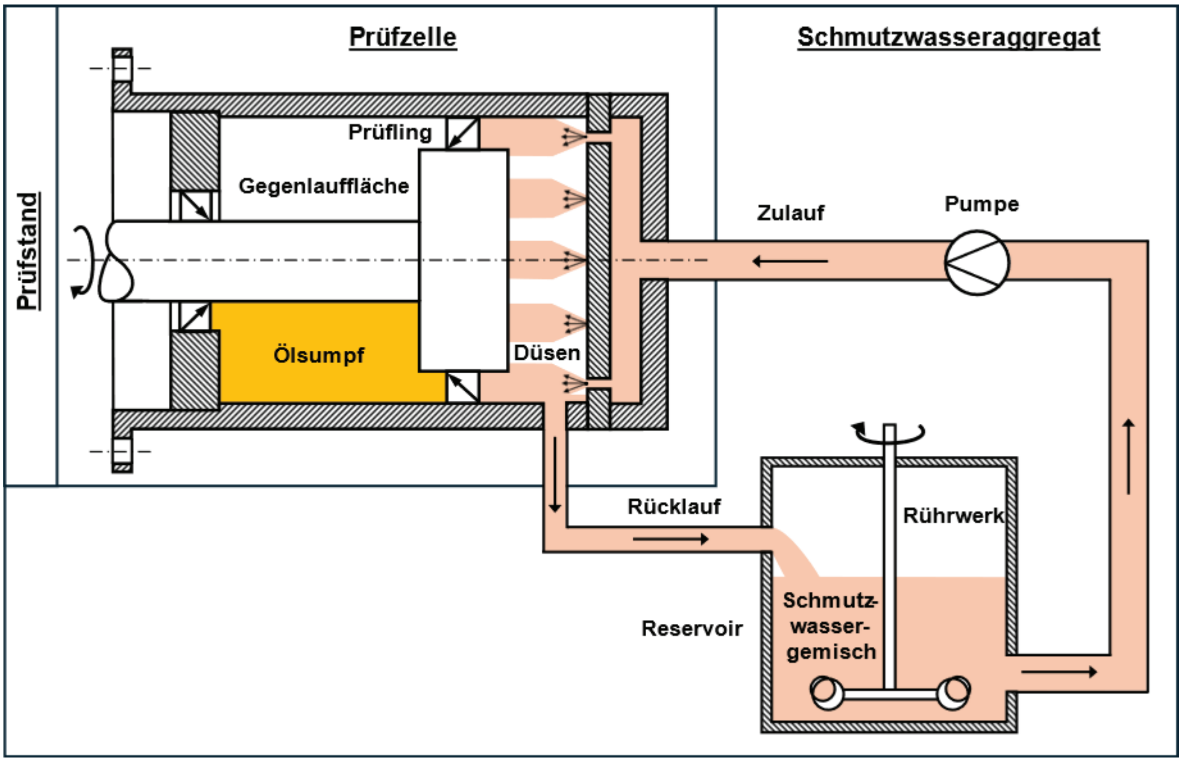


Figure 3: Schematic depiction of test units

General requirements for the test equipment include those described in DIN 3761-10.

Test-bench

A test bench suitable for long-term testing is recommended for carrying out the test. The test bench should be able to cover the speed range up to approx. 6000 min-1 described in DIN 3761-10. The coaxiality and concentricity tolerances specified in DIN 3761-2 and DIN 3760 apply with regard to the alignment deviation.

Test-cell

The test cell consists of the cell itself and the spraying unit. Adequate accessibility of the test sample is important both for the applying of the dirt-mixture and for subsequent testing and documentation. It is recommended to design the test cell according to the schematic structure shown in Figure 3. Here, the test sample is placed on the side of the test cell facing away from the test bench. With this setup, the test sample can be sprayed with dirt-mixture by means of an appropriately mounted loading unit.

When designing the test cell, particular care must be taken to ensure that the dirt-mixture completely washes around the protective lip of the test sample during exposure.

Dirt is applied to the test sample through dirt outlets arranged evenly around the circumference. It is recommended to provide 0.032 dirt outlets per millimeter of circumferential distance *U*. Figure 4 shows the dimensions to be taken into account using the example of an RSS with an internal diameter of 80 mm, whereby the following sizes are recommended:

- Dirt outlet diameter: d_1 = 3-5 mm
- Circular diameter of dirt outlets: d_2 = Nominal -⌀ Shaft
- Distance dirt outlets: a = 20-40 mm
- Number of dirt outlets: n = 0,032 1/mm * U
  n (U = 251 mm) = 8

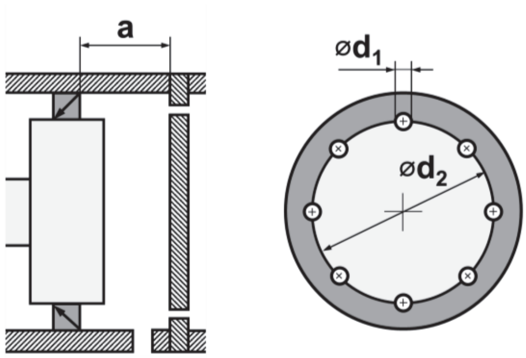


Figure 4: Design loading-unit

The test cell size must be designed in such a way that the minimum oil quantity of 0.75 litres or 1.0 litre specified in DIN 3761-10 can be met.

The specifications of DIN 3761-2 and DIN 3760 must be followed when designing the mounting of the RSS.

Further design criteria for the test cell:

- Backflow of dirt-mixture
- Withdrawal point / oil drain
- Temperature regulation
- Temperature detection / temperature control
- Leakage control device, if applicable
- Funnel, if applicable

Figure 5 below shows an example of the exploded view of the test cell used in the FVA-551 project series.

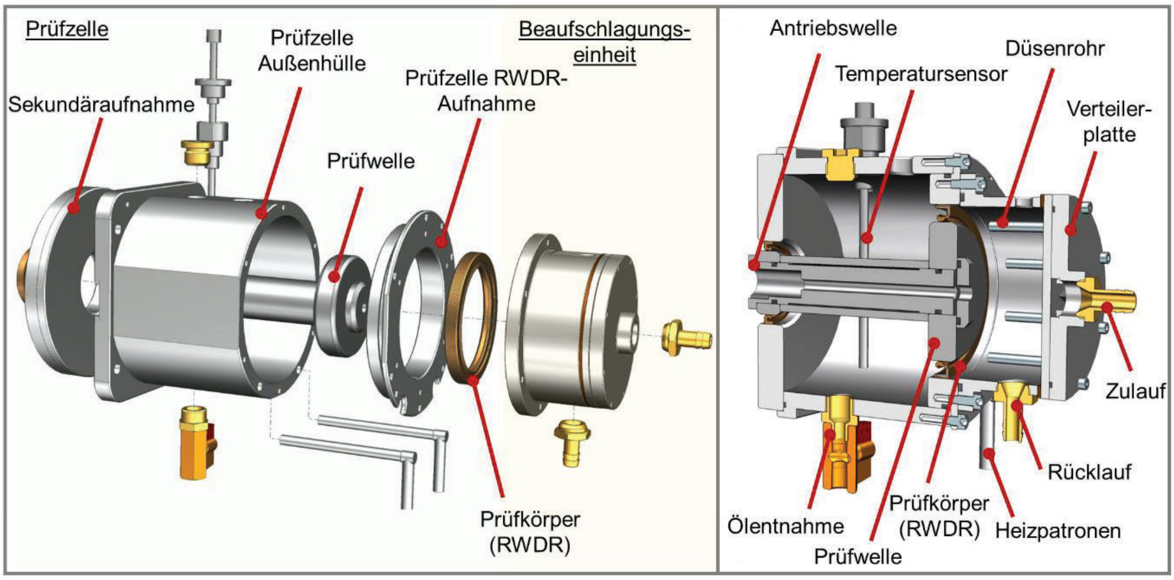


Figure 5: Exploded view (left) and sectional view (right) of an exemplary test cell

Figure 6 shows an additional view of the loading unit. The corresponding technical drawings can be found in the appendix to these guidelines.

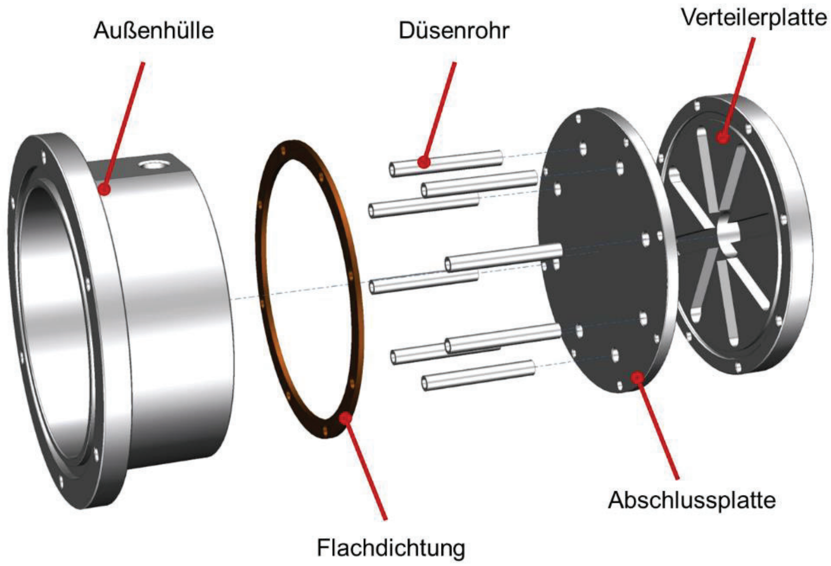


Figure 6: Exploded view of an exemplary loading unit

Dirt water unit:

The dirt water unit stores the dirt water mixture, ensures that it is homogeneously mixed and delivers it to the test cells for spraying. It can be subdivided into the dirt water reservoir and the distribution system.

Dirt water reservoir:

Figure 7 below shows an example of the sectional view of the dirt water reservoir used in FVA project 551-IV. The technical drawings can also be found in the appendix (see section 0).

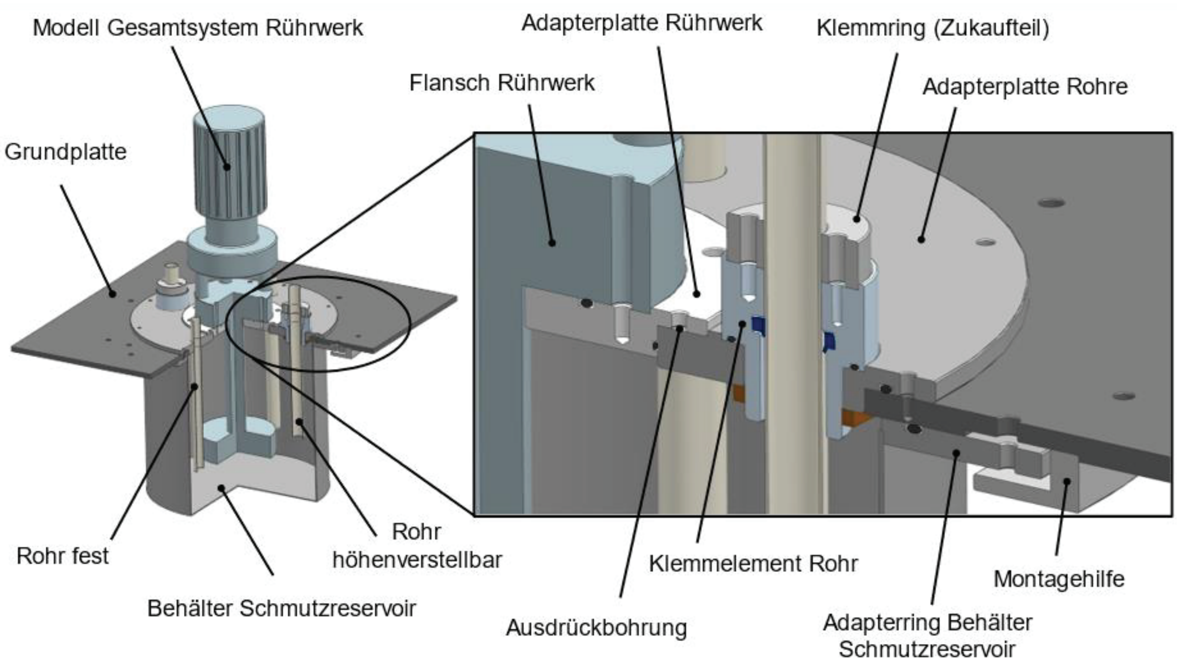


Figure 7: Sectional view of dirt water reservoir

The following design criteria must be considered when designing the dirt water reservoir:

- Ensuring homogeneous mixing* of the dirt water mixture
- Sufficient size of the dirt water reservoir: Recommended minimum volume of 6 litres of dirt water
- Extraction options for dirt water samples. It is recommended that samples are taken via the supply line that feeds the mixture to the test cells
- Sufficient depth of immersion of the extraction points, such as the feed. It is recommended to carry out the extraction at an immersion depth of approx. 50 %
- Air outlets

In the interests of user-friendly handling, it is also recommended that the following additional design criteria be considered:

- Simple assembly and disassembly: e.g. for cleaning
- Modular design: E.g. for easy replacement of individual components
- Height adjustability of the supply and return lines: e.g. for parameterising the mixer used

<u>Distribution system:</u>

The following design criteria must be observed when designing the distribution system:

- Compatibility of all components used with regard to the oils, greases and dirt water used
- Avoid the formation of secondary reservoirs (areas in the distribution system where the dirt water mixture can gather and settle)
- When several test cells are supplied:
  - Same distance of delivery feed
  - Test cells at the same height
- Air outlets

In particular, care must be taken to ensure that all dirt water is held exclusively in the reservoir provided for this purpose and that there is no residual water in the distribution system. If necessary, the supply and return lines must be designed in such a way that the dirt water mixture can flow back into the reservoir after distribution.

It is recommended to use a delivery device** that can realise a volume flow of 6600 ml / minute at the test cells. A powder disperser*** can be used, when applying dirt with air as the carrier medium.

It is recommended that connecting elements in the distribution system in the form of pipes or hoses - depending on the pump used - have the following internal diameters:

- Supply line: 9-13 mm
- Return line: 9-24 mm

* *VISCO JET Tank stirrer VJ500 mit VJ875 VISCO JET Sondersteuerung*
** *Verderflex Vantage 5000 Cased Drive Tube Pump mit Verderprene 9.6 ID x 2,4 Tubing*
*** *Palas RBG 1000 Powder disperser*

5.2 Experimental analysis tools

In order to evaluate and classify the operational behaviour of RSS exposed to dirt, the parameters listed in the following sections are recorded in accordance with the described procedures as part of the test bench tests defined here. Figure 23 in the appendix shows a brief overview of the recorded values, at which time and on which elements of the sealing system they are gathered and a prioritisation of the values to be recorded with regard to the subsequent analysis. The measurement sequence shown in Figure 8 below is recommended.

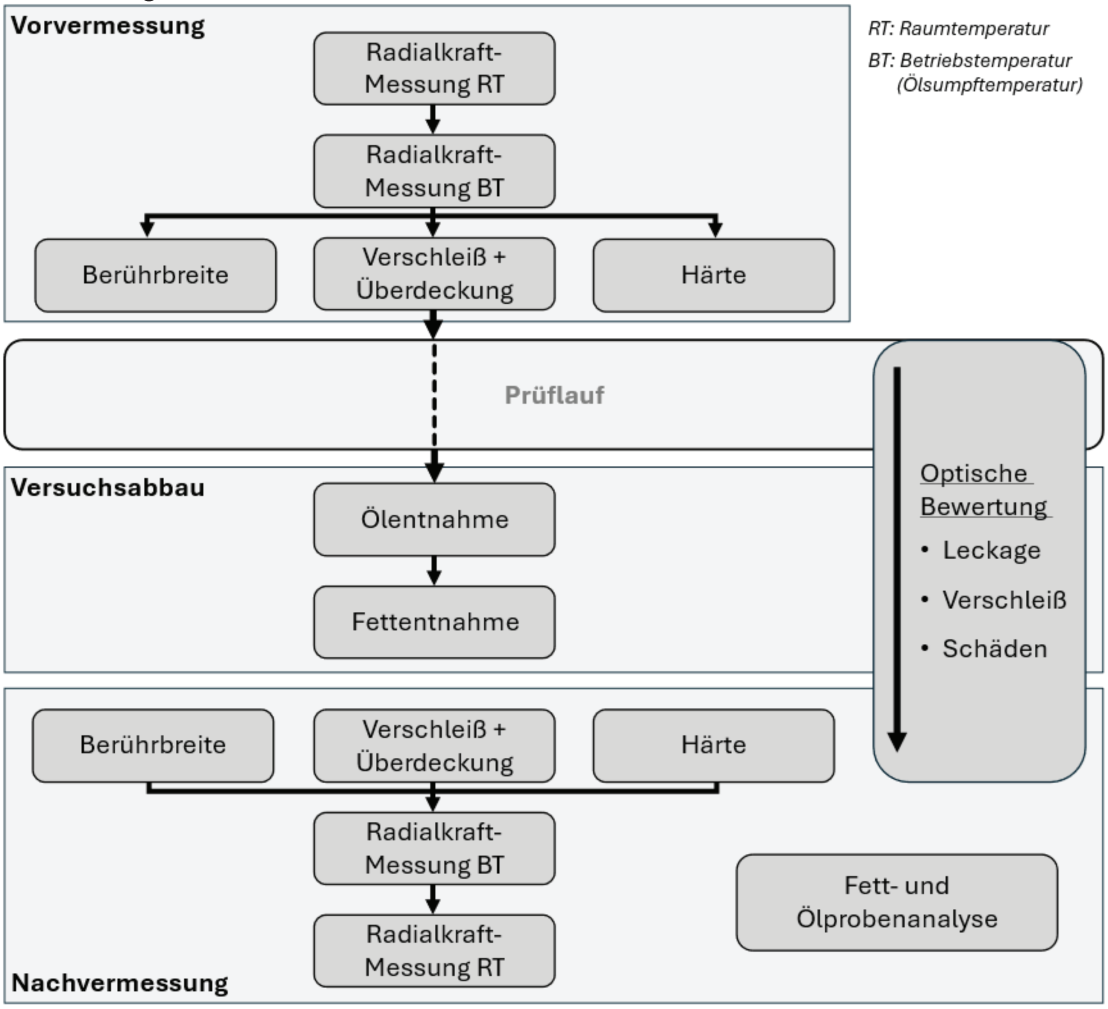


Figure 8: Flowchart measurement data acquisition

It is recommended to record at least four, ideally eight or more data points evenly distributed over the sample circumference to improve statistical confidence.

The analysis tools presented in this guideline are only recommendations. The parameters described can also be recorded using alternative methods or supplemented with additional parameters.

Information on measuring RSS with regard to the measuring conditions and measuring equipment can also be found in DIN 3761-5.

If it is necessary to clean the test samples, this must be done with appropriate care. Neither the test shaft nor the RSS must be damaged or impaired during cleaning. It is recommended that the RSS is cleaned with a lint-free, white cloth*. The main sealing and dust lip should be cleaned with moderate pressure until no more residue is visible on the cloth. The same is recommended for cleaning the test shaft. If the test shaft is degreased as part of the cleaning process, it must be conditioned again after cleaning to protect it against corrosion.

The measuring equipment used must be regularly calibrated in accordance with the applicable standards.

During the measurements, the necessary personal protective equipment must be worn in accordance with the methods used. When handling the samples, care must be taken not to contaminate or damage them.

The appendix contains sample accompanying documents for the RSS (see Figure 29), the shaft (vgl. Figure 30) and the grease and oil samples (see Figure 31 and Figure 32).

**KIMTECH SCIENCE precision wipes white*

5.2.1 Wear measurement

According to worksheet 7 of the German Society for Tribology [05], wear is the loss of material caused by contact with relative movement. This affects both the main sealing and dust lip of the RSS and its counter surface. Different values can be recorded as characteristic values for this. For the main sealing lip and dust lip, these are primarily the planimetric wear and the wear width. In addition to these two values, the wear depth can also be determined on the counter surface (see Figure 9).

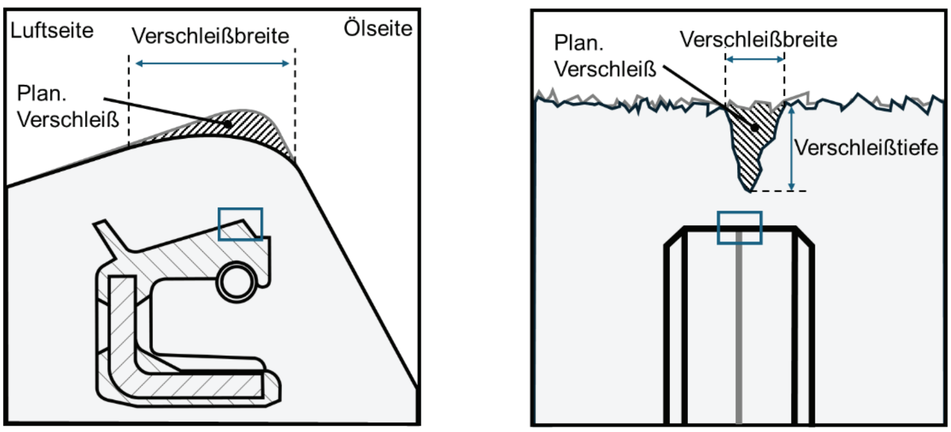


Figure 9: Wear parameters on RSS and counter surface based on [06]

Various measurement methods can be used to determine the aforementioned parameters. For example, all parameters can be acquired using the laser triangulation principle*. Other methods include reflected light microscopy to determine the wear width on the RSS and counter surface, confocal microscopy or the profile method to determine the wear depth on the counter surface or the stripe light projection to determine the planimetric abrasion on the RSS.

The wear parameters *planimetric wear* and *wear width* are both applicable with regard to the assessment described in section 6.3 and can be substituted with each other accordingly.

Ensure that the surface of the samples is clean during measurements. Dirt or contamination could impair the subsequent data evaluation. During the measurement, care must be taken to ensure that the sealing edge of the RSS is not damaged by components of the measuring equipment. When measuring using laser sensors, personal protective equipment corresponding to the laser class used must be worn.

The measurement data is acquired at room temperature. Pre-measurement and post-measurement are necessary for subsequent evaluation. When measuring the counter surface, the pre-measurement can be replaced by measuring a reference shaft, which eliminates the influence of tactile measuring methods on the surface.

The measurement data should be acquired at at least four points around the circumference. This may also allow the influence of the oil used and the oil level on the elastomer as well as any misalignment between the RSS and the counter surface to be assessed.

**LJ-X8020 2D/3D Profile sensor including control unit from Keyence – Possible installation see appendix*

5.2.2 Hardness measurement

Various standards are used to measure the hardness of elastomers. ISO 7619-1 describes the determination of Shore hardness using a durometer method. ISO 7619-2 and ISO 48 describe the hardness measurement according to the IRHD method (International Rubber Hardness Degree), which is comparable to the Shore A scale. The IRHD method in accordance with DIN 3761-12 using method M (micro hardness) is recommended for hardness measurement.

In the standard, the hardness measurement is carried out on RSS samples with a thickness of 1.00 mm and an expansion of 4 mm x 6 mm (better 4 mm x 20 mm). Such a measurement is not possible on the RSS. Nevertheless, the hardness measurement described below is recommended, as it enables a comparison of identical RSS with each other.

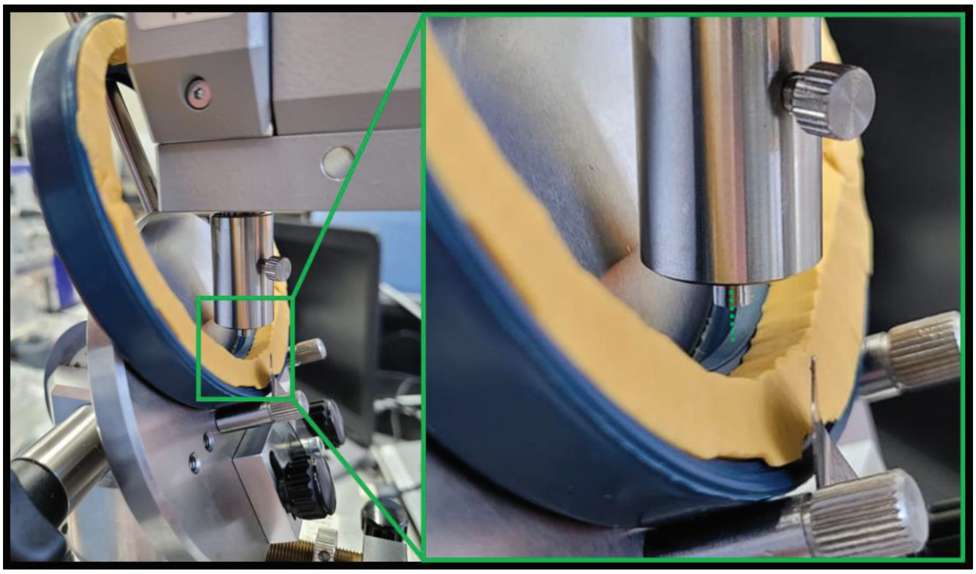
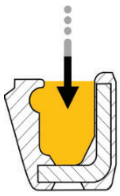


Figure 10: IRHD measurement to determine the elastomer hardness of an RSS sealing edge

When measuring, ensure that both the surface of the RSS and the contact surface are clean. Dirt or contamination could impair the subsequent sealing function of the RSS. During the measurement, particular care must be taken to ensure that the sealing edge is not damaged by the indenter.

The measurement is carried out at room temperature. Pre- and post-measurement is necessary for subsequent evaluation.



Before carrying out the measurement, the free area of the RSS including the spring groove behind the membrane surface must be filled with a suitable counterpart (remove the spring for this). This secures the sealing lip against being pressed away or bent. The counterpart is made from a special potting or moulding compound* for the respective design of the RSS.

