Instruction Manual

Installation and Maintenance of all Types of Force Plates for Biomechanics

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Operating Instructions

Installation and Maintenance of All Types of Forces Plates for Biomechanics

Your Competent Distributor:

Kistler Instrumente AG Winterthur, CH-8408 Winterthur, Schweiz Tel. + 41 52 224 11 11, Fax + 41 52 224 14 14

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1 Introduction

1.1 Our Thanks

We thank you for choosing a KISTLER quality product. By so doing you have opted for precision, long life and technical innovation.

Please read these instructions through carefully so that you can use your equipment properly and get the most out of it.

1.2 Other KISTLER Products

KISTLER offers a wide range of measuring instruments and complete systems:

- quartz sensors for force, pressure, acceleration, shock and vibration.
- associated charge amplifiers and charge calibrators.
- electronic control, display and evaluation equipment

KISTLER also designs entire measuring facilities for special duties, as in the automobile industry, plastics processing and biomechanics for example.

Our overall catalog will provide you with an overview of our products. Detailed data sheets are available on practically all of them.

1.3 KISTLER Service

The worldwide KISTLER customer service is at your disposal for any special questions still open after perusing these instructions. It can also give you competent advice on details connected with applications.

1.4 Important Information

Please keep to the following rules without fail. This will ensure your personal safety when working, and assure long, trouble-free performance by the instrument.

1.4.1 For your Safety

- The force plate has to be be installed, operated and maintained only by persons who are familiar with it and adequately qualified for their particular tasks.
- When it must be assumed that safe operation is no longer possible, the instrument has to be taken out of operation and secured against unintentional use.

It must be assumed that safe operation is no longer possible if:

- the instrument is visibly damaged,
- it no longer functions,
- it has been in lengthy storage under adverse conditions,
- it has received rough treatment during transport.

According to safety requirements for medical electrical systems EN60601-1-1+A1 the following has to be observed.

⚠ The force plate has to be connected to earth using the Potential Equalization Conductor provided in the scope of delivery to meet the CE-standards for medical electrical equipment regarding Earth Leakage Current.

⚠ The data acquisition computer and persons who are in direct contact with it have to remain in a distance of 1,5 m from the patient at all times for the same reason.

1.4.2 How to Treat the Instrument

- The force plate may be used only under the specified environmental and operating conditions.
- Protected the signal output against dirt and do not touch it with your fingers. When the connection is not being used, cover it with the cap provided.
- When the force plate is not in use, protect it by keeping it in the packing case supplied.
- When performing long-time measurements, make sure that the temperature of the force plate remains as constant as possible.

1.4.2.1 If you have an External Amplifier

- The insulation resistance is crucially important with piezoelectric systems. It must be around 10^{14} Ohm (but at least 10^{13} Ohm).
- To obtain this resistance, all plug and socket connections must be kept meticulously clean and dry.
- The insulation resistance can be measured with the insulation tester Type 5493.
- The connecting cable from force plate to charge amplifier is highly insulating. Use only the proper cable.
- Do not remove the connecting cable from the force plate.

2 Location and Environment

A KISTLER force plate is a very sensitive though robust measuring device. It is able to resolve forces down to 10 mN and still cover a measuring range of up to 20 kN (depending on the type of force plate).

To take advantage of the full range, resolution and accuracy, proper mounting is essential.

2.1 Basic Requirements

- The force plate should be mounted level with the surrounding floor to make it easily accessible and safe.
- The top plate of the force plate must never touch the walls of the pit or neighboring force plates at any point.
- The force plate should have the same floor covering as the surroundings (safety, psychological effects, etc.).
- The ground on which the force plate is mounted has to be solid, rigid and as much as possible free of vibrations.

2.2 Environment

To obtain good results, the environment in which the force plate is operated must meet certain criteria:

- The temperature has to be kept reasonably constant. Temperature transients can easily lead to temperature errors in the measurements.
- Large temperature changes can create inner stress and excessive load due to thermal extension of the force plate structure

Protect the force plate against direct sunlight to avoid temperature transients.

Force plate and mounting frame must have same temperature before tightening the bolts.

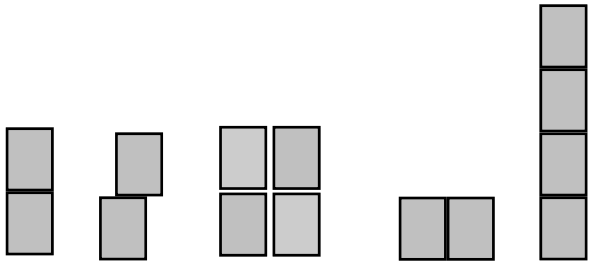
- Condensation of humidity on the force plate or the foundation must be prevented. In critical cases simple measure is to place a light bulb (25 or 20 W) beneath the force plate.

Leave the charge amplifier switched on at all times. This creates a warm and protective atmosphere inside.

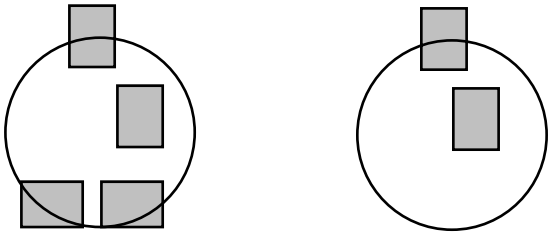
Note: Force plate sensitivity is not affected by environmental parameters.

2.3 Force Plate Layout

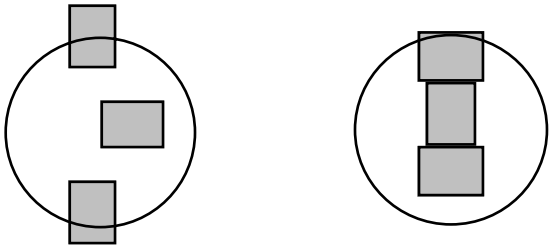
Force plates are used in a wide variety of applications and therefore available in different sizes and designs. They are arranged case-by-case depending on the application as is illustrated by the examples given below.



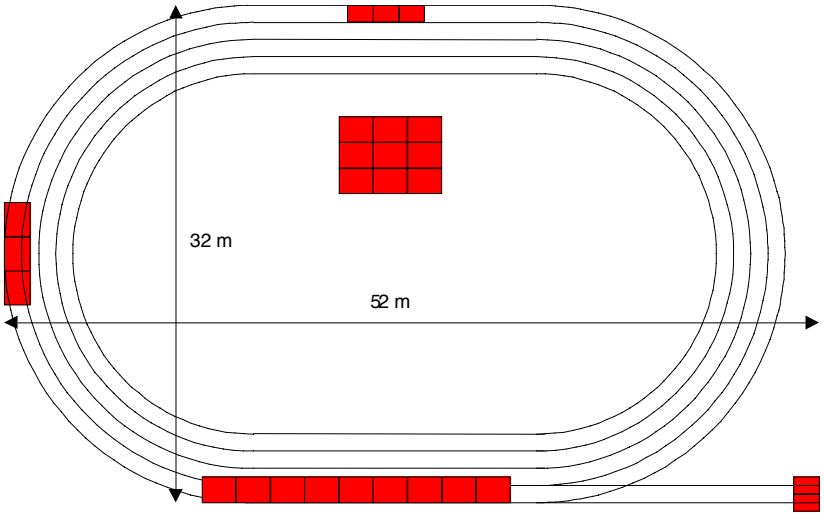
Setups used in gait analysis



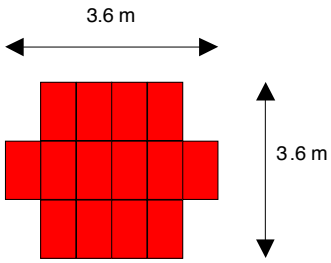
All kinds of throwing

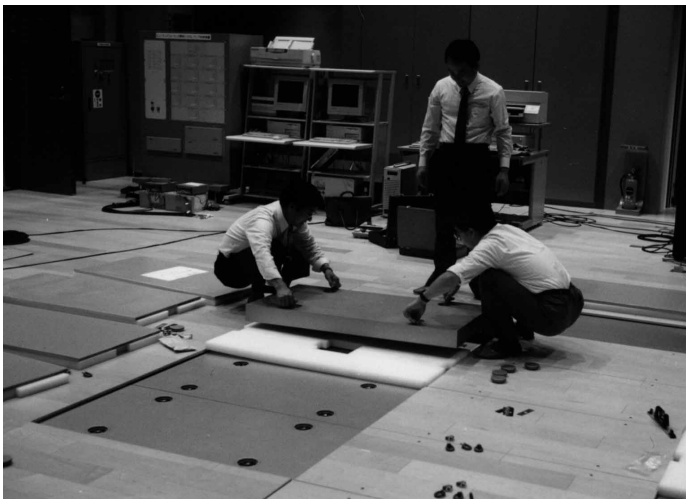


Shot putting



One of the largest indoor biomechanics laboratories for sports science at SUNY Syracuse. The 6 force plates (4x9287BA and 2x9281CA) are moved around as needed while most of the force plate positions are covered with dummies.





An installation with 14 force plates Z15907… (600 x 1200 mm) for virtual reality feedback in a Japanese University.

2.4 Force Plates and Movement Analysis

Most motion analysis systems using video cameras require a certain space for their operation.

As a general rule the force plates should be mounted in the center of a space of at least 10 x 10 x 2 m.

2.5 Special Force Plate Locations

Force plates may be mounted in any position (on ramps, walls, ceilings etc.) and will perform within specifications provided the mounting instructions are followed strictly.

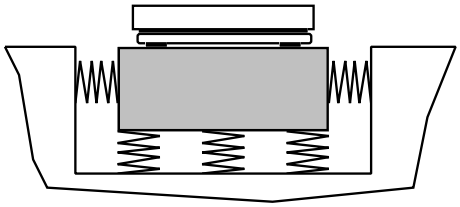
Applications:
- Ergonomics
- Kicking, Boxing
- Industrial force measurements

Water-resistant (submersible) force plates have been used in swimming pools (sports and rehabilitation) and in water tanks (training of astronauts in a low-gravity environment). Regardless of the position of the force plate, neither zero nor sensitivity need to be readjusted. This is an inherent property of piezoelectric force plates.

2.6 Vibrations

2.6.1 External Sources of Vibration (Building Vibrations)

Light force plates are less influenced by vibrations.



Principle of isolating the force plate foundation with damping from external sources of vibration.

External sources of vibrations include machinery (compressors, fans, generators, pumps, elevators, escalators, etc.), traffic (railroads, trams, underground railways, busses, trucks, etc.), pedestrians, gymnastic halls and discos in the same building, construction work and so on.

A force plate location should be as far as possible free of vibrations.

Check for any potential external source before deciding on the final mounting spot.

Basements are usually best. If upper floors must be used, make a thourough investigation.

The disturbance in the force signal due to vibration can be estimated from the formula

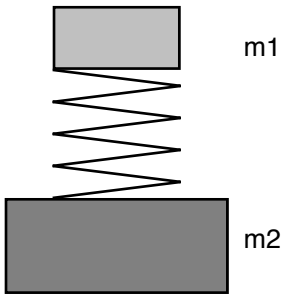
$$F_{disturbance} = m_{force\ plate} \cdot a_{ground\ vibration}$$

For most applications, vibration should not exceed about 0,01 g_{pp} (0,1 $m/s^2{}_{pp}$).

If you have to live with external vibrations, the foundations must be isolated from the surroundings. Call in specialists because foundation mass and damping material must be tuned to the dynamic characteristics of the mounting spot as part of the building structure. Non-professional design can result in worsening instead of improving the situation!

A foundation mass of 2 … 3 t, floating in a suitable damping material, usually gives best results. Another approach is to insert a very rigid and massive column under the mounting area, based on solid ground and isolated from the rest of the building to avoid any coupling. Kistler will be happy to assist you in finding a good solution. Contact us as early as possible, especially before finalizing plans for a new building!

