Instruction Manual

Quartz High-Pressure Sensor Type 6213B

6213B_002-022e-06.21

Foreword

Thank you for choosing a Kistler quality product characterized by technical innovation, precision and long life.

Information in this document is subject to change without notice. Kistler reserves the right to change or improve its products and make changes in the content without obligation to notify any person or organization of such changes or improvements.

Kistler Group
Eulachstrasse 22
8408 Winterthur
Switzerland

Tel. +41 52 224 11 11
info@kistler.com
www.kistler.com

Content

Total Pages 37

1. Introduction

Please take the time to thoroughly read this instruction manual. It will help you with the installation, maintenance, and use of this product.

To the extent permitted by law Kistler does not accept any liability if this instruction manual is not followed or products other than those listed under *Accessories* are used.

Kistler offers a wide range of products for use in measuring technology:

- Piezoelectric sensors for measuring force, torque, strain, pressure, acceleration, shock, vibration and acoustic-emission
- Strain gage sensor systems for measuring force and torque
- Piezoresistive pressure sensors and transmitters
- Signal conditioners, indicators and calibrators
- Electronic control and monitoring systems as well as software for specific measurement applications
- Data transmission modules (telemetry)

Kistler also develops and produces measuring solutions for the application fields engines, vehicles, manufacturing, plastics and biomechanics sectors.

Our product and application brochures will provide you with an overview of our product range. Detailed data sheets are available for almost all products.

If you need additional help beyond what can be found either on-line or in this manual, please contact Kistler's extensive support organization.

2. Description

2.1 Introduction

The high-pressure sensor Type 6213B (Fig. 1) has been developed especially for interior ballistic measurements up to 10 kbar. It is also suitable for measuring dynamic and quasistatic pressures in hydraulic systems.

The anti-strain construction renders the sensor largely insensitive to different tightening torques and tensions at the mounting location.

Thanks to its excellent linearity, the sensor is also well suited for measuring low pressures.

The high-pressure sensor Type 6213B differs from the familiar Kistler high-pressure sensors in its installation dimensions. To accommodate the higher loading, its screw-in thread as been enlarged from M10x1 to M12x1.

Fig. 1: High-Pressure Sensor Type 6213B

The new front end has two major advantages:

- The large contact surface reduces the pressure per unit area despite higher tightening torques.
- Because sealing is effected at the front end (Fig. 2), the dead volume resulting from the installation is particularly small – less than with the previous shoulder sealing high-pressure sensors Types 6201 … 6211.

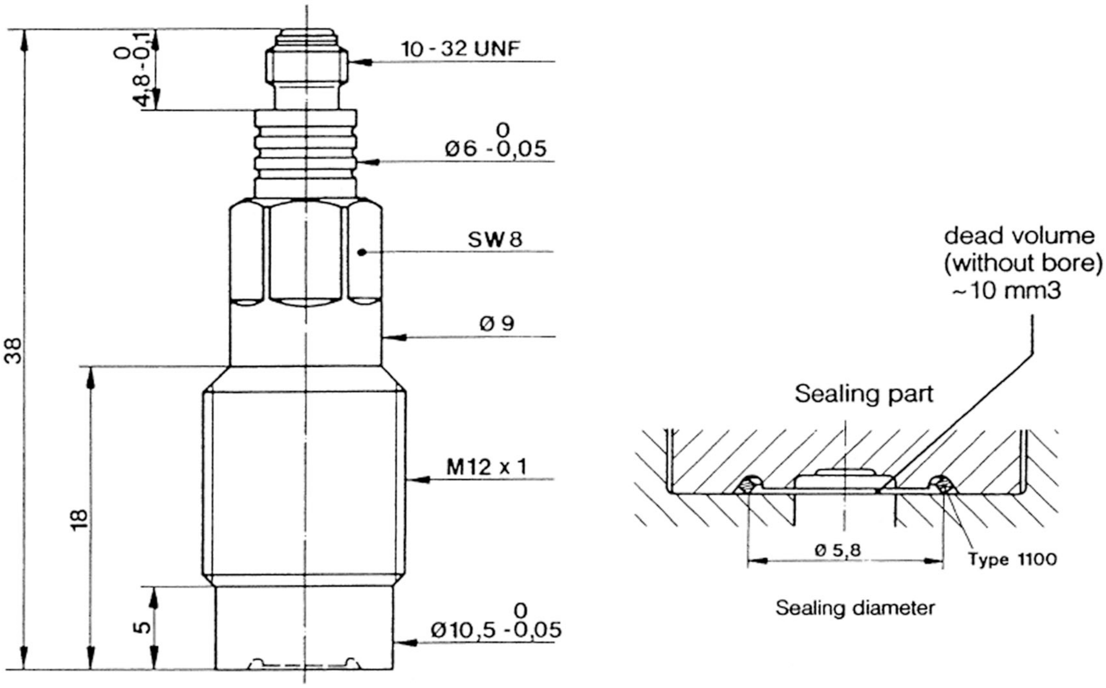


Fig. 2: Dimensions of the sensor Type 6213B and of the sealing part

2.2 Technical data (Table 1)

The technical data are described in more detail in subsection 2.3 below.

Range	bar	0 ... 10 000
Calibrated range (with reference sensor)	bar	0 ... 10 000
Calibrated range (with deadweight tester)	bar	0 ... 8 000
Calibrated partial range	bar	0 ... 1 000
Overload	bar	11 000
Threshold	bar	<0.02
Sensitivity	pC/bar	–1.2
Natural frequency	kHz	>150
Rise time	µs	2
Linearity	%FSO	<±0.5
Hysteresis	%FSO	<1
Acceleration sensitivity	bar/g	<0.006
Shock resistance axial	g	25 000
transverse	g	10 000
Temperature coefficient of sensitivity	%/°C	<+0.03
Operating temperature range	°C	–50 ... 200
Capacitance	pF	≈5.5
Insulation resistance at 20 °C	Ω	$>10^{13}$
Tightening torque	N·m	40
Weight	grams	18

2.3 Explanations to the technical data

2.3.1 Measuring range

The data stated hold good for the corresponding measuring range.

2.3.2 Calibrated range

With the deadweight tester the sensor is calibrated only up to 8 000 bar. Testing up to 10 000 bar is done by comparative measurements with a reference sensor.

2.3.3 Overload

The highest pressure to which the sensor may be exposed without its data deviating outside the specified tolerances.

2.3.4 Temperature coefficient of the sensitivity

Sensitivity change expressed in % per °C. If for example the sensor is used at a temperature of 120 °C, the sensitivity must be expected to increase by about 2 %.

2.3.5 Rise time

The rise time is taken to be the duration of a quarter oscillation of the natural frequency of the sensor.