The RSS is then positioned in a suitable sample holder in the measuring device (see Figure 10) so that the hardness measurement is carried out on the oil side at a distance of approx. 1 mm from the sealing edge. The measurement must be taken perpendicular to the oil-side flank of the sealing lip.

It is recommended to measure the hardness at at least four measuring points around the circumference. This may also allow the influence of the oil used on the elastomer to be assessed.

**Provil novo Putty regular set*

5.2.3 Radial force measurement

For radial force measurement, the two-jaw method for RSS standardised by DIN-3761-9 and shown and described in the appendix is recommended.

When measuring, ensure that the surface of both the RSS and the measuring jaws are clean. Dirt or contamination could impair the subsequent sealing function of the RSS. When measuring tempered RSS, appropriate personal protective equipment must be worn.

According to the standard, the RSS must be positioned vertically and centred within half a second when carrying out the measurement.

After the measurement time has elapsed, which should be between 1 and 10 seconds, the momentary value of the force must be read off or saved.

A pre- and post-measurement is necessary for subsequent data evaluation. It is important to ensure that the same measurement time is used for pre- and post-measurement.

The measurement should be carried out in at least four places around the circumference. To do this, the RSS is removed, rotated by 90°, mounted again and measured.

It is recommended to measure the radial force in the relaxed state - both at room temperature and at operating temperature (oil sump temperature). For relaxation, the RSS are conditioned for 24 hours at the corresponding temperatures - if necessary in an oven - on shafts with the corresponding nominal diameter provided for this purpose.

For the design of the measuring jaws, DIN 3761-9 must be considered; for the conditioning shafts, the specifications for the design of the shaft from DIN 3761-2 must be considered.

5.2.4 Contact width

The axial length of the actual contact area between the RSS and the counter surface is called the contact width. The contact width can be measured using various methods, whereby the measurement can be carried out using optical systems such as an microscope*, as described and illustrated in the appendix to this guideline.

When measuring, ensure that the surface of both the RSS and the measuring shaft are clean. Dirt or contamination could impair the subsequent sealing function of the RSS. Residues such as an oil film can lead to an incorrectly analysed contact width. When designing the hollow shaft, the specifications for the design of the shaft from DIN 3761-2 must be considered.

When mounting the RSS on the measuring shaft, ensure that it is positioned vertically and centred. A corresponding limit stop must be provided on the measuring shaft. When mounting, ensure that the dust lip does not tilt. The RSS is therefore mounted with the oil side towards the stop.

The measurement is carried out at room temperature. Pre- and post-measurement is necessary for subsequent evaluation.

The measurement data should be collected at at least four points around the circumference. For this purpose, a setup as shown in the appendix with a rotatable mount is recommended, with which the measuring shaft including the mounted RSS can be rotated.

Due to the relaxation behaviour of the elastomer, it is necessary to carry out the pre- and post-measurement in a consistent manner when measuring the contact width. In particular, care must be taken to ensure that the period between the mounting of the RSS and the acquisition of the measurement data is kept constant in order to guarantee consistent and comparable results. The measurement of relaxed RSS that have been conditioned on the measuring shaft over a period of 24 hours is recommended.

* *Microscope Typ Olympus SC100*

5.2.5 Oil and grease sampling

For the oil and grease samples, it is recommended to carry out an element analysis to determine wear metals, additives and contaminants as well as to determine the water content*. For this purpose, the respective samples must be taken from the test setup. The procedure for this is described below.

When taking oil and grease samples, appropriate personal protective equipment and other measures to protect against the grease and oil used must be utilised.

Care must be taken to ensure that the samples are not contaminated by environmental substances. Care must be taken to ensure that both oil and fat samples are only placed in clean containers.

1x

A single analysis of the oil and grease used in new condition is recommended as a reference value for both the oil and grease samples.

Grease sampling:

The grease sample is taken directly after removing the RSS mount and before removing the RSS. This reduces the potential for contamination of the grease by external dirt particles. It is recommended to use a spatula** that matches the geometry of the RSS as an aid for grease sampling (see Figure 11).

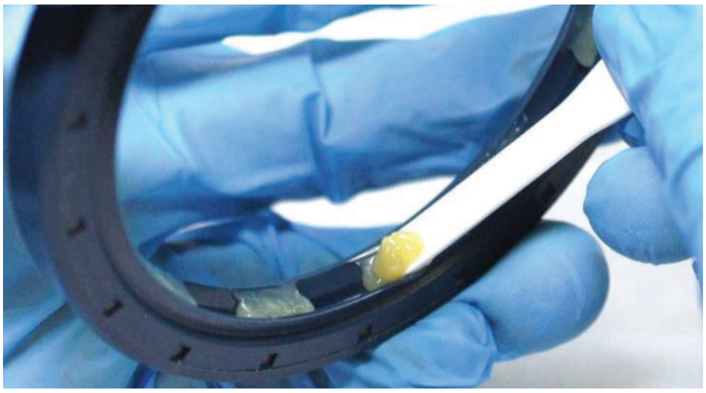


Figure 11: Grease sampling

When taking the sample, make sure that neither the main sealing lip nor the dust lip are damaged and that no dirt particles from the air side of the RSS are picked up by the spatula.

It is recommended to use the log given in the appendix to this guideline for fat sampling (see Figure 28). The appendix also contains a sample record sheet (see Figure 32).

With regard to the visual qualitative assessment of the sealing system, visual documentation of the grease samples taken with the spatula is recommended (see section 5.2.7).

<u>Oil sampling:</u>

For oil sampling, please refer to the procedure described in the FVA guideline for oil sampling from gearboxes and the associated flow chart, although the main points are briefly described below without any claim to completeness.

The oil sample taken should be representative of the test-run and, if possible, should be taken at the same point using the same method while the test stand is running or immediately after the test run at operating temperature.

Depending on the test cell set-up, the sample can be taken, for example, by means of a suction hose, manual vacuum pump or via an appropriate sampling point - e.g. a ball valve. The points described in the aforementioned FVA guideline must be observed when taking samples using a suction hose.

When taking oil samples via a sampling point, ensure that an initial oil-drainage is conducted, which is collected and disposed of in a separate container. A volume of approx. 0.5 litres is recommended. If this corresponds to more than half of the total volume of the test cell, a flow of approx. 35% of the total volume is recommended within the scope of this guideline.

The appendix to this guideline contains a sample accompanying note for the oil samples taken (see Figure 31)

**OELCHEK GmbH:*
Oil-samples: Analyseset 2 (schwarz) (mit KF anstatt NZ)
Grease-samples: Set 2 für Schmierfett (mit KF anstatt PQ und FT-IR)

***Bürkle, Micro-Spatel, Laborplast, PS, 1,0/0,25 m*

5.2.6 Interference

The interference is the difference in diameter between the main and protective lip of the unmounted RSS and the nominal diameter of the mating surface (see Figure 12). It is recommended that this should be done using a suitable method* as part of the wear measurement. The information given in section 5.2.1 must be followed.

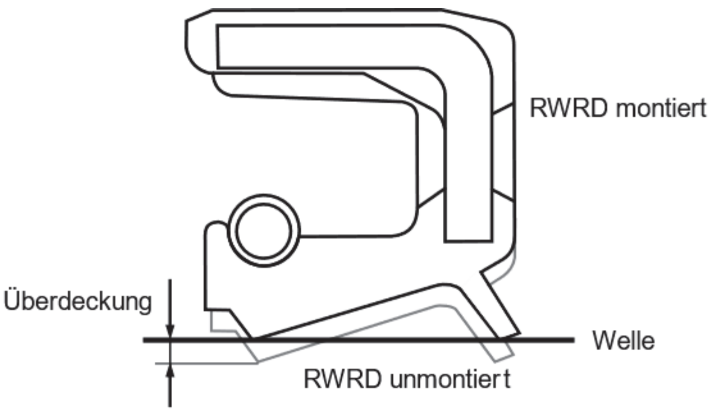


Figure 12: Interference RSS

** LJ-X8020 2D/3D Profile sensor including control unit from Keyence – for possible implementation, see appendix*

5.2.7 Visual examination

The visual inspection is carried out throughout the entire dismantling of the test bench. The aspects considered are:

- RSS
- Counter surface
- Dirt water mixture
- Grease
- Test cell and distribution system

It is recommended that the examination be documented photographically. Any discrepancies in the components mentioned are to be recorded.

The features and characteristics described below, in terms of which the elements mentioned are examined, do not claim to be complete and can be expanded.

A report template for the visual inspection can be found in the appendix to this guideline (see Figure 24).

RSS:

The visual inspection of the RSS is performed in the following states:

- Built into the test stand
- Removed and still fitted in the RSS mount
- Demounted, the grease sample is taken and the part is cleaned

It is recommended to evaluate the RSS with regard to the following characteristics:

- Regarding leakage: Visible signs of oil or grease on the air side
- Cracking / damage to the main and protective lip seal
- Discoloured lane marks
- Inclusions / adhering particles
- Geometric deviations / deformations
- Carbonisation

Further approaches to visual inspection can be found in DIN 3761-4, among other sources.

Figure 13 shows four RSS installed in the test bench following the end of the test. The images show:

I. Excessive leakage:
   a. The air side of the RSS is completely covered in oil
   b. Significant oil residues in the area below the RSS

II. Significant leakage:
   a. Oil-drenched dirt marks over the entire circumference of the RSS
   b. Low oil residue in the area below the RSS

III. Slight to significant leakage:
   a. a. Oil-drenched dirt marks in isolated spots around the circumference of the RSS
   b. No oil residue in the area below the RSS

IV. No leakage

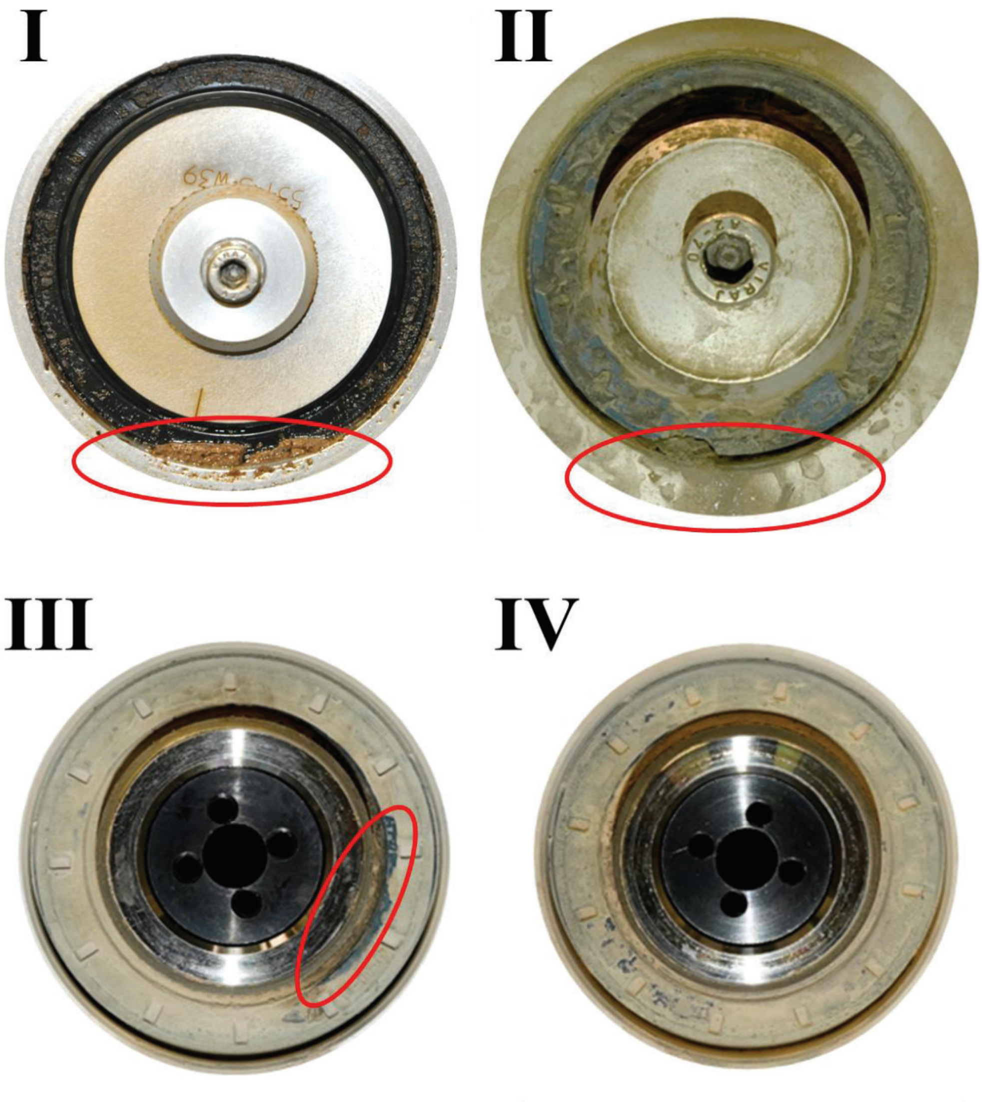


Figure 13: Example of leakage assessment at RSS

Counter surface:

The visual inspection of the counter surface is carried out in the following conditions:

- Mounted with RSS
- Mounted without RSS
- Demounted and cleaned

It is recommended to examine the counter surface with regard to the following characteristics:

- Regarding leakage: Visible signs of oil or grease

- Carbonisation
- Inclusions / adhering particles
- Defects / damage

Dirt water:

The visual examination of the dirt water is carried out in the following states:

- In the reservoir

It is recommended to analyse the dirt water mixture with regard to the following characteristics:

- With regard to leakage: oil film or grease residue

As soon as visible oil traces can be seen in the reservoir, it can be assumed that there is significant leakage.

Figure 14: Noticeable oil residue in the dirt water reservoir – 15,000 km friction distance, 5 h / 10 s exposure

Grease:

The visual examination of the grease is carried out in the following states:

- On the demounted and still-pressed-in RSS
- After taking the sample

It is recommended to analyse the grease with regard to the following characteristics:

- Quantity
- Colour
- Inclusions / adhering particles

Figure 15 below shows example images of three RSS with different residual quantities of grease (still pressed in):

I. Grease remains to a large extent, spread over the circumference of the RSS
II. Grease no longer present in significant portions, residues smeared over the circumference of the RSS
III. Practically no more visible grease

Figure 15: Grease evaluation at the pressed-in RSS

The grease should also be assessed and documented as part of the grease sample collection. The following Figure 16 shows exemplary images of such grease samples as an assessment aid.

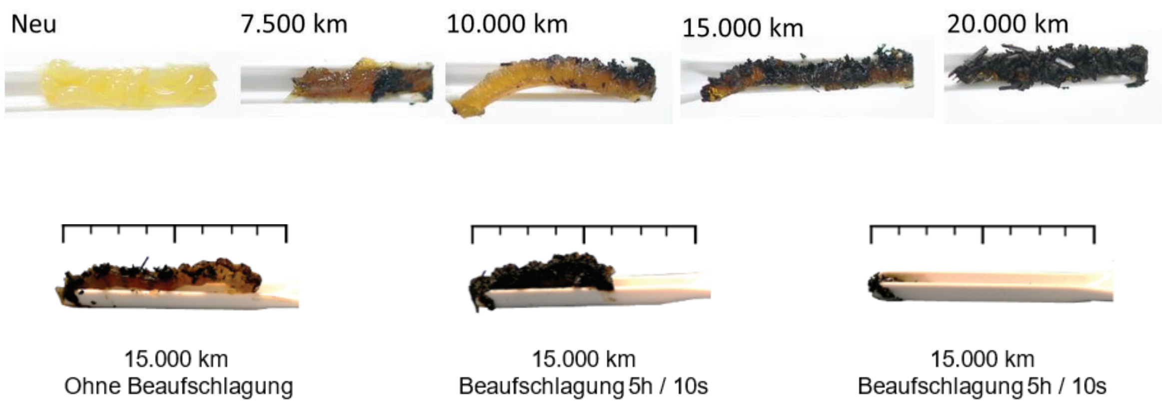


Figure 16: Grease samples with variation of the friction distance (top), grease quantities with the same friction distance of 15,000 km, exposure 5 h / 10 s (bottom)

Test cell and distribution system:

The visual inspection of the test cell and the distribution system is to be carried out during the dismantling.

It is recommended to analyse the test cell and the distribution system with regard to the following characteristics:

- With regard to leakage: oil and grease residues in:
    - Test cell
    - Distribution system
- Dirt particle / sediment:
    - Test cell
    - Distribution system

Figure 17 below shows three images of test cells, ranging from significant oil.

Figure 17: Oil residue in the test cell – 15,000 km, exposure 5 h / 10 s (left: extensive leakage – centre: flung-off oil drops – right: no leakage)

For the evaluation of the test cell, dry particle residues of the dirt substance are crucial, since even small oil or grease residues can be clearly visible in these.

6 Test procedure

This chapter covers methods and instructions for carrying out test bench tests to evaluate the operating behaviour of dirt-exposed RSS. It includes operating parameters, preparation and follow-up of the test, and an approach to evaluate the results.

For a more reliable statistical certainty, it is recommended to test at least three RSS per test configuration, consisting of test parameters and sealing system. For each test configuration, a reference run should also be performed, also with at least three RSS and without any dirt exposure. This allows the influence of changed conditions to be analysed independently of the dirt exposure.

6.1 Operating parameters

The operating and test parameters shown in Table 2 below must be defined and documented as part of the test. A corresponding example log can be found in the appendix to this guideline.

Table 2: Operating and test parameters

Zuordnung	Parameter	Beschreibung	Einheit
Dichtsystem	RWDR	Hersteller	
		Typ	
		Größe d-D-b	mm
		Werkstoff	
	Welle	Material	
		Oberfläche	
	Prüfschmutz	Schmutzsubstanz	
		Schmutzkonzentration	%
		Trägermedium	
	Öl	Hersteller	
		Typ	
	Fett	Hersteller	
		Typ	
Prüfkenngrößen	Bewegungs-Charakteristika	Drehzahl	1/min
		Umfangsgeschw.	m/s
		Reibweg	km
		Laufzeit	h
		Kinematik	
	Ölsumpf	Temperatur	°C
		Füllstand	
	Befettung	Menge	gramm
		Befettungsgrad	%
	Beaufschlagung	Intervalldauer	s
		Intervallabstand	min
	Statistik	Anzahl geprüfter RWDR	

With regard to the contamination, the combination of Arizona Dust A2 dissolved in water has proven to be recommended in the FVA 551 projects with regard to the reproducibility of the test results.

In summary, the test parameters shown in Figure 18 proved to be advantageous, with RSS of the BAU4SLX2, 80-100-12/8 and BAU3SLX2, 40-60-10/7 design being used [03].

Größe	**Wert / Einstellung**
RWDR-Typ	Mit berührender Schutzlippe, keine Förderhilfen
RWDR-Werkstoff	72 NBR 902 75 FKM 585
Fett	Petamo GHY133N Befettungsgrad Zwischenraum: 40 %
Wellenmaterial	42CrMo4 (55 HRC)
Wellenoberfläche	Nach DIN 3760 / DIN 3761-2
Versuchsöl	FVA PAO 2 (Gargoyle Arctic SHC 226E)
Reibweg / km	15.000
Öltemperatur / °C	70
Ölschmierung	Öl anstehend bis Wellenmitte
Umfangsgeschwindigkeit / m/s	6
Schmutz	Arizona Dust A2 in Wasser Schmutzkonzentration 3 %
Beaufschlagung	Dauer 10 s / Intervall 5 h
Statistik	Mindestens 3 Versuche

Figure 18: Recommended test parameters

The following details are recommended for the exposure interval per Test cell:

- Applied volume V = 1,46 ml/mm * U *(circumferential distance)*
- Flow-rate: 36 ml/s

It is important that the test smaple is completely exposed to the spray during each application (depending on the number of dirt outlets around the circumference, the feed rate may need to be adjusted here).

The main influences of the operating and test parameters can be seen in Figure 22 of chapter 7.

6.2 Conducting the experiment

This section deals with the test procedure, consisting of test preparation, the test run and the end of the test. The steps to be carried out here are based on the recommendations for the test equipment and the operating parameters and are shown in the following flowchart.

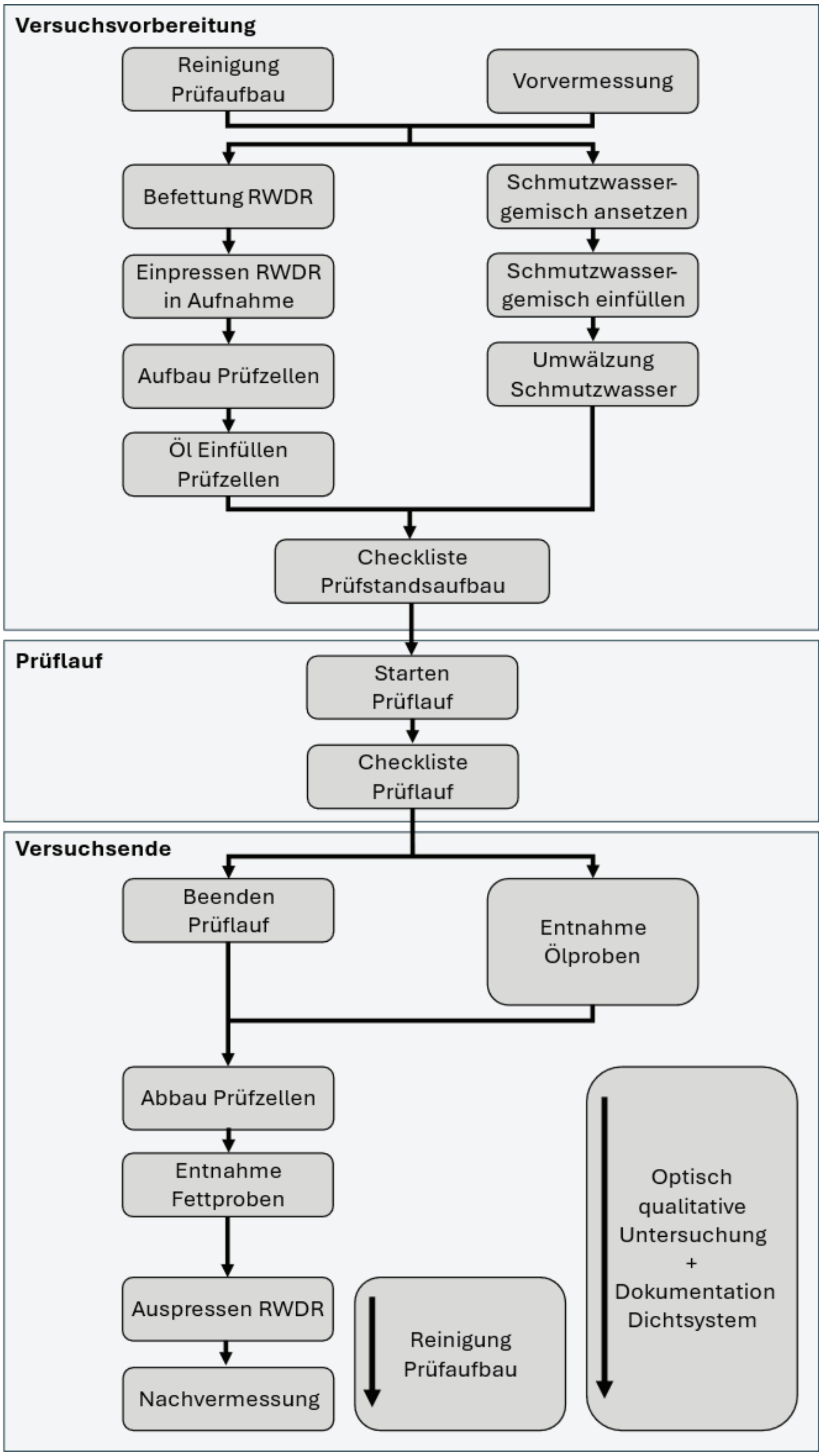


Figure 19: Flowchart conducting the experiment

Test preparation:

It is recommended that the pre-measurement should be documented. The relevant sample information forms in the appendix to these guidelines can be used for this purpose.

The test setup should be documented using a checklist. The checklist from the appendix of this guideline can be used for this purpose. This includes the essential work to be carried out (see Figure 27). The run-out and coaxiality deviations of the test shafts are to be documented accordingly (see Figure 26)

When greasing the RSS, care must be taken to ensure that both the RSS and the greasing device are clean. Dirt or impurities could impair the subsequent sealing function of the RSS.

Before setting up the test bench, make sure that the individual components of the test setup are free of contamination such as

- Dirt particles
- Grease
- Oil

In particular, this applies to:

- Test cell
- Distribution system (supply and return lines, valves, etc.)
- Dirt reservoir

When setting up the test stand, care must be taken to ensure that both the shaft and the RSS are not damaged or contaminated. When mounting the RSS, the respective manufacturer's specifications must be followed.

Test run:

Before starting the test, it must be ensured that the test stand has been set up correctly. To do this, the corresponding documentation, such as the aforementioned checklist, should be checked again and compared with the test setup.

During the test run, the operating parameters are to be regularly checked and documented (see Figure 26). For that purpose, the test log from the appendix can be used.

The dirt concentration of the dirt water mixture is to be regularly checked during the test run. A checking interval of at most seven days is recommended. For this, a sample should be taken at the corresponding point and the water removed by evaporation (e.g. in an oven). The dirt concentration is determined by weighing the dirt water sample before evaporation and the dust residue after evaporation.

During the test run, the fluid level of the dirt water mixture in the reservoir is to be checked regularly. Care must be taken to ensure that the immersion depth of the dirt water supply in the reservoir is sufficient to allow the desired flow rate to be applied. A checking interval of no more than seven days is recommended.

