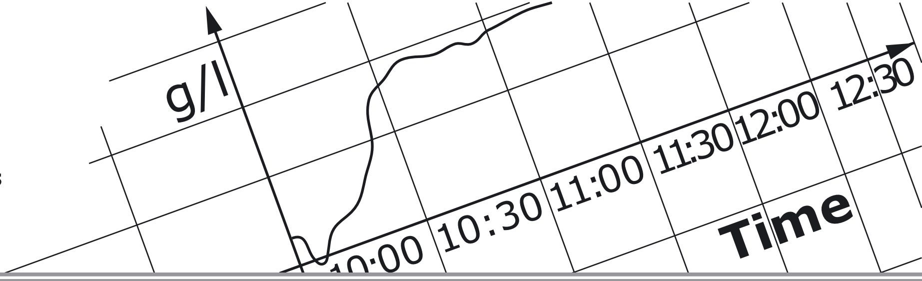
BERTHOLD TECHNOLOGIES



detect and identify

Process Control

Moisture Meter
LB 350

User's Manual

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1

General Information

IMPORTANT

Please observe the warnings and safety instructions given in this User's Manual to rule out personal injury and property damage. They are identified by the following symbols: DANGER, CAUTION, ATTENTION or IMPORTANT.

DANGER

Indicates a possibly dangerous situation. The consequences may be death or most severe injuries if proper precautions are not taken.

CAUTION

Indicates a dangerous situation. The consequences may be slight or minor injuries if proper precautions are not taken.

ATTENTION

Indicates a possibly harmful situation. The product or something in its vicinity may be damaged if proper precautions are not taken.

IMPORTANT

Includes application tips and draws your attention to particularly important information.

Typographical conventions

The symbols and typefaces used in this manual have the following meaning:

▶	prompts you to carry out an action.
1, 2, 3,...	refers to a graphic.
•	identifies enumerations.
italic typeface	indicates important information.
SMALL CAPS	are used to identify buttons.

If you do encounter problems despite careful study of the documentation, please do not hesitate to contact us.

Your Moisture Meter LB350 team

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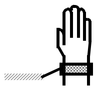
1.1 General Safety Precautions

Electrical shock hazard

During installation and service work on the Moisture Meter LB350, the system and the relay contacts have to be disconnected from power to ensure that contact with live parts will be avoided.

ESD protective measures

The electronics of this measuring system uses electrostatic sensitive devices. We recommend that you wear an ESD wrist strap during installation or repair work. Connect this wrist strap to the grounding conductor.



When you open the instrument: Please take precautions when working with printed circuit boards (ESD). Discharge yourself before touching the components by touching a grounding point.

Maintenance

The Moisture Meter LB350 may be installed, serviced and repaired only by trained personnel.

Only install fuses which match the rating specified by BERTHOLD TECHNOLOGIES.

Parameter settings

Never change the parameter settings without a full knowledge of these operating instructions, as well as a full knowledge of the behavior of the connected controller and the possible influence on the operating process to be controlled.

1.2 Correct Usage

The Moisture Meter LB 350 has been designed for measurement of the moisture on bulk material in bunkers and on weighing and feeding containers. The measuring system may be used for this purpose only.

If it is used in any manner not described in this documentation, the safety of the system may be impaired and the warranty claim is void. BERTHOLD TECHNOLOGIES does not assume any liability and guarantees only that the device meets the published specifications.

1.3 Radiation Protection Guidelines

The Moisture Meter LB 350 utilizes radioactive sources.

Local regulations controlling the use of radioactive sources must be followed. This is the law.

Installation, dismantling, relocation, maintenance and testing involving the radioactive source or its shielding shall only be performed by trained and specifically licensed persons.

IMPORTANT

When using a 3,700 MBq neutron source, the controlled area in the air (dose rate >3 µSv/h) already ends in a distance of 115 cm from the source. For most applications, it therefore lies within the vessel dimensions and is not accessible, which reduces the radiation protection efforts.

2 System Description

The Moisture Meter LB 350 is used to measure the moisture content of various products in bunkers and weighing or feeding containers.

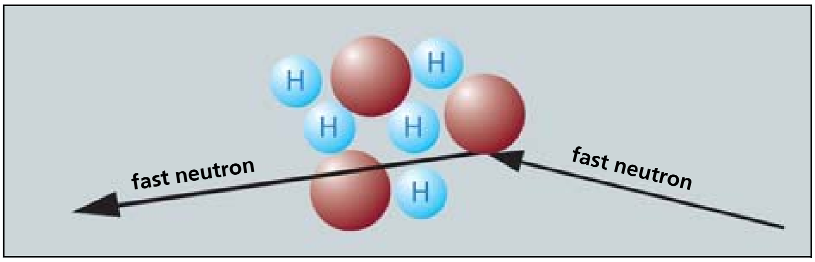
Special benefits of the measuring system LB 350:

- Representative measurement data due to large measurement volume of up to 1 m diameter
- Accurate measurement due to highly sensitive ^{3}He counter tubes
- Not affected by temperature, pressure, pH value and color

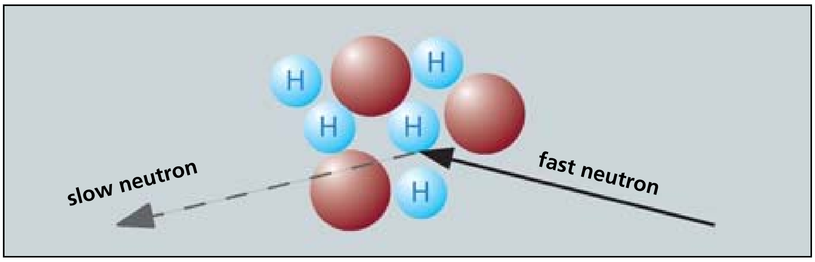
2.1 Principle of Measurement

The nuclear method of moisture measurement is based on the principle that fast neutrons are slowed down by hydrogen nuclei. A source of fast neutrons is combined with a counter tube which is sensitive to slow neutrons into a bunker or surface probe.

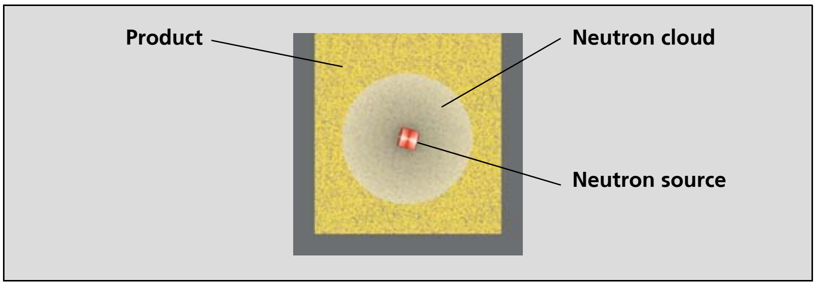
A neutron has nearly the same mass as the core of a hydrogen atom, whereas all other relevant atomic nuclei are heavier by a factor of 10 to 200. If a fast neutron hits an atomic nucleus with a large mass, scattering takes place without any essential energy loss according to the laws of elastic collision.



On the other hand, a fast neutron colliding with a hydrogen nucleus transfers more than half of its kinetic energy to the hydrogen nucleus, so that it is slowed down to thermal energy in hydrogen- containing media after about 19 collisions.



Due to the disordered scattering of the neutrons as a consequence of the collisions - comparable with the propagation of light in dense fog - a cloud of slow neutrons is created around the source of fast neutrons; the density of the slow neutrons decreases with increasing distance. The higher the hydrogen content in the volume, the more closely the cloud is concentrated around the source and the higher is the density of the thermal neutrons in the vicinity of the source. The reading of a detector for thermal neutrons located in this position is nearly proportional to the volume content of hydrogen.