2.3.6 Operating temperature range

The temperature at the installation point must lie within this range to enable continuous use of the sensor. The gas temperatures may be higher (briefly).

2.3.7 Tightening torque

For the prescribed tightening torque it is guaranteed that the sensor fits well enough to the sealing surface so that an adequate sealing is guaranteed for the entire specified pressure range.

2.4 Functional principle

The pressure to be measured acts on the diaphragm, which converts it into a proportional force. This force is transmitted onto the quartz elements, which generate an electrostatic charge under load. A contact spring picks up this (negative) charge and leads it to the connector, where its converted into a (positive) voltage by the connected charge amplifier.

The tensions of the material acting onto the sealing part of the sensor – caused by the tightening torque and tensions at the mounting location – are not transmitted onto the measuring element thanks to "anti-strain" construction of the sensor.

Compared to the existing sensor Types 6201 ... 6211 the sealing part has been transferred form the shoulder to the front. By this measure the high loads, which act onto the sensor at 10 000 bar, could be reduced. The measuring pressure acts onto a relatively small surface (≈28 mm^2). The dead volume disturbing the measurements is very small for this design (≈9.5 mm^3).

The piezoelectric system is suited mainly for measuring rapid dynamic and quasistatic pressure phenomena. Static measurements over an unlimited period of time are not possible.

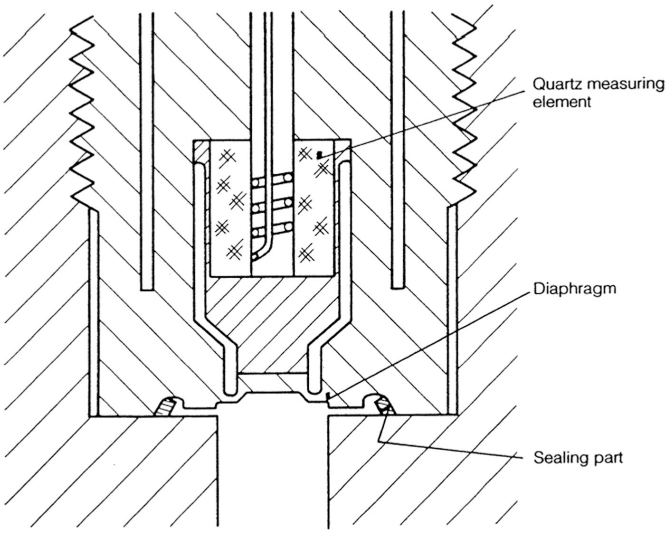


Fig. 3: Schematic section through front part

2.5 Typical applications

Typical applications for the high-pressure sensor Type 6213B are all kinds of pressure measurements in hydraulic and ballistic systems. Only a short life may be expected if it is employed in hydraulic systems where steep pressure rises and numerous load cycles are encountered (e.g. injection pumps).

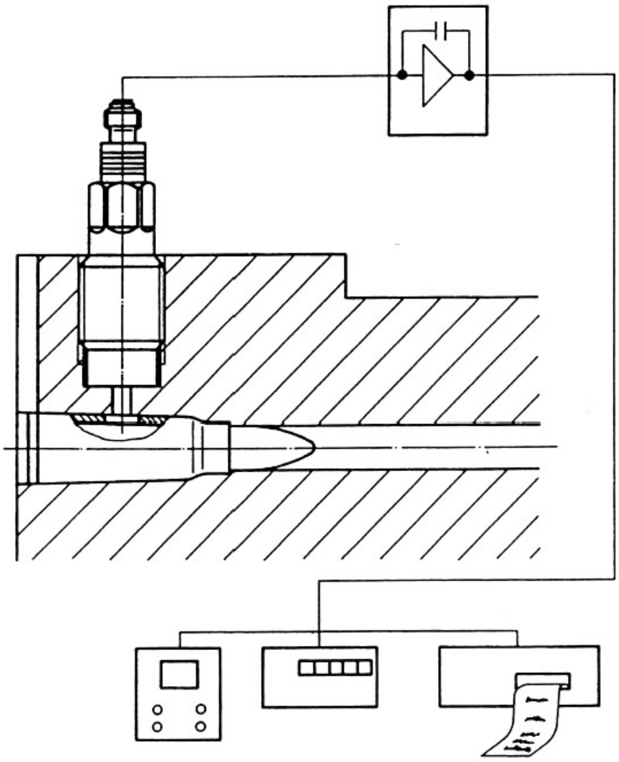


Fig. 4: Pressure measuring on a gas pressure measuring barrel (cartridge chamber)

3. Installation

3.1 General remarks

In the course of time the various measuring rigs have given rise to an almost endless variety of installation modes.

There are measuring rigs for:
- cartridge chamber measuring
- cartridge mouth measuring
- pressure measuring in the barrel (port-pressure)
- pressure measuring in large-caliber cartridge cases, case base measurements
- pressure bomb measuring
- etc.

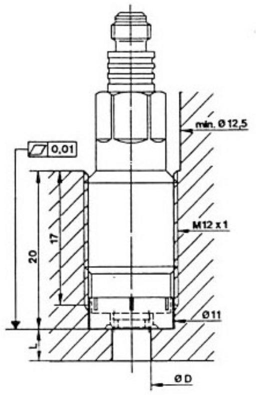
For these rigs there are alternative installations, like:
- direct fitting
- adapter fitting

3.2 Suggested installation

In order to guarantee a deformation as small as possible at the mounting location, we suggest to adapt the diameter (D) and the length (L) of the measuring bore to the measuring barrel as follows:

	Length (L)	**Diameter (D)**
Small caliber	>4 mm	≥2.5 mm
Medium caliber	4 ... 8 mm	4 ... 5 mm
Large caliber	8 ... 15 mm	4 ... 5 mm

For recessed mounting (large wall thickness) the upper part of the bore must be bored open to min. diameter 12.8 mm so that the hex key Type 1373A1 can be used.



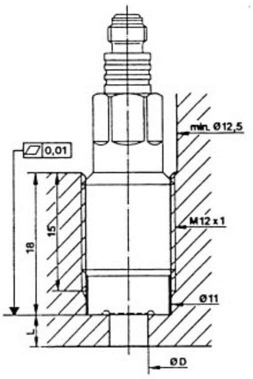


Fig. 5a: Mounting with thermal protection shield Type 6563A

Fig. 5b: Mounting without thermal protection shield

3.3 Proper use of the seal

For the recommended installation mode the steel seal ring Type 1100 supplied with the sensor must be used. This ring of chromium-nickel steel has been developed and patented by Kistler (see Fig. 6).