Refilling of dirt water: When refilling the dirt water, the concentration should be adjusted according to the missing water quantity:

- Refilling after sampling: dirt concentration according to the test parameters
- Refilling due to evaporation: pure water, no dirt substance

End of test:

At the end of the test, the test bench must be shut down properly. With regard to the visual evaluation, the dirt application to the test cells should be stopped 5 hours before the end of the test run.

It is recommended that the visual inspection be carried out as part of the dismantling process and that it be documented accordingly. The aforementioned checklist contains the essential work to be carried out.

6.3 Evaluation of the results

When evaluating the results of an experiment, the following components are considered:

- RSS
- Counter surface
- Oil
- Grease

The results can be evaluated using the following evaluation scheme. This consists of qualitative and quantitative evaluation criteria, which are weighted differently and incorporated into an individual key factor, the performance indicator (see Figure 20).

The scaling factors can be adjusted according to individual specifications; this must be documented and recorded accordingly. It is recommended that the key performance indicator be expressed as a percentage of the maximum achievable score. 0% corresponds to a new sealing system and 100% to a total failure of the sealing system. The maximum number of points is 104 for the weighting shown in Figure 20 and recommended in this guideline.

The performance indicator can be used to compare different sealing systems. In addition, limit values can be set for the overall system.

In addition to the performance indicator, individual limit values can be defined for the individual evaluation criteria.

The visual inspection is not described in detail in this scheme. The assessment of the findings is based on the overall evaluation, which is carried out using the evaluation criteria described in section 5.2.7.

<table>
<tr><td colspan="3">Versuch-Nr.:</td><td colspan="2">Zelle/n:</td></tr>
<tr><td colspan="3">Ende Prüflauf:</td><td colspan="2">Prüfkörper:</td></tr>
<tr><th></th><th>Bewertungskriterium</th><th>Befundung</th><th>Gewichtungsfaktor</th><th>Evaluationskennzahl</th></tr>
<tr><td rowspan="3">Opt. Qualitative Betrachtung</td><td>Leckage</td><td></td><td>5</td><td></td></tr>
<tr><td>Auswaschung Fett</td><td></td><td>3</td><td></td></tr>
<tr><td>Opt. Untersuchung</td><td></td><td>3</td><td></td></tr>
<tr><td rowspan="8">Messgrößen</td><td>Partikel Öl</td><td></td><td>3</td><td></td></tr>
<tr><td>Überdeckung SL</td><td></td><td>3</td><td></td></tr>
<tr><td>Verschleiß HL</td><td></td><td>3</td><td></td></tr>
<tr><td>Wasser Öl</td><td></td><td>2</td><td></td></tr>
<tr><td>Radialkraft SL</td><td></td><td>1</td><td></td></tr>
<tr><td>Fett - Partikel / Wasser</td><td></td><td>1</td><td></td></tr>
<tr><td>Verschleiß Welle</td><td></td><td>1</td><td></td></tr>
<tr><td>Berührbreite HL</td><td></td><td>1</td><td></td></tr>
<tr><td colspan="2"></td><td colspan="3">Leistungskennzahl</td></tr>
<tr><td colspan="5">Legende für Befundung: 0 - ohne / neuwertig || 1 - gering || 2 - deutlich || 3 - stark || 4 - sehr stark</td></tr>
<tr><td colspan="5">Name</td></tr>
<tr><td colspan="5">Datum</td></tr>
<tr><td colspan="5">Unterschrift</td></tr>
</table>

Figure 20: Evaluation of the results - performance indicator

7 Transfer to user-specific load collectives

When deriving application-specific conditions for the load spectrum, the effects of the individual operating and test parameters shown in Figure 22 must be taken into account and selected according to the desired specification. This information is supplemented by the results of the FVA project series FVA 696 *Load Collectives*, some of which are included in Figure 22 and complemented by the findings of the project series FVA 551 *Dirt Classification*.

In general, care should be taken to ensure that the test equipment is compatible with the operating fluids used. When defining load spectra, the manufacturer's specifications for the test equipment must be observed.

Exposure collective

In addition to Figure 22 the main design aspects of dirt exposure are discussed in more detail below, whereby the exposure collective can be separated into three sub-aspects:

- Exposure intensity: defined by interval spacing and interval duration
- Contaminant mixture: defined by dirt substance, dirt concentration and carrier medium
- Dirt outlet: defined by number and position of the exposure outlets

The intensity of the exposure, defined by the interval spacing and interval duration, is of lower significance in terms of the resulting wear compared to the other test parameters. However, it is recommended to ensure that the protective lip of the test specimen is completely rinsed with the dirt mixture in each exposure cycle. This must be taken into account when designing the test cell – in particular the positioning of the dirt outlets.

**Increasing the intensity of the load application sixfold (doubling the interval spacing and tripling the interval duration) led to an increase in wear of approx. 35-40% with increasing scatter of the test results [02]*
**Halving the interval duration led to a reduction in wear on the protective lip of approx. 15%*

The mixture of dirt and, in particular, the dirt substance used are crucial for the resulting wear. The particle shape has the greatest influence on the formation of wear. An increased concentration of dirt also leads to an increase in wear, but to a much lesser extent than a change in the particle shape**. When selecting the carrier medium, it should be noted that the use of air in combination with an increasing dirt concentration results in a dramatic increase in wear***. Therefore, the use of water is recommended as a carrier medium, as this allows a gradual progression of wear to be set via the dirt concentration.

** *A six-fold increase in the dirt concentration – from 0.5 % to 3 % – results in a 10 % increase in wear at the main seal and a 26 % increase at the dust lip [02]*

**** No change in wear of the main sealing lip and protective lip wear with an increase in dirt concentration from 0.5 g/min to 1.5 g/min. 10-fold wear of the SL with an increase in dirt concentration from 1.5 g/min to 2.5 g/min [02]*

The configuration of the dirt outlets has a limited influence on the wear that occurs****. During the design process, for example when adjusting the seal diameter, attention must be paid to the specifications mentioned in section 5.1.3 regarding the number of dirt outlets and, consequently, the distance between the outlets.

***** Halving the number of outlets has a similar effect on wear at the protective lip as halving the interval time (approx. 15% less wear) [04]*

The interval duration in combination with the configuration of the dirt outlets determines the flow around the seal. Here, it is recommended to ensure complete flow around the seal at every exposure. This is possible by complying with the given recommendations regarding the interval duration (see section 6.1) and the nozzle spacing.

The effect of the dirt substances used on the resulting wear and the spread of the test results can be taken from Figure 21 below.

Schmutzsubstanz	Verschleiß	Schwankung / Streuung
Arizona Dust A1	○ ○ ○ ○	● ○ ○ ○
Arizona Dust A2	● ● ○ ○	● ● ○ ○
Arizona Dust A4	● ● ○ ○	● ● ● ●
Quarz fein	● ● ● ●	● ● ○ ○
Quarz grob	● ● ● ●	● ● ● ○
Korund fein	● ○ ○ ○	● ● ○ ○
Korund grob	○ ○ ○ ○	● ● ● ○
SiC fein	○ ○ ○ ○	● ● ● ●
Glaskugeln	● ○ ○ ○	● ● ○ ○

○ ○ ○ ○ Kaum Einfluss ● ● ● ● Starker Einfluss

Figure 21: Influence on wear and scattering of the test results depending on the dirt substance

A more demanding collective of exposure can primarily be achieved by adjusting:

- Particle shape
- Exposure intensity
- Dirt concentration

It should be noted that deviations from the load spectrum recommended in section 6.1 will lead to a greater spread in the test results and thus to more limited interpretability of these results. To ensure that the test results are as stable and reliable as possible, reference is made to the load spectrum described in section 6.1.

When using a significantly more demanding exposure collective, it is recommended to increase the statistical validation by testing at least six RSS.

Sealing system

The recommendations in this guideline are based on the findings and results of FVA project series 551-I to 551-IV [01][02][03][04] and were primarily collected on RSS of the BAU4SLX2, 80-100-12/8 design. The parameters shown in Table 3 below were determined for these. Deviations from these values and their effects must be taken into account when selecting the operating parameters, the load spectrum and when interpreting the results (the information in Figure 22 below can be used for this). This applies in particular to the line load and the interference of the main and dust lip*****.

Table 3: Selected characteristic parameters of RSS of design BAU4SLX2, 80–100–12/8

Kenngröße	**NBR**	**FKM**
Linienlast HL bei Raumtemp.	0,089 N/mm	0,078 N/mm
Linienlast SL bei Raumtemp.	0,088 N/mm	0,084 N/mm
Linienlast HL bei 70°C	0,089 N/mm	0,068 N/mm
Linienlast SL bei 70°C	0,085 N/mm	0,066 N/mm
Überdeckung HL	1,82 µm	1,66 µm
Überdeckung SL	0,77 µm	0,54 µm
Berührbreite HL	79,3 µm	87,4 µm
Berührbreite SL	52,3 µm	62,9 µm

******For example, a smaller interference of the dust lip can lead to a greater amount of particles entering the grease and to greater wear on the main sealing lip*

When making changes to the sealing system, it is important to ensure that the exposure volume and the number of dirt outlets are adjusted accordingly (see sections 6.1 and 5.1.3). To maintain the intensity of the exposure, it is recommended that you follow the information given in the previous sections:

- Exposure volume per test cell: Section 6.1 – Operating parameters
- Number of dirt outlets: Section 5.1.3 – Test unit, exposure unit

If RSS with a seal diameter other than 80 mm are tested, it must be ensured that the speed required for the recommended circumferential speed of 6 m/s is within the permissible range for the respective seal. The manufacturer's specifications must be taken into account here. If the recommended circumferential speed of 6 m/s cannot be realised, the circumferential speed that will later be present in operation can be used to carry out the test.

When the seal diameter is changed, the following influences must be taken into account when evaluating the results:

- In general, the change in heat dissipation due to the adjustment and the associated change in temperature in the sealing contact must be taken into account.
- Furthermore, when adjusting the relative speed, the influence of the circumferential speed on the wear that occurs and the thermal damage must be taken into account.

Merkmal	Wirkung auf Verschleißentstehung	Anmerkung
Reibweg	●●●●	Zunehmender Verschleiß mit zunehmenden Reibweg
Umfangsgeschwindigkeit	●●●○	Abnehmender Verschleiß bei zunehmender Temperatur → Stark zunehmende thermische Schädigung infolge steigender Temperatur [07]
Kinematik	●●●○	Zunehmender Verschleiß bei Drehrichtungswechseln mit zunehmender Periodendauer sowie zunehmender Verschleiß unter zunehmender Sprunghöhe der Umfangsgeschwindigkeit [07]
Partikelform	●●●○	Stark zunehmender Verschleiß bei scharfkantigeren Partikeln **Wichtig**: Zunehmende Streuung der Versuchsergebnisse in Abhängigkeit der verwendeten Schmutzpartikel
Partikelhärte	○○○○	Kein Zusammenhang zwischen Partikelhärte und Verschleiß an Dichtkante oder Gegenlauffläche feststellbar
Partikelgrößenverteilung	●○○○	Allgemein kein wesentlicher Einfluss der Partikelgrößenverteilung auf den Dichtringverschleiß. Tendenz einer Verschleißerhöhung mit steigender Partikelgrößenverteilung
Schmutzkonzentration / Partikelmenge	●○○○	Steigende Schmutzkonzentration führt zu einer geringen Verschleißsteigerung an der Hauptdichtlippe und zu einer moderaten Verschleißsteigerung an der Schutzlippe
Beaufschlagungsintensität (Intervalldauer & Intervallabstand)	●●○○	Steigerung der Beaufschlagungsdauer und Verkürzung des Intervallabstands führt zu einer geringen Verschleißsteigerung an der Hauptdichtlippe und einer moderaten Verschleißsteigerung an der Schutzlippe **Wichtig**: Steigerung der Beaufschlagungsintensität führt zu einer zunehmenden Streuung der Messergebnisse
Trägermedium (Wasser oder Luft)	●●○○	**Wichtig**: Unvorhersehbare und Sprunghafte Änderung bei Verwendung von Luft anstelle von Wasser als Trägermedium
Füllstand Öl	●●●●	Starke Verschleißzunahme mit sinkendem Schmiermittelangebot [07]
Ölsumpftemperatur	●●●●	Starke Verschleißzunahme mit sinkender Temperatur; Stark zunehmende thermische Schädigung infolge steigender Temperatur [07]

○○○○ Kaum Einfluss ●●●● Starker Einfluss

Figure 22: Influence of operating and test parameters on the formation of wear

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[03] FVA e.V.: Wirkmechanismen in schmutzbeaufschlagten Dichtsystemen. Forschungsvorhaben 551 III, Forschungsvereinigung für Antriebstechnik e.V.

[04] FVA e.V.: FVA Richtlinie Schmutzklassen. Forschungsvorhaben 551 IV, Forschungsvereinigung für Antriebstechnik e.V.

[05] GfT e.V.: Arbeitsblatt 7 Tribologie: Verschleiß, Reibung: Definitionen, Begriffe, Prüfung, hrsg. von Gesellschaft für Tribologie e.V.

[06] Burkhart, C.: „Ein Beitrag zum Verständnis des Verschleißverhaltens im System Radialwellendichtring“, Dissertation, Technische Universität Kaiserslautern.

[07] FVA e.V.: Gestaltung von Lastkollektiven zur Prüfung von Radial-Wellendichtungen. Forschungsvorhaben 696 III / 696 IV, Forschungsvereinigung für Antriebstechnik e.V.

Appendix

Bedeutung	Kenngröße	Erfasst an	Zeitpunkt	Potenzielles Analysewerkzeug	Anmerkungen
🔴	Opt. qualitative Bewertung	Dichtsystem HL + SL Gegenlauffläche	nach Prüflauf		Optische Untersuchung hinsichtlich Schäden, Leckage, etc.
🔴	Verschleiß	HL + SL Gegenlauffläche	Vor- und Nachvermessung	Streifenlichtmikroskop Lasertriangulationsensor Auflichtmikroskop	Erfassung der Verschleißkenngrößen Verschleißbreite oder Planimetrischer Verschleiß bei Raumtemperatur an mindestens 4 Messstellen über den Umfang sowie ggf. der Verschleißtiefe an der Gegenlauffläche.
🟡	Radialkraft	HL + SL	Vor- und Nachvermessung	Zwei-Backen-Radialkraftmessgerät	Radialkraftmessung an mind. 4 Messstellen über den Umfang im relaxierten Zustand (24h Relaxation) bei Raum- und Ölsumpftemperatur nach DIN-3761-9
🟡	Berührbreite	HL + SL	Vor- und Nachvermessung	Lasertriangulationsensor Auflichtmikroskop	Erfassung der Berührbreite bei Raumtemperatur an mindestens 4 Messstellen über den Umfang. Dabei das Relaxationsverhalten des RWDR berücksichtigen
🟡	Überdeckung	HL + SL	Vor- und Nachvermessung	Lasertriangulationsensor Auflichtmikroskop	Erfassung der Überdeckung bei Raumtemperatur an mindestens 4 Messstellen über den Umfang
⚪	Härte	HL	Vor- und Nachvermessung		Erfassung der Härte bei Raumtemperatur an mindestens 4 Messstellen über den Umfang
🟡	Öl- und Fettproben	Dichtsystem	nach Prüflauf	Fett: Elementanalyse mit AES Wassergehalt nach Karl Fischer Öl: Elementanalyse mit ICP Magnetischer Metallabrieb Oxidation und Wasser in % Wassergehalt nach Karl Fischer	Entnahme der Ölprobe direkt nach Versuchsende mittig aus dem Ölsumpf respektive aus dem Mittelstrahl Entnahme der Fettproben direkt nach Abbau der Prüfzellen vor dem Auspressen der RWDR
⚪	Reibmoment	Dichtsystem	während Prüflauf		
🔴	Leckage	Dichtsystem	während Prüflauf		Feststellung ob Leckage vorliegt sowie ggf. Erfassung der Leckagemenge

🔴 Zu erfassen 🟡 Ggf. erfassen ⚪ Vernachlässigbar *HL: Hauptdichtlippe* *SL: Hauptdichtlippe*

Figure 23: Messdatenerhebung - Kurzübersicht der erfassten Kenngrößen

Versuch-Nr.:	Ende Prüflauf:	Zelle/n:	Prüfkörper:
Betrachtungsgegenstand	**Zeitpunkt / Zustand**	**Merkmale / Charakteristika**	**Befundung**
RWDR	Verbaut im Prüfstand Ausgebaut und eingepresst Ausgepresst, nach Fettprobenentnahme und Reinigung	Hinsichtlich Leckage: Öl- und Fettrückstände an der Luftseite	
		Rissbildung / Verletzungen der Haupt- und Schutzlippe	
		Laufspurverfärbung	
		Einschlüsse / Anhaftende Fremdkörper	
		Geometrieabweichungen / Deformation der Haupt- und Schutzlippe	
Gegenlauffläche	Verbaut mit RWDR Verbaut ohne RWDR Ausgebaut und gereinigt	Hinsichtlich Leckage: Sichbare Öl- und Fettrückstände	
		Kohlebildung	
		Einschlüsse / Anhaftende Fremdkörper	
		Defekte / Schäden	
Schmutzwasser	Im Reservoir	Hinsichtlich Leckage: Ölfilm oder Fettrückstände	
Fett	Am ausgebauten noch eingepressten RWDR Nach Probenentnahme	Menge	
		Verfärbung	
		Einschlüsse / Anhaftende Fremdkörper	
Prüfzelle / Verteilersystem	Begleitend zum Abbau	Hinsichtlich Leckage: Öl- und Fettrückstände	
		Schmutzpartikel / Sediment	
Legende für Befundung: **0** - ohne / neuwertig || **1** - gering || **2** - deutlich || **3** - stark || **4** - sehr stark			
Datum:	Name:	Unterschrift:	

Figure 24: Protokoll optisch qualitative Bewertung

Versuch-Nr.: Daum: Name: Unterschrift:

Zuordnung	Parameter	Beschreibung	Einheit	Wert
Dichtsystem	RWDR	Hersteller		
		Typ		
		Größe d-D-b	mm	
		Werkstoff		
	Welle	Material		
		Oberfläche		
	Prüfschmutz	Schmutzsubstanz		
		Schmutzkonzentration	%	
		Trägermedium		
	Öl	Hersteller		
		Typ		
	Fett	Hersteller		
		Typ		
Prüfkenngrößen	Bewegungs-Charakteristika	Drehzahl	1/min	
		Umfangsgeschw.	m/s	
		Reibweg	km	
		Laufzeit	h	
		Kinematik		
	Ölsumpf	Temperatur	°C	
		Füllstand		
	Befettung	Menge	gramm	
		Befettungsgrad	%	
	Beaufschlagung	Intervalldauer	s	
		Intervallabstand	min	
	Statistik	Anzahl geprüfter RWDR		

Figure 25: Protokoll Betriebs-/Prüfkenngrößen

Versuchs-Nr.	Aufbau:		Versuchsstart:	Name:	Unterschrift:
DD.MM.YY / HH.MM	**Schmutzkonz.**	**Zelle**			
		Koaxialität			
		Rundlauf			
		RWDR			
		Gegenlauffläche			
		Temperatur			
		Leckage			
		Bemerkung			
		Temperatur			
		Leckage			
		Bemerkung			
		Temperatur			
		Leckage			
		Bemerkung			
		Temperatur			
		Leckage			
		Bemerkung			
Kommentar					
Versuchs-Nr.	Versuchsende:		Abbau:	Name:	Unterschrift:

Figure 26: Versuchsprotokoll

Versuch Nr.		
A Aufbau	**Ja**	**Nein**
A1. Vorvermessung durchgeführt		
A2. Sauberkeit Prüfaufbau:		
A2.1. Prüfzellen		
A2.2. Schmutzreservoir		
A2.3. Verteilersystem		
A2.4. RWDR		
A2.5 Gegenlauffläche		
A3. Öl in Prüfzellen eingefüllt		
A4. Schmutzreservoir gefüllt		
A5. Temperierung Ölsumpf		
A6. Temperaturüberwachung Ölsumpf		
A7. Erdung Prüfzellen		
A8. Vorrichtung Leckagekontrolle		
A9. Abzug		
Datum		
Name		
Unterschrift		
B Abbau	**Ja**	**Nein**
B1. Prüfstand ausschalten		
B2. Ölprobenentnahme		
B3. Dokumentation Zustand Schmutzwassergemisch		
B4. Abschließende Probenentnahme Schmutzwasser		
B5. Abschließende Leckagekontrolle		
B6. Dokumentation Zustand RWDR		
B6.1. In Prüfaufbau verbaut		
B6.2. Ausgebaut in RWDR-Aufnahme verpresst		
B6.3. Ausgepresst		
B7. Dokumentation Zustand Gegenlauffläche		
B7.1. In Prüfaufbau verbaut		
B7.2. Demontiert		
B8. Dokumentation Zustand Prüfzelle / Verteilersystem / Schmutzreservoir		
B9. Reinigen Prüfaufbau:		
B9.1. Prüfzellen		
B9.2. Schmutzreservoir		
B9.3. Verteilersystem		
B10. Fettprobenentnahme inkl. Dokumentation		
B11. Nachvermessung		
Datum		
Name		
Unterschrift		

Figure 27: Checkliste Prüfauf- und abbau

Vorgang	Ja	Nein
1. Arbeitssicherheit		
2. Ausreichende Anzahl Probenbehälter		
3. Ausreichende Anzahl Entnahmewerkzeug (Spatel)		
4. Beschriftung Probenbehälter		
5. Sauberkeit Behälter und Werkzeug		
6. Reinigungstücher		
7. Entnahme der Probe		
8. Dokumentation der Probe (Bilder)		
9. Ausfüllen des Probenbegleitscheins		
10. Versand der Fettprobe		
Datum		
Name		
Unterschrift		

Figure 28: Checkliste Fettprobenentnahme

Probenbegleitschein RWDR - Probenkennung:			
Hersteller			
Typ			
Größe d-D-b			
Werkstoff			
Versuchs-Nr.			
Zelle			
Gegenlauffläche			
Vorvermessung	**Erfasst am**	**Name / Unterschrift**	**Wert**
Radialkraft RT			
Radialkraft BT			
Berührbreite			
Geometrie			
Härte			
Nachvermessung	**Erfasst am**	**Name / Unterschrift**	**Wert**
Opt. Bewertung			
Ölprobe			
Fettprobe			
Berührbreite			
Geometrie			
Härte			
Radialkraft BT			
Radialkraft RT			

Figure 29: Probenbegleitschein - RWDR

Probenbegleitschein Gegenlauffläche - Probenkennung:			
Material			
Oberfläche			
Versuchs-Nr.			
Zelle			
RWDR			
Vorvermessung	**Erfasst am**	**Name / Unterschrift**	**Wert**
Radialkraft RT			
Radialkraft BT			
Berührbreite			
Geometrie			
Härte			
Nachvermessung	**Erfasst am**	**Name / Unterschrift**	**Wert**
Opt. Bewertung			
Ölprobe			
Fettprobe			
Berührbreite			
Geometrie			
Härte			
Radialkraft BT			
Radialkraft RT			

Figure 30: Probenbegleitschein - Gegenlauffläche

Probenbegleitschein Öl - Probenkennung:	
Hersteller	
Typ	
Versuchs-Nr.	
Zelle	
RWDR	
Gegenlauffläche	
Laufzeit	
Reibweg	
Relativgeschwindigkeit	
Entnahmestelle / Vorlauf	
Entnahmegerät	
Probenentnahme (laufend / abgestellt)	
Bemerkung	
Name	
Datum	
Unterschrift	

Figure 31: Probenbegleitschein - Ölprobe

Probenbegleitschein Fett - Probenkennung:	
Hersteller	
Typ	
Versuchs-Nr.	
Zelle	
RWDR	
Gegenlauffläche	
Laufzeit	
Reibweg	
Relativgeschwindigkeit	
Bemerkung	
Name	
Datum	
Unterschrift	

Figure 32: Probenbegleitschein - Fettprobe

Appendix: Laser triangulation method for wear measurement

The wear and geometry measurement can be carried out by means of laser triangulation using the structure shown in Figure 33 as an example.

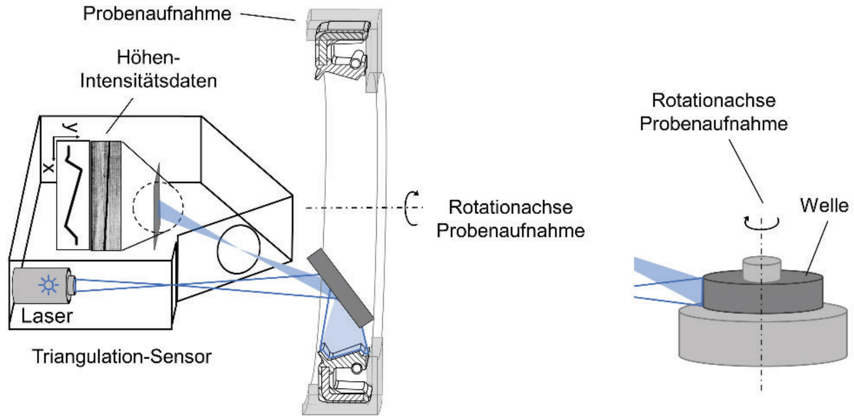


Figure 33: Wear measurement using the laser triangulation principle

This system uses a triangulation sensor that projects a laser line onto the object to be measured. For the measurement of inward lying surfaces, as they occur in RSS, the beam is directed onto the surface to be measured by using a plane mirror. For the measurement data collection, the samples are set in rotation. Thus, a large number of cross-sections with height and intensity data can be recorded over the circumference of the sample and analysed with regard to the wear characteristics mentioned in section 5.2.1 and the interference mentioned in section 5.2.6.

Appendix: Contact width measurement using light microscopy

Figure 34 shows the measurement setup for contact width measurement on a light microscope, in which the RSS is mounted on a transparent glass or PMMA hollow shaft. This is inserted into a rotatably mounted holder. The contact area between the RSS and the measuring shaft can be captured and evaluated using a plane mirror at a 45° angle to the optical axis.