2.6.2 Internal Source of Vibration

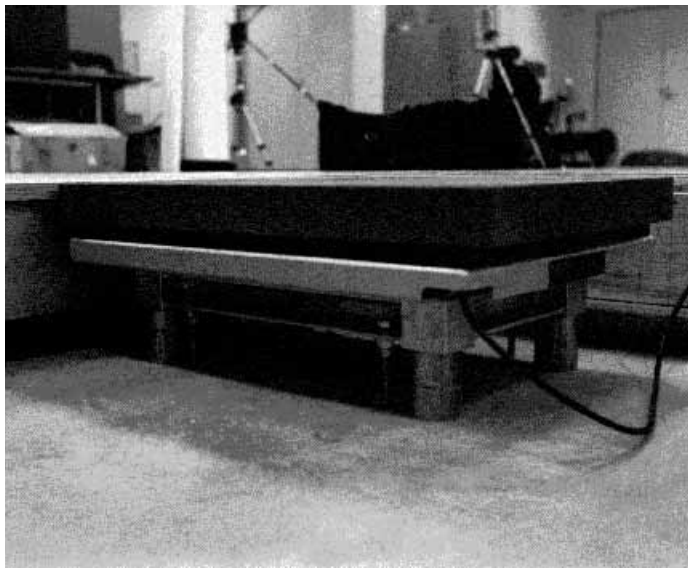


Two mass oscillator consisting of force plate and foundation.

The internal source of vibrations is the dynamic interaction between the force plate and its foundation. Two masses – the force plate (mainly the top plate only) and the foundation block – are "elastically" coupled by the force sensors. Ideally, the foundation should have an infinite mass or be at least much heavier than the force plate.

The foundation of a force plate should have at least 10 times the mass of the force plate mounted on it:
$$m_2 > 10 \cdot m_1$$

Mounting has to be as rigid as possible.



Example of a weak mounting where internal vibrations caused major disturbance and the natural frequency of the setup dropped to 50 Hz.

2.7 Cables (with external charge amplifier)

Between force plates and charge amplifiers special highly insulating cables, available only from Kistler, must be used exclusively. Otherwise signals may show drift. Keep all connectors meticulously clean and dry.

Two types of cables are available:

- Cable with plastic covering is quite flexible and thin, suitable for indoors, not exposed to rough handling.
- Cable in metal tubing is rugged, 12 mm thick, and suitable for rough environments and handling. Water-resistant versions are available for force plates Types 9253... and 9366AB… .

Cable ducts must be dry and connections (except water-resistant ones) must never be submersed (see 4.5).

3 Mounting Methods

The mounting methods differ significantly with different force plates and different applications.

Force Plate Type	9253...	9281...	9285...*	9286…	9287...	9288...	9366...
Concrete foundation with mounting frame or steel plate	**A**	**A**	**A**		**A**		**A**
Directly bolted to the floor with special adapters							
Fixed on the floor with double-sided adhesive tape		C			C		
Without fixation to the floor		C		**A**	C	**A**	

A Full exploitation of the force plate performance as specified in the data sheet.

B Low impact applications only (up to 25 % of range)

C Noncritical applications (such as measuring low, mainly vertical forces) with reduced measuring range and reduced accuracy of COP center of pressure.

***** A special mounting frame Z12627 is available for filming from underneath.

3.1 Concrete Foundation Block

Mounting a force plate on a rigid, heavy foundation ensures full performance of the force plate and is preferred over all other mounting methods.

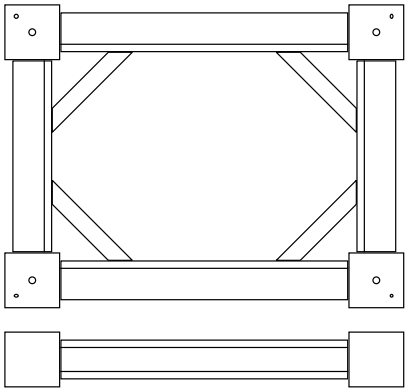
A mounting frame or steel plate is used to bolt the force plate down to the foundation block.

The mounting frame is grouted into the foundation using non-shrinking mortar or epoxy resin (castable grout such as Sikadur 42 of Sika).

For a steel base plate non-shrinking mortar is preferable because the plate is likely to warp with epoxy resin, which heats up while hardening.

Do not use ordinary mortar: It shrinks!

3.1.1 Mounting Frame

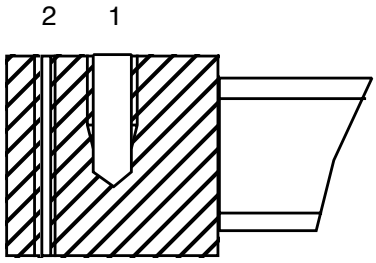


A mounting frame is recommended when the force plate is always mounted in the same position.

It provides ground surfaces and threaded holes to attach the force plate.

The mounting frame has four leveling screws.

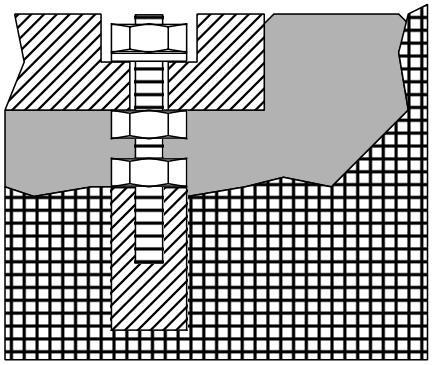
Kistler provides mounting frames for most force plates. They are specified in the data sheets of the force plates.



1 M12 for force plate mounting

2 Leveling screw (for leveling and height adjustment)

3.1.2 Steel Plate



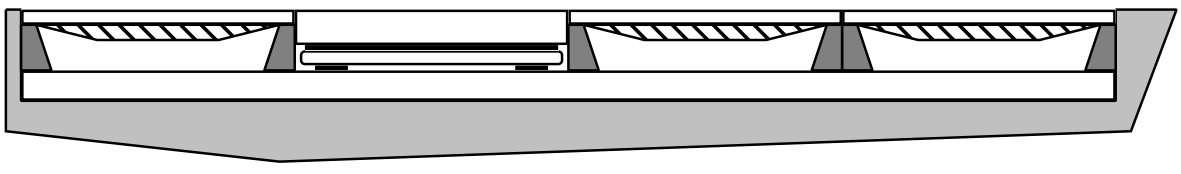
Foundation with steel plate

A steel plate is used if a more flexible force plate installation is necessary. A suitable pattern of tapped holes allows fixing the force plate in any desired position.

The steel plate should be at least 25 ... 30 mm thick and have surfaces ground flat. Heat treatment before final grinding to relieve internal stresses is strongly recommended. Flatness should be within 0,2 mm for each force plate location. Shimming, although not easy to do, must always be done to obtain best results.

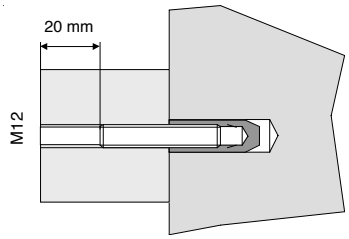
The steel plate should not only be grouted in but bolted down to the foundation as well with barb bolts. Otherwise it may become loose after some time.

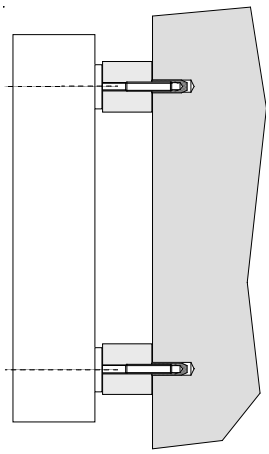
A pit wider than a force plate is useful when either a single force plate needs to be mounted in different positions or especially when several force plates are used in various configurations. Spaces between the force plates and the pit walls must be filled with modular filler pieces.



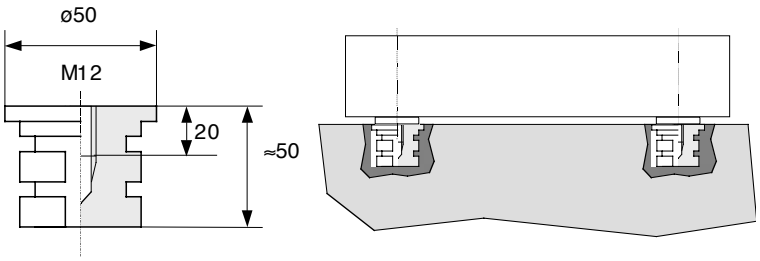
Pit for multiposition mounting

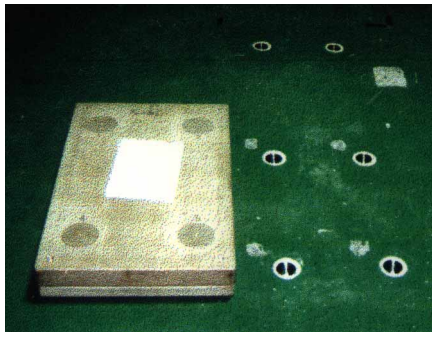
3.1.3 Mounting with Anchors



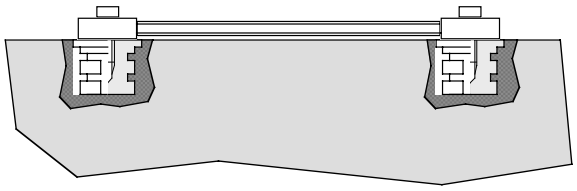


Mounting with anchors where only small holes can be drilled or where grouting is impossible like in vertical situations.





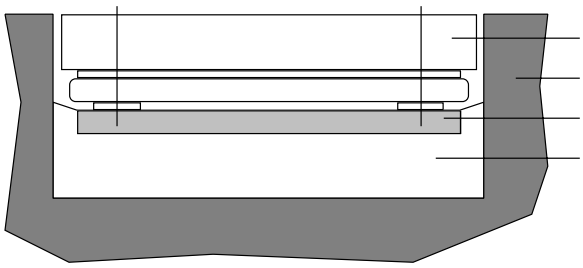
Special anchors have been used where the total height was critical but where it was only possible to make small holes into the concrete floor instead of a major recessment (pit) for the entire force plate.



A fixation is necessary to hold the anchors during the grouting and curing of the grout.

3.1.4 Temporary Foundation for Outdoor Use

For installing a force plate temporarily outdoors, a pit filled with fine gravel or sand may be used. Mount the force plate on a ground steel plate which is carefully embedded in a layer of sand, preventing any voids.

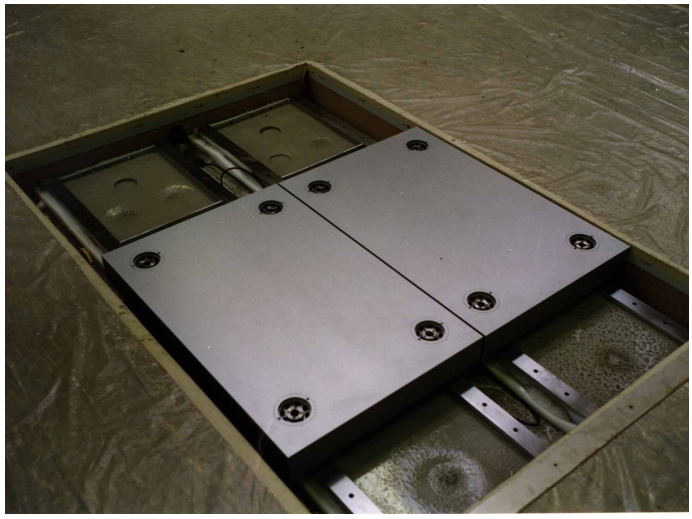


3.1.5 Mounting Frame for Glass Force Plate Type 9285

The "cube" frame Z12627 is designed to mount a camera undermeath the transparent top plate. Depth of the pit: 150 mm (force plate) + 540 mm (frame) + 5 … 10 mm (tolerance).

Scratch protection of the glass top plate with self adhesive plastic foil. The pit will be covered with a removable frame to maintain access to the cameras.

3.1.6 Mounting Frame with Multiple Mounting Positions



Two mounting frames Z16666 to mount force plates 9287B… side by side in multiple positions.

4 The Foundation

4.1 General Requirements

All force plates are sensitive to ground vibration because they are like accelerometers: a mass (top plate!) on force sensors. Therefore, a force plate must be mounted on a solid and heavy foundation, free of ground vibrations.

Always check first if there are any vibrations.

Quick test: touch the floor with hand and have a person jump up and down on and around the mounting spot. Vibrations cannot be felt clearly: hardly any problems with usual applications.

More reliable is to measure ground vibrations with a suitable accelerometer.

Sources of vibrations can be external or internal.

The lighter the force plate the less sensitive it is to vibration.

4.2 Rigid Foundation Block

In order to eliminate any internal source of vibration, the foundation must have at least 10 times the mass of the force plate.

If external vibrations are present (see 4.1.1), the foundation block can be isolated from the surroundings by a suitable damping material.

Call in specialists because foundation mass and damping material can be tuned to the dynamic characteristics of the mounting spot as part of the building structure. Non-professional design can result in worsening instead of improving the situation!

4.3 Outside Location

The foundation block must be laid on a frost-protected gravel bed

A drain for rain-water is absolutely important.