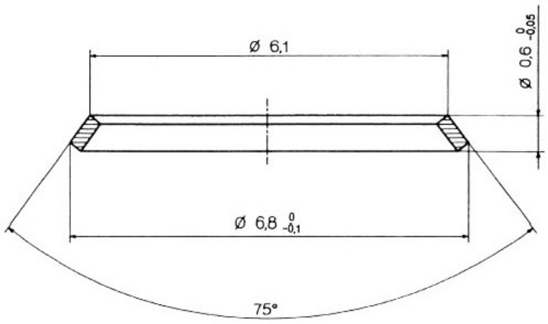


Fig. 6: Seal ring Type 1100

This seal ring acts similarly to an O-ring. The soft Cr-Ni steel is deformed plastically when the sensor is tightened, so that it seals against the measuring medium. The higher the pressure to be measured rises, the more the ring is pressed against the sealing surface (see Fig. 7). Make sure that the seal ring is not inserted wrong way round.

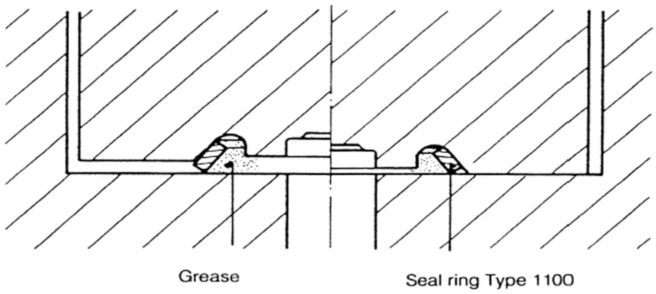


Fig. 7: Action of the seal ring

Left: after contact with sealing surface
Right: after tightening

Fig. 7 shows the sensor and seal ring in the measuring bore before the onset of plastic deformation (left) and after this is completed (right). The Klüber grease Type 1063 serves to hold the ring in position during screwing-in. This renders the mounting possible in all positions without the seal ring to taper off.

The seal ring Type 1100 has performed very well in practice. For the prescribed tightening torque, sealing is assured over the specified range. To ensure unvarying friction conditions on the thread and optimal preload force, the threads must always be greased before screwing-in, using Klüber grease Type 1063. The seal ring may be used a number of times over. The relatively high surface pressure usually leaves impressions on the sealing part, but this is not detrimental to the sealing action.

3.4 Tightening torque

Tightening torque for low-pressure applications.

The relatively high tightening torque is necessary to guarantee a proper sealing over the entire pressure range.

If the sensor is used for measuring low pressures, the tightening torque can be reduced according to the low pressure range.

Allowed tightening torques:

0 ... 7 500 bar	30 N·m
0 ... 5 000 bar	20 N·m
0 ... 2 500 bar	10 N·m

A tightening torque of 10 N·m must under no circumstances fall short of this value for pressure ranges <2 500 bar. Although the influence of the tightening torque onto the sensitivity is reduced, the sensors should be calibrated with the tightening torque specific to the application.

3.5 Influence of the measuring bore

Long measuring holes constitute a low-pass filter. Low frequencies are measured without error. Medium frequencies in the range of the resonance frequency of the liquid or gas column cause a strong spurious signal which may exceed the amplitude of the measuring signal many times. High frequencies are strongly attenuated or not measured at all. With rapid pressure rise (step function) a damped oscillation is exited.

The effect of a liquid or gas column on the measured result when brief pressure peaks occur is shown very impressively in Fig. 8, using a hydraulic system as an example. If the measuring bore is too long, a brief pressure peak cannot be measured even with sensors of high natural frequency.

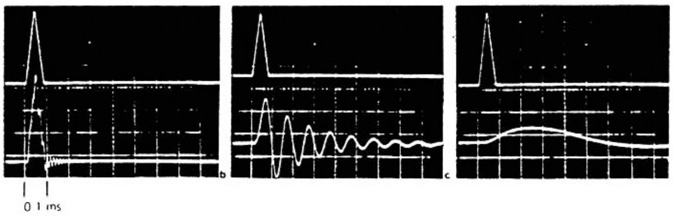


Fig. 8: Influence of long measuring bores

Here the pressure peak (base width 80 µs) in a hydraulic system (water) versus the resonance frequency of a measuring bore of different length before the sensor is plotted:

Figure:	**8a**	**8b**	**8c**
Length of measuring bore:	3.5 mm	35 mm	350 mm
Resonance frequency:	≈100 kHz	≈10 kHz	≈1 kHz

For an approximate estimation of the resonance frequency of a liquid column, a mean sound velocity v = 1 400 m/s is assumed (water: v = 1 400 m/s). The measuring bore sealed by the pressure sensor oscillates with quarter-wavelength (1/4). With the measuring bore length L known, the natural frequency is calculated as follows:

$f = v / (4 \cdot L)$ e.g. (for L = 35 mm)
$1\,400 / (4 \cdot 0.035) = 10\,000$ Hz

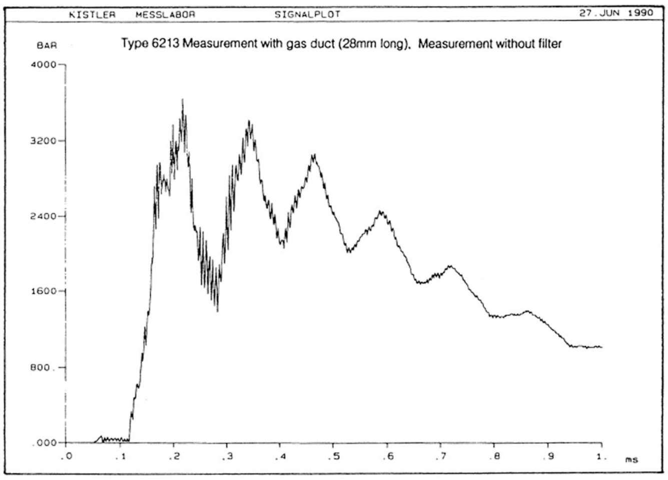


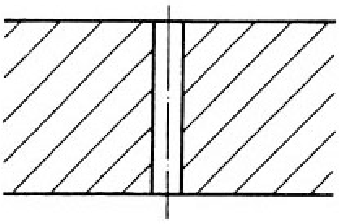
Fig. 9: Pipe oscillations with gas duct 28 mm long

3.6 Preparing the measuring hole

When producing the measuring hole it is essential that the threads are concentric with the bore and the sealing part is flat. This is assured without difficulty if the threads are cut in the same setup on the drill. It is enough to use a center point on an ordinary drill, enabling the tap to be centered when cutting by hand.