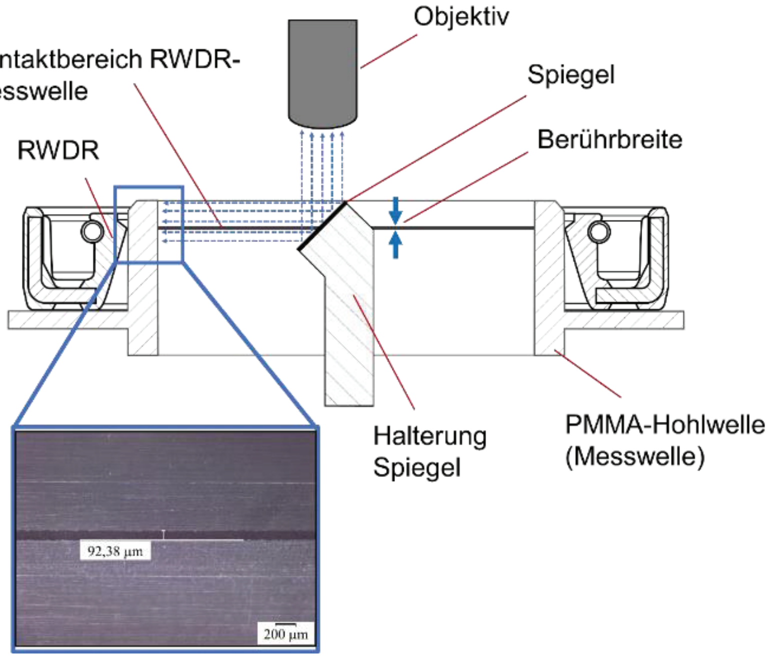


Figure 34: Measurement set-up for contact width measurement using a light microscope

Appendix: Radial force measurement according to DIN 3761-9

When measuring radial force according to DIN 3761-9, the measurement setup shown in Figure 35 is used. The corresponding dimensions and the calibration of the measuring device can be found in the standard mentioned.

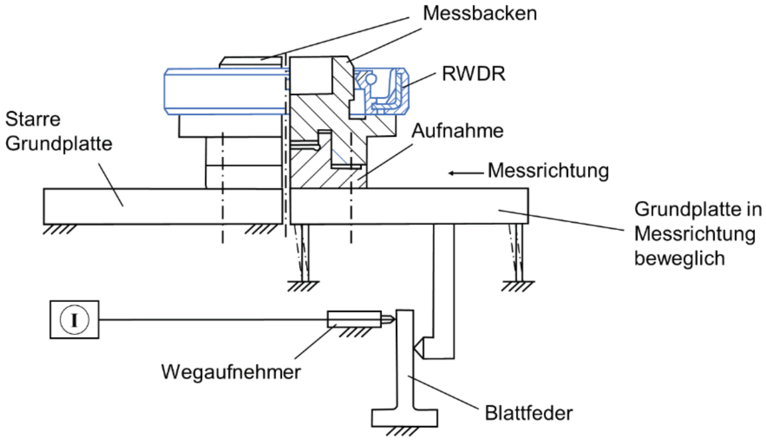


Figure 35: Radial force measurement using the two-jaw principle according to DIN-3761-9

The structure includes a rigid base plate on which one of the two measuring jaws is firmly mounted. The second measuring jaw is connected to a bending spring of known stiffness, so that when the RSS is mounted, the movable measuring jaw is pushed in the direction of the fixed measuring jaw. The bending of the spring is detected by a displacement sensor, for example a micrometer dial indicator, so that the springback force of the beam can be converted into a radial force using equation (1. 1).

$$F_R = F_b \times \pi \qquad (1.\ 1)$$

To counteract cooling of the RSS due to the thermal conductivity of the measuring jaws, the further development of the two-jaw measuring method described by Burkhart in [06] can be used. In this method, temperature control of the measuring jaws is possible via a fluid circuit, for example with temperature-controlled silicone oil.

Appendix: Technical drawings of the test cell and load unit

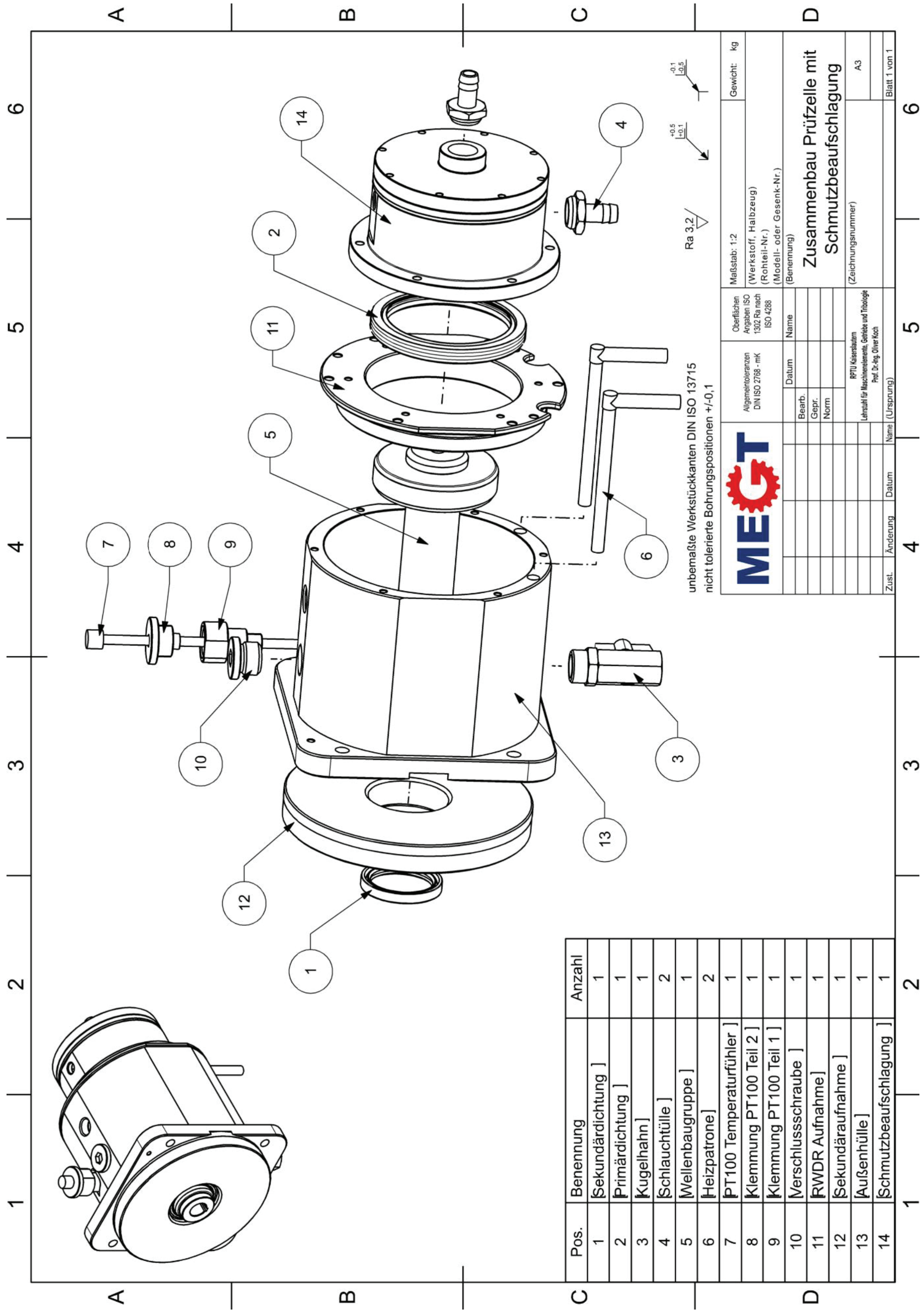


Figure 36: Explosionszeichnung Prüfzelle mit Beaufschlagungseinheit

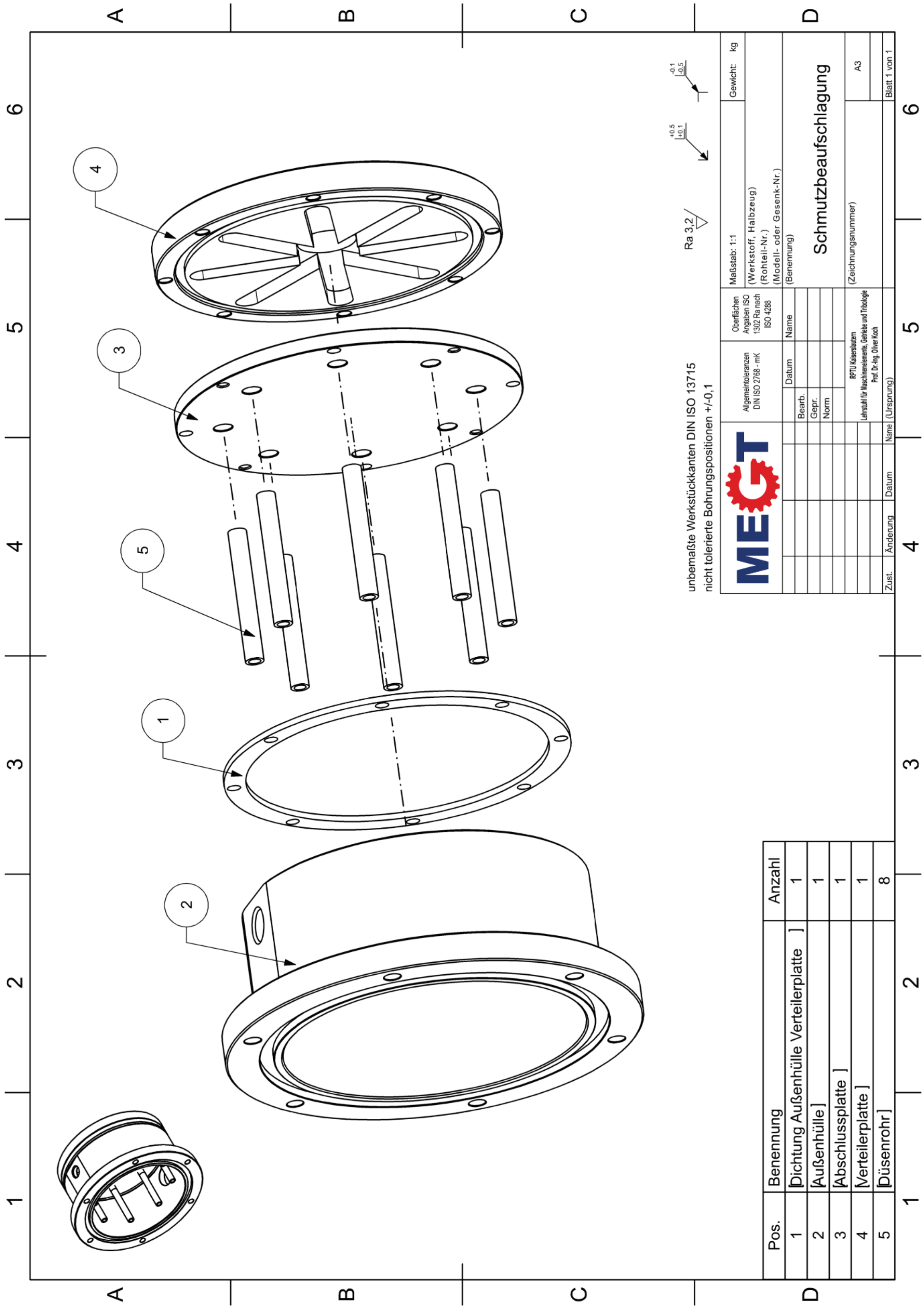
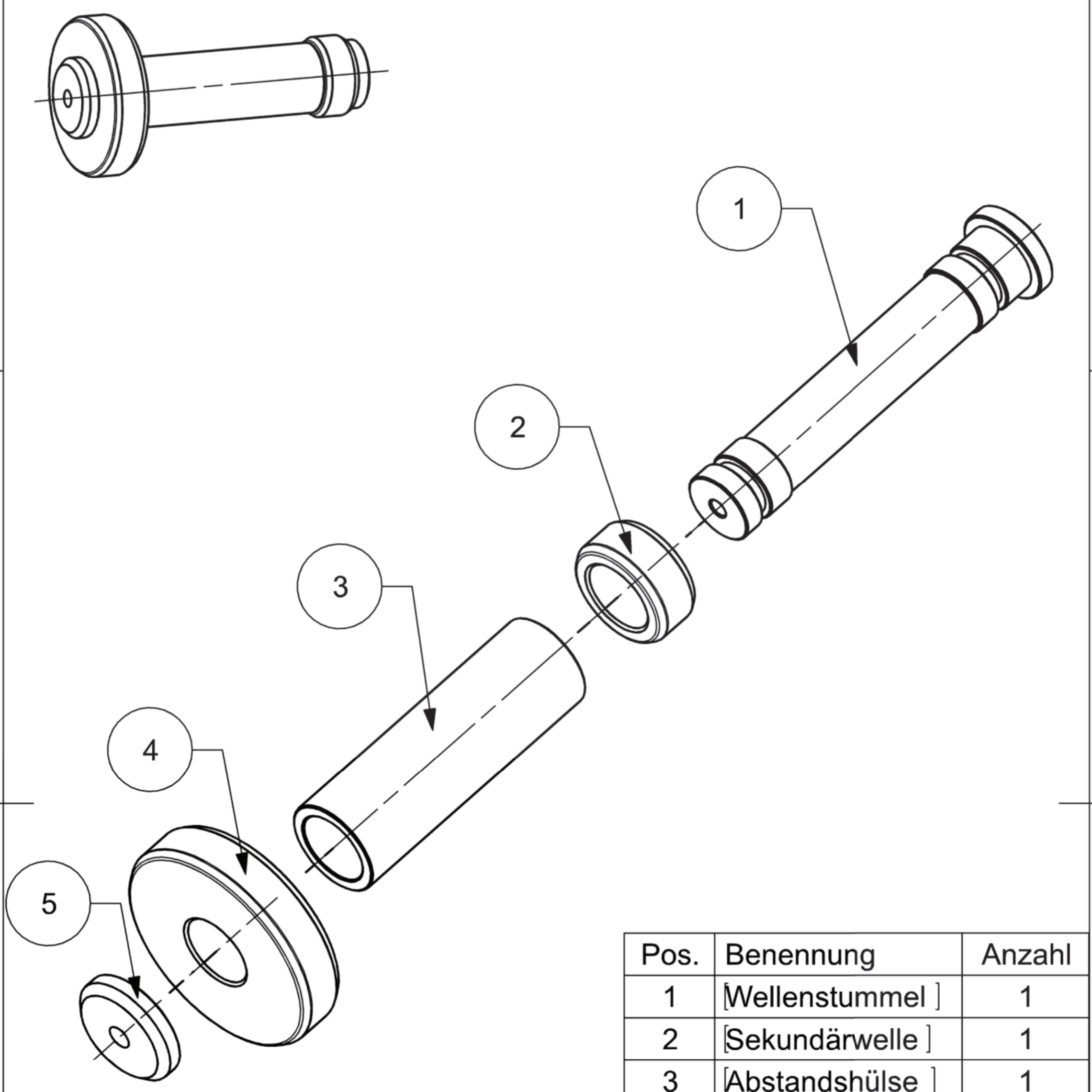


Figure 37: Explosionszeichnung Beaufschlagungseinheit



Pos.	Benennung	Anzahl
1	Wellenstummel	1
2	Sekundärwelle	1
3	Abstandshülse	1
4	Prüfwelle	1
5	Wellendeckel	1

unbemaßte Werkstückkanten DIN ISO 13715
nicht tolerierte Bohrungspositionen +/-0,1

Ra 3,2 +0.5 +0.1 -0.1 -0.5

MEGT

Allgemeintoleranzen DIN ISO 2768 - mK

Oberflächen Angaben ISO 1302 Ra nach ISO 4288

Maßstab: 1:2 Gewicht: kg

(Werkstoff, Halbzeug)
(Rohteil-Nr.)
(Modell- oder Gesenk-Nr.)

(Benennung)

Wellenbaugruppe

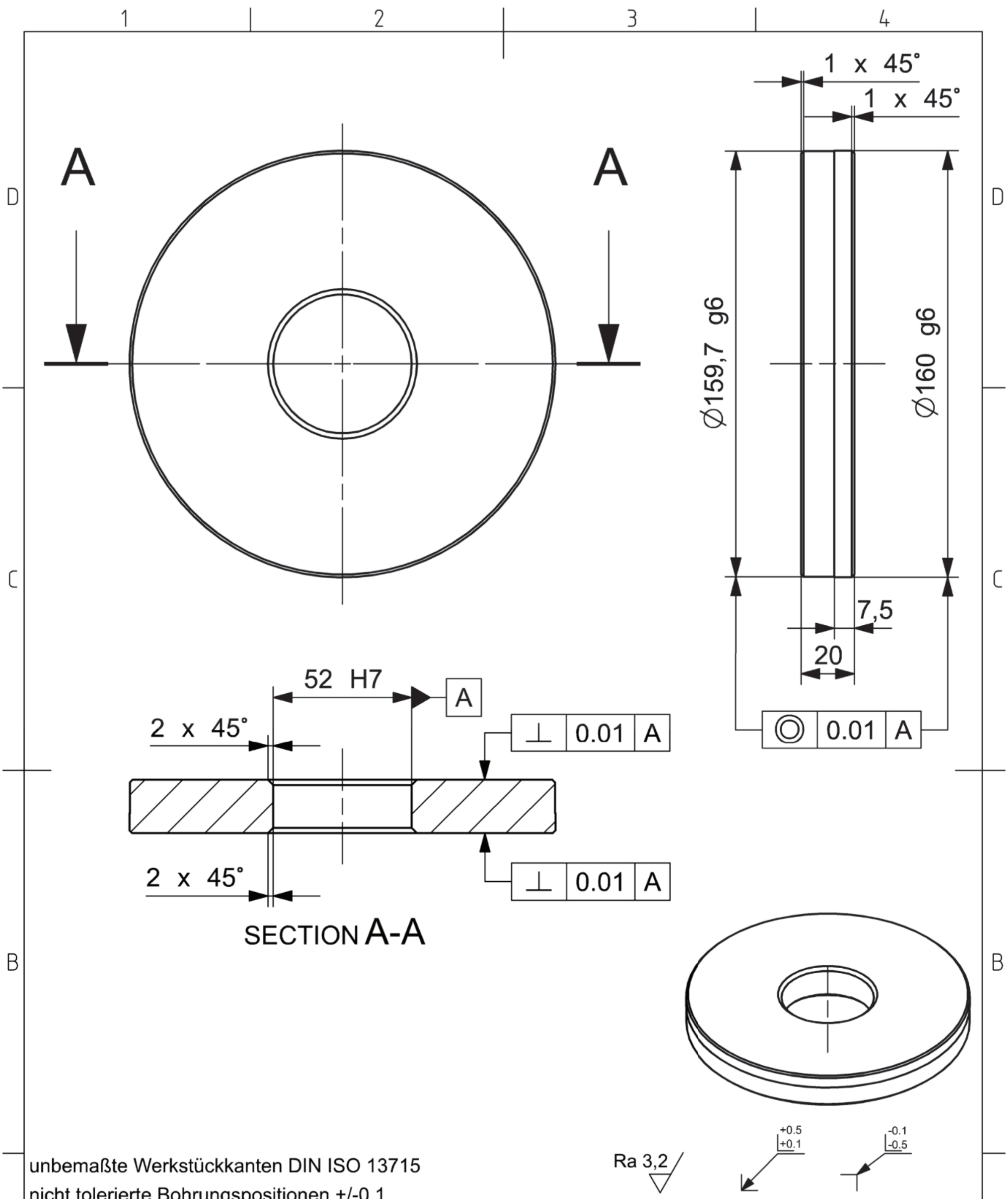
	Datum	Name
Bearb.		
Gepr.		
Norm		

RPTU Kaiserslautern
Lehrstuhl für Maschinenelemente, Getriebe und Tribologie
Prof. Dr.-Ing. Oliver Koch

(Zeichnungsnummer) A4

Zust. Änderung Datum Name (Ursprung) Blatt 1 von 1

Figure 38: Explosionszeichnung Wellenbaugruppe



unbemaßte Werkstückkanten DIN ISO 13715
nicht tolerierte Bohrungspositionen +/-0,1

Allgemeintoleranzen DIN ISO 2768 - mK	Oberflächen Angaben ISO 1302 Ra nach ISO 4288	Maßstab: 1:2	Gewicht: kg
		(Werkstoff, Halbzeug) Aluminium (Rohteil-Nr.) (Modell- oder Gesenk-Nr.)	
	Datum / Name	(Benennung)	
Bearb.		Prüfzelle Sekundäraufnahme	
Gepr.			
Norm			
RPTU Kaiserslautern Lehrstuhl für Maschinenelemente, Getriebe und Tribologie Prof. Dr.-Ing. Oliver Koch		(Zeichnungsnummer)	A4
Zust. / Änderung / Datum / Name	(Ursprung)		Blatt 1 von 1