4.4 Mounting Pit

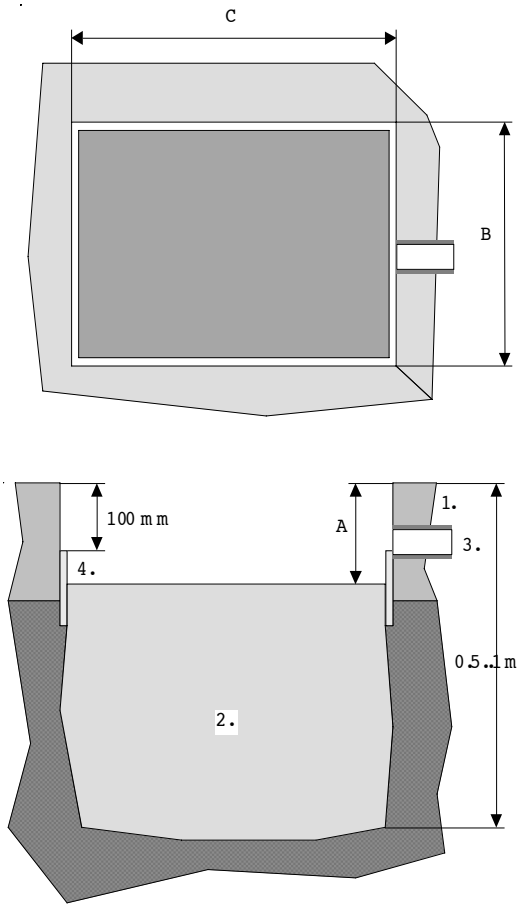
A mounting pit allows to install force plates flush with the surrounding floor.

4.4.1 General Rules

- Depth of pit is determined by the height of the force plate used. Usually the force plate is covered with the same flooring material already used. Make sure that this is properly taken into account. Once set a mounting frame can not be lowered any more while it is possible to rise a force plate by up to about 10 mm, using precise space washers.
- Top plate(s) of force plate(s) installed in the pit must not touch the pit walls or each other. Otherwise measuring errors result from the force shunt at the points of contact!
- A gap of at least 1 mm, better 2 ... 5 mm, must exist all around the top plate, also between top plates of neighboring force plates.
- Regularly check to make sure these gaps are open and no foreign matter (sand, wood slivers, etc.) is jammed in the gap, especially in outdoor installations.
- **Hint:** pass with a strip of solid cardboard all around the edge of the top plate(s) to detect any jamming.
- Pits must always have a drain, even in indoor locations, to allow accidentally spilled water (cleaning crew), rain, etc. to drain off quickly. If cable connections are submerged, there is a risk of water entering and degrading the high electric insulation, resulting in measuring errors.
- Cable duct must be laid out in such a way that there are no water traps and that water drains clearly either into the pit or at the other end. However the cable duct must never serve as the main drain for the pit!

A mounting pit ensures that the force plate can be mounted flush with the floor.

4.4.2 Pit for One Force Plate



1 Floor

2 Foundation

3 Cable channel

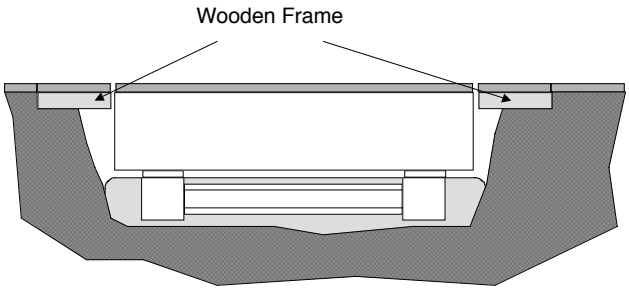
4 Isolation material

A Force plate height $+55^{+5}$ mm
for mounting frame 9423

Force plate height $+65^{+5}$ mm
for mounting frame 9427

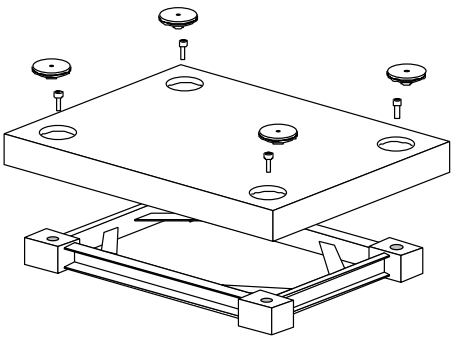
B Force plate dimension $^{+25}{}_{+15}$ mm

C Force plate dimension $^{+25}{}_{+15}$ mm



Sometimes it is not possible to build the recessment very accurate. It is then advisable to use a wooden frame to close the gap.

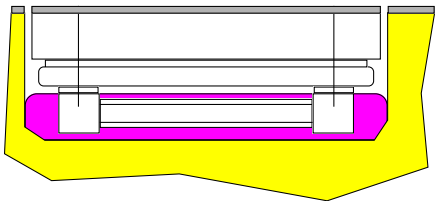
5 Installation with Mounting Frame



Installation with a mounting frame supplied by Kistler gives the best results and, if done correctly, will let the force plate perform at full specifications.

Carefully follow the instruction given here to obtain best results. If a solid, ground steel plate is used instead of a mounting frame, proceed in a similar way.

Remember to always take great care in keeping all electrical connectors on the force plates, cables and charge amplifiers meticulously clean and dry.



The mounting frame ensures firm fixation of the force plate on the foundation.

5.1 Procedure

1 Prepare mounting pit, clean and dry it, doublecheck for correct size (width, length and height).

2 If necessary insert shuttering frames (wood) and optional filler pieces to save castable epoxy grout.

3 Clean and degrease the mounting frame with water and household detergent to ensure a good bond with the castable epoxy grout. Protect the ground mounting surfaces and the tapped holes with adhesive tape.

4 Remove the covers over the 4 sensors of the force plate using the M6 eye bolts. Insert the four M8 eye bolts for lifting the plate.

5 Bolt the force plate to the mounting frame but tighten the bolts only lightly by hand. Place it back into the pit and make sure there is sufficient clearance all around the top plate and that the isolating material is not touched either.

6 Measure the distance from the top of the force plate to the top of the concrete floor.

7 Detach force plate carefully from mounting frame.

8 Adjust leveling screws until the height is about equal to the measured distance in step 8.

9 Carefully bolt down force plate onto mounting frame again, check if it is even with the floor.

10 Repeat steps 9 to 11 if necessary. If surrounding floor is uneven, level to the lowest point.

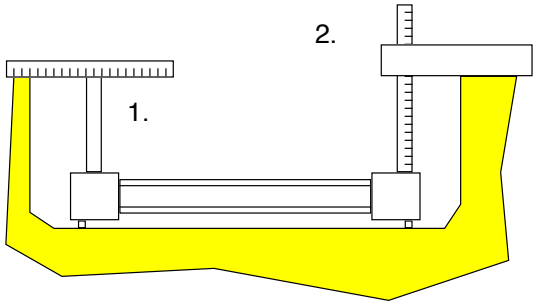
11 Once the force plate is exactly even with the surrounding floor, remove it carefully and make sure the isolation material in the mounting pit is level with the top of the mounting frame.

12 Prepare Sikadur 42 (or equivalent) castable epoxy grout (Note: it must be of the "non-shrinking" type!). First fill the center of the mounting frame. Then fill around the sides. Note: Fill in castable grout only up to 5 mm below the mounting surfaces.

13 Let cure according to manufacturers specifications.

5.2 Positioning Aids

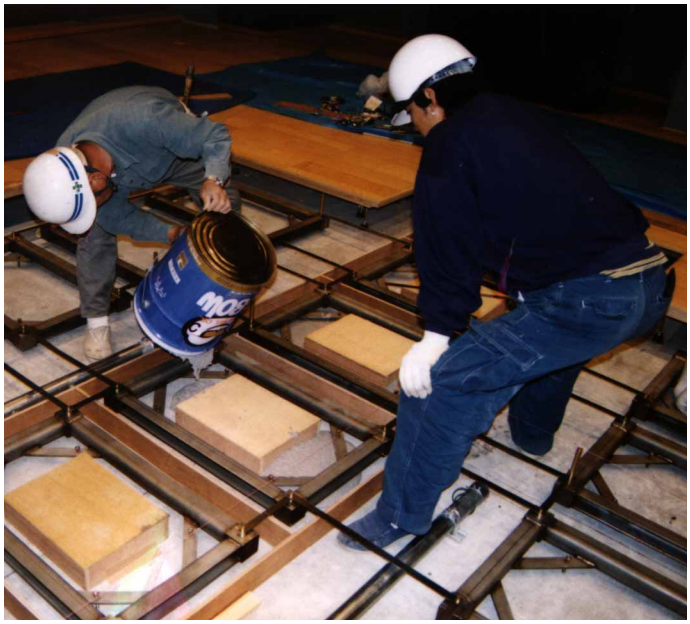
Other Leveling and positioning aids:



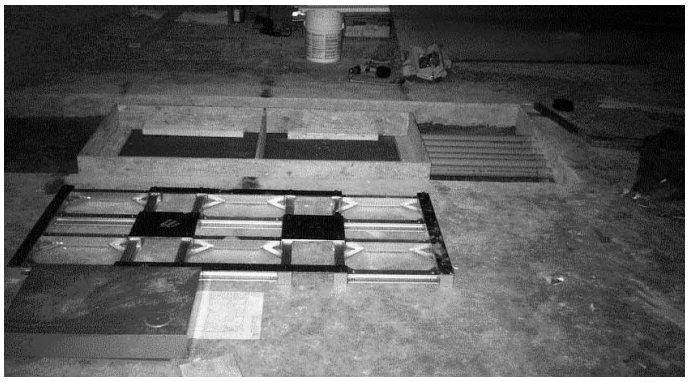
1 Distance rod (made by user), screwed to tapped M12 hole in mounting frame

2 Straight edge and measuring stick

Mounting frames Type 9423 during installation. Note the positioning aid which is being used and the careful protection of the floor with plastic.



Rods and bolts to accurately position and space multiple mounting frames. The rods and bolts will be removed after the grout has cured.

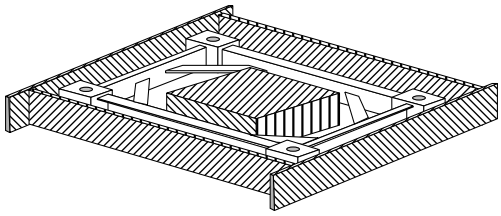


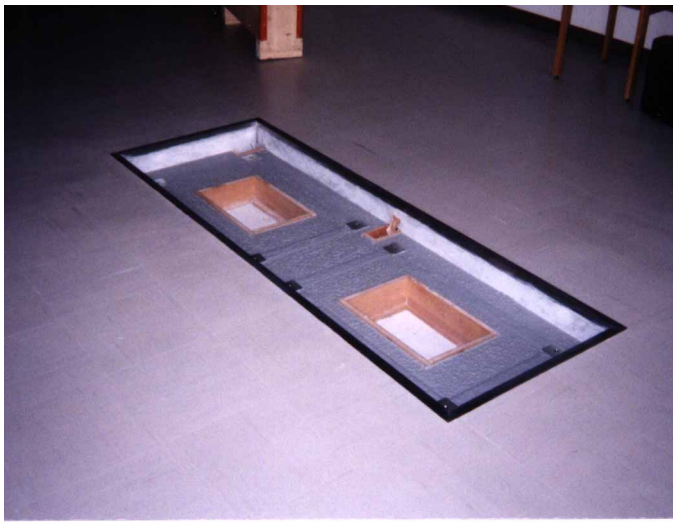
Mounting frames layed out to check the positioning aids. In the background the shuttering which is ready for grouting in the mounting frames.

Positioning the mounting frames with the help of positioning aids.

A long life of mounting frames is positioned and ready for grouting.