The range of neutrons in the material is dependent on the hydrogen content per volume unit or on the volume moisture. This is important because the range of neutrons determines the material volume, or measurement volume, acquired during the measurement. The following approximation formula can be used to estimate the diameter **D** of the measurement volume, which contains 95% of all slow neutrons:

$$F_V = \rho \times F_G$$

$$D = 30 \times \sqrt[3]{\frac{100}{F_V}}\,\text{cm}$$

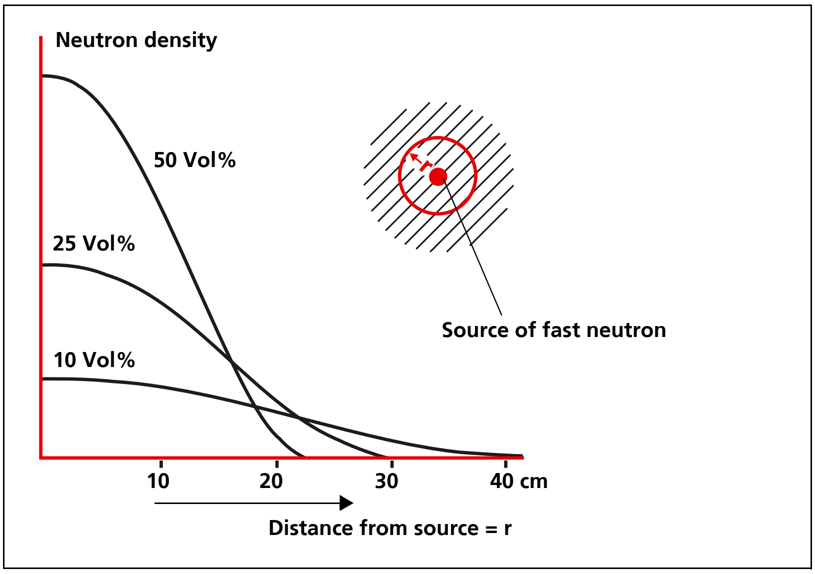
F_V = volume moisture in %

F_G = weight moisture in %

ρ = bulk density

D = diameter of the spherical measurement volume

The illustration below shows in addition the density distribution of thermal, i.e. slowed down neutrons at different volume moistures. From this one can also estimate the diameter **D** of the spherical measurement volume.



The entire hydrogen content in the material is measured, i.e. the hydrogen contained in the crystal water is measured just like the hydrogen in the moisture. The share contributed by the crystallization water has to be eliminated by a suppression of the zero point, which is automatically done by the calibration.

2.1.1 Nuclear Moisture Measurement Parameters

Chemically bound hydrogen crystallization water

Essentially, the moisture measurement method with neutrons is used to determine the hydrogen content per volume unit, the chemically bound hydrogen content and the crystallization water content also affect the result display. The fluctuations of the crystallization water content cause the same percentage fluctuations of the moisture reading. On the other hand, the chemically bound hydrogen content and its fluctuations cause a 9-fold contribution to the result display (H_2:H_2O=2:18).

Provided the hydrogen content chemically bound in the material to be measured or the crystallization water content is constant, the "zero reading" caused by this influence when measuring dry material can be suppressed via the zero point suppression.

Influence of density

If **Fv** is the moisture in volume percent, **Fg** the moisture in weight percent and δ the bulk density, the following equation holds:

$$Fg = \frac{Fv}{\delta}$$

Generally, it is quite common in the industry to indicate the moisture in weight percent. Since the nuclear method determines the moisture in volume percent, the measured value reading can be calibrated in weight percent only when the bulk density is sufficiently constant. If this condition is not fulfilled, the bulk density has to be measured in addition and the moisture reading has to be compensated using the density measured value (see chapter 2.3).

Essentially, the bulk density value consists of two components:

- one is determined by the type of material, grain size and the type of filling (dry bulk density) and
- one is determined by the influence of the moisture.

The second component is measured automatically. On the other hand, all changes of the first component enter into the non-density compensated moisture reading with the same percentage. In other words, the fluctuations of the dry bulk density or the fluctuations of the bulk density at constant moisture value decide on whether any additional density compensation is required.

Statistical reading fluctuations

In the course of nuclear measurements, the probe pulses arrive in irregular succession; therefore, the pulse values registered at the same time will vary around an average value.

For intensity measurements using a continuously reading device (ratemeter), a display inertia τ is required for averaging.

If the average pulse number is **n cps**, then the average relative fluctuation of the reading is:

$$\frac{\Delta I}{I} = \sqrt{\frac{1}{2n\tau}}$$

The maximum statistical fluctuations are about three times as high as the average fluctuations specified.

The collision number **n** is roughly proportional to the volume moisture **Fv** and to the probe sensitivity.

For example, if it is 20 cps per volume percent moisture and if τ = 25s, then the average fluctuation at 10 volume percent moisture is ±1% of the reading; i.e. it corresponds to ±0.1 volume percent moisture.

Short-term moisture fluctuations over a period of one minute can be safely identified if they are at least ±0.3 volume percent. However, permanent moisture changes of only ±0.05 volume percent can still be detectable from a record of the moisture signal of at least 30 minutes duration, provided all other error influences remain negligible.

Time constant and reaction of measured value

In the weighing hopper

For the installation of bunker probes in a weighing hopper one has to keep in mind that (usually) a discontinuous moisture measurement is to be carried out. When filling in the material, the effective measurement volume initially builds up around the probe. The final reading value will be reached with a certain delay, depending on the display inertia set at the main amplifier. The time constant causes an immediate but subdued reaction of the display. Already after 1x time constant, e.g. 20 s, the display will reach 63.2% of the final value. The table shows how the reading value behaves after each additional time constant.

A reading value of 95% is reached already after 3x time constants, in our example after 60 s.

Time	**1X**	**2X**	**3X**	**4X**	**5X**	**6X**	**7X**
Reading in % of final value	**63.2**	**86.5**	**95.0**	**98.2**	**99.3**	**99.8**	**99.9**

According to this purely mathematical relationship, the set display inertia should never be greater than 1/5 of the available measurement time for discontinuous measurements (1% value).

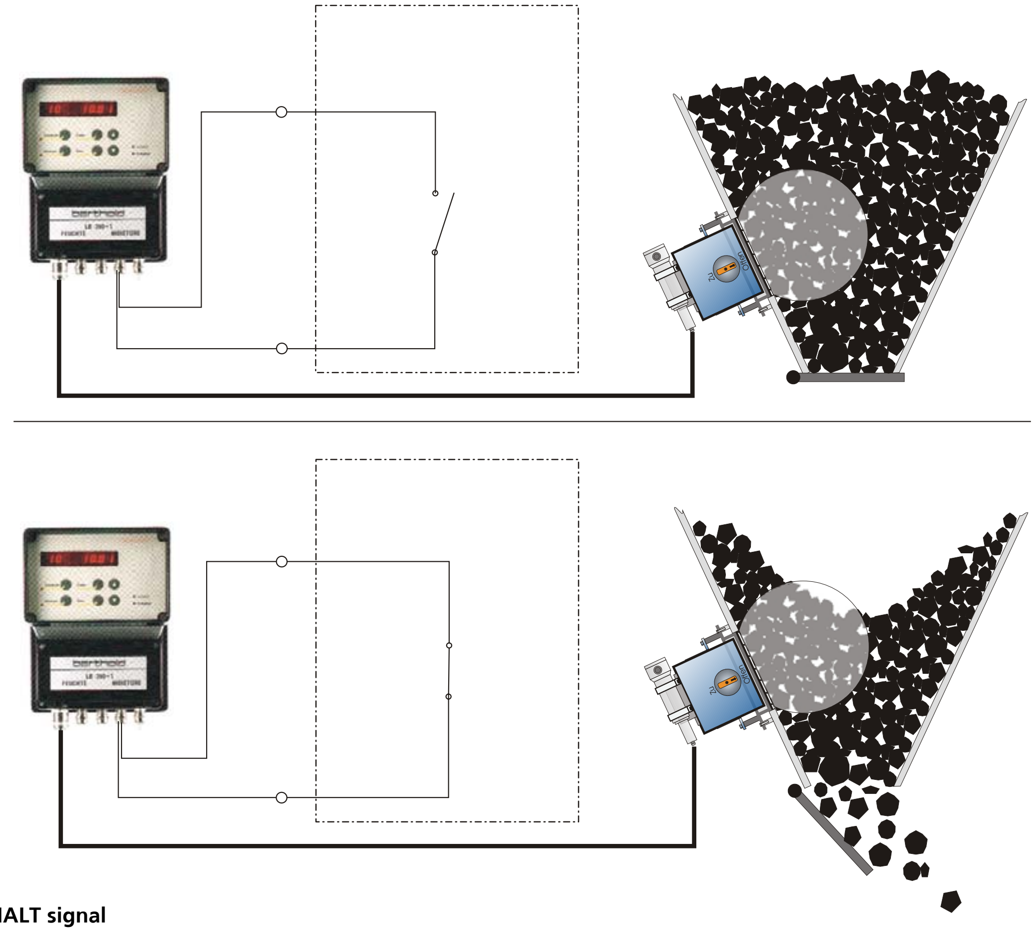
With short measurement times, the statistical measurement error becomes very high due to the still lower display inertia. As countermeasure, we recommend increasing the activity of the neutron source, which will reduce the statistical reading fluctuation and thus permits shorter time constants, or using the HALT input on the evaluation unit LB 350. The HALT input freezes the measurement value, as soon as the weighing hopper has been emptied. If the weighing hopper is filled again, the measurement process is cleared again. The HALT input has to be activated by opening the weighing hopper and after filling it has to be cleared again by the weight reached, i.e. the probe is completely covered by at least 0.5 m material.