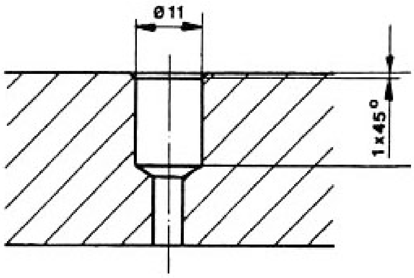
NOTE

The special drilling tool Type 1321 and the reamer Type 1300A23 are used advantageously when preparing the measuring bore.



1. Coarse drilling

with max. diameter 5 mm
(ideal: diameter 2.5 ... 4 mm)

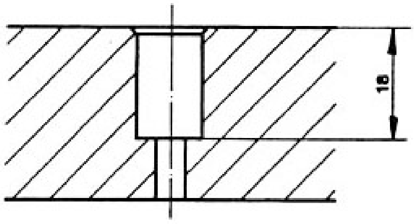


2. Drilling

diameter 11 mm/depth 16 mm

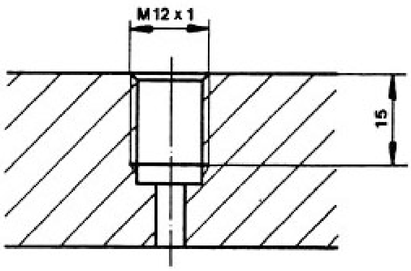
3. Countersinking

1 x 45 °



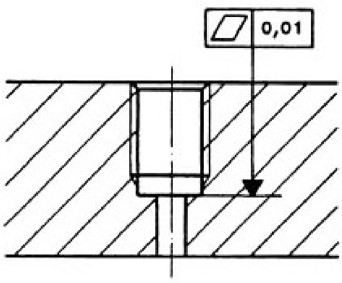
4. Flat Boring

with special drilling tool Type 1341
Important:
If a thermal protection shield is used Type 6563A the bore diameter 11 mm must be drilled open to 20 mm.



5. Thread Cutting

The screw tap must be guided exactly centered in the drilling head.
If the threads are cut on the slant, proper sealing will not be possible.



6. Reaming

In order to guarantee an optimum measuring accuracy, it is necessary to ream the sealing surface with the reamer Type 1300A23.
The reaming procedure is described in detail in the following subsection 3.8.

Fig. 10: Drilling instructions for mounting bore for Type 6213B

3.7 Avoiding installation errors

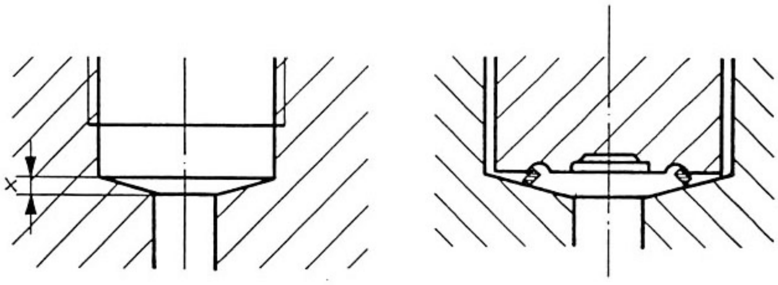


Fig. 11: Concave sealing part

If the sealing part is made concave instead of flat, measuring errors will be unavoidable. Tests have revealed a sensitivity increase around 2 % with 0.02 mm concavity (x) on the sealing surface. The trouble is avoided by making the measuring bore exactly in accordance with the instructions in subsection 3.6 above.

3.8 Reamer Type 1300A23

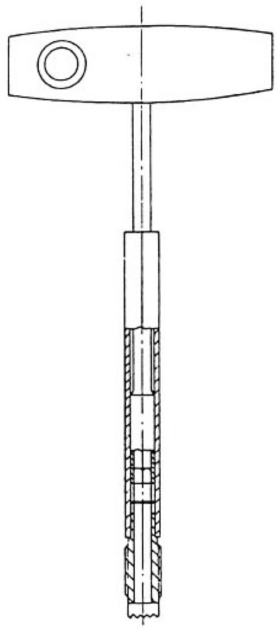


Fig. 12: Reamer Type 1300A23

Assembling of the tool
The actual reamer is assembled in our works, the swivel nut is hold on the reamer with a snap ring. The hex tube which is used as an extension can on one side slightly be deformed with a hammer. The deformed side is then pressed onto the tool in order to hold the two pieces together. The so assembled tool is screwed into the mounting bore. Take care that only one side of the hex tube is deformed, otherwise the tubular socket wrench cannot be inserted anymore. During the reaming the hex tube remains on the tool in order to guide the tubular socket wrench.

Reaming of the sealing surface
The tubular socket wrench is inserted in the hex tube and allows to turn the tool. With a little care very good sealing surfaces can be produced. It is recommended that the tool is tried out on an old measuring gun. A faulty handling of the tool may damage the sealing surface.

Procedure to be followed with the reamer Type 1300A23:

- Fill out the grooves of the cutter with high density grease such as Klüber grease Type 1063. The grease absorbs the rupped-off parts and avoids their squeezing between cutter and sealing surface. The lubricity of the grease reduces the danger of pitting
- The force of the reamer against the sealing surface shall be small at the beginning in order to keep the friction force small
- Dismount the reamer after 2 ... 4 turns and visually control the reamed surface. The amount of turnings and the location of the turnings on the cutter tell you what the condition of the sealing surface is
- If the cuttings are not equally distributed on the cutter and if the sealing surface seems not to be visually ok, (deep grooves, concave or convex sealing surfaces or an inclined thread towards the bore)
- In this case clean the reamer again and refill the cutter grooves with grease
- Remount the reamer and increase the force on the tool continuously during turning. This increase of the force must be done with care in order that the friction force does not increase too much. Pitting must be avoided
- Dismount the reamer every several turns, check it and clean it
- Ream only as long as absolutely necessary
- Clean the mounting bore before re-installing the sensor

How often is a rereaming or relapping of the measuring bore necessary?
Prior to the first operation, each measuring bore should be rereamed for evenness of the sealing surface. In order to verify the evenness, the sealing surface is colored before the reaming with water proof felt tip pen or with blue ink.

After heavy use or after blow offs, the sealing surface should be controlled and rereamed. With care, the reamer can also be used to remove powder residuals.

3.9 Firing with thermal protection

Without thermal protection the diaphragm surface will be heated by the hot combustion gases impinging upon it after firing. As a result the diaphragm is distorted (tin lid effect); this counteracts the pressure to be measured and causes a measuring error which is reflected in a too low pressure indication over the entire pressure profile and a zero offset after the firing.

With sensor Type 6213B the pressure can be indicated by up to 2 % too low (for ammunition 7.5x55).