5.3 Shuttering and Grouting



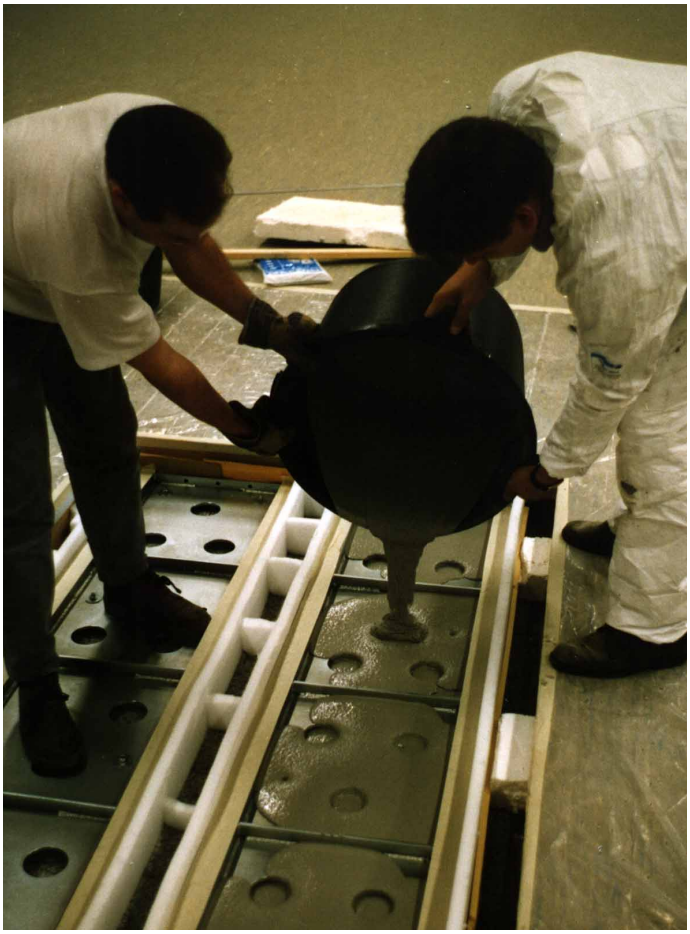


Use shuttering and filler piece to save castable grout.

Use silicone cement to seal the shuttering. The grout is very liquid and escapes through the smallest gaps.

Protect the mounting surfaces with tape and a large area around the pit with plastic.

Thoroughly mix the castable grout with a stirrer and a drilling machine. Only mix portion by portion. Note the protection of the floor with plastic and cardboard.



Mix and pour the grout portion by portion but all in one session. The grout warms a little during curing and temporarily becomes more liquid. In this particular installation the grout ran into the cable channel unnoticed during the night and it was impossible to chip it out. A new cable channel had to be installed.

5.4 Shimming

Careful shimming is essential for obtaining accuracy measurements!

- Clean the mounting surfaces on both, force plate and mounting frame. They must be dry and free of burrs. Remove any burrs with a rubstone.
- Lower the force plate carefully onto the mounting frame. Use the eye bolts to do this safely.
- Push down a corner of the force plate with one hand and **tap opposite** corner with the other hand. The slightest rocking will produce a clearly audible sound. Note in which diagonal the force plate is rocking. One corner of that diagonal must be shimmed.
- Lift the force plate and insert a shim.
- Lower the force plate and recheck for rocking.
- Repeat with different shims until no rocking can be detected any more. Both diagonals must sound alike when being tapped.

Shim only one foot of the force plate.

5.5 Mounting

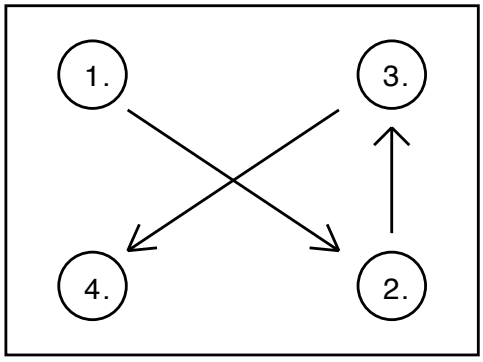
- Clean and lightly grease the mounting surfaces on the force plate and mounting frame as well as the shims to protect against corrosion.

Keep all connectors meticulously clean and dry. When connecting cables, always snap together the caps of both connectors too, to keep them clean.

- Connect the cable which you have run through the cable channel.
- Carefully lower the force plate onto the mounting frame with the correct shims in place. Double-check that there is no wobble. Do not jam the cable.

Force plate and mounting frame must be at the same temperature before tightening the bolts.

Let stabilize temperatures for at least two hours, especially if it was inadvertedly exposed to sunshine or brought into a heated room from outside cold (e.g. car trunk in winter).

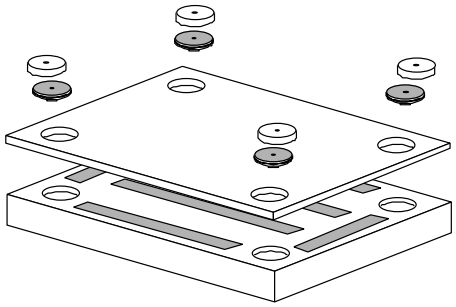


- Grease and insert the M12 bolts, but do not tighten yet. Fine-adjust the position of the force plate.
- Tighten the M12 bolts in the indicated sequence, using a torque wrench:

  - each bolt to 1/3 of the specified torque in a first round
  - then each bolt to the full specified torque (usually 60 … 90 Nm)

6 Covering and Protection

6.1 Floor Covering



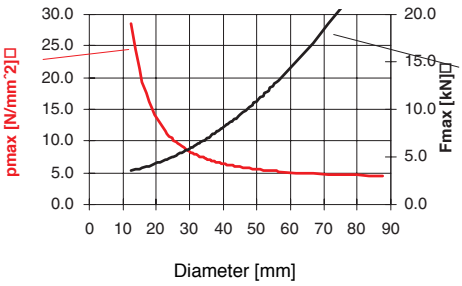
Usually force plates are covered with the same floor covering as that of the surrounding floor. The reasons are:

- Safety: the surface of the force plate is too slippery for most applications.
- Force plate should not be visible to the subject to prevent hesitation or involuntary change in the natural movements (e. g. trying to hit the plate)

The easiest way to attach a piece of floor covering is to use double-sided adhesive tape as is used in fixing wall-to-wall carpets. This also allows for easy removal if the force plate has to be taken out again.

The floor covering on the force plate must not touch the surrounding floor.
A gap of 1 … 3 mm must be open all around.

6.2 Protective Covering



Maximum stress (surface pressure) tolerated in function of the loaded area

Depending on the top plate material of the force plate, it has to be protected for certain applications.

Lightweight sandwich top plate tolerate only a limited stress (surface pressure) of ≤5 N/mm^2. The full load of 20 kN must be spread over an area of e. g. at least 70 mm in diameter!

However higher surface pressures easily result e. g. from spikes, crutches, high heels and so on. Extensive tests have shown that in practically any reasonable application with human subjects the surface of lightweight sandwich top plates will not be damaged.

Warning: None of the standard force plates, including those with solid aluinum ro steel force plates, may be used in heavy weight lifting!

A dropped weight will destroy standard force plates. Consult Kistler for special designs suitable for such applications.

Great care should be exercised in shot putting or when working with dumbells. Dropping weights, even of less than 10 kg, produces very high force peaks which can easily overload the sensors in the force plate.

Hard floor coverings such as linoleum or ordinary carpet will not damp an impact. Some protection is given by materials such as tartan for weights up to about 10 kg.

Important: The thickness of any material added to the force plate must be included in the value of a_{z0}, unless a_{z0} is determined experimentally in situ with the material in place (see 7.3.5).

Force plates with solid aluminium or steel top plate have to be protected if there is danger of overload due to falling weights. This can be done for certain cases with a layer (40 mm) of plywood.

Adding material to the force plate increases the active mass and consequently reduces the natural frequency of the force plate.

6.2.1 Fixation

Protective covers can be fixed with double-sided adhesive tape or, on force plates with massive metal top plates only, by using the tapped holes in the top plate.

If the force plate is moved frequently, cut out the floor covering or protective cover over the four circular covers of the holes for the fixing bolts. The fixing bolts remain accessible without having to remove the entire protection.

6.3 Overload

After an overload, quartz force sensors will either continue to work properly or – if the overload was too severe – clearly not work correctly anymore (heavy drift, much lower or no signal at all).

Such failure are always obvious but will never present a safety hazard!

Nevertheless it is good measurement practice to make a functional check of the complete force plate system regularly, especially after a suspected overload and certainly before starting a new series of experiments (see chapter 7).

7 Functional Check and Calibration

Kistler force plates exploit the piezoelectric effect in quartz, which is a material constant. Therefore, sensitivity and linearity of a quartz sensor will not change with time. There is no fatigue, aging, creep or wear whatsoever. A quartz sensor can only be destroyed by extreme overload or excessive temperatures.

Nevertheless we strongly recommend to make regular functional checks to ensure that all electrical connections are intact, that the electronics (charge amplifiers and data processing electronics) are in perfect operating conditions and that all settings and adjustments are correct. Also a check of the drift should be made to detect if humidity has entered connectors or electronics in order to get good results. Drift of more than ±50 mN/s is excessive and the cause has to be found and rectified (see 8.2).

Useful information is also given in CAMARC-II (Computer Aided Movement Analysis in a Rehabilitation Context II) and is available as No. 24 "Standards for Instrumentation and Specifications" from the Strathclyde University, Glasgow, Scotland, UK.

7.1 Regular Functional Checks

Quartz force plates and charge amplifier are very stable and reliable. Yet regular checks are recommended to detect errors such as a disconnected cable or a wrong setting of an amplifier. A thorough check is highly advisable before starting any important new series of measurements, especially if the equipment has not been used for some time.

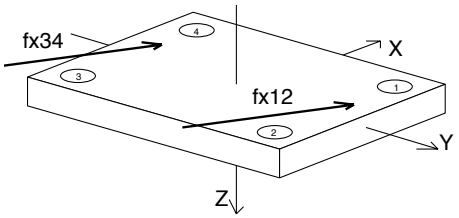
7.1.1 System Check

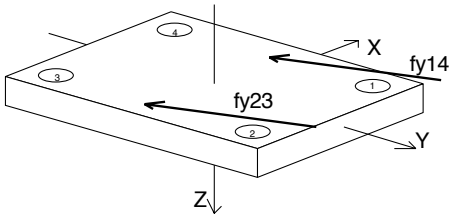
The system check verifies that all channels of the force plate are connected and that their signals are correctly amplified by the charge amplifiers and received by BioWare or any other data acquisition system used.

The BioWare function "`Tools : Voltmeter`" provides a realtime reading which is very useful for such a test.

The test is performed by just applying loads on the force plate by hand along the edges and on the corners.

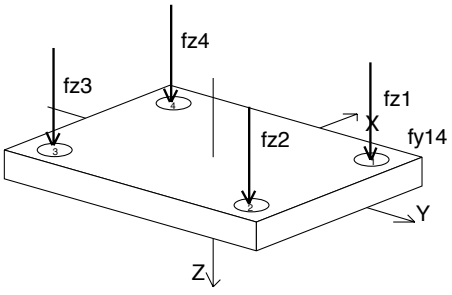
Horizontal forces





Applied force should appear in	**Significant output voltage**
F_{x12}	Channel 1
F_{x34}	Channel 2
F_{y14}	Channel 3
F_{y23}	Channel 4

Vertical forces



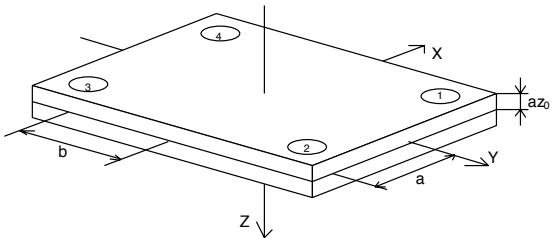
Applied force	**Significant output voltage**
F_{z1}	Channel 5
F_{z2}	Channel 6
F_{z3}	Channel 7
F_{z4}	Channel 8

If a channel does not work,
go to chapter 8: Trouble shooting

7.1.2 Setup Parameters

Regularly verify that the force plate setup parameters set in BioWare (or any other system used) are valid for the force plate used.

- Sensitivity (see individual calibration certificate of the force plate, identified by the serial number)
- Dimensions
  (see operating instructions of the force plate)
- Position of force plates relative to each other
  (see BioWare operating instructions)



Force plate Type	Top plate width (x axis) mm	Top plate length (y axis) mm	Overall height (z axis) mm	Sensor offset in x direction a [mm]	Sensor offset in y direction b [mm]	Offset of top surface in z direction [E] a_{z0} [mm]	Sensitivity [C] F_x, F_y pC/N	Sensivity [C] F_z pC/N
9253A…	400	600	100	120	200	–58	≈ –3,7	≈ –3,8
9261A	400	600	60	132	220	–37	≈ –7,5	≈ –3,3
9281B…	400	600	100	120	200	–63	≈ –8	≈ –3,8
9281C…	400	600	100	120	200	–49	≈ –8	≈ –3,8
9284	500	500	80	220	220	–45 [A] –39 [B]	≈ –7,8	≈ –3,7
9285	400	600	150	120	200	–42	≈ –7,4	≈ –3,8
9286	400	600	35	175	275	–22	≈ –7,8	≈ –3,3
9287	600	900	100	210	350	–57	≈ –7,8	≈ –3,8
9287A	600	900	100	210	350	–53	≈ –3,7	≈ –3,9
9288 [D]	400	600	35	175	275	–22		≈ –3,3

A Mounting solution A (removable)

B Mounting solution B (screwed down)

C Nominal values only. For exact values see the calibration certificate supplied with each force plate

D One-component force plate (vertical forces only)

E See also 7.3.5 In-situ Determination of the Effective Value of a_{z0}

7.2 Regular Check of the Charge Amplifier

We recommend to regularly check the charge amplifiers for correct functioning, especially

- Zero offset
- Drift

This can be done by using the "voltmeter" function in BioWare or with a voltmeter directly on the analog output pins. With some charge amplifier models, the zero offset can be adjusted from outside the unit.