Thus, the measurement can be started from the last measurement value and does not need to start all over again from 0% moisture. Since the moisture, as a rule, does not change drastically from one batch to the next, much higher time constants are possible.

If a weighing hopper is filled suddenly, the probe may be exposed to very strong impact loads. In these cases, one should select a slightly bigger internal diameter of the dip tube. Three thin, narrow rubber or plastic strips serving as shock absorber have to be wrapped around the probe pipe, one strip at each end of the prope pipe and one in the middle. In addition, a sturdy angle iron can be welded into the weighing hopper as baffle plate approx. 60-70 cm above the dip tube.

Using the HALT signal with short measurement times

In the batch processing mode, e.g. with weighing containers for blast furnaces, filling and emptying takes place in intervals. A turnaround time > 1-2 minutes with full vessel is adequate for an accurate measurement. To ensure that the measurement does not have to run up from the moisture value at empty vessel to the value at full vessel, the Halt input of the LB 350 can be connected to a limit value signal of the vessel scale.
The "Halt signal" freezes the measurement value before the vessel is emptied. If it is filled again, the measurement is cleared and can adjust to the new value. Since the moisture change from one batch to the next is relatively minor, it takes only a short time to determine the new measurement value.



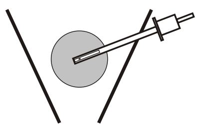
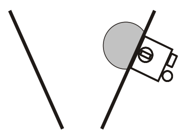
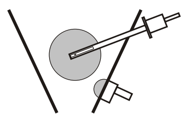
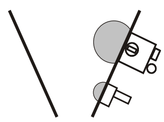
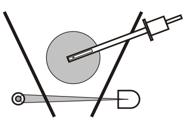
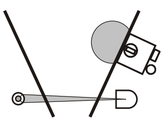
Using the HALT signal

2.2 Measuring Arrangements

The selection of the suitable system configuration depends on:

- the product being measured
- the bulk density
- the measuring range
- the ambient temperature
- the vessel shape and
- the wall construction of the vessel.

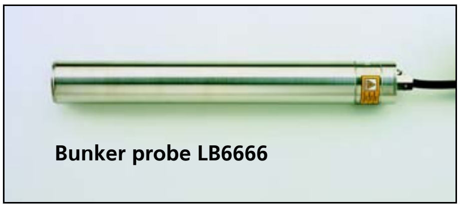
The following measuring methods can be used:

	Bunker probes	Surface probes
without density compensation	 Version 1: Bunker probe without density compensation	 Version 2: Surface probe without density compensation
with density compensation	 Version 1a: Bunker probe with density compensation via *backscattering measurement*	 Version 2a: Surface probe with density compensation via *backscattering measurement*
	 Version 1b: Bunker probe with density compensation via *transmission measurement*	 Version 2b: Surface probe with density compensation via *transmission measurement*

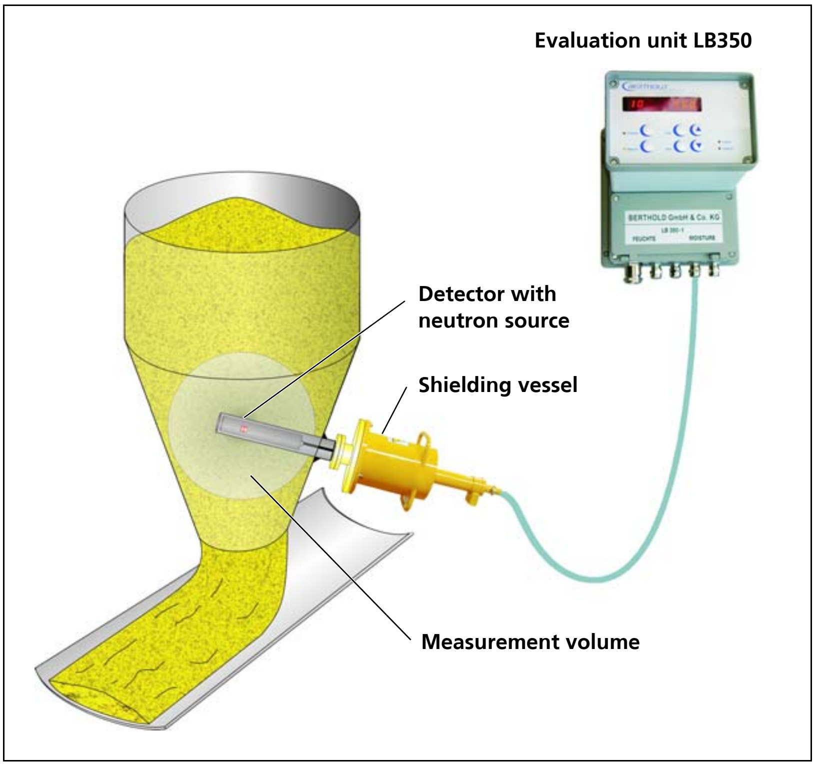
2.2.1 Moisture Measurement with Bunker Probe

In a vessel or bunker

The effective measurement volume with the neutron source at the center should be placed directly into the flowing zone of the material to obtain optimum conditions for the measurements. Ideal would be the outlet of a silo or a bunker, so that the entire material flowing through can be covered.



Bunker probe LB6666



In most cases, the source-detector distance in the probes has been selected such that there is virtually a linear relationship between measured value reading and moisture value.This presupposes, however, that the probe arrangement is planned such that the effective measurement volume is within the material even for the lowest moisture value to be measured.

2.2.2 Moisture Measurement with Surface Moisture Probe

The surface moisture measurement permits the measurement of moisture on the surface of the vessel. A special dip tube is not needed. Depending on the wall thickness of the vessel, the moisture measurement can be installed directly to the vessel wall from the outside or in a prefabricated recess of the vessel by means of a mounting frame.