This temperature error can largely be avoided if the thermal protection is used.

3.9.1 Thermal Protection Shield Type 6563A

The thermal shock error can be greatly reduced by protecting the front part of the sensor with a thermal protective plate Type 1181 and protection shield Type 6563A.

The thermal protective plate Type 1181 lasts about 5 … 20 rounds, depending on application.

NOTE

The thermal protective plate should not be used if the sensor is cooled to temperatures below 0 °C. At these temperatures the thermal protective plate hardens and causes measuring errors. Instead of using the thermal protective plate, coat the diaphragm with some grease (never fill the entire mounting bore with grease).

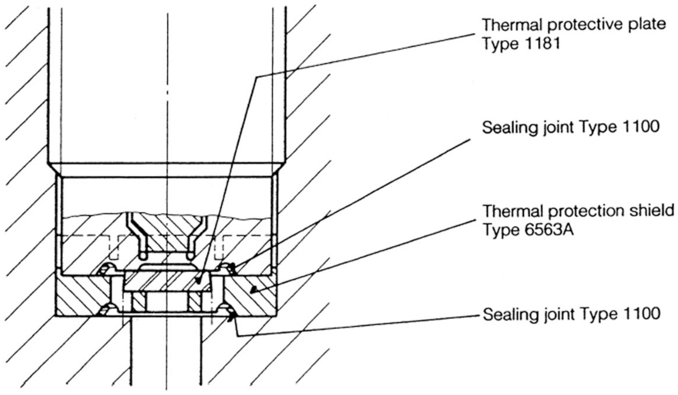


Fig. 13: Thermal protection shield Type 6563A and thermal protective plate Type 1181

3.9.2 Grease shield

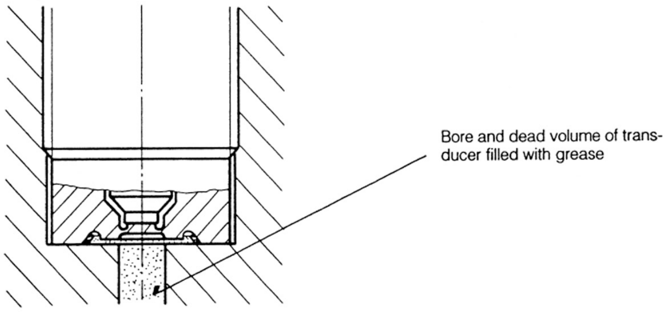


Fig. 14: Grease shield

No measuring errors could be ascertained in tests with silicone grease (Type 1051) up to a pressure <4 000 bar. For pressure >4 000 bar a measuring error of up to –5 % has seen detached. Caution is necessary when using high-viscosity greases, and parallel measurements are advisable. Caution is indicated especially against pastes (silicone) or similar, as these may prevent full pressure propagation.

4. Different measuring rigs for ballistics

4.1 Cartridge chamber measuring

Cartridge chamber measuring yields the most information for the user during the powder burn-up, but it also involves the most care when drilling the cartridge cases and centering the case exactly.

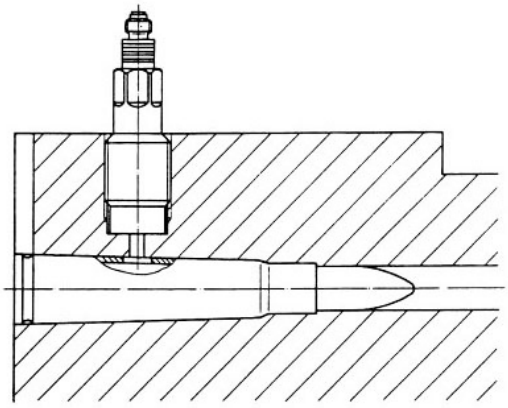


Fig. 15: Cartridge chamber measurement

To allow the cartridge case to seal without blow-by despite the hole in the cartridge chamber, the hole in the case is usually sealed with adhesive insulating tape.

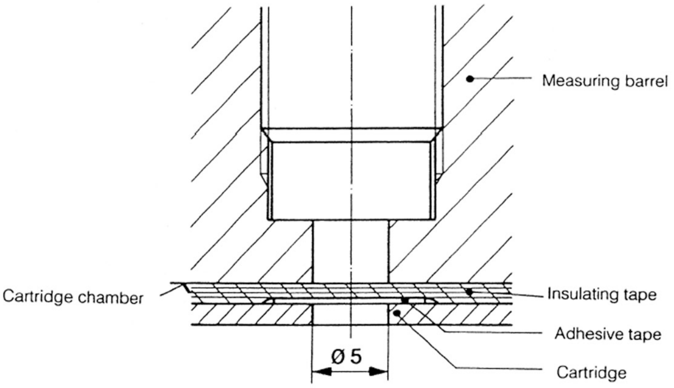


Fig. 16: bore gummed up

The smaller the hole in the cartridge case, the higher the bursting pressure of the gumming. With holes of 2 ... 3 mm diameter the necessary bursting pressure may be a few hundred bar, so that the initial firing phase is lost. This may be remedied by poking through the gumming with a pin several times shortly before firing.

As in this application the sensor is subjected to the hot combustion gases over the entire pressure profile, a thermal protection should always be used (see sub-section 3.9).

4.2 Case base adapter

Mounting the sensor in a case base adapter is only possible with large caliber. This mounting mode yields – like the cartridge chamber measurement – information over the entire pressure profile.

Use thermal protection (see subsection 3.9).

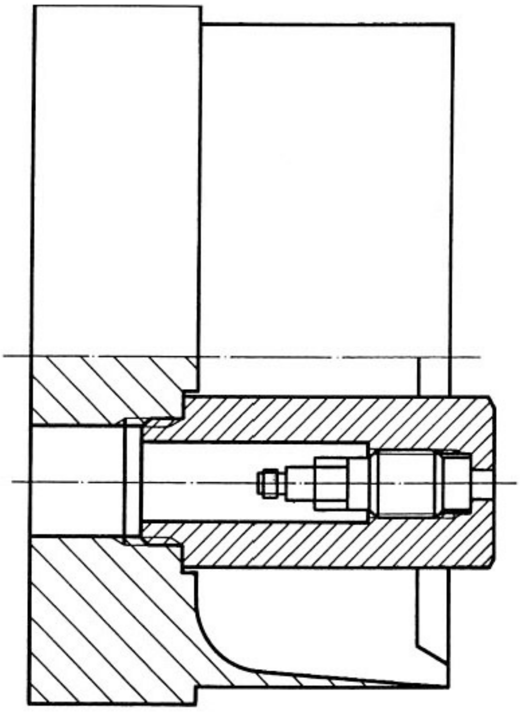


Fig. 17: Case base adapter

4.3 Cartridge mouth measuring

For cartridge mouth measurements which are mainly provided for small calibers, we recommend to use Type 6215 with the pertaining accessory.