- Although the calibration of charge amplifiers is very stable, it is advisable to verify it regularily, especially before starting an important series of measurements or after having left the amplifiers unused for a long period of time. Special equipment and Kistler-trained service staff is needed to do a proper calibration, i. e. to verify and calibrate the transfer factor «Charge at input [pC] / Voltage at output [V]».

See also section 8.4.2

7.3 Calibration of a Force Plate

The calibration of force plates with quartz sensors will not change with time because the sensitivity is a material constant of quartz. Either such a force plate works (and then is accurate) or it will clearly show that it has been permanently damaged. Nevertheless many people want to calibrate their force plates by their own to be very sure.

7.3.1 General Rules for an On-Site Calibration

Do not rely on a single measurement only. Repeat each calibration measurement until you are sure that the result is constant and reproducible.

Forces applied in the calibration should be of similar magnitude as the forces occuring in your measurements. For calibrating F_z in gait analysis applications, a weight of >20 kg is required.

Always choose the range on the charge amplifier so that the output signal comes close to 10 V for the maximum forces. This gives the best signal-to-noise ratio.

7.3.2 Vertical Force (F_z)

- Place a known weight on the center of the force plate
- Switch the charge amplifier to OPERATE
- Lift off the weight carefully
- Read the negative output

Lifting off the weight gives a much cleaner signal (no jitter) than setting down the weight.

The weight should normally be placed in the center of the force plate. The variation in sensitivity across the entire top plate can be verified by placing and the lifting off the weight in different positions.

7.3.3 Horizontal Forces (F_x, F_y)

The forces must be applied exactly in the direction of the axes of the coordinate system.

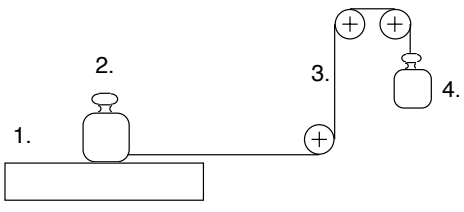
There are two ways to calibrate F_x and F_y:

With a spring balance:

While simple to carry out, this method is not very accurate (at best, the error will be within about ±5 %).

- Place a weight in the center of the force plate
- Switch the charge amplifier to OPERATE
- Apply a horizontal force by pulling with the spring balance attached as low as possible to the weight
- Read the output

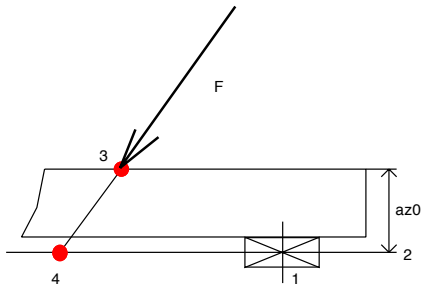
With dead weights and a rope-and-pully system:



1 Force plate
2 Weight
3 Rope-and-pully system
4 Calibration weight

- Place a weight in the center of the force plate.
- Attach the rope as low as possible to the weight and align the direction of the rope precisely with the direction of the coordinate axis. Switch the charge amplifier to OPERATE.
- Apply the force by hanging the known calibration weight on the rope.
- Switch the charge amplifier to OPERATE.
- Lift the calibration weight to remove the force.
- Read the output.

7.3.4 Reducing the Error of the Center of Pressure (COP)



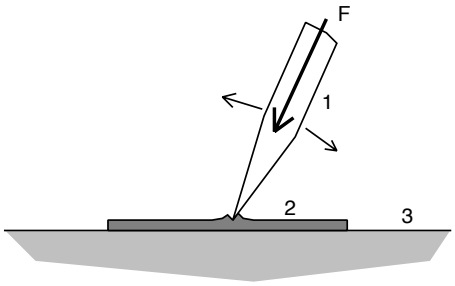
1 Sensor
2 x-y plane of coordinate system
3 COP on force plate surface
4 COP for $a_{z0} = 0$
F Acting force

The x-y plane of the coordinate system is at a distance a_{z0} below the surface of the top plate. This offset a_{z0} can be determined in situ (see 7.3.5). If floor covering such as Tartan is added to the force plate, then the thickness of such material must be added to a_{z0} for obtaining the correct COP on the surface of added material.

Practice has shown that a_{z0} is slightly influenced by the rigidity of the mounting.

We found a practical way to determine experimentally in situ the effective value of a_{z0} which, when used in the calculation, gives the least error in the COP.

7.3.5 In-situ Determination of the Effective Value of a_{z0}



1 Forces applied at various angles with a poited rod
2 Metal plate with central punch
3 Force plate

After the force plate has been installed and floor coverings, have been attached, place a metal plate (about 2 ... 3 mm thick) with a centerpunch in the middle of the working surface. Set the geometrical value of a_{z0} as a starting value in the software.

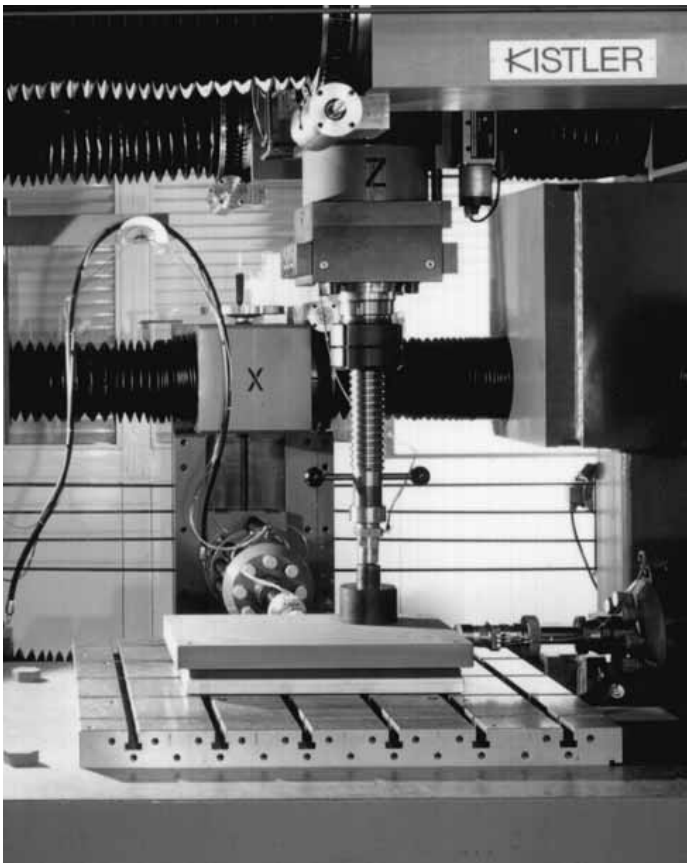
With the measuring system set to display the COP, apply a force by hand, using a pointed rod, on the metal plate.

Apply the force in different directions and observe the indicated COP. If it moves depending on the direction of the applied force, slightly change the value of a_{z0} set in the software and repeat until the a_{z0} is found which gives a constant reading of the COP. This is now the optimum effective value of a_{z0} which you use in your measurements with the given installation.

If the force plate is mounted in a different location, the procedure should be repeated for best results.

Usually the same value can be reused again after remounting the force plate on the same mounting frame and with the same floor covering at a later date.

7.4 Force Plate Calibration at Kistler



This unique 3-component force calibration system is used to calibrate all Kistler force plates. Precisely aligned hydraulic cylinders can apply forces up to 100 kN in the x and y direction, up to 200 kN in the z direction. Specially selected and calibrated quartz 3-component force sensors are used as reference sensors. Their calibration is traceable to national and international standards. Crosstalk can be determined within better than ± 0,1 %.

8 Trouble Shooting

8.1 No Signal

The following guidelines make it easy to quickly identify the most common sources of trouble in a piezoelectric measuring system.

Just to be sure:
- **Is the power switched on?**
- **Is everything correctly connected together?**
- **Is the charge amplifier switched to OPERATE?**

Use a voltmeter or the BioWare function "`Tools : Voltmeter`" for diagnosis.

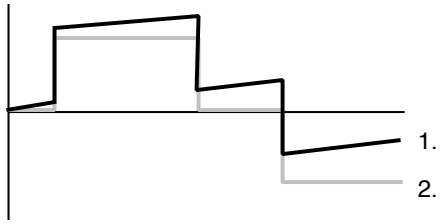
Disconnect the force plate, set the charge amplifier to OPERATE and short-circuit the charge input of the charge amplifier with a piece of wire.		
Amlifier saturates at once at ≈±12,7 V	No signal Connect voltmeter to output	
Charge amplifier OK	Signal	Still no signal
Check input and output cabling, see 8.2.2	Check BioWare cabling and A/D card	Charge amplifier defective, repair by Kistler trained service personnel

8.2 Drift

Drift is defined as «An undesired change in output over a period of time which is not a function of the measurand».

Charge amplifiers and therefore piezoelectric systems have a slight drift, because there exist no semiconductors such as the MOSFET at the charge amplifier input which have absolutely no leakage current. The best ones available still have a few fA (10^{-15} A) leakage current. Also there exist not insulating materials with infinitely high insulation resistance! The highest available is around $10^{14}\Omega$.

8.2.1 Charge Amplifier in DC-Mode (Time constant: LONGE or OFF)



1 Applied force (or charge)

2 Output signal of charge amplifier operating in DC mode (long time constant) with superimpoed drift

A good charge amplifier has a drift of <±0,03 pC/s. With quartz force sensors, having a sensitivity of about 3 … 8 pC/N, this means in practice that the output signal drifts away within <±10 mN/s. Therefore, after 1 minute the error due to this drift is <± 3 N. This is the reason why true static measurements are not possible with piezoelectric systems. One can only measure "quasistatically", i. e. in a "near" DC-mode.

A charge amplifier on LONG TIME CONSTANT has a little bit of drift (<±0,03 pC/s) when set to OPERATE, even if no charge is applied to the input or if no force is acting on a connected sensor.

If the output signal drifts away (this can be up or down) faster than ±0,03 pC/s (±10 mN/s), the measuring chain has excessive drift.

Causes can be

- Input transistor (MOFET) of the charge amplifier is defective.
- Insulation resistance of sensor, cable or amplifier input has dropped below 10^{12} Ω (moisture, dirt, etc.)

A charge amplifier on MEDIUM or SHORT TIME CONSTANT always goes to zero when set to OPERATE and no drift is seen! If it saturates, it has excessive drift!