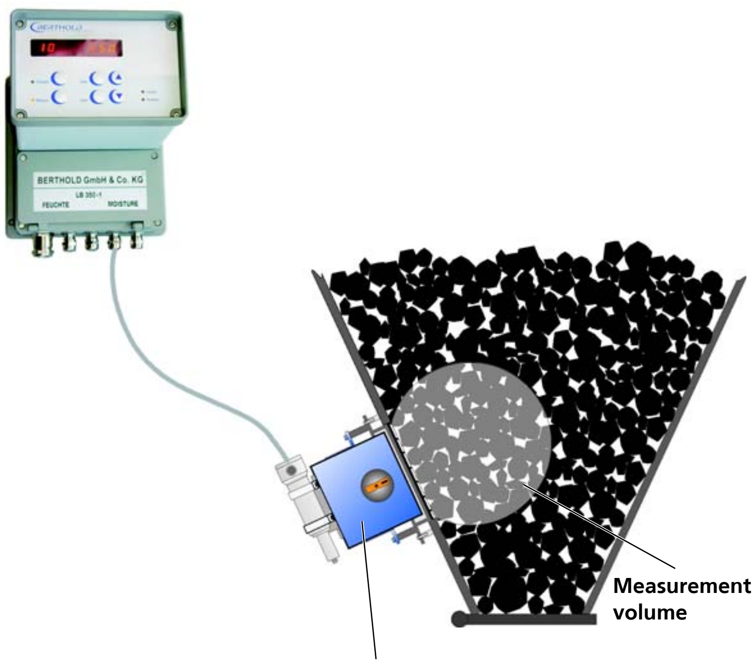
One major benefit of the surface moisture measurement is that the source inside the shielding can be rotated to a shielded position and to a measuring position. Thus, it is very simple to carry out revisions or other work in the vessel, without having to dismantle the measurement.

A surface moisture measurement has to be used when:

- the dip tube for the bunker probe is exposed to too much abrasion due to the product falling down (e.g. coke),
- the product being measured may fall directly onto the dip tube,
- a dip tube is likely to cause troubles in the material flow,
- the bunker has to be accessed for revision purposes.

Surface moisture probe LB7410

Evaluation unit LB350



The surface moisture probe LB 7410 is installed directly on the vessel. The steel wall of the vessel should not be thicker than 20 mm to make sure that the measurement sensitivity will not be diminished too much.

IMPORTANT

We recommend using a mounting frame in order to reach a high measurement sensitivity (see page 17).

Mounting frame

Basically, we recommend using a mounting frame which offers you:

- accurate measured values, since the measurement signal is not attenuated by the vessel wall,
- fast installation, since the support for the surface moisture probe is integrated into the mounting frame,
- long useful life due to wear-resistant ceramic surface.

The mounting frame is installed in a prepared opening in the vessel wall.

Mounting frame

2.3 Bulk Density Compensation

The bulk density compensation increases the accuracy of the moisture measurement if the bulk density of the product being measured varies.

The bulk density compensation comprises a scintillation detector and a shielded Gamma radiation source. An additional measurement amplifier determines the bulk density to compensate for the moisture measurement.

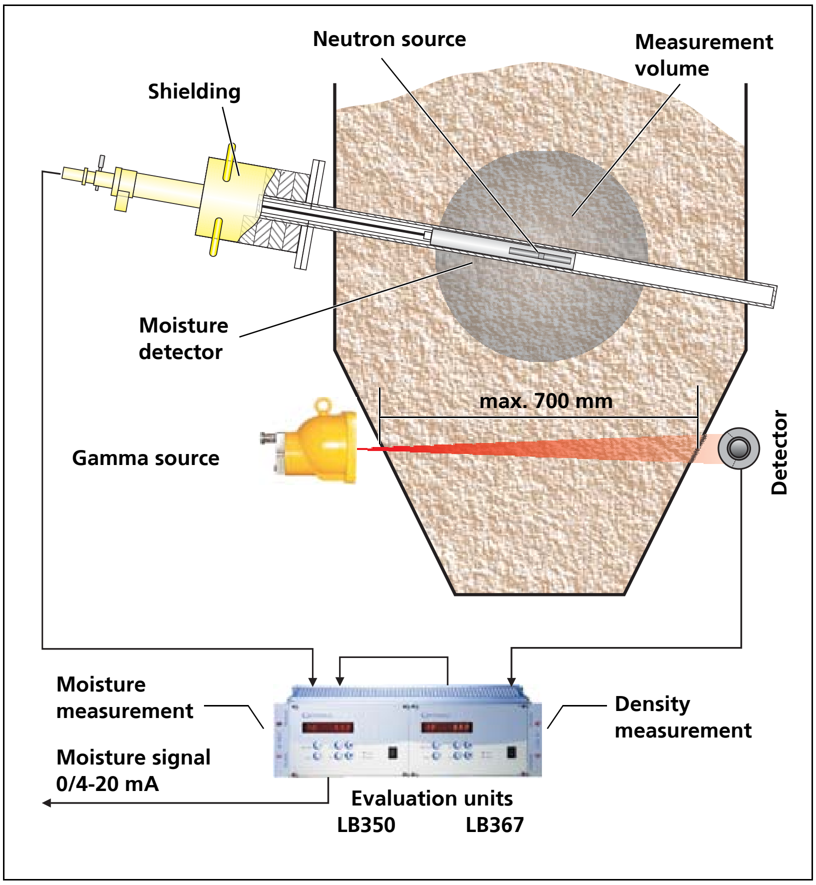
Depending on the measurement path through the vessel we recommend different measurement systems to measure the bulk density:

- Transmission measurement (see page 18)
- Backscattering measurement (see page 19)

Transmission measurement

The radiation emitted by a Gamma source is attenuated as it passes through matter. If the bulk density changes, the attenuation changes as well.

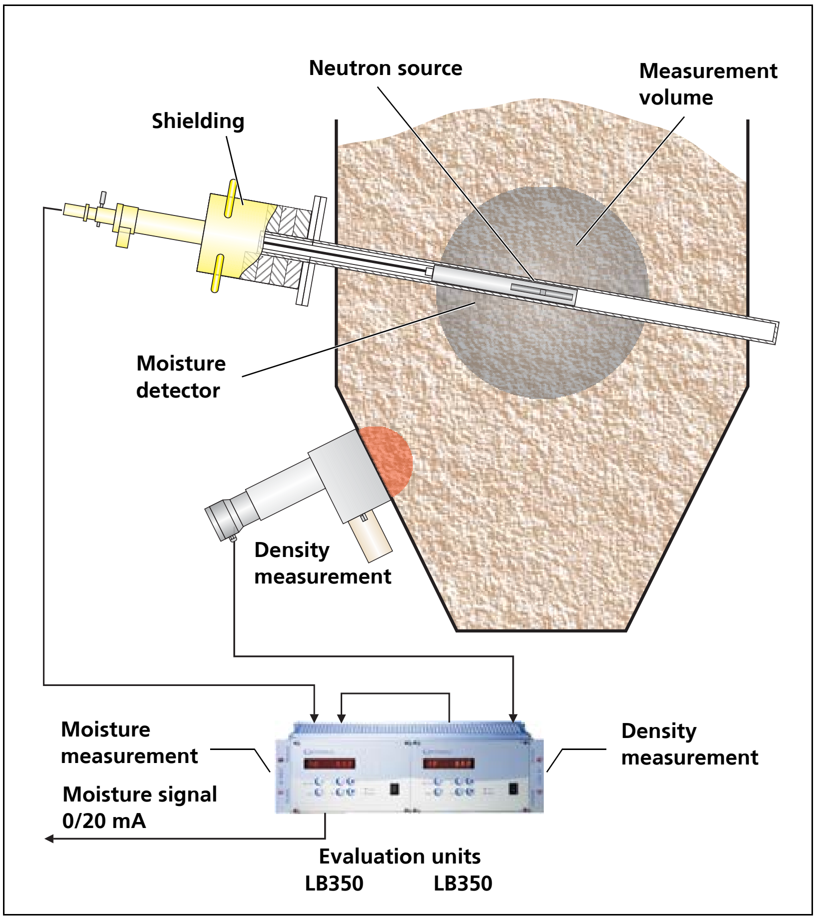
The transmission measurement is only possible with transmission distances of max. 700 mm, but if offers a decisive advantage as compared to the backscattering measurement: the reading is more representative since a large measurement volume is covered.



Backscattering measurement

The radiation emitted by a Gamma source is scattered back by the product being measured. The intensity of the backscattered radiation is a measure for the bulk density.

If a surface probe is used instead of a bunker probe, then the backscattering measurement can simply be installed into the mounting frame.