This rig is employed mainly for ammunition acceptance tests. It is much simpler than cartridge chamber measuring, because no work has to be done on the ammunition. Only the peak pressure is evaluated by this method; depending on ammunition it is up to 3 % lower than the pressure yielded by cartridge chamber measuring.

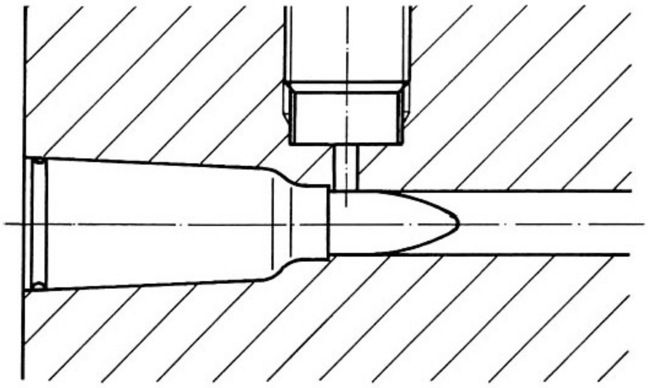


Fig. 18: Cartridge mouth measurement

Cartridge mouth measuring is the method making the heaviest demands on the sensor, i.e. shortening its life. Because as a rule the projectile uncovers the measuring bore only shortly before the peak pressure, there is a big pressure jump and the rise time is short. As a result, owing to the small measuring bore the dead volume in front of the sensor may be made to oscillate. These oscillations, usually in the range of a few 10 kHz, are commonly attenuated by electronic filters following. But the sensor is loaded additionally by the oscillations, the peaks of which are often higher than the effective peak pressure. Moreover there is a risk of the diaphragm getting damaged by metal parts from the projectile, or from the cartridge case if the distance between this and the measuring bore is too small.

The following safety precautions are therefore advisable:

- Carry out test measurements with filter of high cutoff frequency (… 180 kHz).
- Keep the dead volume between sensor and barrel as small as possible.
- Work only with a thermal protective plate fitted, for protection against metal parts (volume reduction) and temperature.
- Depending on the application, the situation can occur that the bore is not situated in the free flight section but already in the rifle groove section. In this case attention must be paid that the bore is located in the groove of the rifle.

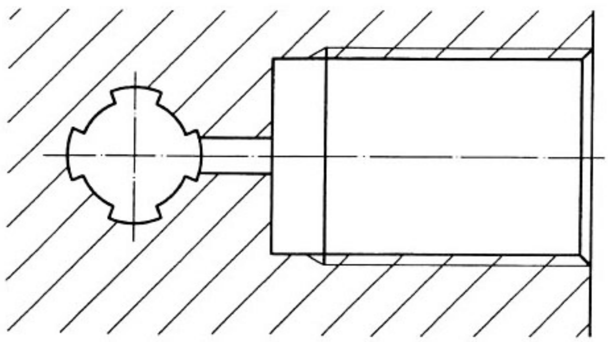


Fig. 19: Disposition of the mounting bore

This measure avoids the peeling-off of firing material and is especially important for port pressure measurements.

4.4 Measuring pressure anywhere along the barrel (Port Pressure)

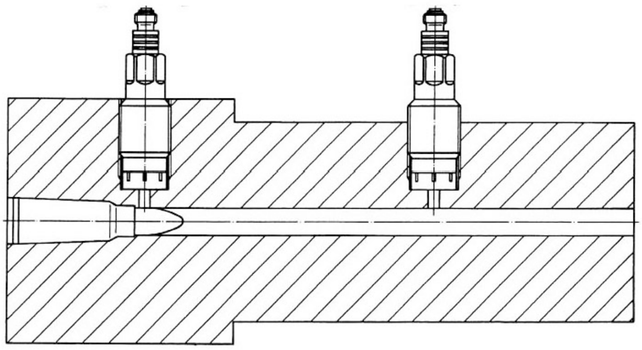


Fig. 20: Measuring pressure anywhere along the barrel (port pressure)

In this measuring mode a dead volume – due to the connecting bore – before the diaphragm cannot be avoided. Therefore the advantage of the shoulder sealing sensor no longer exists (see also subsection 4.2).

Owing to the very short pressure rise time, pressure measurements in the barrel are extremely problematic. Normally more or less strong pipe oscillations are excited by these measurements, depending on the bore. Depending on the kind of weapon and the position of the measuring bore (end or beginning of barrel), the first shock wave on the sensor front may set up a higher pressure than the peak measured in the cartridge chamber.

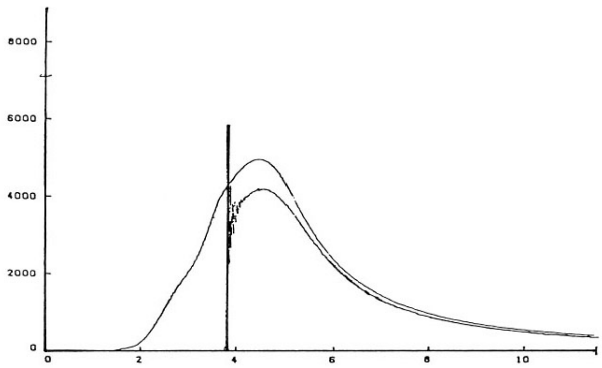
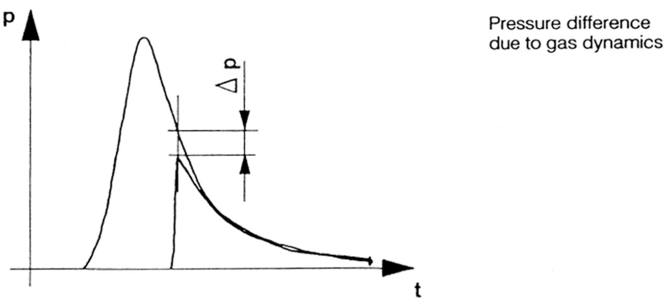


Fig. 21: Barrel measuring on a large caliber weapon compared with cartridge chamber measuring

But in most cases measuring is done only after reaching the peak pressure (e.g. port pressure measuring).

Fig. 22: Port pressure measuring compared with cartridge



chamber measuring.
Port pressure measuring with 10 kHz filter to eliminate pipe oscillations.

With this measuring rig the pressure rise time depends very much on the dead volume before the sensor front, and also on the filter employed in the charge amplifier. Consequently, with different measuring bores (dead volume) or when using different electric filters the indicated maximum pressure will differ.