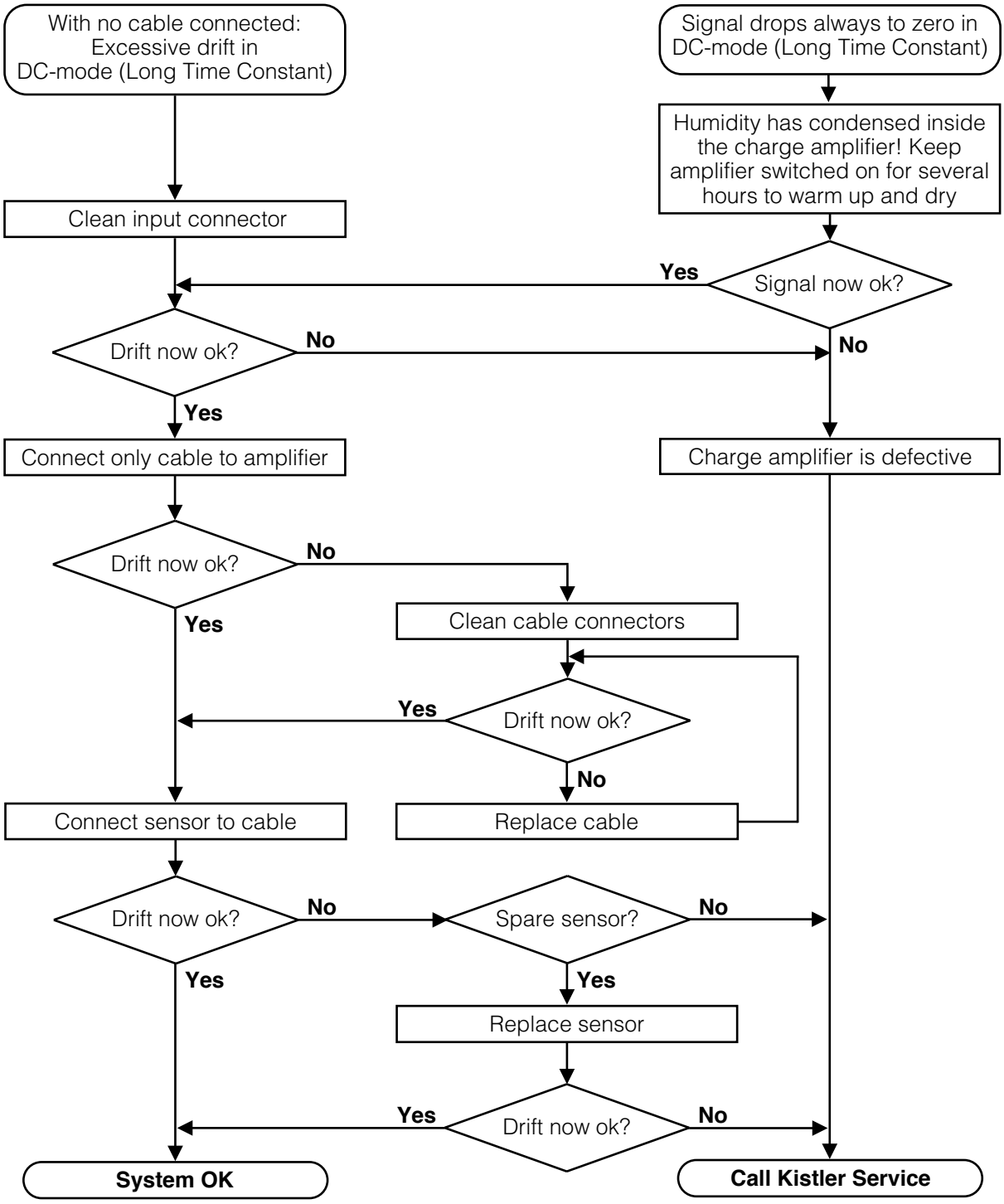
To finde the cause of excessive drift, follow the chart on the next page step by step.

Note:

To clean highly insulating parts, use only Spray Type 1003 from Kistler or pure white gasoline. Never blow dry by compressed air (oil!) or by mouth (saliva!).

To prevent condensation: Keep amplifier in a dry place. Keep amplifier continuously switched on, day and night.

Trouble shooting a piezoelectric system



Charge amplifier in DC-mode (Long Time Constant): Limit for drift is ≤±0,03 pC/s

8.2.2 Charge Amplifier in AC-Mode (Time constant ON, SHORT or MEDIUM)

The output of a charge amplifier set to AC-mode (MEDIUM or SHORT time constant) will always drop exponentially to zero in response to a step input.

This is not drift but the normal intended characteristic of the AC-mode.

This must not be confused with drift (see 8.2.1). Like with an oscilloscope, AC-mode means that the amplifier has now a high-pass filter behavior and only dynamic peak-to-peak signals can be measured. If DC-mode is required (for quasistatic measuring), the amplifier has to be set to LONG TIME CONSTANT or to "time constant off".

If an amplifier set to DC-mode (Time constant OFF or LONG) shows such a behavior, there is most likely condensation of humidity inside. This lowers the insulation resistance of the range capacitors, resulting in a "time constant".

The easiest and safest way to prevent condensation of humidity inside the amplifier (critical in climates with high humidity and large temperature differences between day and night) is to leave the amplifiers switched on continously, 24 hours a day.

If condensation has occurred you can also dry the amplifiers for about 12 … 24 hours at 50 °C in an oven.

8.2.3 Drift from Temperature Effects

Temperature changes during a measurement can lead to temperature drift because of the different thermal coefficients of expansion of the various materials. When a force plate is mounted on a cold mounting frame, thermal drift occurs until the temperatures have been equalized. Temperature has no influence on the zero offset of the charge amplifier.

To prevent thermal drift, let the temperature of the force plate stabilize and make sure that no temperature transients are produced, e. g. by sunlight hitting the force plate.

Hint:
Similar drift on all four F_z signals and at the same time no drift on the four F_x and F_y signals is almost always thermally induced.

8.3 Problems with BioWare

8.3.1 BioWare does not find A/D Board

Check base address on A/D board and appropriate setup in BioWare.

Other plug-in boards such as network cards, additional COM and LPT ports, other A/D boards and SCSI units sometimes have their address within the address range of the BioWare A/D board.

Hint: The BioWare A/D board occupies an address range of base address ... base address + 20 d.

Otherwise you may have to try by removing all other boards or even by installing BioWare and its hardware on a different computer.

To clean the contacts of the A/D board, a pencil eraser (rubber) can be used carefully.

8.3.2 BioWare does not Measure

Check cabling and connectors, unplug and replug them a few times.

Check switch positions on the A/D board.

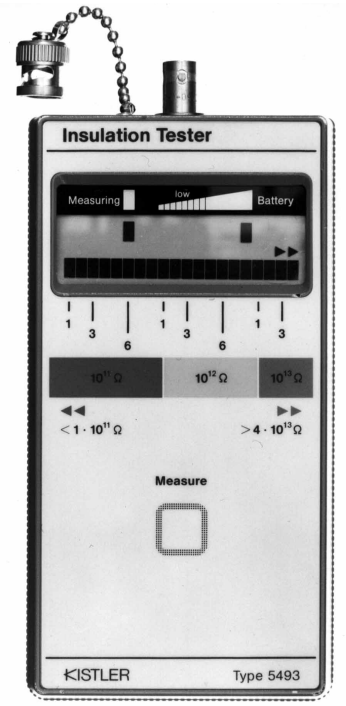
Switch charge amplifier to OPERATE manually and try again.

Try the BioWare tools `Oscilloscope` and `Voltmeter`.

8.4 Available Service Equipment

Qualified technical personnel (preferably Kistler-trained) and the following equipment is mandatory to perform maintenance and service works.

8.4.1 Insulation Tester Type 5493



Description:

Battery-operated service instrument for measuring very high insulation resistances up to $4 \cdot 10^{13}\ \Omega$ (see Data sheet 15.5493).

Use:

Testing the insulation of cables and sensors. The insulation should be $>10^{13}\ \Omega$ for proper operation.

8.4.2 Calibration Capacitor Type 5371A...

Description:

Highly insulating precision capacitor for converting a voltage into an electric charge. Capacitors of 10, 100, 1000, 10 000, 100 000 pF (≤30 V) are available (see Data sheet 13.5371).

Use:

Connected to a voltage source (AC or DC), combined with a precise voltmeter, an electric charge can be generated ($Q = U \cdot C$) which allows calibrating charge amplifiers or complete measuring chains.

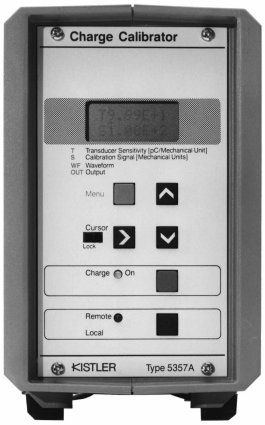
8.4.3 Charge Calibrators Types 5357 and 5395

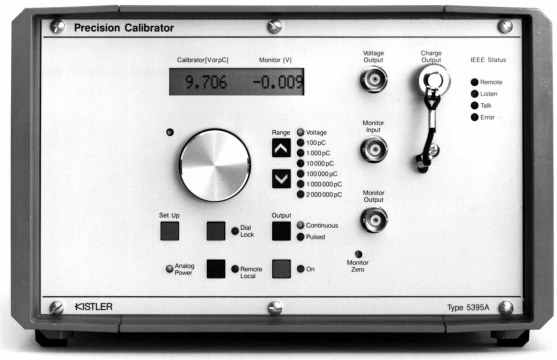
Description:

Electronic unit providing a precise electrical charge.

Use:

Calibrating charge amplifiers and complete measuring chains. The output of a piezoelectric sensor for a given sensitivity and mechanical load can be simulated. The calibrator connects in lieu of a sensor to the charge amplifier to be calibrated.





Type 5357 is a general-purpose instrument while Type 5395 is a high-precision instrument with traceable calibration and exceptional stability (see Data sheets 13.5357 and 13.5395).

8.4.4 BNC-BNC Connecting Cable Type 1601B...

Description:

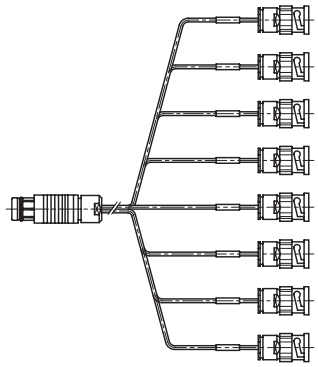
Highly insulating low-noise connecting cable with 2 x BNC positive connectors (see Data sheet 15.011).

Use:

To connect e. g. an insulation tester or charge calibrator to a charge calibration.

Only these special highly insulating low-noise cables must be used between sensors and charge amplifiers (Kistler cables Types 16xx only).

8.4.5 Test Cable Z16620sp



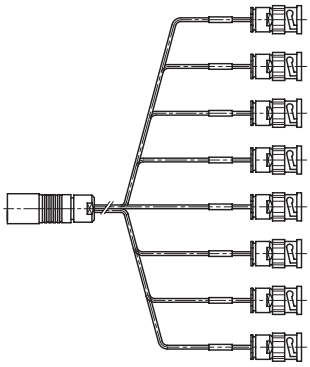
Description:

Fischer 9-pin positive connector to 8 BNC positive connectors.

Use:

- Access to individual force plate channels for checking the insulation
- Access to individual charge amplifier channels for calibration.

8.4.6 Test Cable Z16634sp



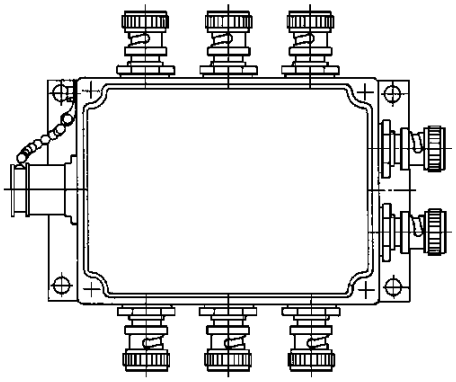
Description:

Fischer 9-pin negative connector to 8 BNC positive connectors.

Use:

- Access to individual pins of the cable between force plate and charge amplifier for checking the insulation or for connecting charge amplifiers with BNC inputs.

8.4.7 Distribution Box Type 5405



Description:

Fischer 9-pin neg. connector to 8 BNC negative connectors.

Use:

- Similar as Type Z16634sp

8.5 Available Mounting Frames

See enclosure

9423	Standard mounting frame for 9253…, 9281…, 9285
9427	Standard mounting frame for 9287…
Z12627	Special mounting frame for 9285 for place camera underneath
Z16666	Special mounting frame for 9287… with multiple mounting positions

8.6 Sikadur 42 Data Sheet

See enclosure

9 Warranty

Regarding the warranty reference is made to the agreement between the respective contracting parties.