Backscatter chamber for density measurement

3 Mechanical Installation

3.1 Scope of Supply

Depending on the measurement arrangement, the following components are included in the scope of supply:

Moisture probe

- Moisture bunker LB 6666 probe or LB 6669 with preamplifier LB 2018, shielding vessel

alternatively

- Surface moisture probe LB 7410, mounting frame (optional)

Evaluation unit

- LB 350-1 in a wall-mounted housing
- LB 350-2 in a 19" rack
- LB 350-3 in a 19" rack with density compensation LB 350 or LB 367

Accessories

- Terminal box (IP 65), connection cable (7-wire, screened), radiation danger sign

Bulk density compensation

For compensation of the bulk density, we supply in addition:

- For a transmission measurement:
  Source Cs-137 or Co-60,
  detector Sz5 D1 50/50, shielding LB 7440 or LB 7442
  evaluation unit LB 367
- For a backscattering measurement:
  Backscatter chamber, source Cs-137
  detector Sz AR 1 44/5
  second evaluation unit LB 350

IMPORTANT

Please check that the delivery is complete according to the delivery note.

ATTENTION

Storage and transport only in a non-corrosive environment. Please observe the technical data on page 105.

3.2 Installation of the Bunker Probe

The bunker LB 6666 probe or LB 6669 is supplied along with the source. The source is located in the probe and the probe is located in the shielding LB 7409. The probe should be shielded until the dip tube has been installed.

The probe should be inserted into the dip tube only after the dip tube has been installed and the measurement has been taken into operation.

If work has to be carried out in the bunker in the vicinity of the dip tube in which the probe has been installed, you have to put the probe into the shielding.

The probe may be removed from the shielding by or under supervision of an authorized specialist, usually the Radiation Safety Manager or a Berthold service engineer, and inserted into the dip tube, or removed from the dip tube again.

See also the technical drawings for the probes and shieldings in the Appendix starting on page 106.

Optimum installation site and preparation

- At low moisture, one has to expect a measurement volume of approx. 60 cm radius. This means that even at lowest filling level the probe has to be covered by at least 60 cm material. If this is not the case, the measurements will be incorrect.
- Inside the bunker the distance of the measurement to the next wall must be at least 60 cm, otherwise the calibration characteristic curve will be nonlinear.
- Inflowing material must not fall directly onto the probe or the dip tube, as otherwise the probe will be destroyed prematurely by vibrations.
- Ceilings, floors, supports and other installations which may prevent or disturb the assembly have to be taken into account prior to assembly.
- No deposition of material must occur at the planned measurement point; the material must drain off completely.
- If any abrasion detection is planned, the required electrical installation has to be prepared.
- A representative sampling location has to be foreseen for calibration (options: e.g. while filling, emptying or in the filled bunker).

Installation position

When installing the bunker probe, make sure that the material flow will not be adversely affected, or only to a minor degree, by the probe configuration. A vertical probe configuration would be preferable. If the dip tube is installed horizontally, loose spots or even cavities may be created in the material below the dip pipe. Therefore, this type of installation should be avoided. Apart from the vertical installation, we also recommend an inclination of the dip pipe of at least 30-35° relative to the horizonal.

Dip pipe dimensions

The internal diameter of the dip pipe should be adapted to the external diameter of the bunker probe as much as possible. For a bunker probe with an external diameter of 70 mm, one has to select an internal diameter for the dip pipe between 72 and 76 mm (approx. 3"). Please keep in mind that possible welding seams in/on the dip pipe do not obstruct the insertion of the bunker probe. Since the thermal neutron intensity per mm steel wall is reduced by about 5%, the wall thickness of the dip tube should be between 4 and 6 mm, if possible. In special cases, a max. dip pipe wall thickness of 8 mm is OK. When measuring strongly abrasive materials such as coke, wear-resistant stainless steel (e.g. material no. 1.4571) has to be used as material for the dip pipes.

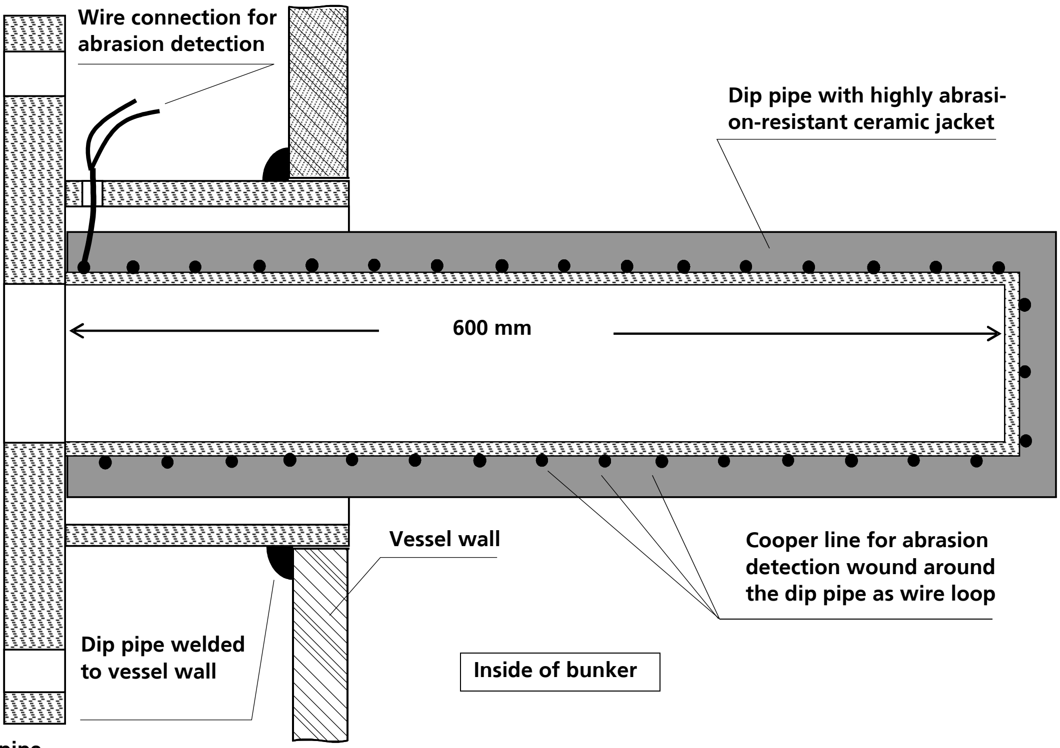
Dip pipe with ceramic jacket

When working with abrasive materials such as sinter mixtures, fine coke or quartz sand, the steel dip pipe would be ground right through within a very short time period. For this reason, a dip pipe with ceramic jacket has to be used.

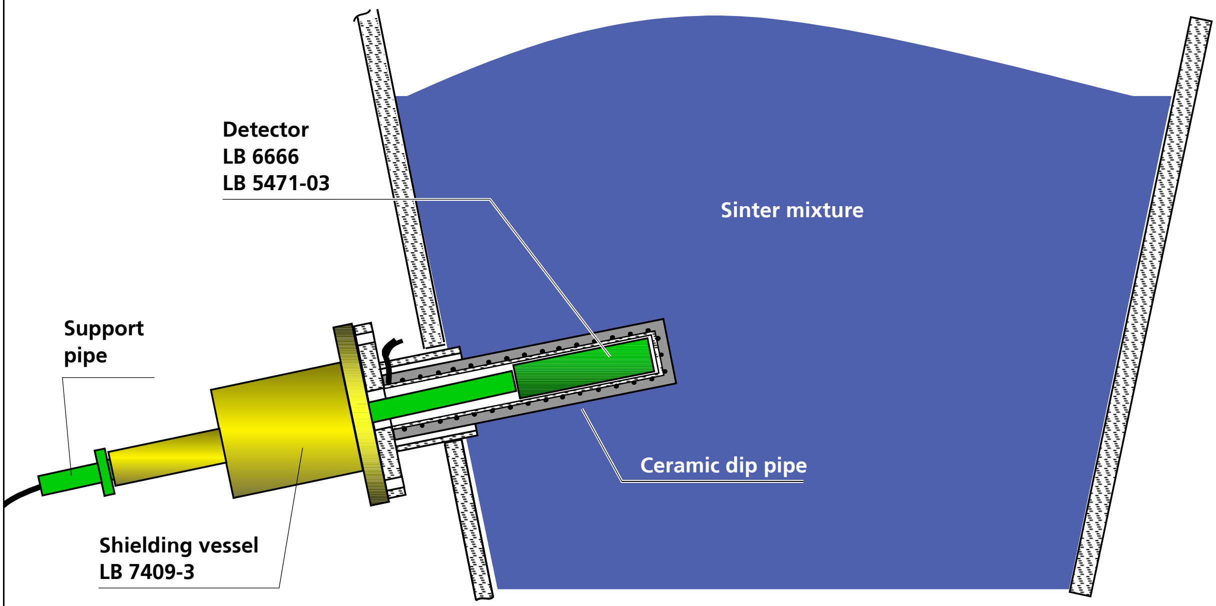
This dip pipe can be used for temperatures up to 120°C (for 70°C and higher, a special cable has to be used at the detector) and includes an abrasion detection via a wire loop. It is available in three lengths: 600 mm, 900 mm, 1200 mm.