Figure 39: Prüfzelle - Aufnahme für Sekundärdichtung

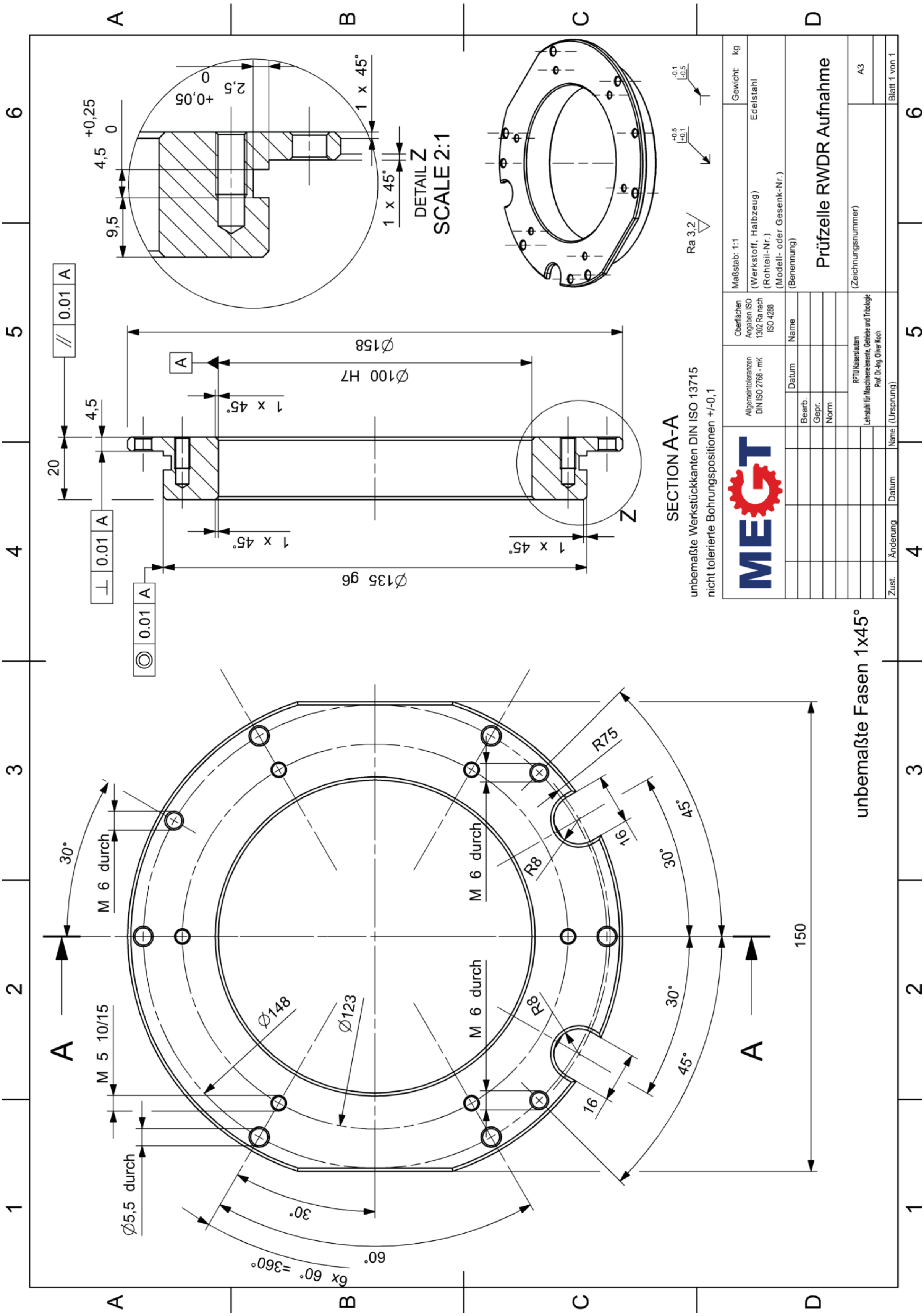


Figure 40: Prüfzelle - Aufnahme Prüf-Dichtung

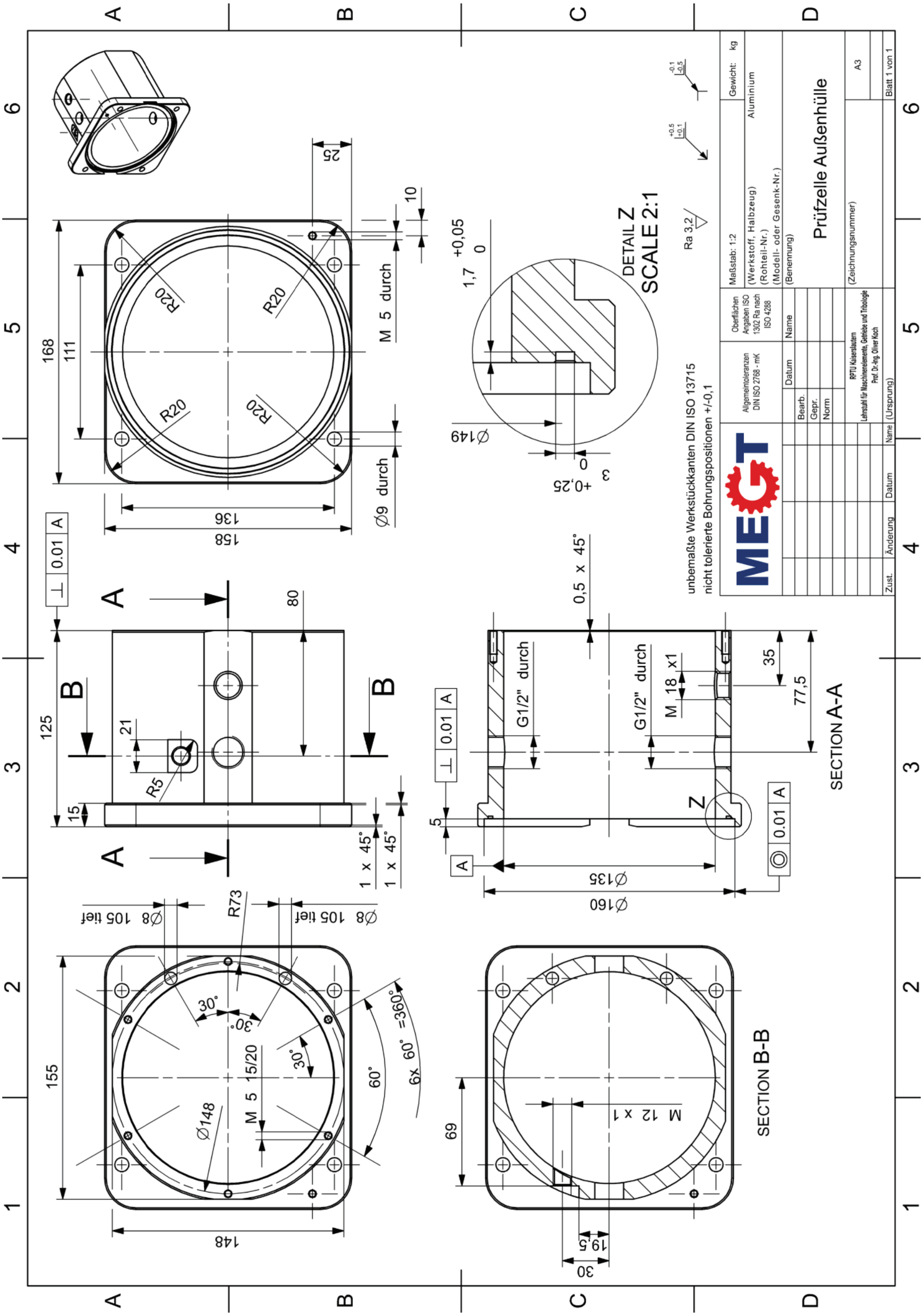


Figure 41: Prüfzelle - Außenhülle

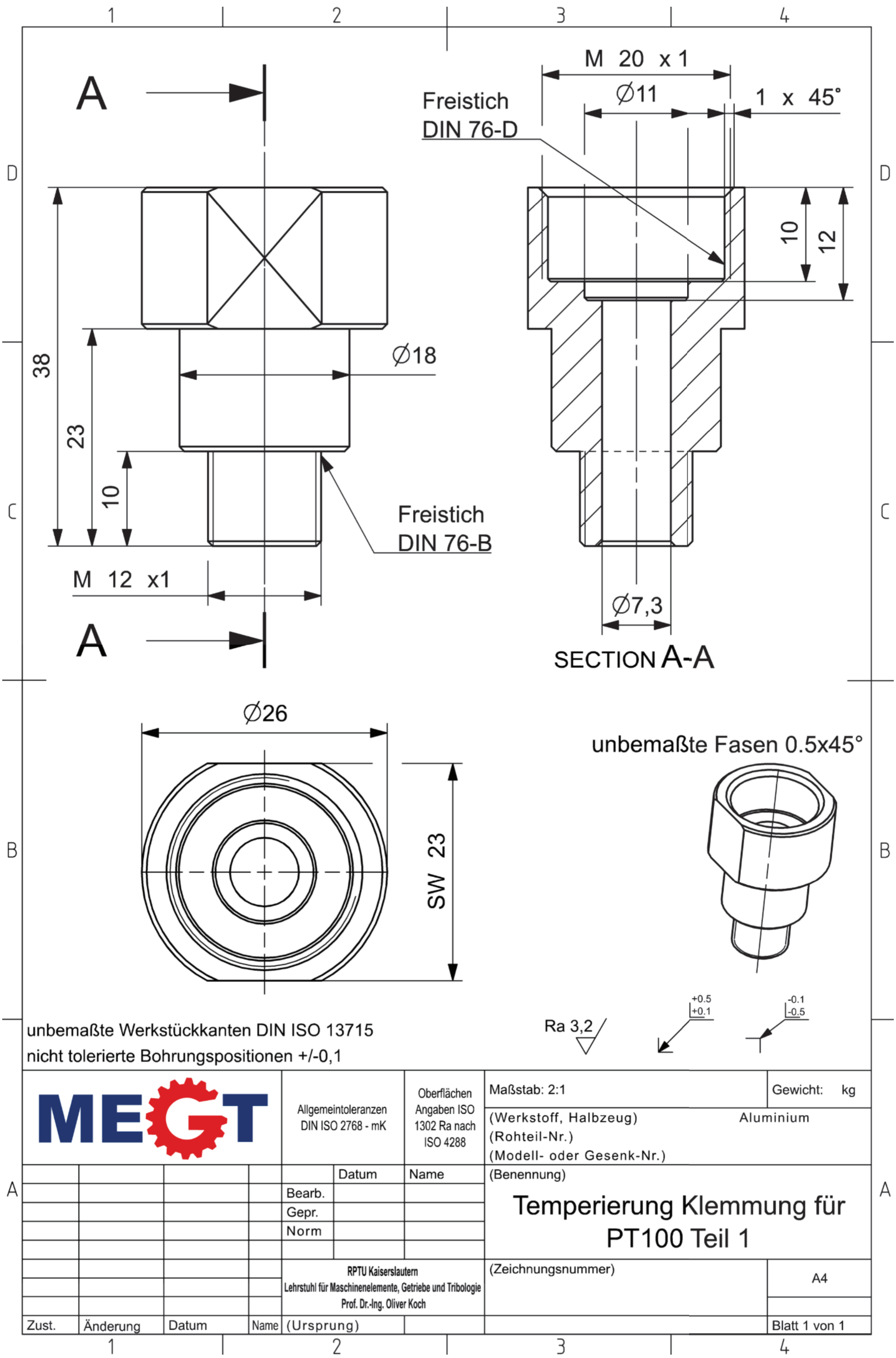


Figure 42: Prüfzelle - Klemmung für PT100 Teil 1

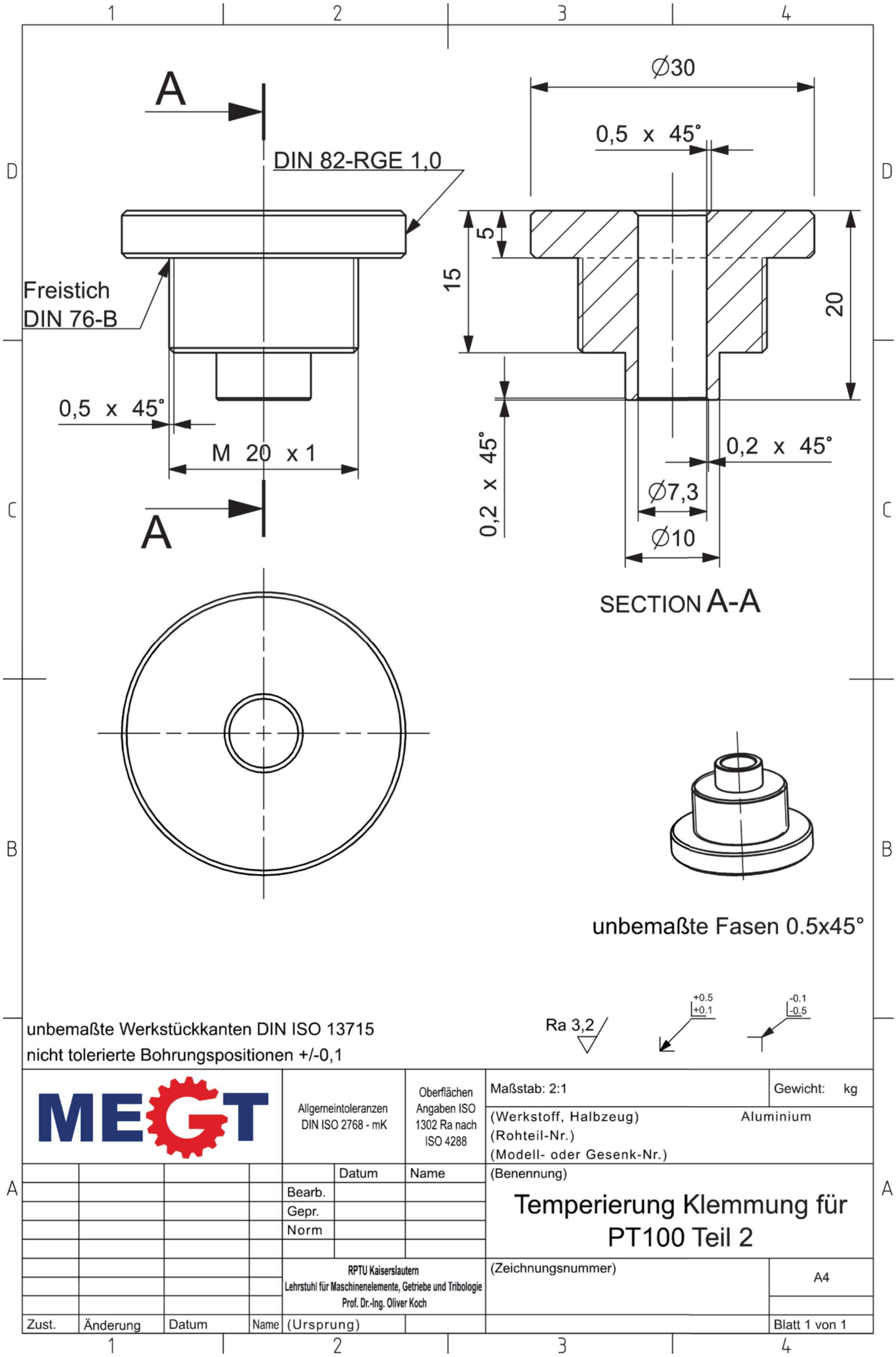


Figure 43: Prüfzelle - Klemmung für PT100 Teil 2

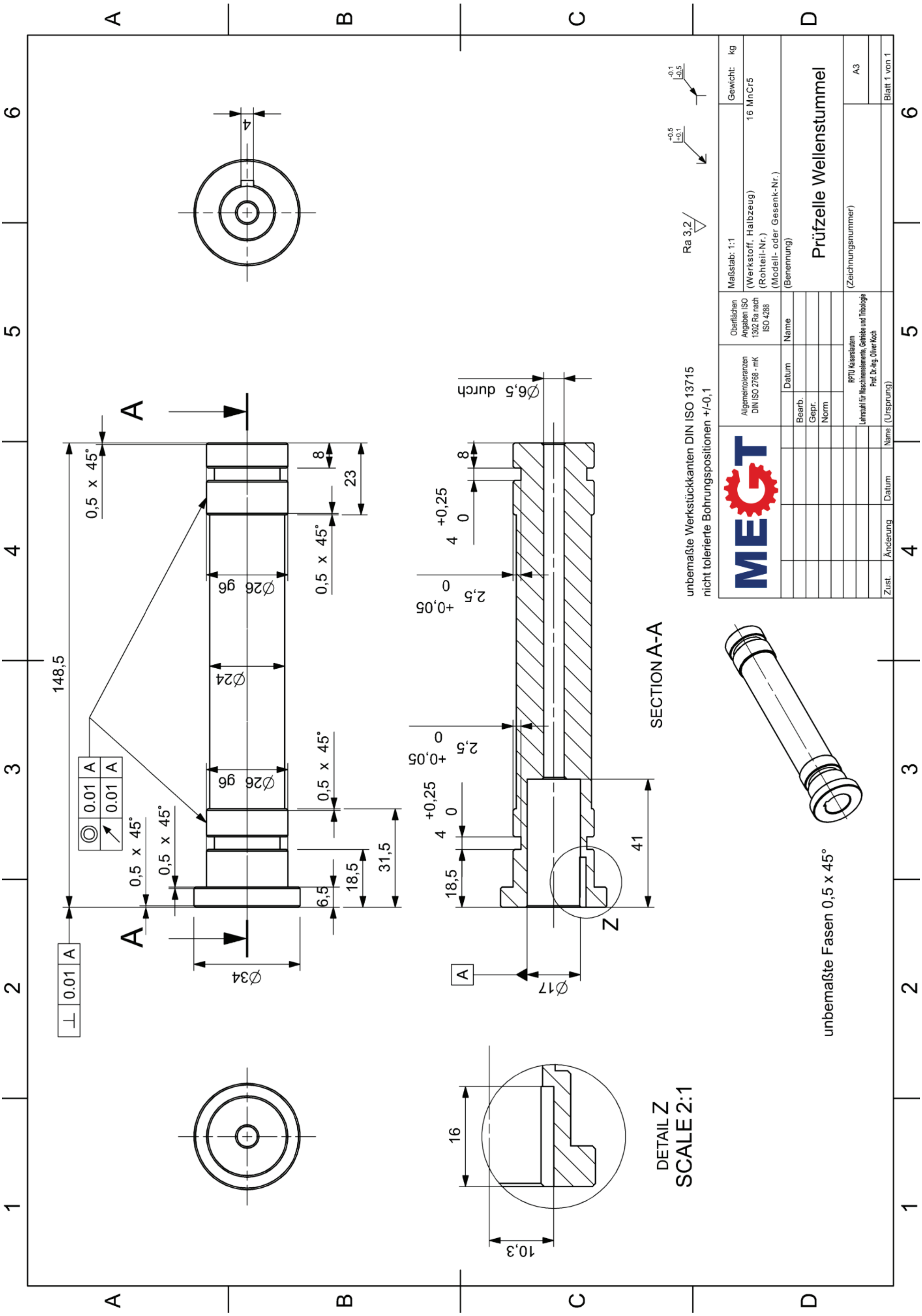


Figure 44: Wellenbaugruppe - Wellenstummel

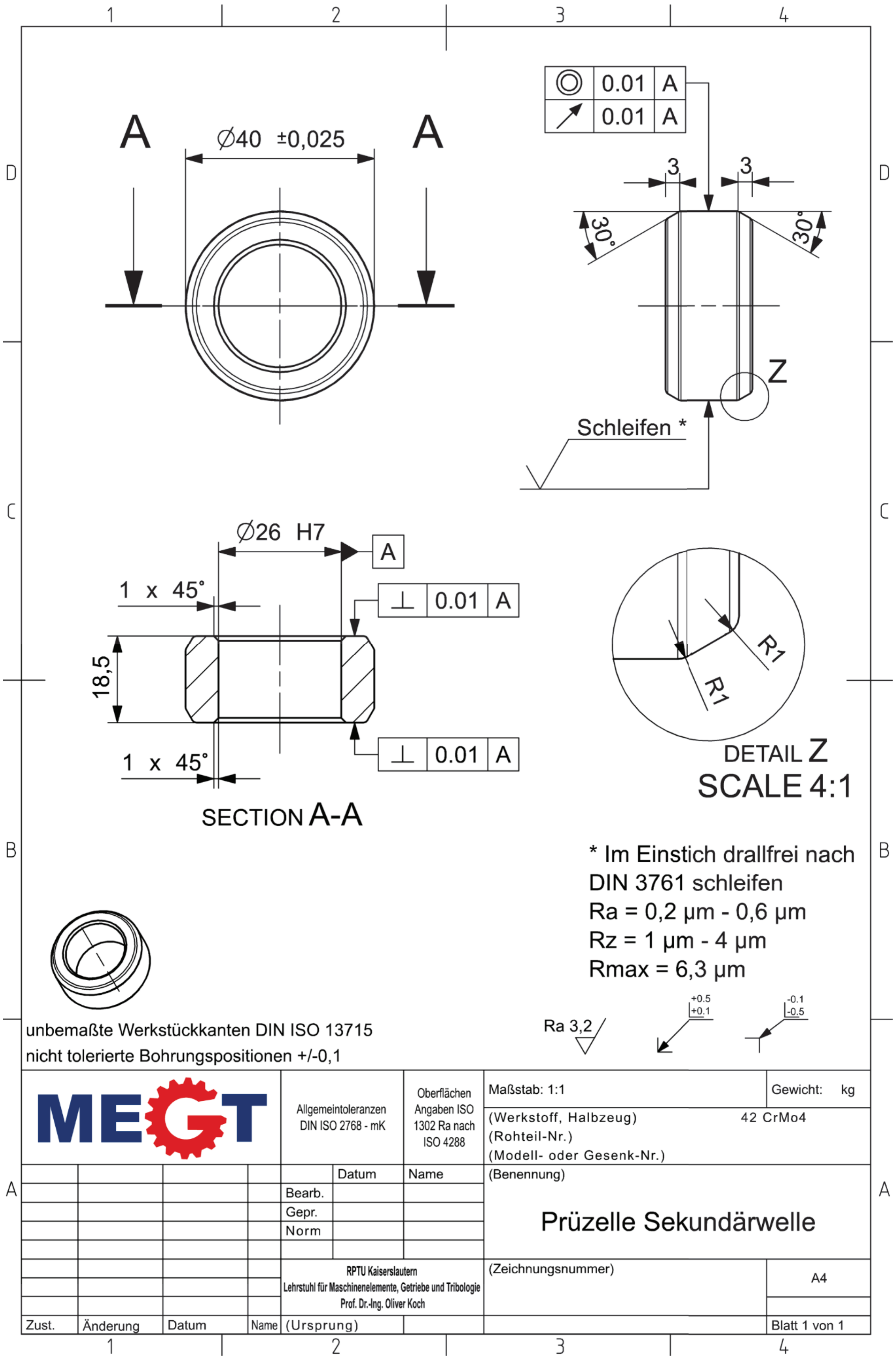


Figure 45: Wellenbaugruppe - Sekundärwelle

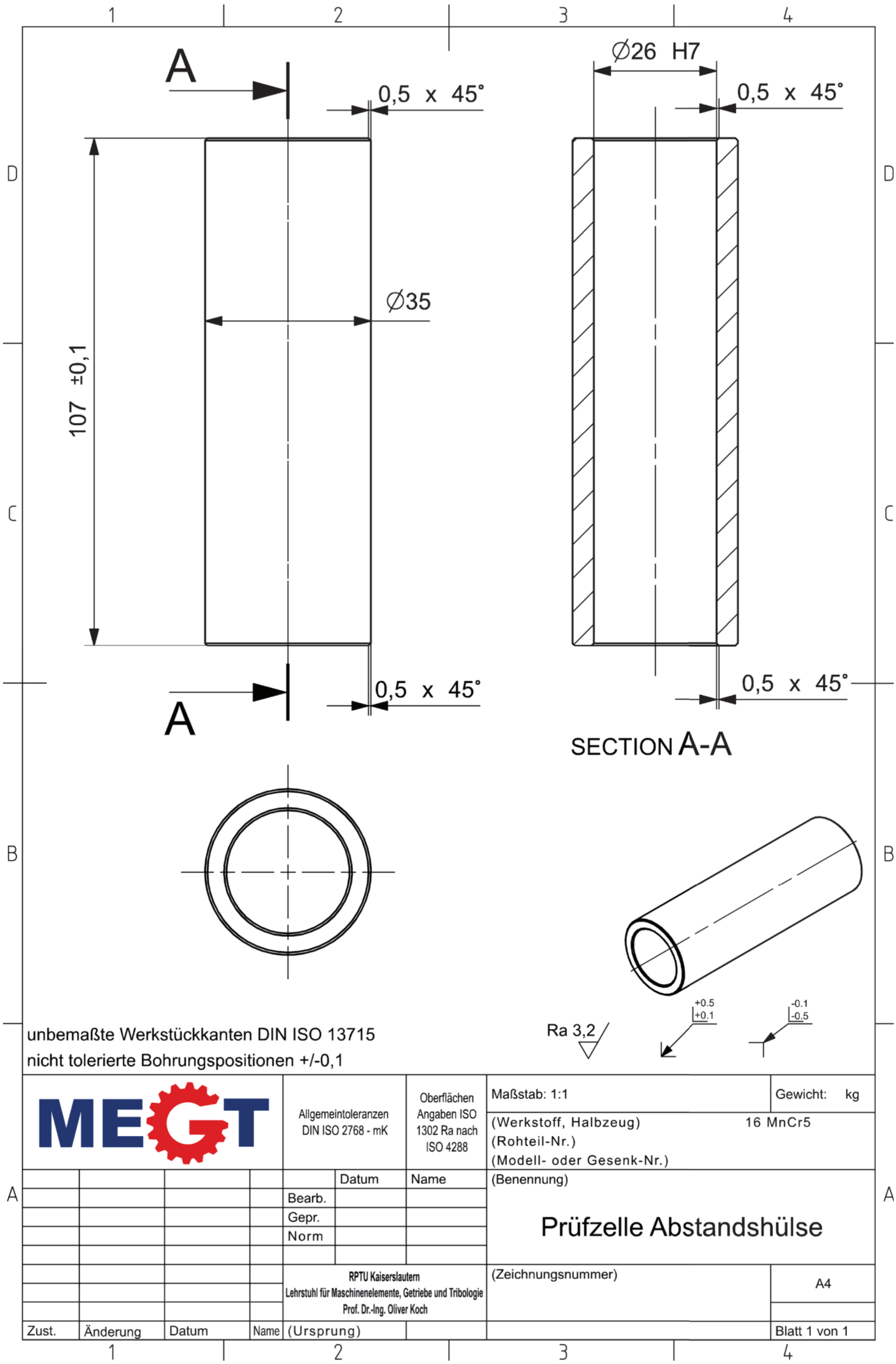


Figure 46: Wellenbaugruppe - Abstandshülse

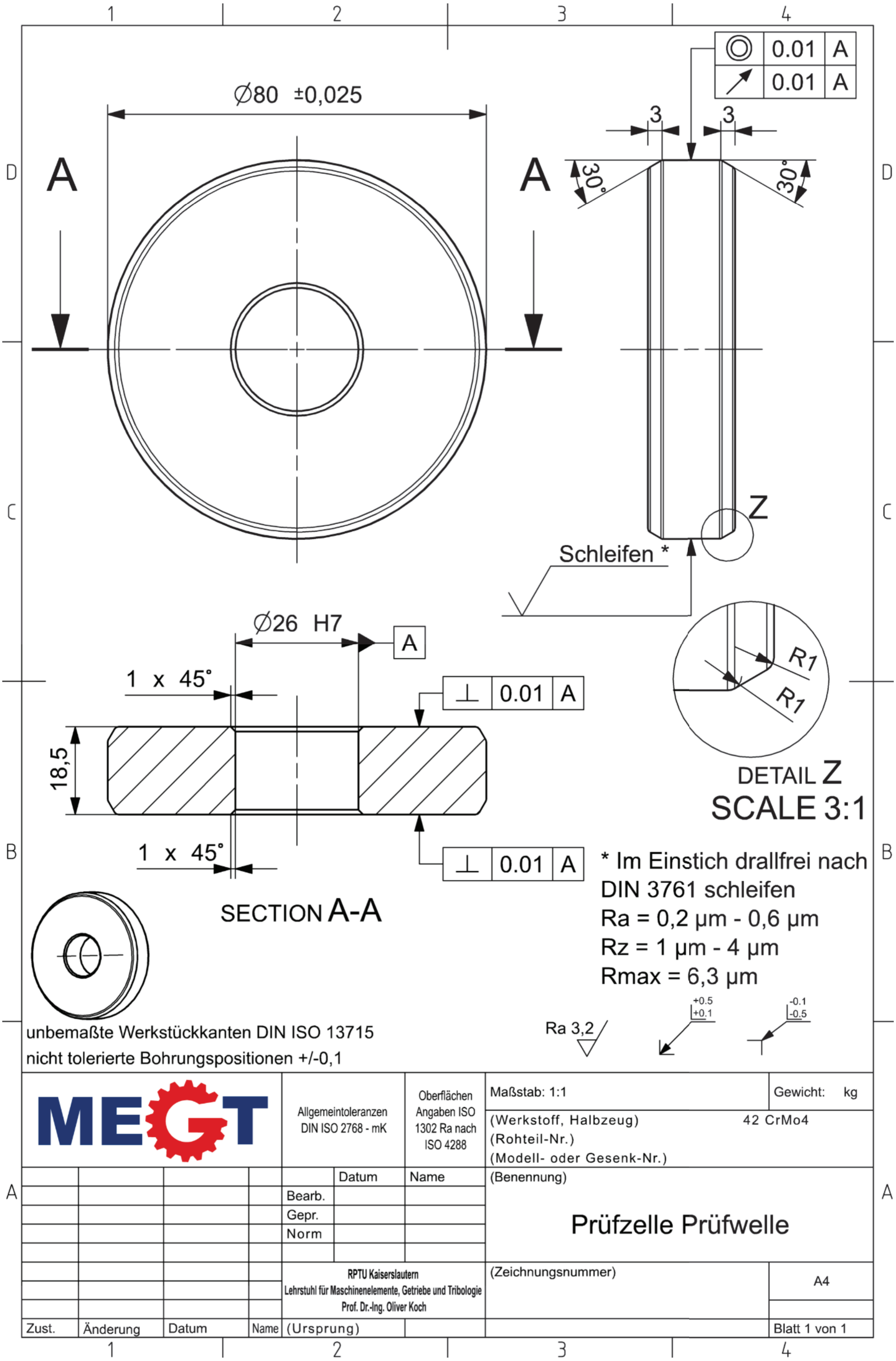


Figure 47: Wellenbaugruppe - Prüfwelle

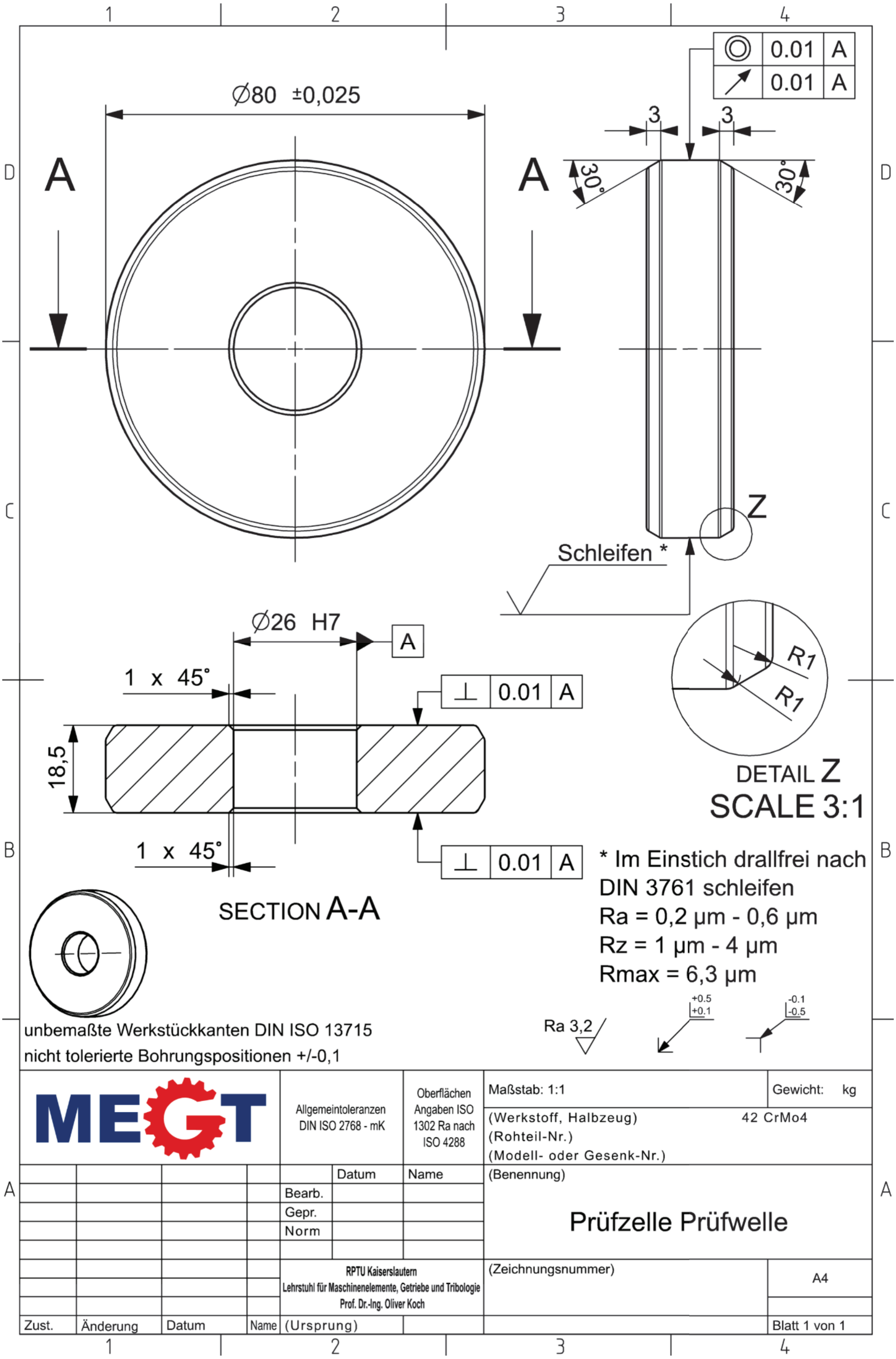


Figure 48: Wellenbaugruppe - Wellendeckel