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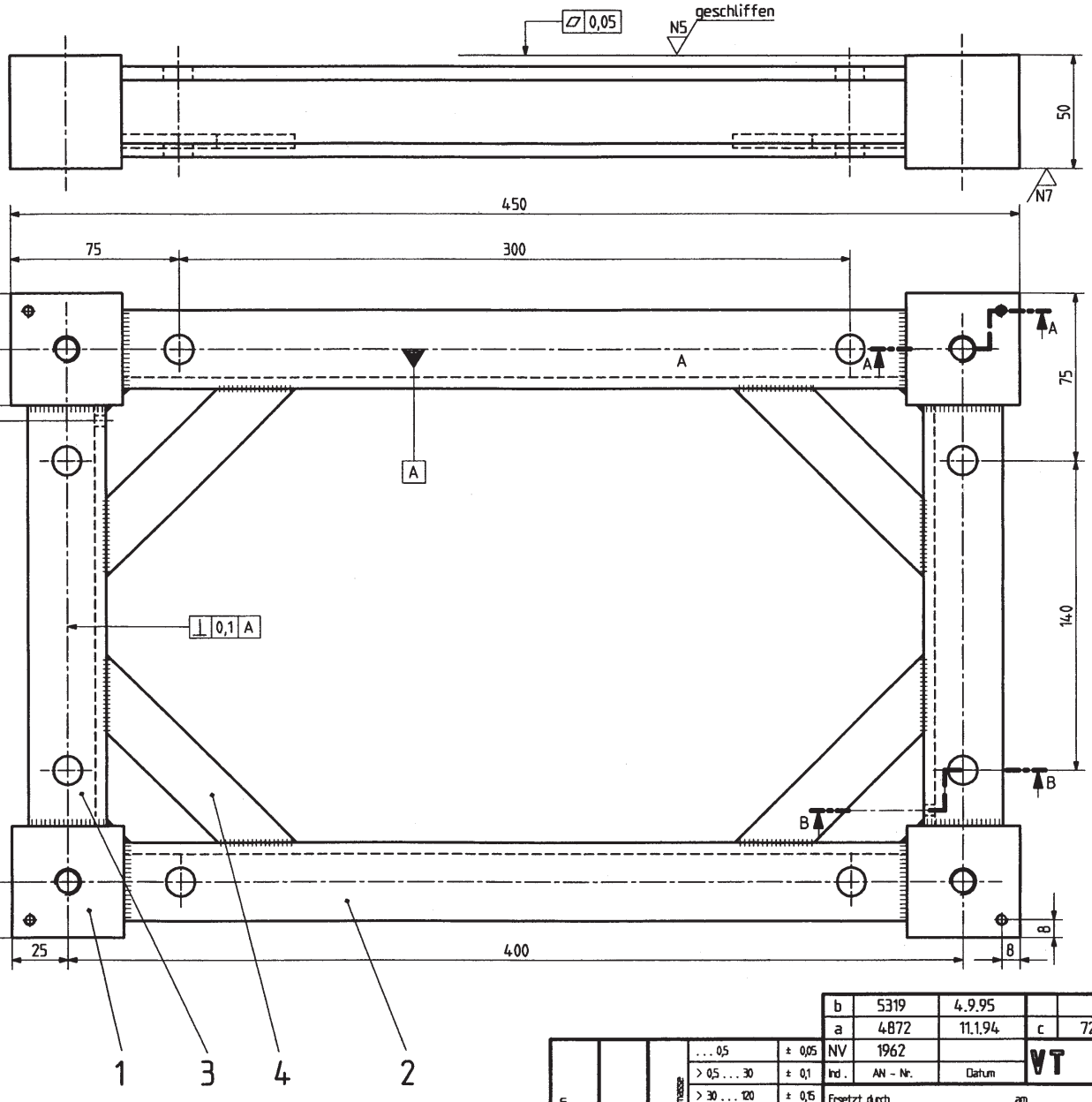

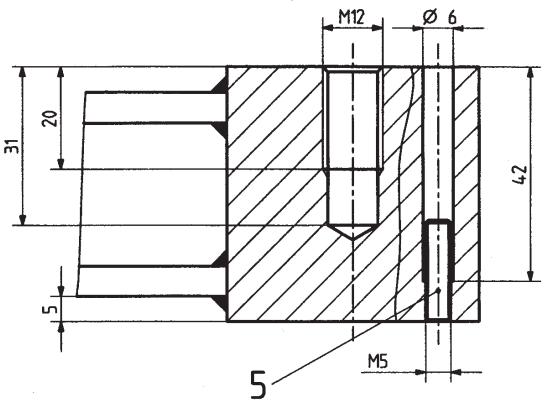

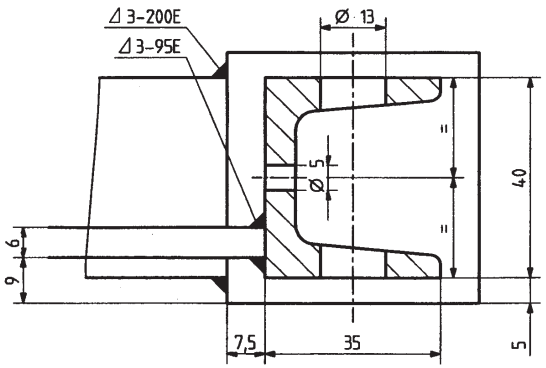

Spannungsfrei glühen
Bearbeifung: Galvanisch verzinkt (V)

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Allg. Aussenkanten gebrochen max.

Allg. Innenkanten gebrochen R max.

Unbekannte Masse

Längenmasse		Winkelmasse	
... 0,5	± 0,05	kuerz. Schenkel	Abw.
> 0,5 ... 30	± 0,1	L: ... 10mm	± 1°
> 30 ... 120	± 0,15	> 10 ... 50	± 30'
> 120 ... 315	± 0,2	> 50 ... 120	± 20'
> 315 ...	± 0,3		

b	5319	4.9.95						3D-Modell
a	4872	11.1.94	c	7213	8.12.97			3D-Schnitt
NV	1962		VT			Kopie Datum 19 DEZ. 1998	Blatt 1 von 1	M: 1:2 1:1
Ind.	AN – Nr.	Datum						

Ersetzt durch am
Ersatz fuer vom

Erstmals verwendet bei: 9281A11

Werkstoff

Montagerahmen kompl.

Art. Nr. / Typen Nr. / Zeichn. Nr.: 9423 | Index: c

gez.	28.01.77	Wey
gepr.	31.1.77	Dä
ges.	31.1.77	Wo

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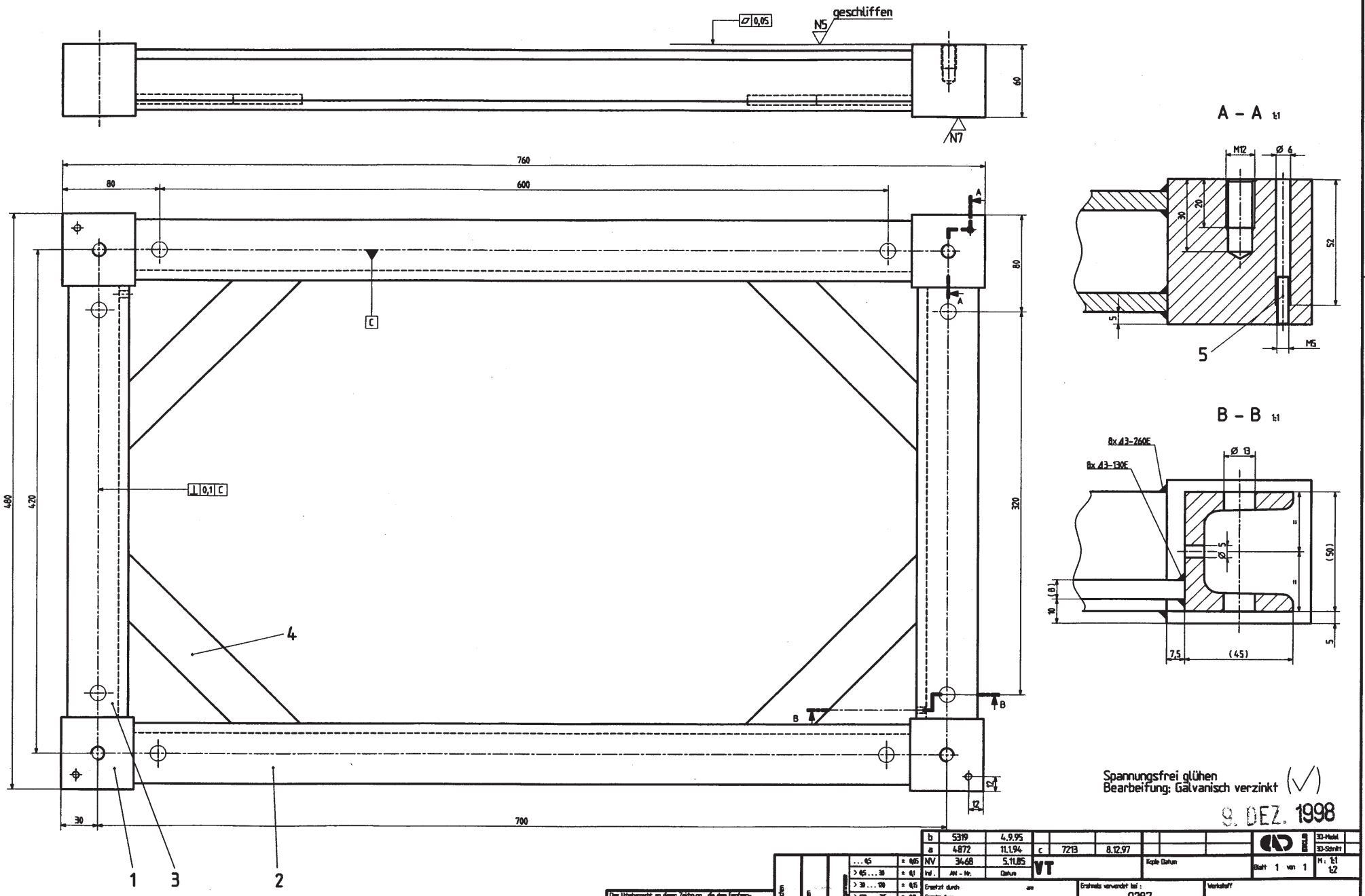
PSK – Sach. Nr.



b	5319	4.9.95							3D-Modell	
a	4872	11.1.94	c	7218	8.12.97				3D-Strikt	
NV	3468	5.11.85	VT			Kopie Datum		Blatt 1 von 1	M: 1:1 1:2	
Ind.	AN - Nr.	Datum								

Ersetzt durch am | Ersetzt für von | Ersatzteil verwendet bei: 9287 | Werkstoff

Montagerahmen kompl.

Art. Nr. / Typen Nr. / Zeichn. Nr. 9427 | Index c

gez.	29.10.85	Sq
gepr.	4.11.85	Hp
gen.	4.11.85	Dm

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PSK – Sach. Nr.

Urtoleranz Längenmass		Winkelmass
... 6	± 0,05	
> 6 ... 30	± 0,1	
> 30 ... 120	± 0,15	
> 120 ... 315	± 0,2	
> 315 ...	± 0,3	
Isometr. Schenkel.	Abw.	
L: ... 10mm	± 1°	
> 10 ... 50	± 30'	
> 50 ... 120	± 20'	

Alle Ausmassen gebraten max. 0,5x45°

Alle Innenecken gebraten R max.

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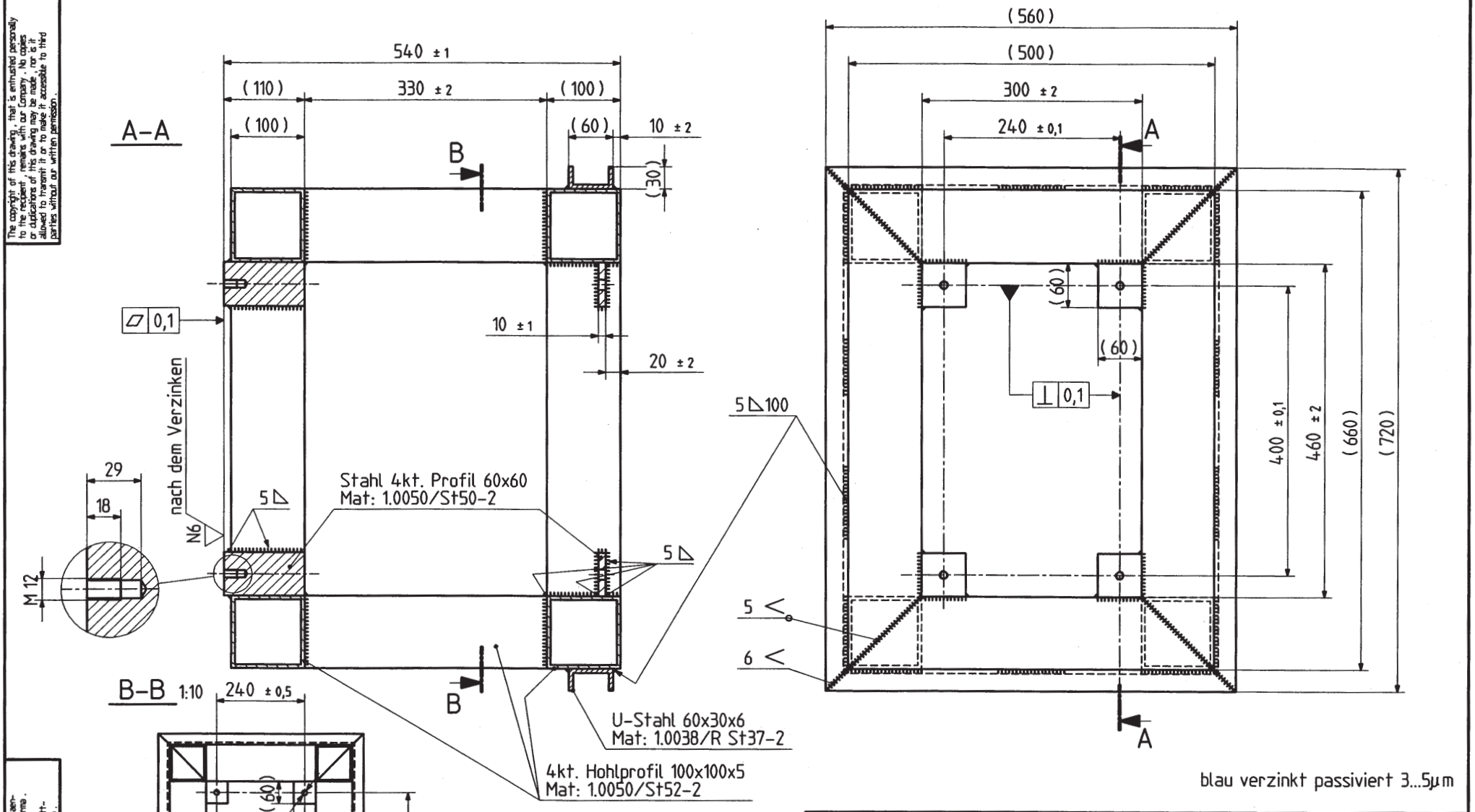