IMPORTANT

Material that falls onto the dip pipe from a large height may destroy the ceramic. For this reason, coke applications in blast furnaces are ruled out.

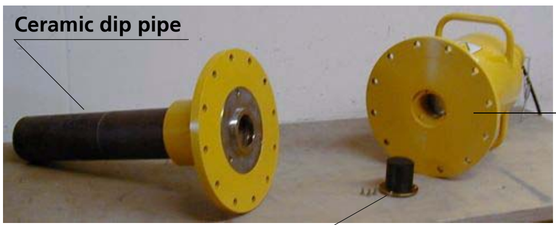


Ceramic dip pipe



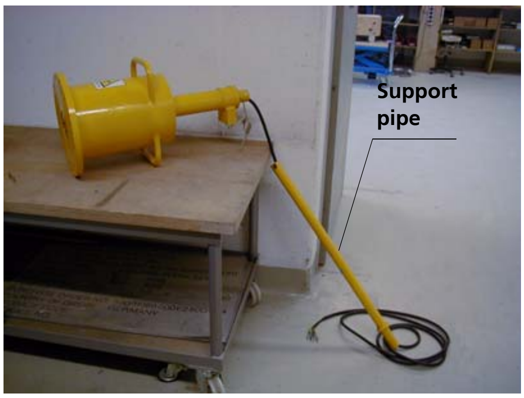
Ceramic dip pipe

Ceramic dip pipe, assembled on shielding LB 7409-03



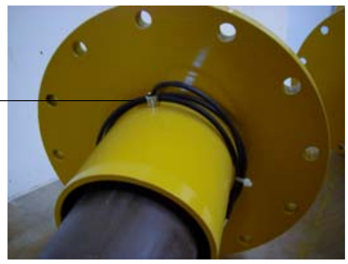
Shielding
LB 7409-02
or
LB 7409-03

Remove stopper from shielding prior to the installation with the dip pipe. Unscrew the three Allen screws.

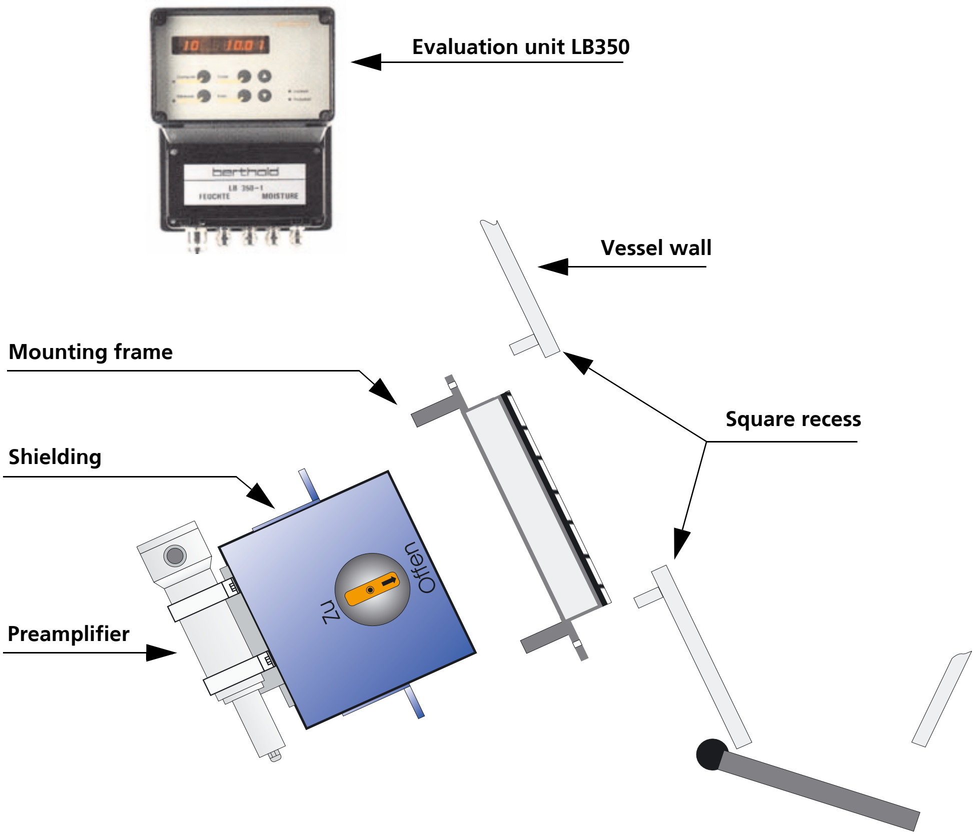


Support pipe positions the moisture probe.
Its length is adapted to the respective installation situation.

Cable outlet for the abrasion detection



3.3 Installation of Surface Moisture Probe



Components

The shielding LB 7410 is supplied with the source. The source is in a shielded position. The source should remain shielded as long as the shielding is being assembled or work has to be carried out in the bunker in the vicinity of the radiation path.

Open the source only after the measurement has been taken into operation.

In the shielded position, the source may be locked by a lock security pin even in the open position.

The padlock on the side of the shielding prevents access to the source.

The source may be removed or exchanged only by an authorized specialist, typically the Radiation Safety Manager, or a Berthold service engineer.

Installation with mounting frame

If a mounting frame is used, then a window having the following size has to be cut out:

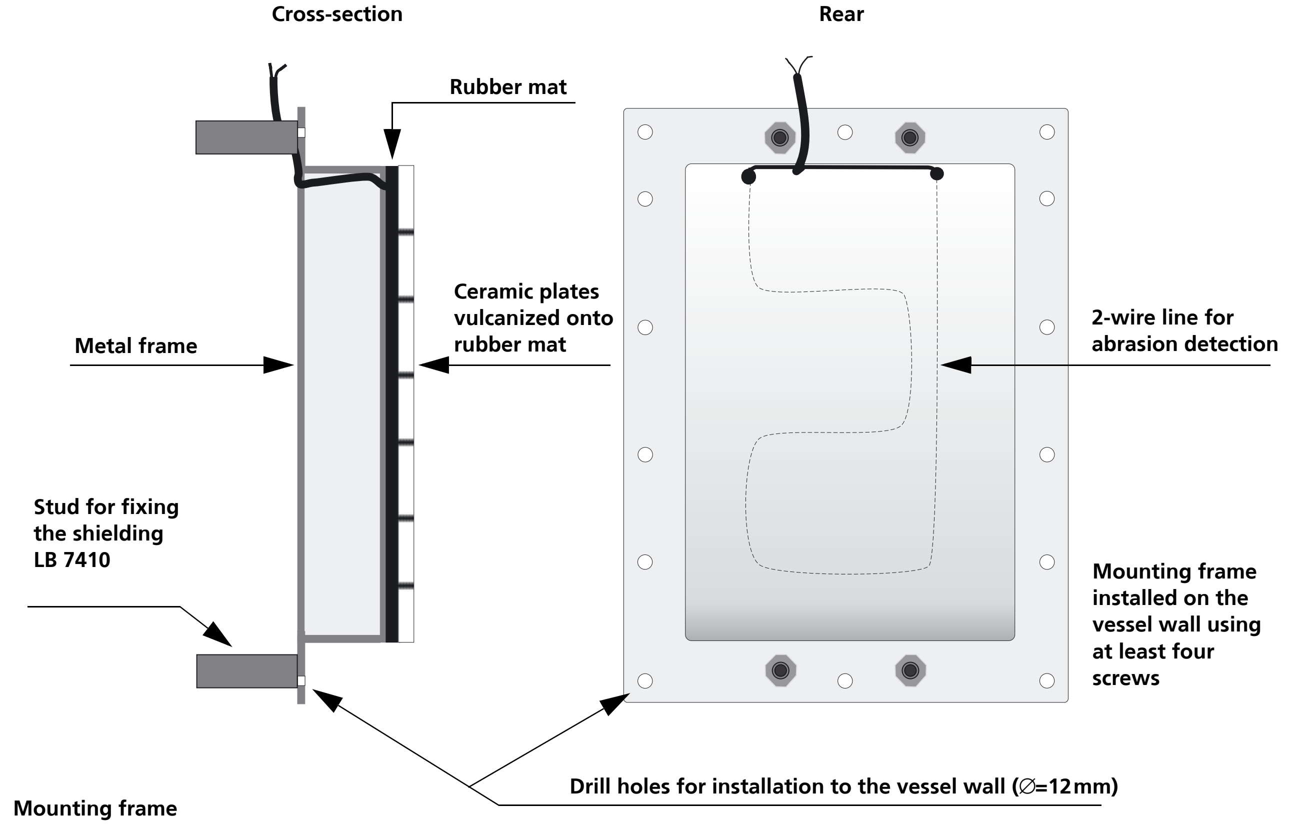
For moisture measurement
without density compensation: 280 x 360 mm
with density compensation: 360 x 460 mm