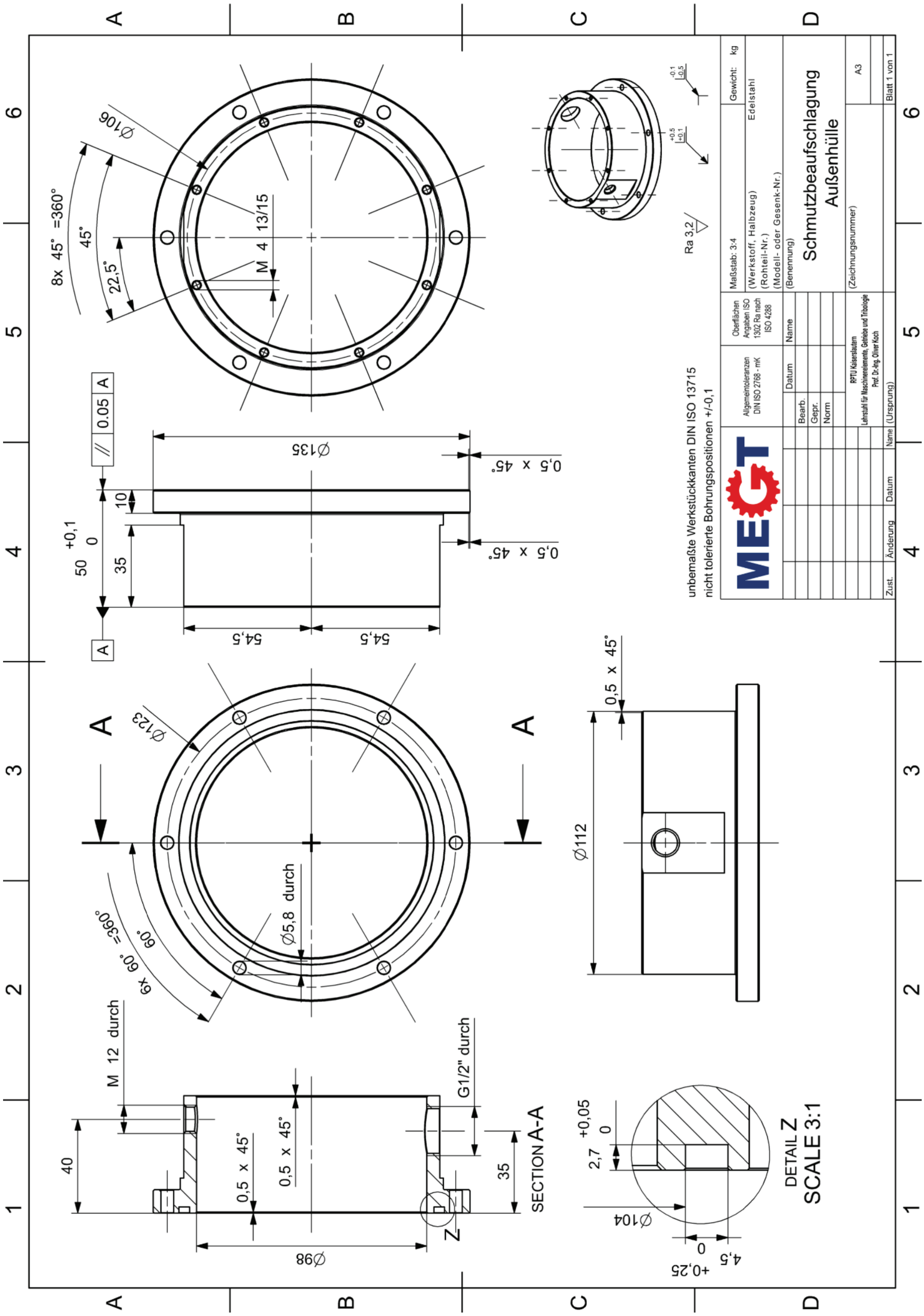


Figure 49: Beaufschlagungseinheit - Außenhülle

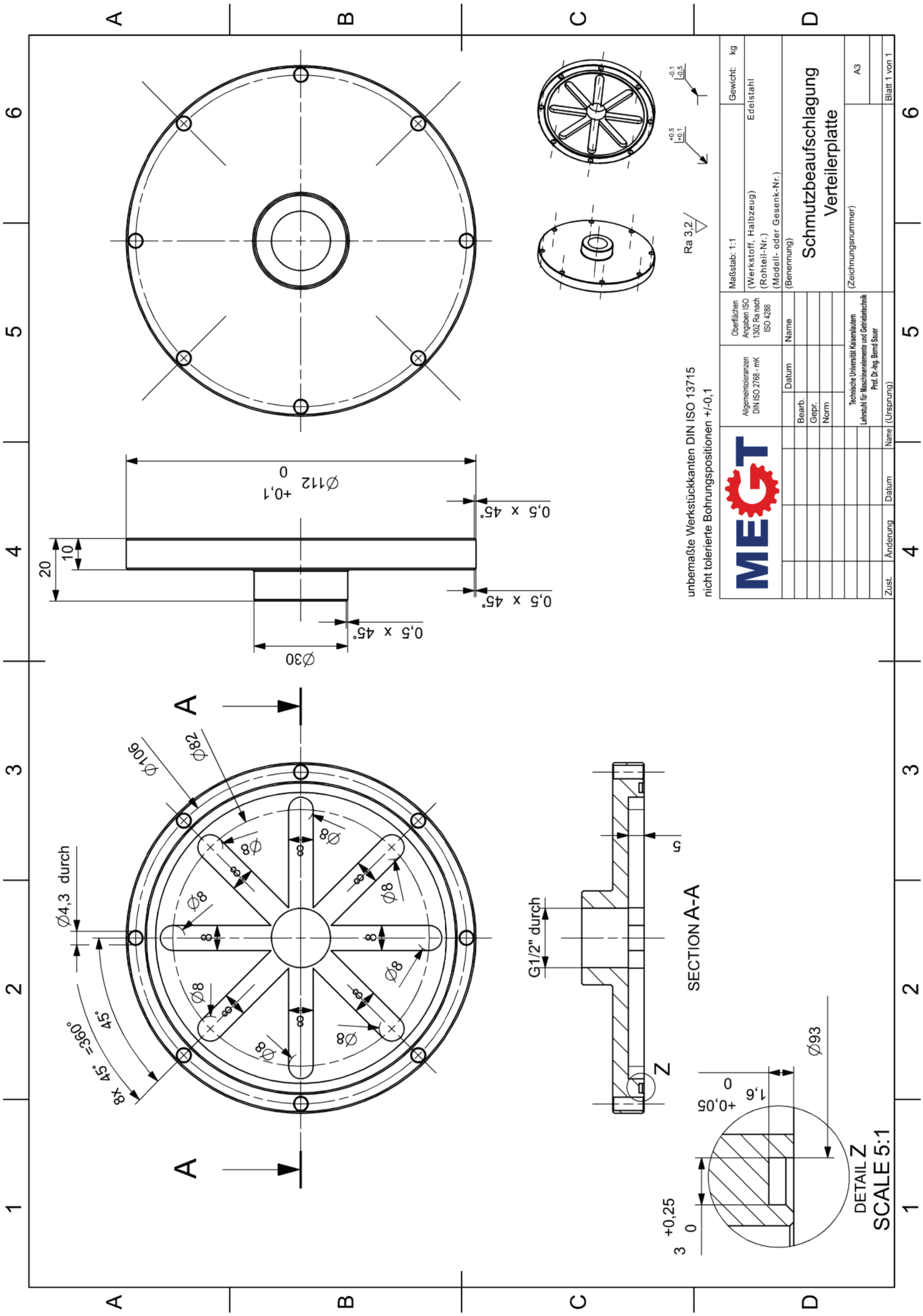


Figure 50: Beaufschlagungseinheit - Verteilerplatte

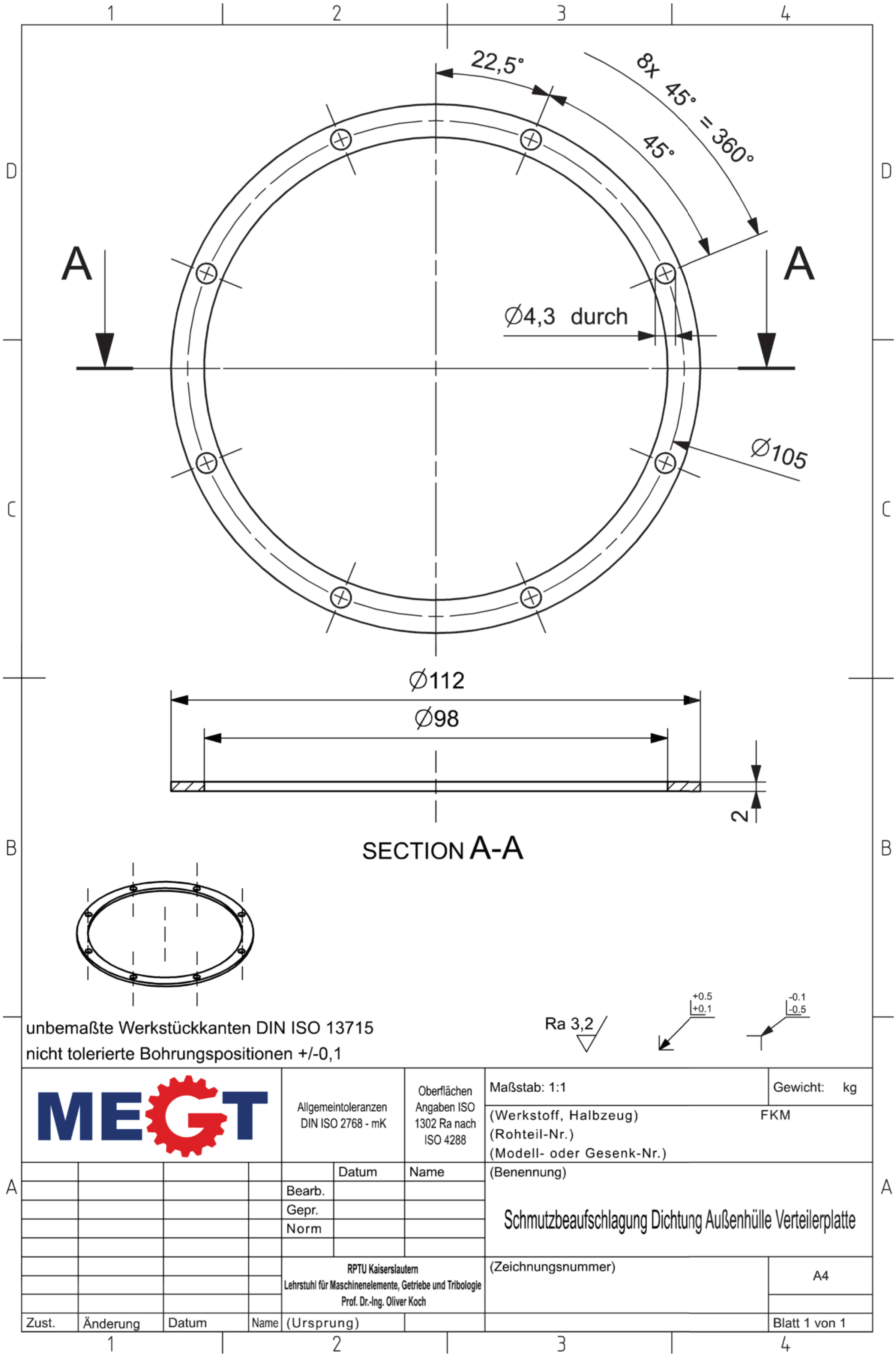


Figure 51: Beaufschlagungseinheit - Flachdichtung Außenhülle Verteilerplatte

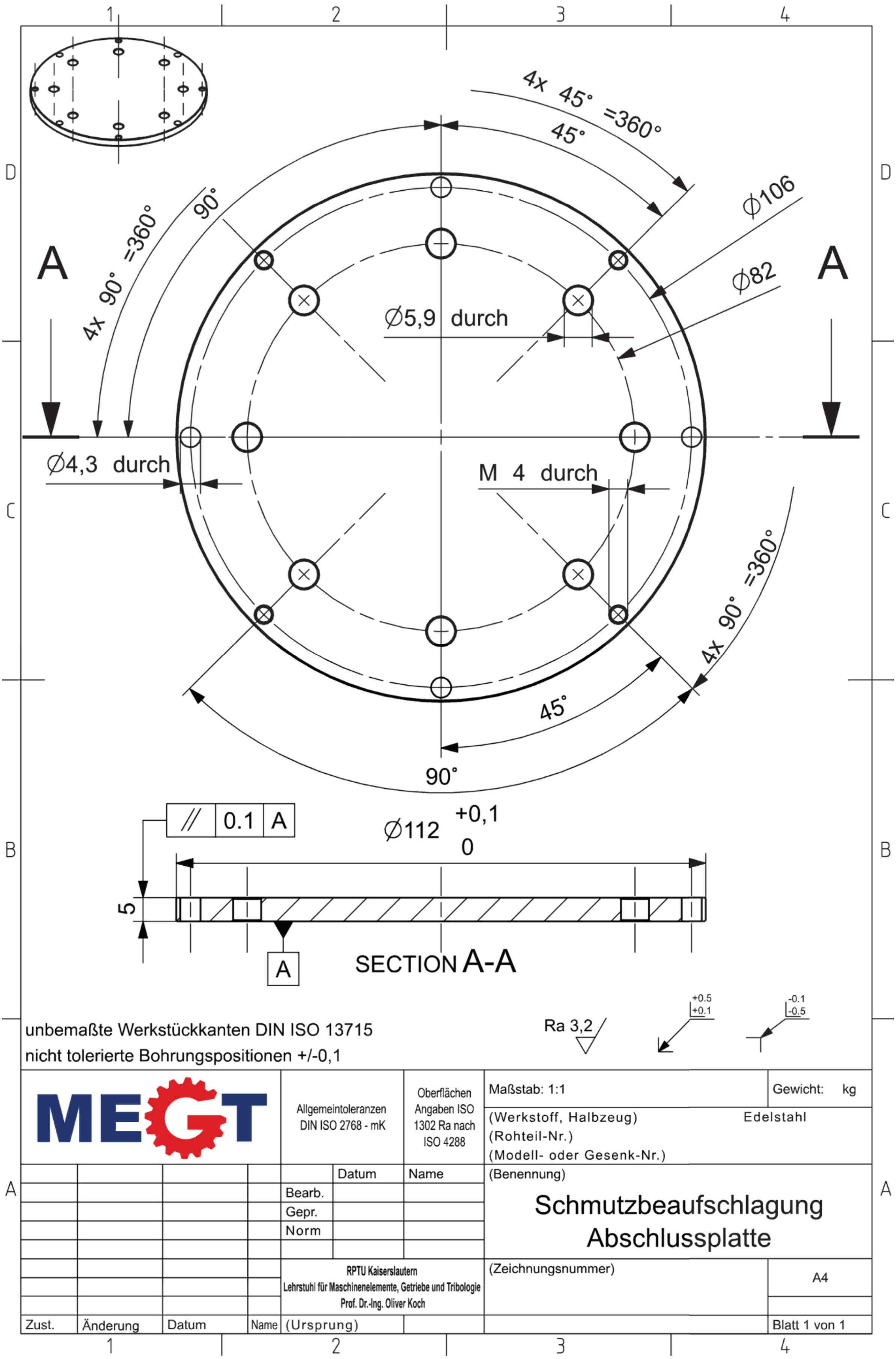


Figure 52: Beaufschlagungseinheit - Abschlussplatte

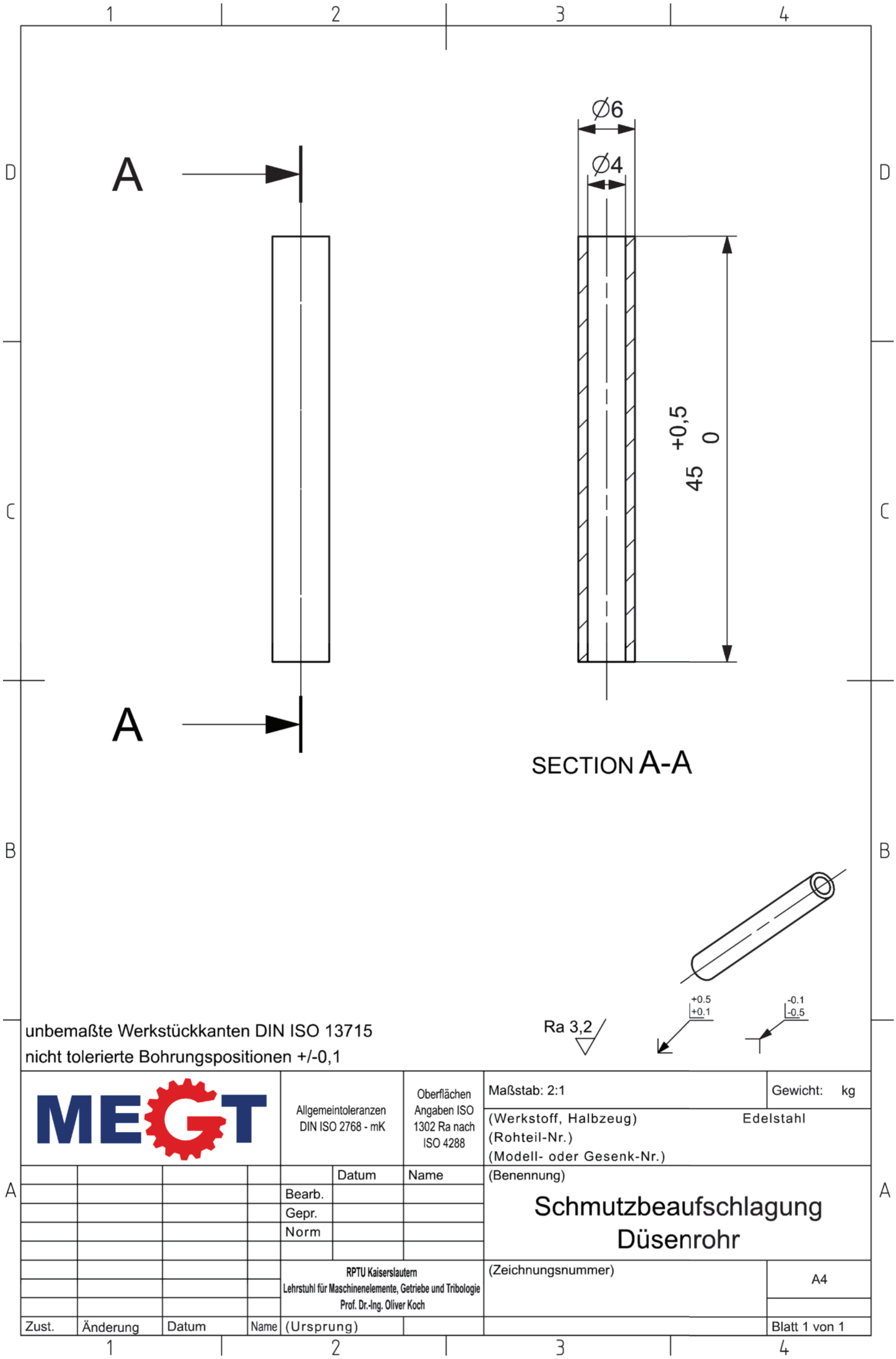


Figure 53: Beaufschlagungseinheit - Düsenrohr

Appendix: Technical drawings of the dirt reservoir

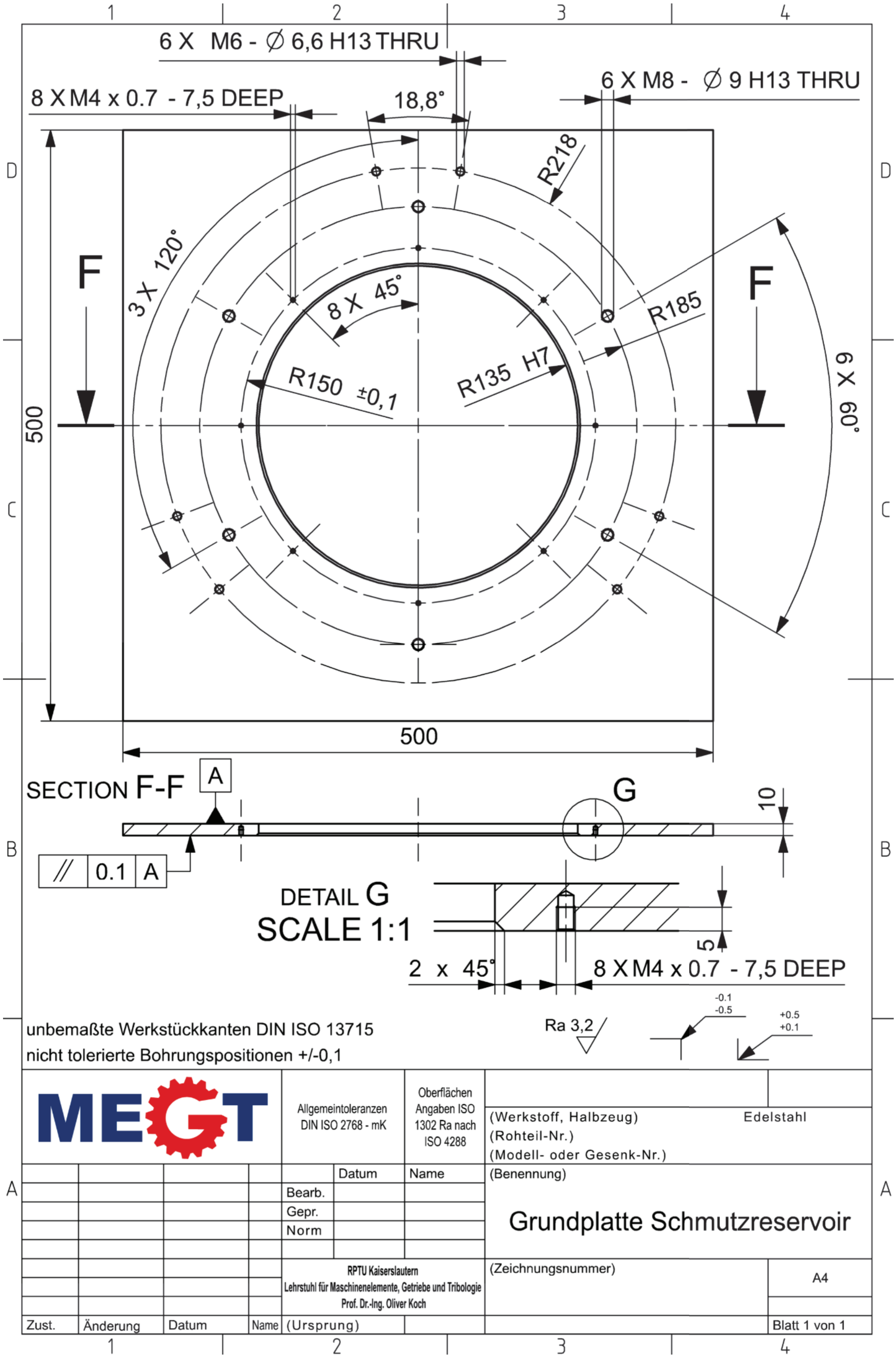


Figure 54: Schmutzwasserreservoir - Grundplatte

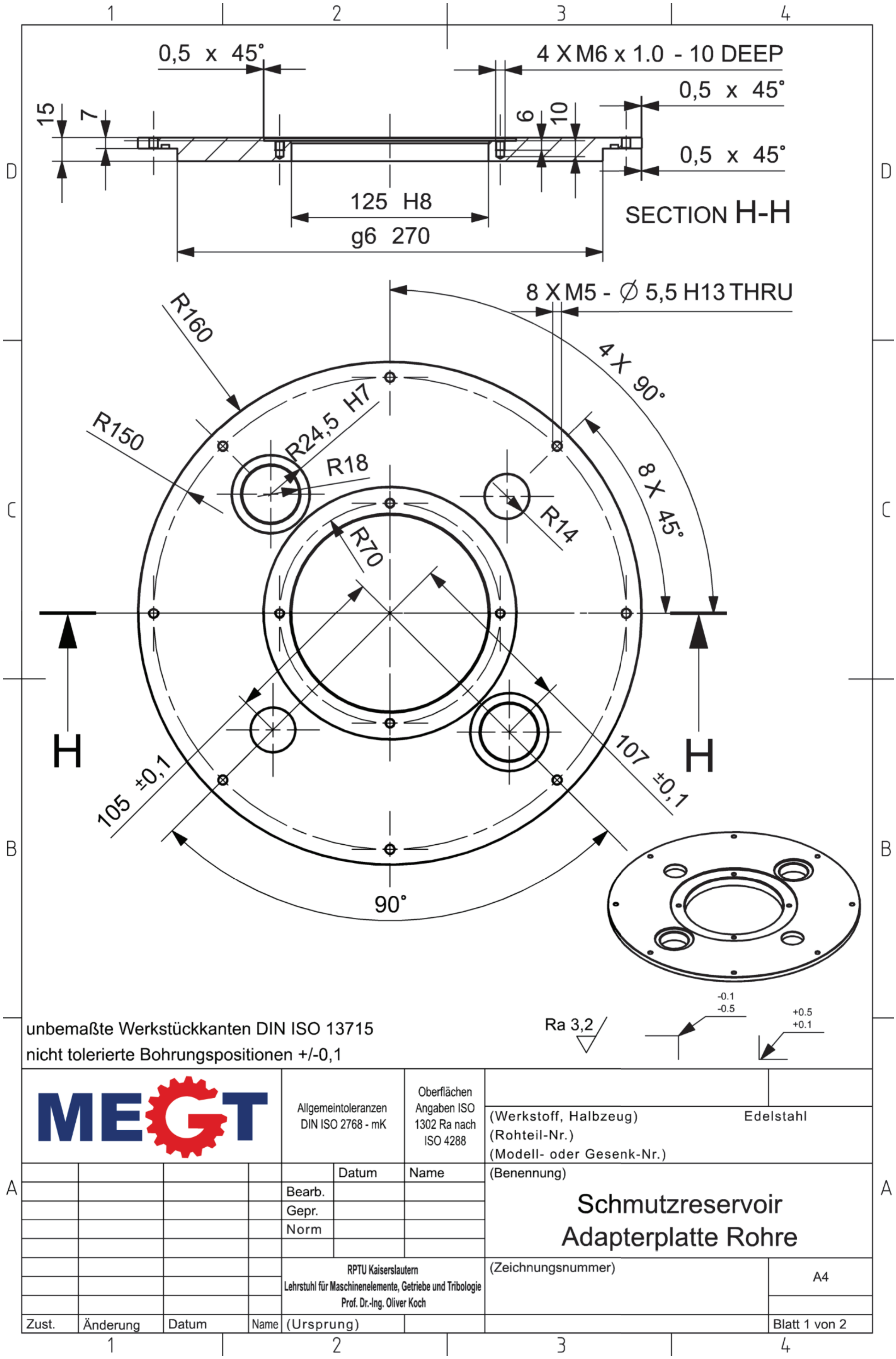


Figure 55:Schmutzwasserreservoir - Adapterplatte Rohre Blatt 1

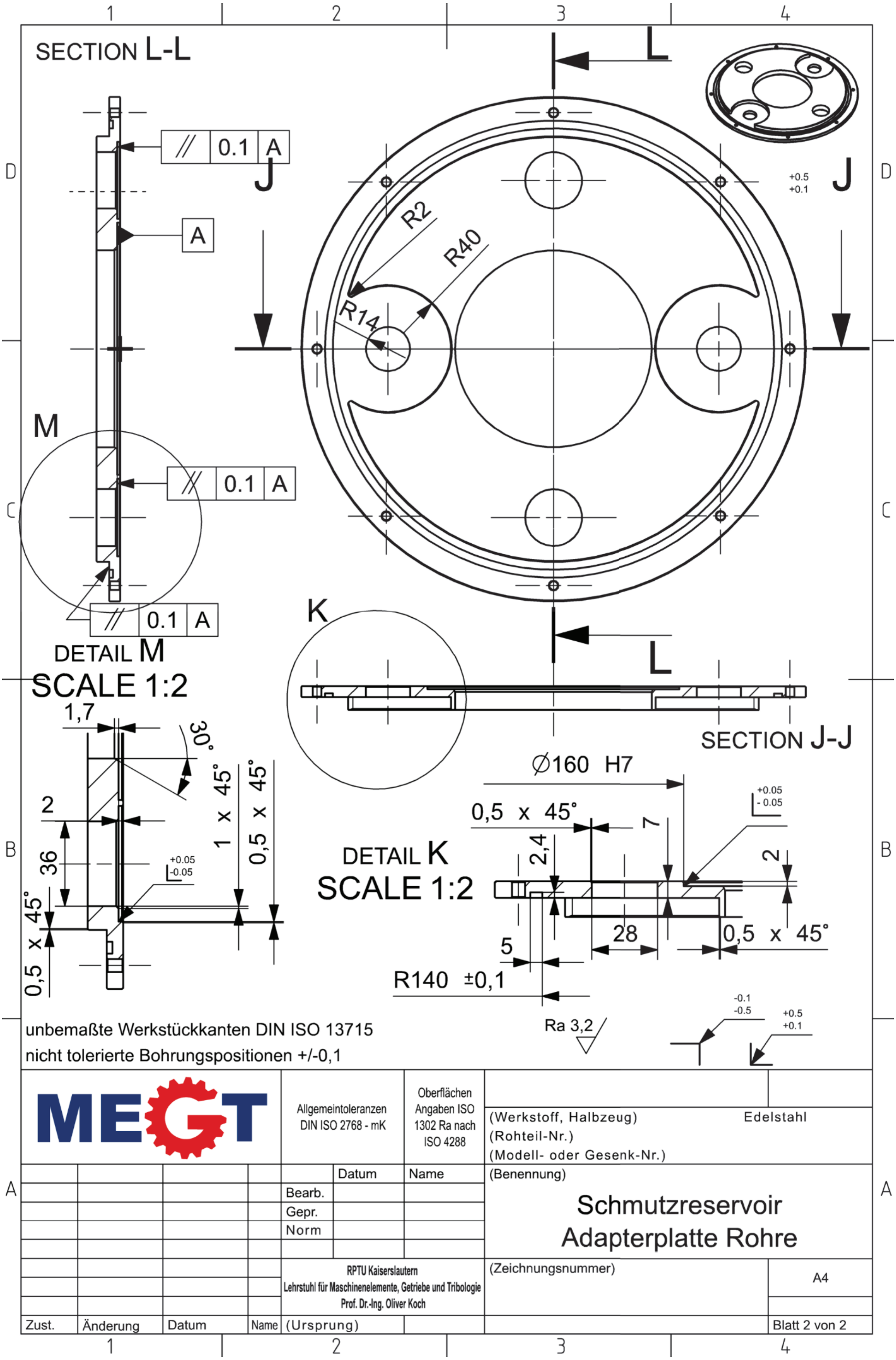


Figure 56: Schmutzwasserreservoir - Adapterplatte Rohre Blatt 2