blau verzinkt passiviert 3...5µm

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Allg. Aussenkanten gebrochen max.	Allg. Innenkanten gebrochen R max.	Unbenannte Längenmasse			Winkelmasse	
		... 0,5	± 0,05		L : ... 10mm	± 1°
		> 0,5 ... 30	± 0,1		> 10 ... 50	± 30'
		> 30 ... 120	± 0,15		> 50 ... 120	± 20'
		> 120 ... 315	± 0,2			
		> 315 ...	± 0,3			
		kuerz. Schenkel	Abw.			

a	5856	6.1.97	VT	Kopie Datum 15 DEZ. 1998	Blatt 1 von 1
Ind.	AN – Nr.	Datum			M : 1:5,1:10

Ersetzt durch — am
Ersatz fuer Z12627 vom 5.8.83

Erstmals verwendet bei : 9283U014

Werkstoff

Montagerahmen für 9285

Art. Nr. / Typen Nr. / Zeichn. Nr. Z12627 — Index a

gez.	10.12.96	Kk	
gepr.	6.1.97	Sul	
ges.	6.1.97	Ug	

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PSK – Sach. Nr. 31 2627 0000 001

3D-Model
3D-Schnitt

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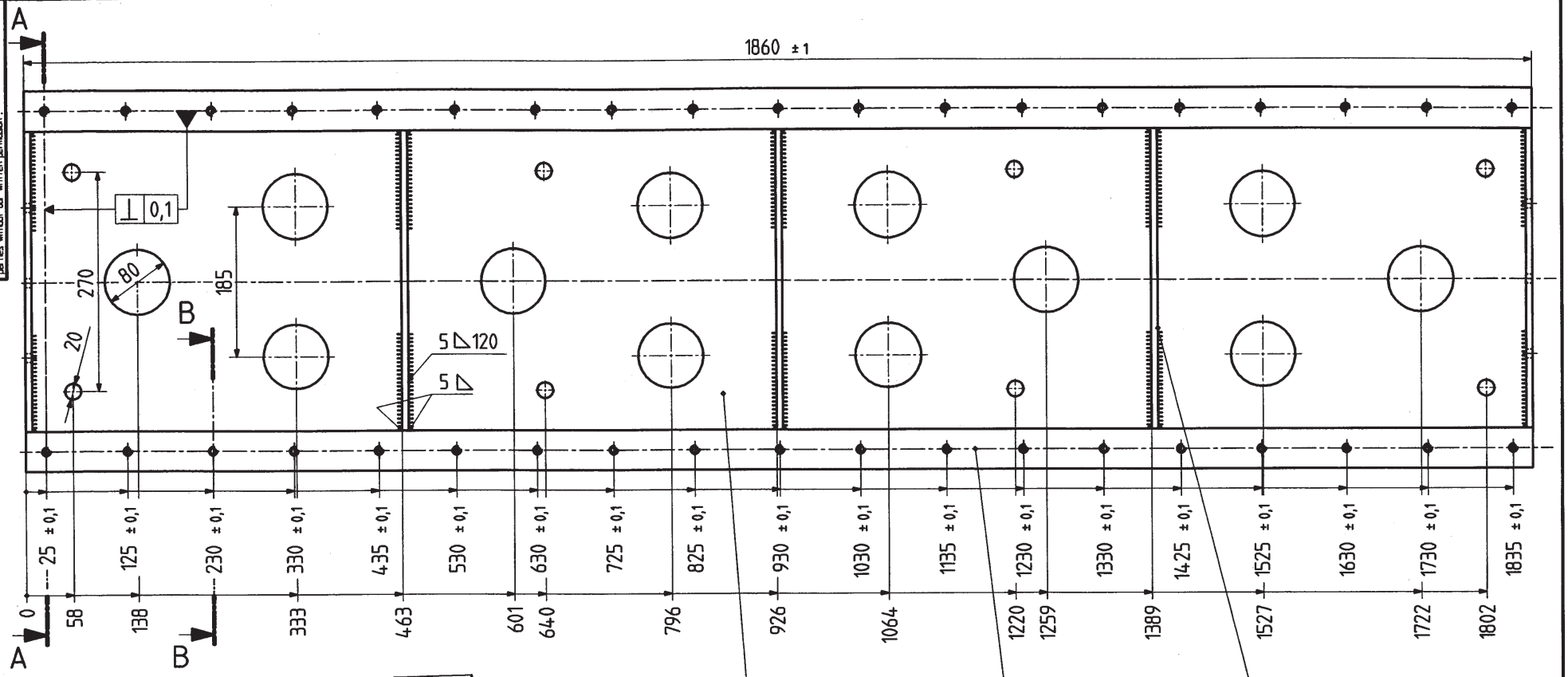

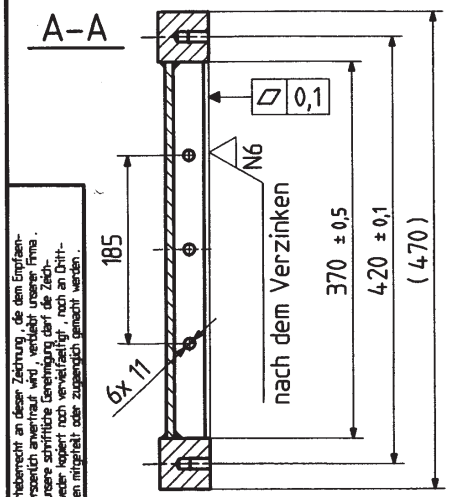

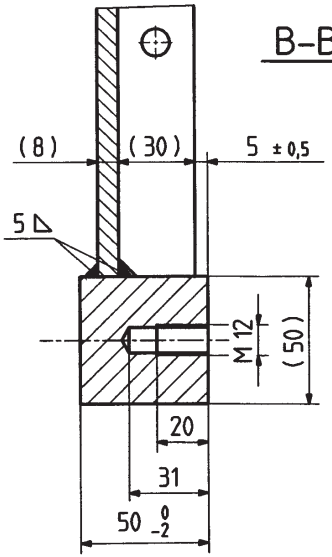

Nicht tolerierte Koordinatenmasse ± 0,3

blau verzinkt passiviert 3...5µm

Allg. Aussenkanten gebrochen max.

Allg. Innenkanten gebrochen R max.

Unt. Längenmasse		Unt. Winkelmasse	
...0,5	± 0,05	L: ...10mm	± 1°
>0,5 ... 30	± 0,1	>10 ... 50	± 30'
>30 ... 120	± 0,15	>50 ... 120	± 20'
>120 ... 315	± 0,2		
>315 ...	± 0,3		
kuerz. Schenkel	Abw.		

a	5523	15.3.96	VT 1688
Ind.	AN - Nr.	Datum	
Ersetzt durch		am	
Ersatz fuer		vom	

Kopie Datum 19. DEZ. 1998

3D-Model

3D-Schnitt

Blatt 1 von 1

M: 1:5,1:2

Erstmals verwendet bei:

Werkstoff

Montagerahmen für 9287A

Art. Nr. / Typen Nr. / Zeichn. Nr.: Z16666

Index: a

gez.	6.3.96	Kk	
gepr.	15.3.96		
ges.	15.3.96		

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PSK - Sach. Nr.: 31 6666 0000 001

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Sika AG
P.O. Box 1300
CH-8048 Zurich/Switzerland
Phone 01 62 40 40
Telex 822 254 sik ch
Telefax 01 432 33 62

Directions given on or in the packages or containers will always prevail.

The information contained in this leaflet is, to the best of our knowledge, true and reliable and is supported by the present state of our knowledge. According to the care taken and the method of application, upon which we have no influence, the values are subject to divergence. Our guarantee is, therefore, limited to the quality of the materials delivered.
The Company reserves itself the right to change the formulation of Sika products if so required by new research and development.

Technical Data

Colour:	Grey (A: transparent, B: transparent, C: grey)
Storage Conditions:	+5°C to +40°C
Shelf Life:	12 months when unopened and stored correctly
Density:	Approx. 2 kg/litre
Mixing Ratio:	Comp. A : B : C = 2 : 1 : 12 parts by weight Normal/L.P. 2 : 1 : 7 parts by volume Normal/L.P.
Pot Life: (2 kg)	Normal type: 10°C = 80 min. 20°C = 40 min. 30°C = 20 min.
(10 kg)	L.P. type: 20°C = 2 hrs. 30°C = 60 min. 40°C = 40 min.
Compressive Strength:	80 – 90 N/mm²
Flexural Strength:	30 – 35 N/mm²
Tensile Strength:	15 – 20 N/mm²
Bond Strength to Concrete:	3.5 N/mm² (Concrete Failure)
Bond Strength to Steel:	20 N/mm² (20°C, 65% r.H., 1 day)
Young's Modulus:	19 000 N/mm²
Packaging:	Normal type: 2 and 10 kg (A + B + C) L.P. type: 10 kg (A + B + C) Industrial packing on request.

Swiss Association for Quality Assurance Certificates
SQS
Category A

Sikadur® 42

3-Component Epoxy Resin Castable Grout

Description

A solvent-free, 3-component, pourable grout, based on a combination of high strength epoxy resins and specially graded aggregates. After mixing, it forms a flowable mortar, suitable for grouting and filling.

Uses

Sikadur 42 is a high strength material with no shrinkage. It is suitable to grout:
Bridge bearing plates,
Machine bases,
Fixing bolts and anchors,
Crane rail tracks,
Reinforcement
And to fill cavities in concrete.

Advantages

Sikadur 42 is available in 2 different grades of reactivity (normal and long pot life), according to the climatic conditions. Other benefits are:
Solvent-free,
Good flow characteristics even in thin layers,
Rapid hardening according to grade used,
Suitable for both, dry and damp surfaces,
Shrinkage-free hardening,
Curing is not affected by high humidity,
High mechanical strengths,
Tough vibration-resistant material.

Instructions for Use

Surface Preparation

All surfaces should be clean, free from standing water and all loosely adhering particles. Cement laitance should be removed.

Priming

Primer is not required.

Mixing

Mix components A and B together for at least one minute with a low speed electric drill (max. 400 R.P.M.). Then add aggregate (component C) and continue mixing until a homogeneous, flowing mortar is achieved.

Application

When grouting under bearing plates, ensure there is sufficient pressure to maintain movement of the grout. Air must be allowed to escape. For large volumes, apply in more than one layer, ensuring that the previous layers have hardened and cooled.

Cleaning

Clean all tools and equipment immediately after use with Colma-Cleaner.

Important Recommendations

Maximum thickness per layer = 4 cm.
Minimum age of new concrete = 3 – 6 weeks, depending on climate.
Minimum substrate temperature = 5 °C.
Maximum substrate temperature = 40 °C.

For additional information please ask for "A brief guide to the use of Sika ready-mix mortars" (all about bedding and grouting).