8 holes with a diameter of 12 mm are foreseen to fix the mounting frame. The mounting frame can be fixed to the vessel wall using bolts or screws.

See also the technical drawings for the mounting frame in the Appendix on page 106.

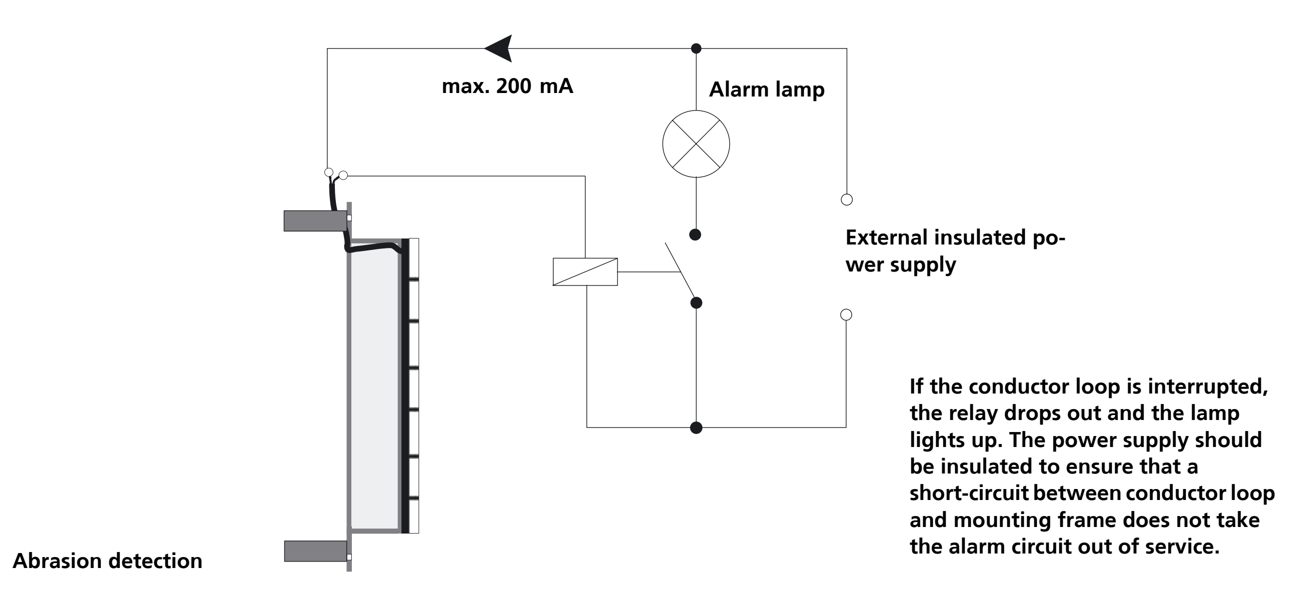
The mounting frame is installed in a prepared opening in the vessel wall.

After an operation time of several years, a broken wire in the integrated conductor loop alerts you that the ceramics surface has been worn out.

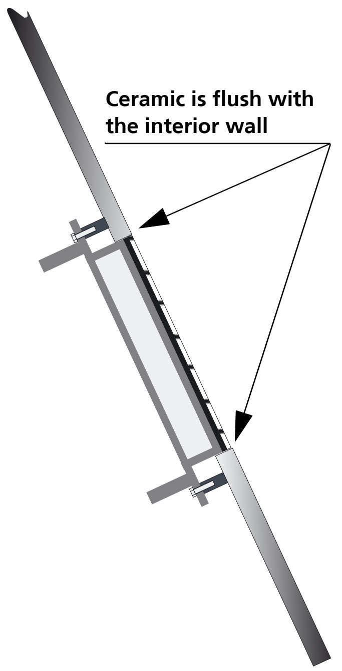


Mounting frame

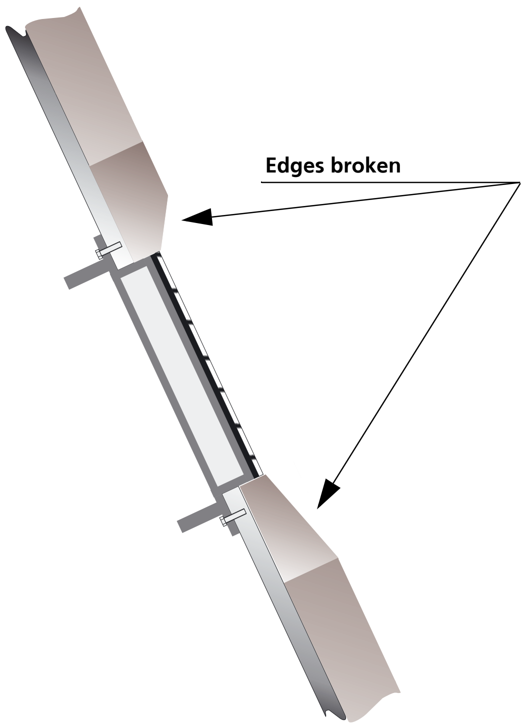
The following illustration shows a circuit example. Alternatively, the conductor loop for generating a message can be directly connected to the input of a control.



Install the ceramic surface of the mounting frame flush with the interior wall.



In case of heavy lining of the inner vessel wall, the edges of the lining have to be broken. When emptying the vessel, the material at the measurement site must be able to flow off safely.



Installation without mounting frame

For vessel walls with a thickness of less than 8 mm, the measurement can be installed directly outside on the surface of the vessel, without recess and without mounting frame.

This allows simple and fast installation without having to stop the production process.

3.4 Installation of the Density Compensation as Transmission Measurement

3.4.1 Installing the Shielding

The shielding LB 7440 is supplied along with the source. The source is in a shielded position. The source should remain shielded as long as the shielding is being assembled or work has to be carried out in the bunker in the vicinity of the radiation path.