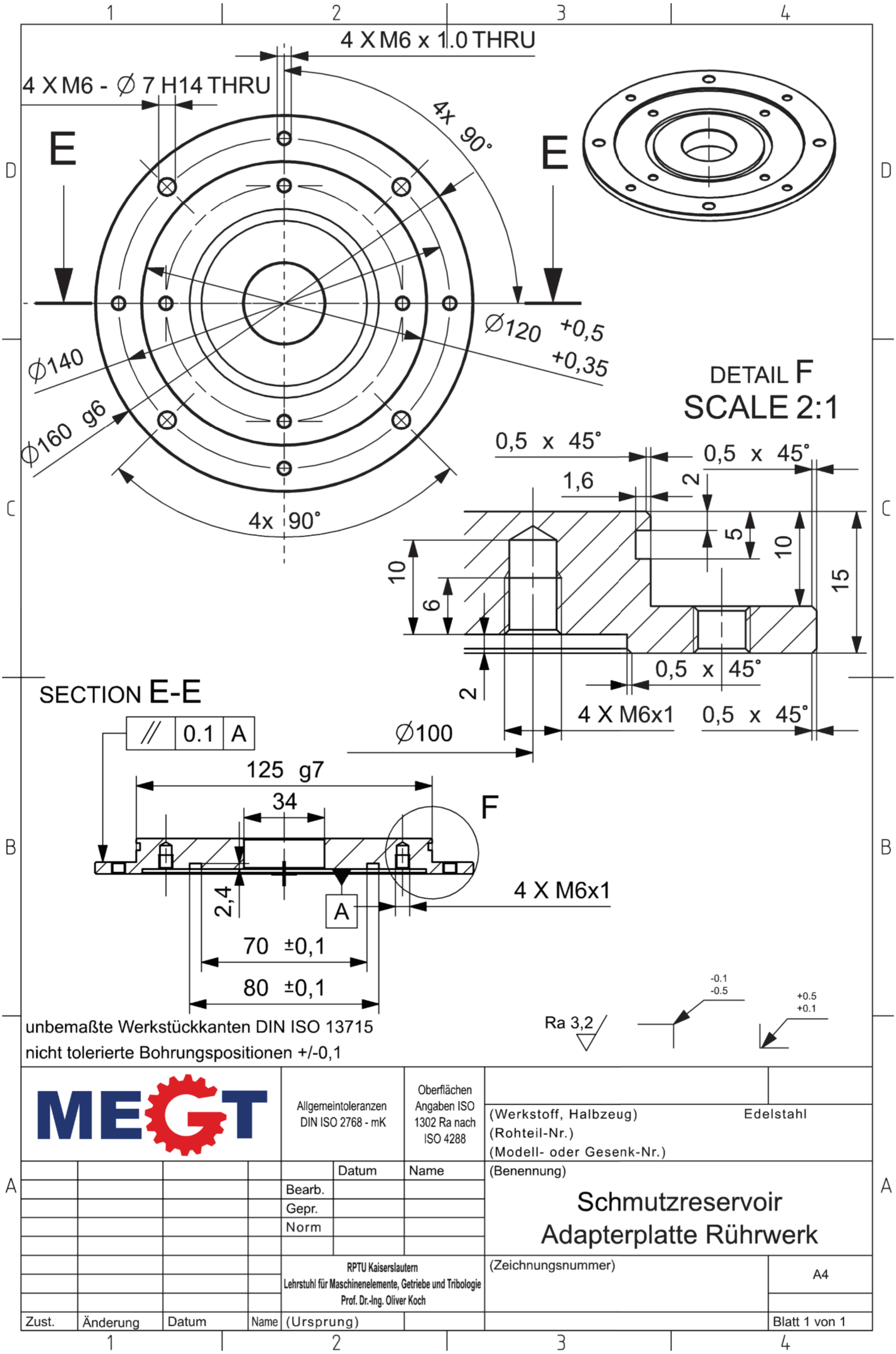
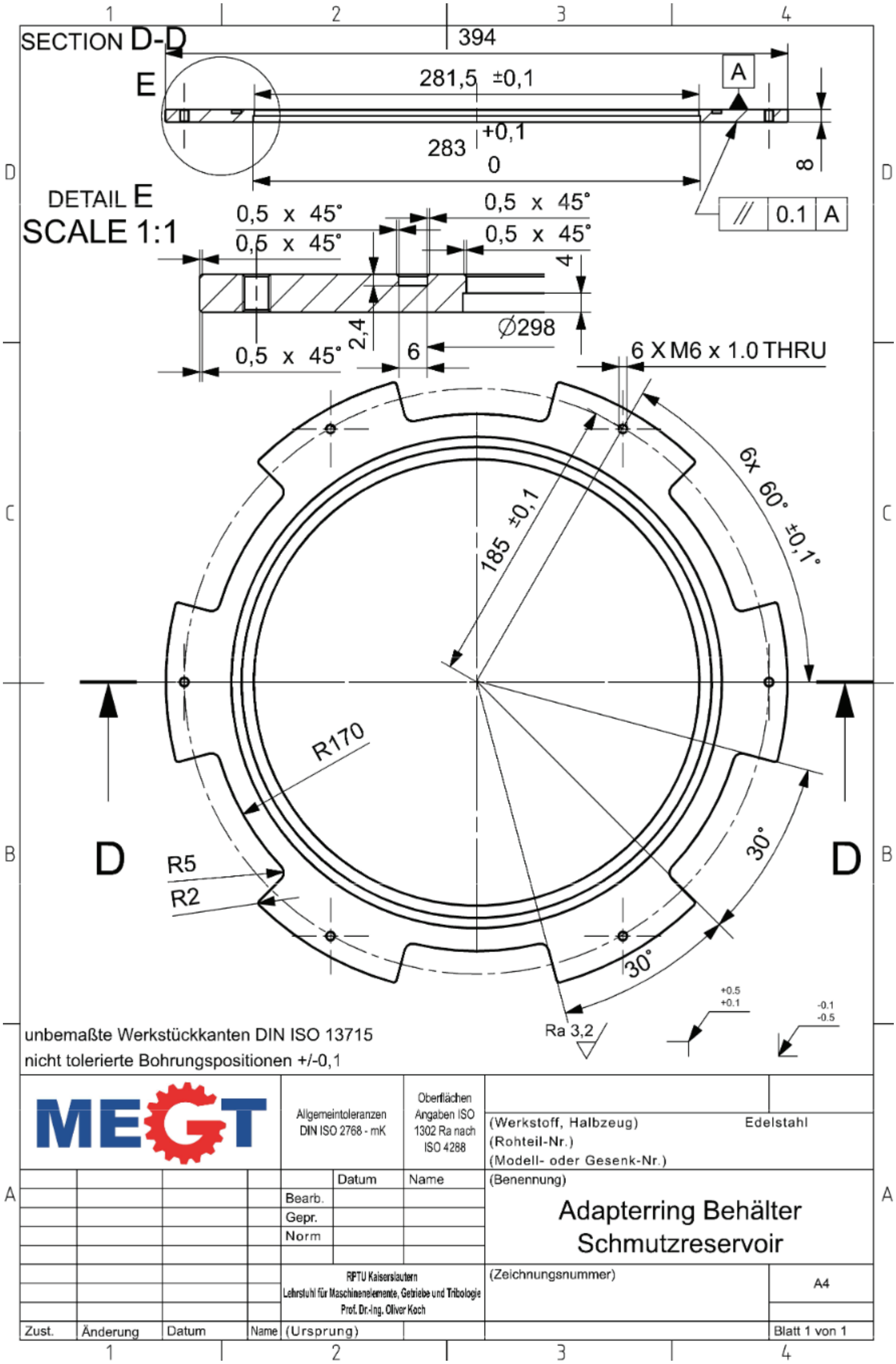


Figure 57: Schmutzwasserreservoir - Adapterplatte Rührwerk


SECTION D-D
394
281,5 ±0,1
A
E
283 +0,1 0
8
// 0.1 A
DETAIL E
SCALE 1:1
0,5 x 45°
0,5 x 45°
0,5 x 45°
0,5 x 45°
0,5 x 45°
4
2,4
6
∅298
6 X M6 x 1.0 THRU
185 ±0,1
6x 60° ±0,1°
R170
R5
R2
30°
30°
D
D
Ra 3,2
+0.5 +0.1
-0.1 -0.5
unbemaßte Werkstückkanten DIN ISO 13715
nicht tolerierte Bohrungspositionen +/-0,1
MEGT
Allgemeintoleranzen DIN ISO 2768 - mK
Oberflächen Angaben ISO 1302 Ra nach ISO 4288
(Werkstoff, Halbzeug)
Edelstahl
(Rohteil-Nr.)
(Modell- oder Gesenk-Nr.)
Datum
Name
(Benennung)
Bearb.
Gepr.
Norm
Adapterring Behälter
Schmutzreservoir
RPTU Kaiserslautern
Lehrstuhl für Maschinenelemente, Getriebe und Tribologie
Prof. Dr.-Ing. Oliver Koch
(Zeichnungsnummer)
A4
Zust.
Änderung
Datum
Name
(Ursprung)
Blatt 1 von 1