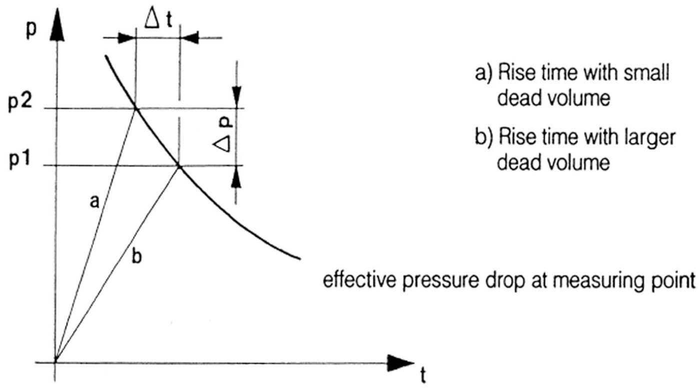


Fig. 23: Pressure difference Δp due to different pressure rise times

Fig. 23 shows that owing to the finite rise time (dead volume) the effective pressure at the measuring point can never be detected. The greater the dead volume and the lower the cutoff frequency of the filter employed, the lower the indicated pressure maximum. The steeper the pressure drop is at the measuring point, the more noticeable are the pressure differences (dead volume, filter).

The sensor with small dead volume shows p_2, the sensor with large dead volume only p_1.

To allow comparison of values from different testing points, with this rig it is crucially important that the installation conditions and also the instrumentation (filter, evaluation) are absolutely identical.

As safety precautions to protect the sensor, the same measures are recommended as for cartridge mouth measurements (see subsection 4.3).

4.5 Pressure Bomb Measuring

Pressure bomb measuring is used to monitor current production of chemical propellant charges, and also in the development of these.

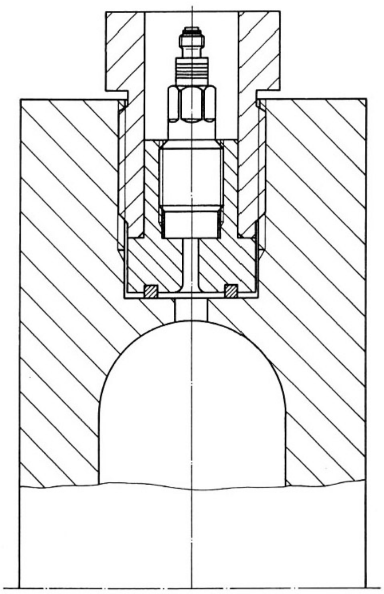


Fig. 24: Sensor mounting: Type 6213B in a pressure bomb

For pressure bomb measuring the sensor is usually not fitted straight into the housing but with an adapter, for better handling.

The front sealing sensors Type 6213B (and Type 6215) are more suited for use in pressure bombs than the shoulder sealing Types 6201 … 6211. If Type 6213B or Type 6215 are employed together with the thermal protection shield Type 6563A or Type 6565A and the inserted thermal protective plate Type 1181, it is usually possible to do without any further thermal protection.

Moreover the sensor Type 6213B is able to cover completely the pressure rage (10 000 bar) usual for pressure bomb measurements. In particular its very good linearity enables it to be used for measurements in small pressure ranges too.

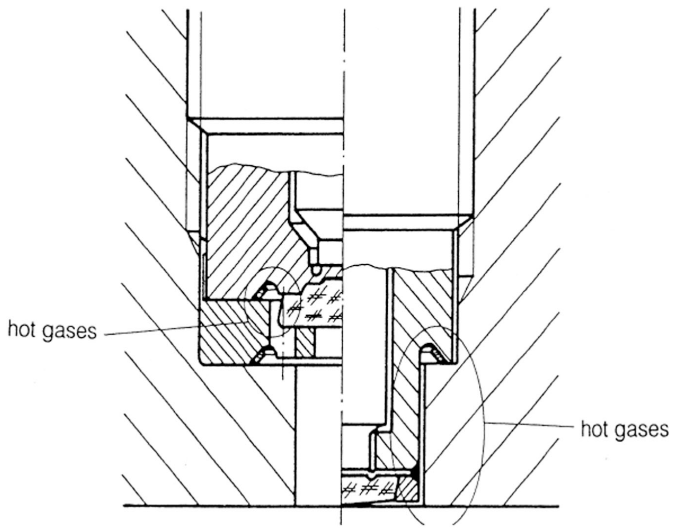


Fig. 25: Front part of a face seal compared with a shoulder seal

Left: front sealing sensor
Right: shoulder sealing sensor with thermal protection

Fig. 25 shows the sensor surface exposed to the hot combustion gases, with a thermal protective plate fitted on the front and shoulder sealing sensors. The comparison shows that with shoulder sealing the surface exposed to the temperature exceeds that with front sealing many times.

Adapters for high-pressure sensors must therefore be designed for minimal material stressing at the installation point (see Fig. 26).

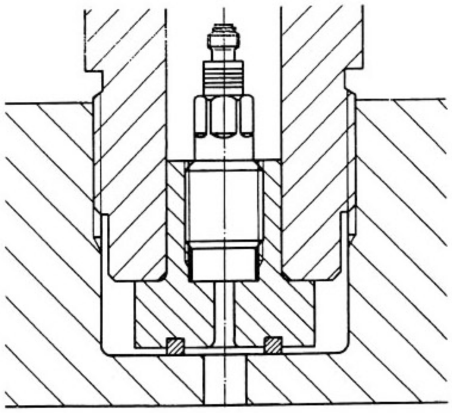


Fig. 26: Adapter causing minimal material stresses at installation point

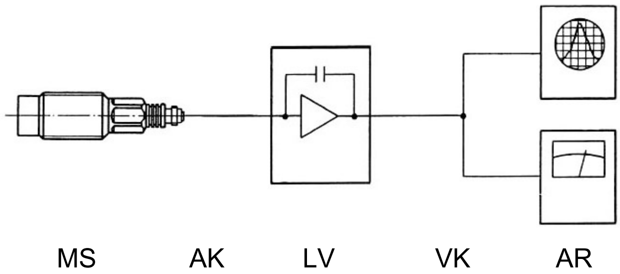
The following safety precautions are advisable for pressure bomb measuring:

- Work only with a thermal protective plate fitted
- With bombs of large volume the front of the sensor should be further protected with a suitable grease. This is also necessary with water-cooled bombs
- Work only with seal Type 1100 if possible
- Calibrate the sensor together with its adapter
- If possible use an adapter with low material stressing at the sensor installation point
- Keep the sealing diameter on the adapter as small as possible
- Because adapters are exposed to high loads as a rule (relatively large sealing diameter), pressure relief ports after the adapter seal and appropriate protective devices are to be provided

5. Operation

5.1 Basic circuit of a measuring rig

A measuring facility consists primarily of the piezoelectric part, i.e. the quartz pressure sensor, a highly insulating low-noise connecting cable and the charge amplifier. This is supplemented by a non-piezoelectric part comprising display or recorder and/or a peak pressure indicator.



MS: sensor
AK: connecting cable, highly insulating, low-noise
LV: charge amplifier (converting charge into voltage)
VK: connecting cable, not low-noise
AR: display/recording equipment/data processing

Fig. 27: basic circuit or a measuring rig

The electric charge set up in the sensor is converted into a proportional voltage in the charge amplifier. This voltage may be indicated, recorded or processed further. The connecting cable for the sensor must be highly insulating and low-noise. The influence of the cable length (>15 m) is given in the operating instructions for the charge amplifier employed.

From the charge amplifier to the display or recorder, ordinary cables may be used.

General information is given in Operating Instruction 002-001, Piezoelectric Measuring System.

5.2 Range selection and threshold

A distinction must be made between the measuring range of the pressure sensor and that of the charge amplifier. The high-pressure sensor is calibrated in the 100 % and 10 % range. It is even possible to select a lower range, i.e. 1 % of the actual measuring range.

The measuring range required for performing a measurement can be freely selected on the charge amplifier (e.g. Type 5011). The charge amplifier Type 5011 offers continuously adjustable measuring ranges. Of course the maximum pressure tolerated for the sensor must not be exceeded.

It is for example possible to select a measuring range of 10 bar (1 bar/V) in order to measure small pressure variations superimposed upon a static basic pressure of say 1 000 bar. A 100-time overloading of the measuring range will not harm the charge amplifier.

The threshold of the high-pressure sensor Type 6213B is around 0.02 bar.

5.3 Measuring High-Frequency Phenomena

The ability to measure high frequencies is limited either by the natural frequency of the sensor or by the upper cutoff frequency of the charge amplifier or recorder as the case may be. As shown in subsection 3.5, "Influence of long measuring bore", the restricting factor may also be the measuring bore itself. A quartz pressure sensor constitutes a very weakly damped system. Its resonance ratio is about 30 dB. Depending on the accuracy required, the measuring frequency may amount to a maximum of 10 ... 40 % of the sensor resonance frequency.

The upper cutoff frequency of the application can be adjusted by means of the low-pass filter (8 steps) at the charge amplifier Type 5011.

5.4 Measuring quasistatic phenomena

Purely static measurements over any length of time are not possible with the piezoelectric measuring principle.

The time interval during which so-called quasistatic measurements can be performed depends on the insulation resistance of the sensor and its connecting cable, and on the properties of the charge amplifier employed.

With an insulation resistance of $10^{13}\,\Omega$ and 0.03 pC/s sensor drift current, using a high-pressure sensor there is an error of 1 bar/minute. With a measuring range of 1 000 bar the resulting error is thus ≈1 % if the measurement lasts 10 minutes.

5.5 Directions and safety precautions

- Seal ring Type 1100 must not be inserted wrong way round
- If there is leakage, don't just tighten up. If the sensor does not seal despite being tightened with the prescribed torque, the seal needs changing. If the leakage persists, inspect the mounting bore and touch it up if necessary
- The sensor should not be left fitted on the object unnecessarily long. If work is continued without measuring, fit the plug Type Z13195 in place of the pressure sensor. This holds especially where high pressures occur
- To maintain the high insulation resistance the connector must be protected against dirt. The same applies to the cable plug. Clean them if necessary with rectified benzene. When the cable is detached from the sensor, a protective cap should be screwed on in its place

6. Calibration and maintenance

6.1 Calibration

The sensor has been calibrated at the works. The calibration sheet is supplied with it. A duplicate may be requested any time.

For internal ballistics pressure measurements, periodic recalibration may be advisable. The interval between two calibrations depends a great deal on the application. In case of doubt or after a long operation, a recalibration should be performed.

Deadweight testers are employed usually for these recalibrations. The sensor is loaded quasistatically. Because quasistatic measurements stress the sensor far more than firings (dynamic measuring), quasistatic calibrations should be kept a minimum, otherwise the sensor life will be shortened unnecessarily. If for example cartridge mouth measurements (peak pressure measurements for ammunition acceptance tests) are carried out with 6 000 bar peak pressure, it is not very advisable to calibrate in steps, (as for acceptance tests), up to typically 10 000 bar. In this example, recalibrating the 6 000 bar point is sufficient: any sensitivity changes affecting the measurement will be revealed.

In order to calibrate reliably at all, however, it is essential to calibrate the entire measuring chain by means of a standard charge or precision charge calibrator. The insulation of the highly insulating connecting cable must also be checked. Cables with less than $10^{13}\ \Omega$ insulation resistance should no longer be used for calibration.

A field recalibration can be performed with the high-pressure generator Type 6905A or the pulse generator Type 6909 if the pressure calibrator Type 6907A is used.

6.2 Recommended preliminaries

- The sensor insulation resistance should exceed $10^{12}\ \Omega$
- Apply a little Klüber grease Type 1063 to the sensor threads
- Calibrate with the seal that will be employed later
- Tighten with the torque appropriate to the used seal
- Tighten with the torque used, but within the prescribed range in the normal case 40 N·m
- If adapters are to be used later, calibration must be done in the same adapter
- Do not take the first loading as calibration value when calibrating
- Check the reference sensor periodically (when calibrating by comparative measurement, e.g. with Type 6903A)
- Check the complete calibration measuring chain by means of a standard charge

6.3 Maintenance

The sensor is welded throughout. Repairs are seldom possible, and then only at the markers' works.

No periodic maintenance is needed. Visual checks of the diaphragm part are advisable, also of the sealing part for any cracks or damage.

If the connecting plug is dirty, it may be cleaned with rectified benzene and a clean paper tissue.

6.4 Aids for calibration and maintenance

Calibration aids:

Hydraulic high pressure generator up to 7 000 bar	Type 6905A
Hydraulic pulse generator up to 4 000 bar max.	Type 6909

Maintenance aids:

Special high-pressure oil for hydraulic generator	Type 1053
Special grease for sensor threads	Type 1063
Insulation tester	Type 5493

Installation aids:

Special drilling tool	Type 1341
Screw tap M12x1	Type 1355
Reamer	Type 1300A23
Torque wrench	Type 1300A11
Tubular socket wrench SW 8	Type 1373A1
Fork wrench hex. for Type 1300A11	Type 1300A15
Pressure calibrator	Type 6907A…