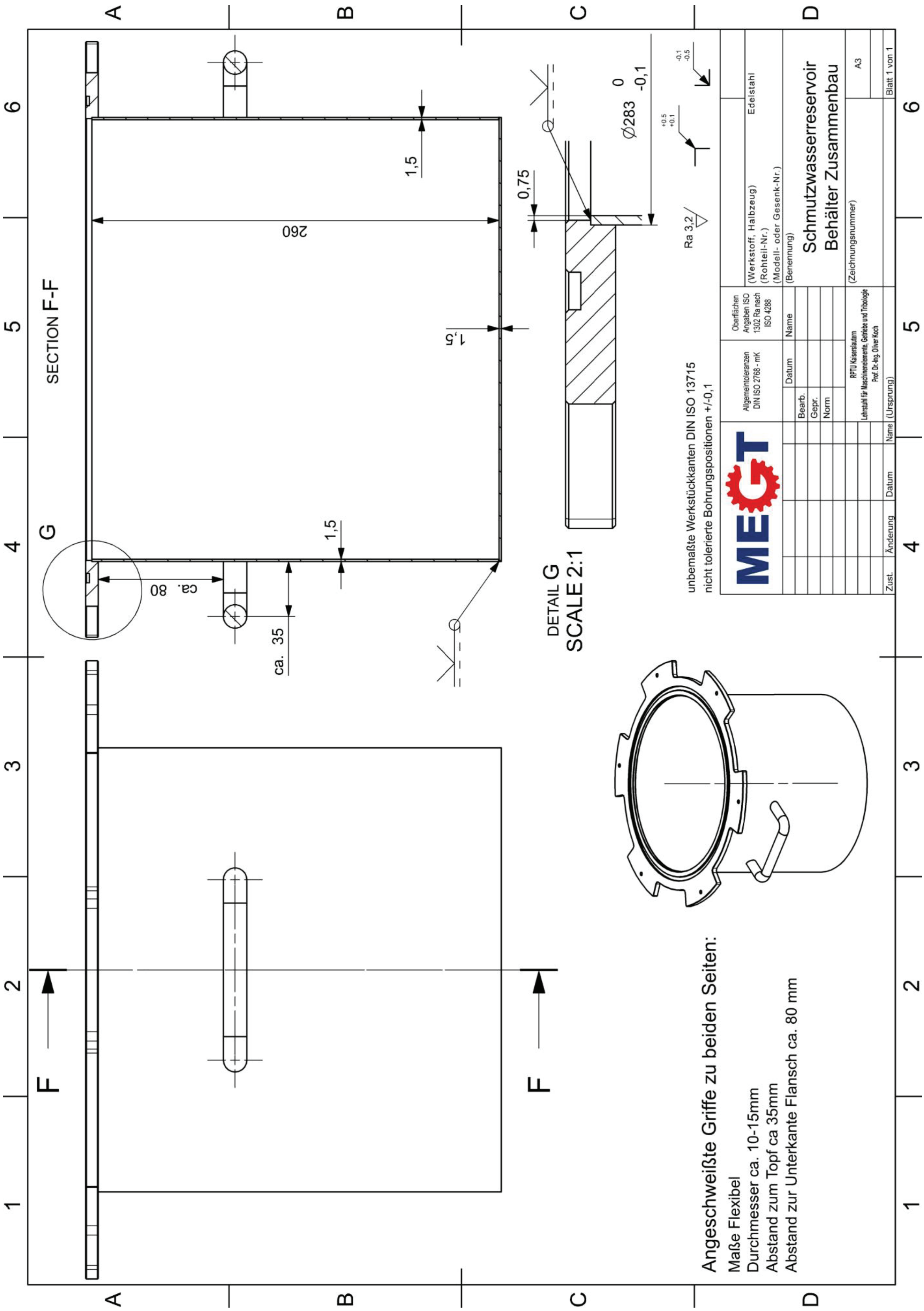


Figure 58: Schmutzwasserreservoir - Behälter Zusammenbau

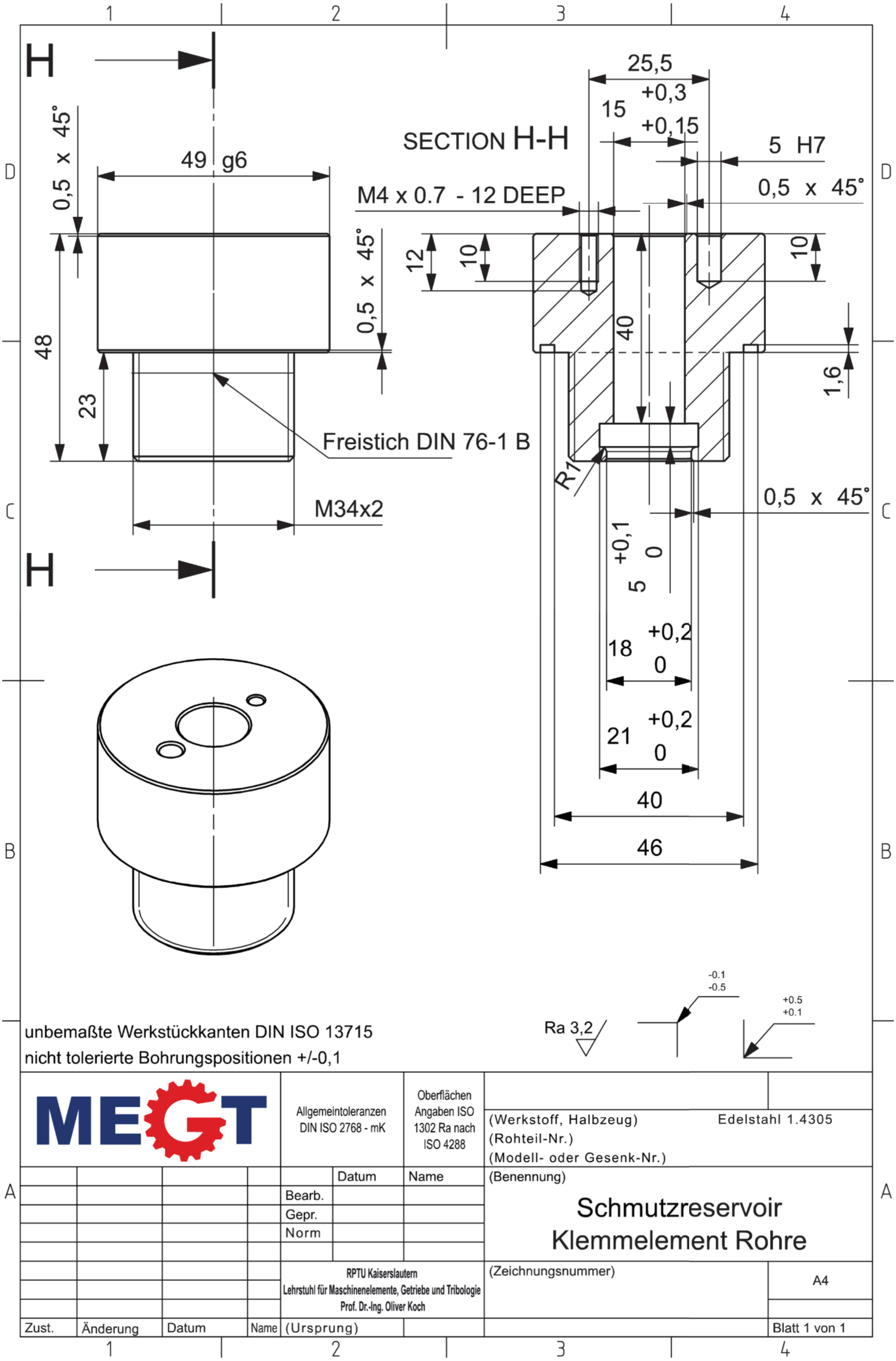


Figure 59: Schmutzwasserreservoir - Klemmelement Rohre

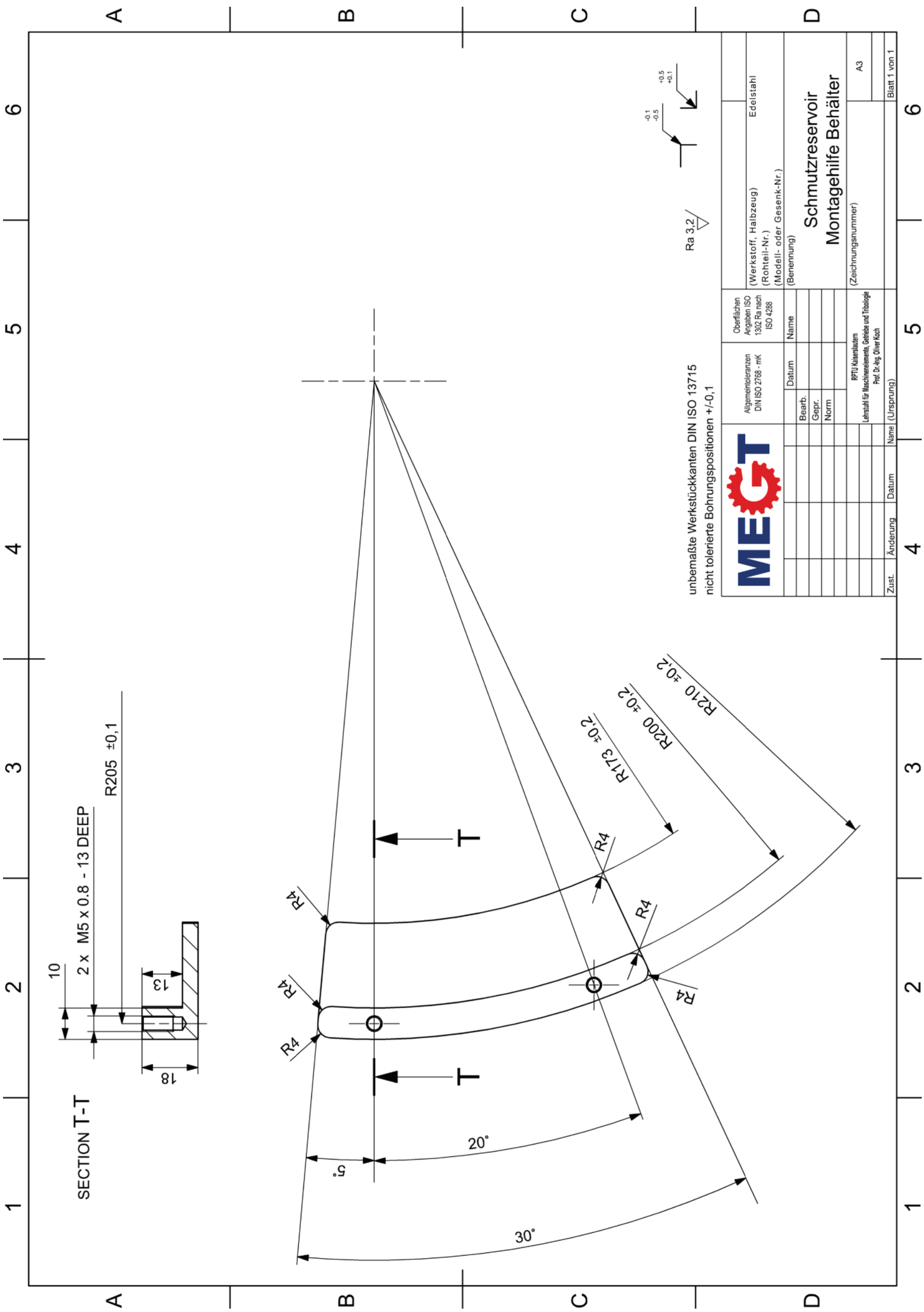


Figure 60: Schmutzwasserreservoir - Montagehilfe Behälter

Appendix: Technical drawings greasing device

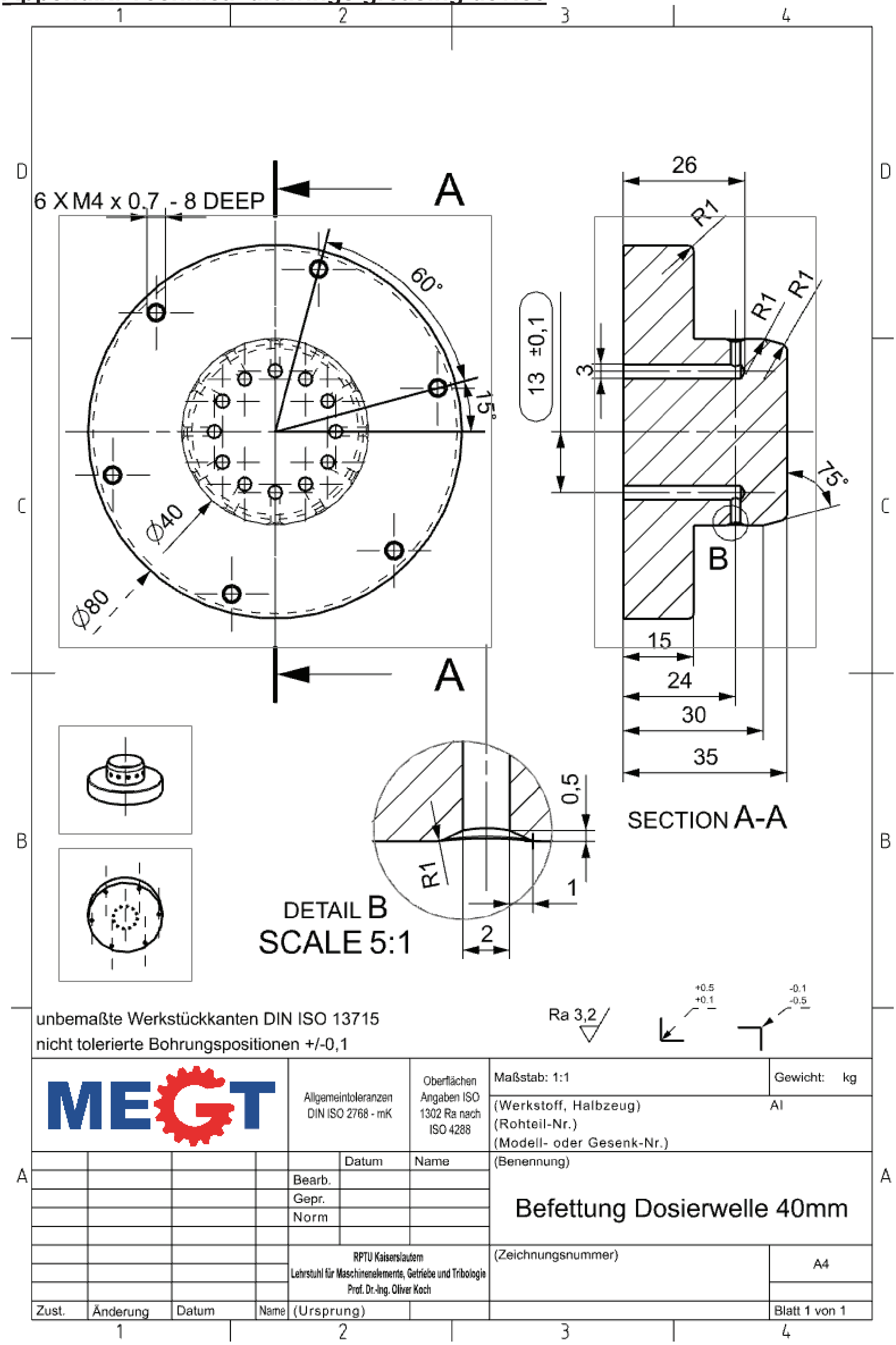


Figure 61: Befettungseinrichtung - Dosierwelle

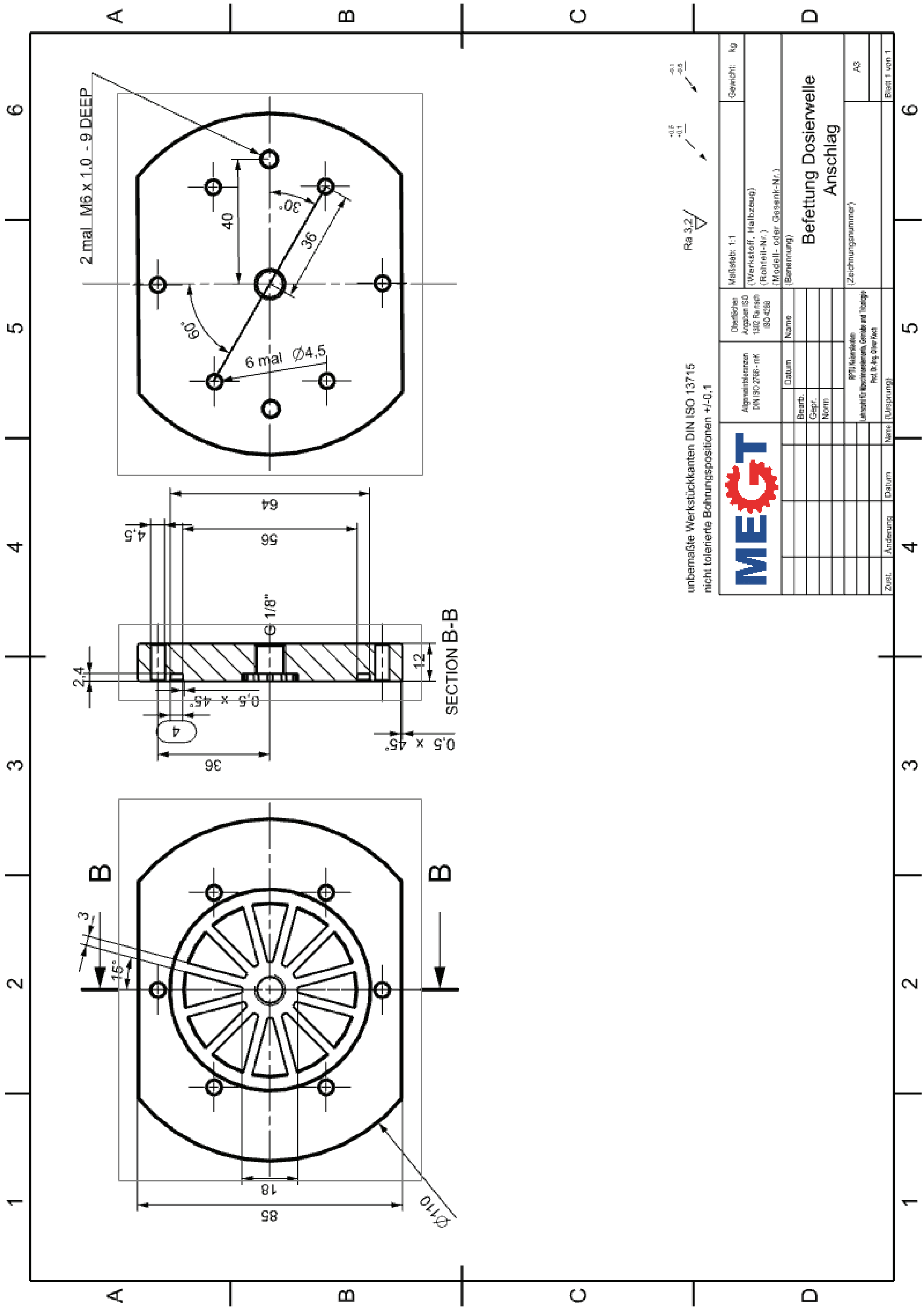


Figure 62: Befettungseinrichtung – Anschlagplatte Dosierwelle

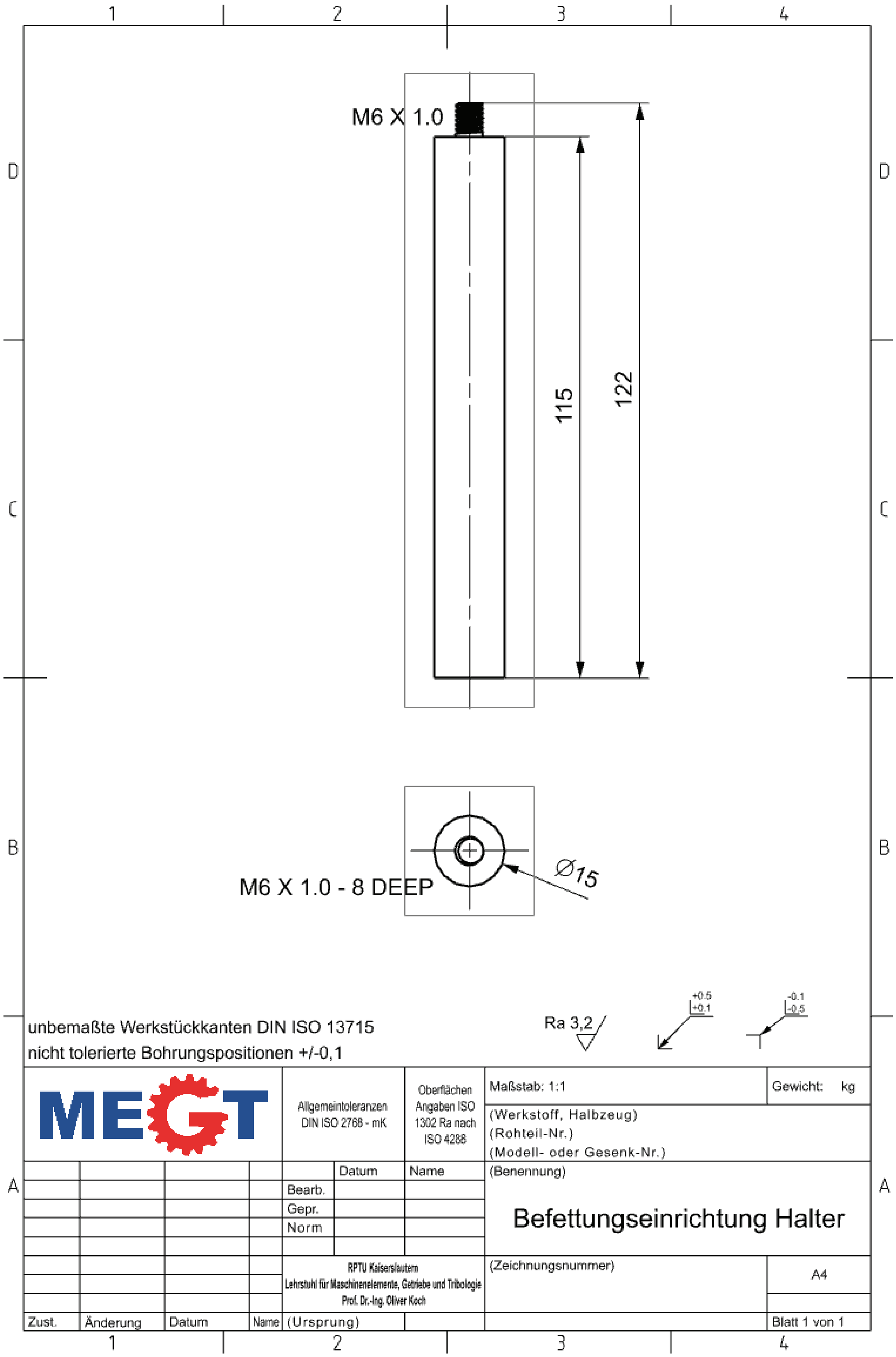


Figure 63: Befettungseinrichtung - Halter

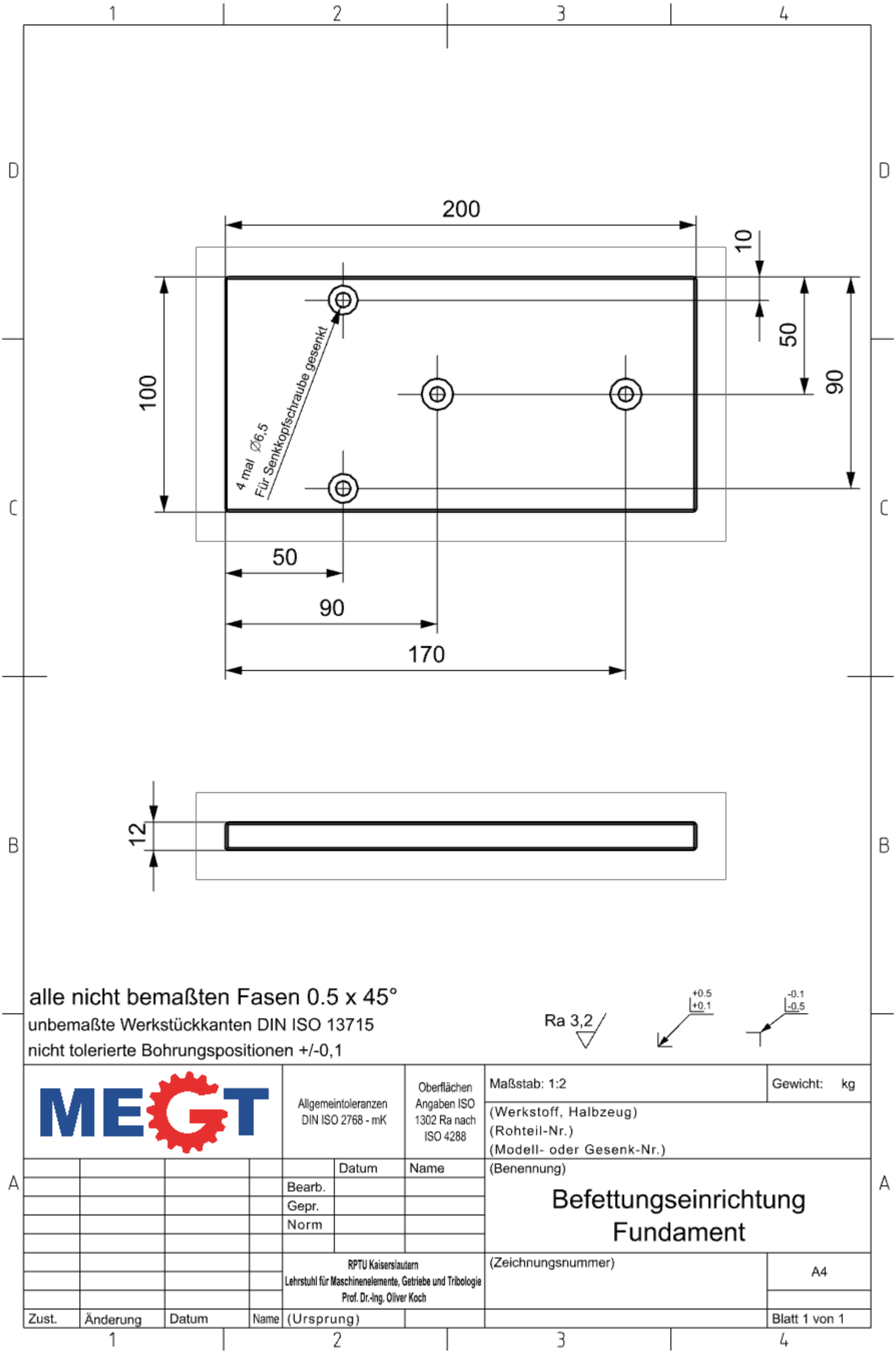


Figure 64: Befettungseinrichtung - Fundament

Appendix: Purchased parts

Dichtungen	
RWDR: Sekundärdichtung Wellenbaugruppe	FKM RWDR 40-52-X
O-Ring: Sekundäraufnahme / Außenhülle Prüfzelle	FKM O-Ring 149 mm x 2 mm
O-Ring: Außenhülle Prüfzelle / RWDR-Aufnahme	FKM O-Ring 130 mm x 3 mm
O-Ring: RWDR-Aufnahme / Außenhülle Schmutzbeaufschlagung	FKM O-Ring 104 mm x 3 mm
Flachdichtung: Außenhülle Schmutzbeaufschlagung / Verteilerplatte	FKM-Zuschnitt nach Zeichnung „Dichtung Außenhülle Schmutzbeaufschlagung / Verteilerplatte“
O-Ring: Verteilerplatte / Abschlussplatte	FKM O-Ring 93 mm x 2 mm
O-Ring: PT-100 Klemmung	FKM O-Ring 7 mm x 2 mm
O-Ring: Wellenstummel / Sekundärwelle + Wellenstummel / Prüfwelle	2x FKM O-Ring 21 mm x 3 mm
O-Ring: Prüfwelle / Wellendeckel	FKM O-Ring 18,5 mm x 3 mm
O-Ring: Klemmelement Rohre	NBR O-Ring 40 mm x 2 mm
O-Ring: Schmutzwasserbehälter	NBR O-Ring 300 mm x 3 mm
O-Ring: Adapterplatte Rührwerk	NBR O-Ring 120 mm x 2 mm
O-Ring: Adapterplatte Rohre	NBR O-Ring 280 mm x 3 mm
Abstreifer: Klemmelement Rohre	NBR AWR-059082
Schlauchtüllen und Fittings	
Schlauchtülle: Schmutzzulauf Prüfzelle / Beaufschlagungseinheit	Gewindetülle G 1/2"-13 (1/2") mm (GT 1213 MS) oder Schnellkupplung Gewindestück 360° drehbar Außengewinde 1/2" und Schnellkupplung Schlauchtülle 360° drehbar 13 mm
Schlauchtülle: Schmutzablauf Prüfzelle / Beaufschlagungseinheit	Gewindetülle G 1/2"-19 (3/4") mm (GT 1213 MS)
Schlauchtülle: Schmutzwasserreservoir Rücklauf	Schnellkupplung Gewindestück 360° drehbar Außengewinde 3/4" und Schnellkupplung Schlauchtülle 360° drehbar 19 mm
Schlauchtülle: Schmutzwasserreservoir Rücklauf	Schnellkupplung Gewindestück 360° drehbar Außengewinde 1/2" und Schnellkupplung Schlauchtülle 360° drehbar 13 mm
Schlauchtülle: Verteiler Zuleitung Prüfzelle	Schnellkupplung Gewindestück 360° drehbar Außengewinde 1/2" und Schnellkupplung Schlauchtülle 360° drehbar 13 mm Schnellkupplung Gewindestück 360° drehbar Außengewinde 3/4" und Schnellkupplung Schlauchtülle 360° drehbar 13 mm
Schlauchtülle: Verteiler Rückleitung	Schnellkupplung Gewindestück 360°

Prüfzelle	drehbar Außengewinde 1/2" und Schnellkupplung Schlauchtülle 360° drehbar 19 mm Schnellkupplung Gewindestück 360° drehbar Außengewinde 3/4" und Schnellkupplung Schlauchtülle 360° drehbar 19 mm
Verteiler: Zuleitung und Rückleitung Prüfzellen	Verteilerrohr G 3/4"(IG/AG), Abgang 3x G 1/2" (IG)
Verschlusskappe: Verteiler Zu- und Rückleitung	Verschlusskappe G 3/4"
Gewindestopfen: Öl-Zulauf	Verschlussstopfen Innenskt. G 1/2"
Kugelhahn Öl-Ablauf	Doppelnippel R 1/2"-R 1/4" (DN 1214 K MS), Minikugelhahn G 1/4" (KH 14 MKHE)
Schläuche und Rohre	
Schlauch: Peristaltikpumpe	Verderprene 9.6 ID x 2,4 Tubing
Schlauch: Zuleitung Zellen	PVC Druckschlauch transparent gewebeverstärkt 13 mm
Schlauch: Rückleitung Zellen	PVC Druckschlauch transparent gewebeverstärkt 19 mm
Rohr: Entnahme Schmutzwasserreservoir (Zuleitung Zellen)	Edelstahlrohr,nahtlos, 15,0x1,5mm, 1.4301
Rohr: Rücklauf Schmutzwasserreservoir	Edelstahlrohr,nahtlos, 22,0x1,5mm, 1.4301
Heizungsreglung	
PT100 Sensor	Mantelwiderstandsthermometer, 7 mm Durchmesser, 150 Länge
Heizpatrone	GC-heat, GC-Cart Heizpatrone, 8 mm -0,02/-0,06 mm Durchmesser, 100 mm Länge, Edelstahl, 200W
Regler	Eurotherm 3216 PID-Temperaturregler
Weitere Komponenten Schmutzaggregat	
Pumpe	Verderflex Vantage 5000 Cased Drive Tube Pump
Rührwerk	VISCO JET Tank-Rührwerk VJ500 mit VJ875 VISCO JET Sondersteuerung
Schaltung Beaufschlagung: Elektrischer Kugelhahn	Kugelhahn mit Elektroschwenkantriebe Failsafe (NG) 1/2" 24V (ICH BVM04S/9AR Kugelhahn Failsafe 0 bis 10 bar)
Schneidringverschraubung: Zuleitung	Aufschraub-Schneidringverschr. G 1/2"-15 L (M22x1,5), Stahl verzinkt
Schneidringverschraubung: Rückleitung	Aufschraub-Schneidringverschr. G 3/4"-22 L (M30x2), Stahl verzinkt
Verschraubung Klemmelement Rohre	Sechskant-Gegenmutter M 34x2,

	Messing
Klemmring Rohre	Geteilter Klemmring aus Edelstahl 1.4305 Bohrung 15mm
Weitere Kaufteile	
Fettpresse	Einhandpresse Wanner-Abnox (0,5 cm^3 / Hub)
Ausgussmasse RWDR	Provil novo Putty regular set
Spatel Probenentnahme	Bürkle, Micro-Spatel, Laborplast, PS, 1,0/0,25 m
Reinigungstücher	KIMTECH SCIENCE Präzisionstücher weiß
Pulverdispergierer	Vorschlag: Palas RBG 1000 Pulverdispergierer

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