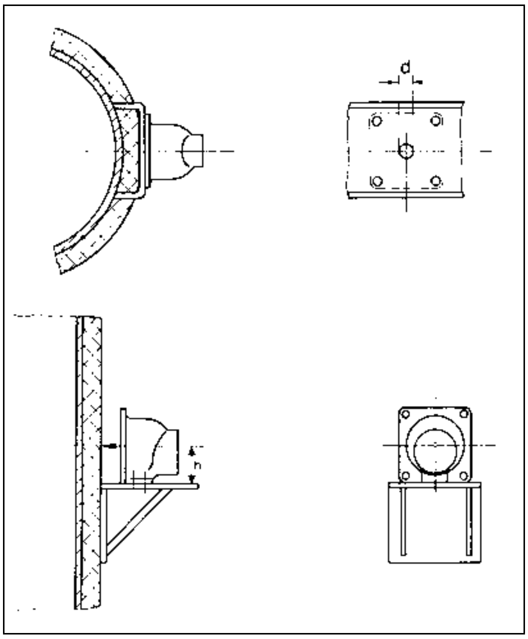
Open the source only after the measurement has been taken into operation.

In the shielded position, the source may be locked by a lock security pin even in the open position.

The source may be removed or exchanged only by an authorized specialist, typically the Radiation Safety Manager, or a Berthold service engineer.

Technical data and dimensions see page 105.

	LB 7440	LB 7442
H	90	120
D	~30	~30



Installation proposal for shielding LB 744x on vessel

3.4.2 Installing the Detector

Mark the monitoring height for the level on the vessel. Position the detector there on a horizontal line with the source.

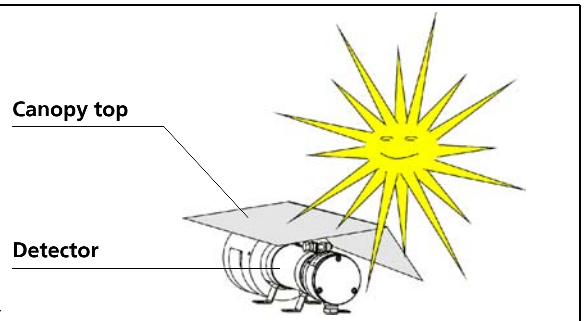
The horizontal line is at the same time the limit level where the device switches. Make sure that the radiation window of the detector is not covered by the support.

The distance to the surface of the vessel or the heat insulation should be approx. 20 mm.

ATTENTION

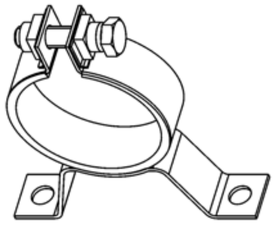
Risk of damage!
The detector may be damaged due to strong mechanical stress, vibrations and high temperatures. The detector has to be installed free from vibrations.

The detector must not be exposed to any mechanical stress during installation and operation.
The ambient temperature must not exceed the values given in the technical data. If higher ambient temperatures are likely to occur, the detector has to be cooled. Appropriate water cooling jackets can be supplied as accessories.
Direct exposure to sunlight is not permitted, as this may lead to an unacceptable increase of the surface temperature. In these cases, a canopy top has to be installed (see illustration below).



Detector with canopy

3.4.3 Fixing Clamps for GM and NaI-detectors

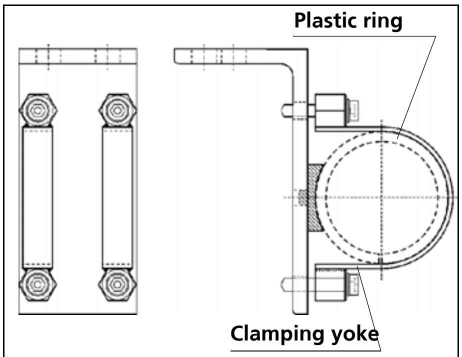


Clamp for GM-detectors and NaI-detector

Stainless steel clamps are available for the detector installation. The dimensions of the clamps are shown in the technical drawings in the Appendix. The technical drawing with dimensions is shown on page 106.

Clamps for detector without water cooling	Clamps for detector with water cooling
ID NO 31346 (1 set = 2 clamps)	ID NO 31347 (1 set = 2 clamps)

3.4.4 Stainless Steel Detector Support (alternative to the clamps)



Detector support

A robust stainless steel support is available instead of the clamps.

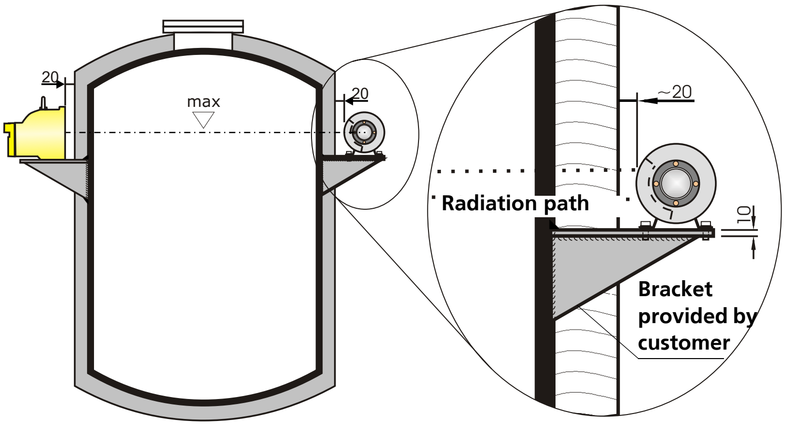
The support consists of an angle on which two clamps have already been mounted. You can screw or weld the support on a bracket. Due to the plastic rings in the clamping yoke, the same support can be used universally for detectors with and without water cooling. All metal parts of this support are made of stainless steel. The technical drawing with dimensions is shown on page 106.

Support for detector complete
ID NO 39246

3.4.5 Installation of the NaI-Detector

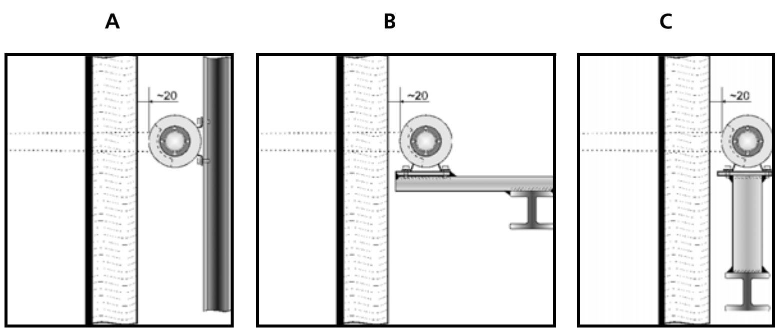
NaI-detector

The aperture on the side (radiation window) of the collimator provides access to the sensitive area of the detector which has to face the source. Detector dimensions see page 118.



NaI-detector mounted on vessel

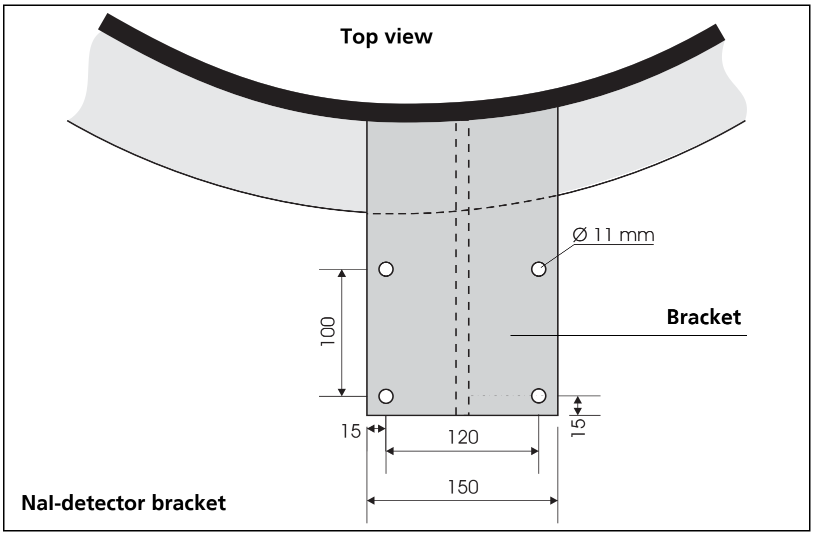
If the bracket cannot be mounted on the vessel, then it has to be mounted on a bracket which is installed in the vicinity. The illustration below shows three alternative proposals (A, B, C) for detector installation.



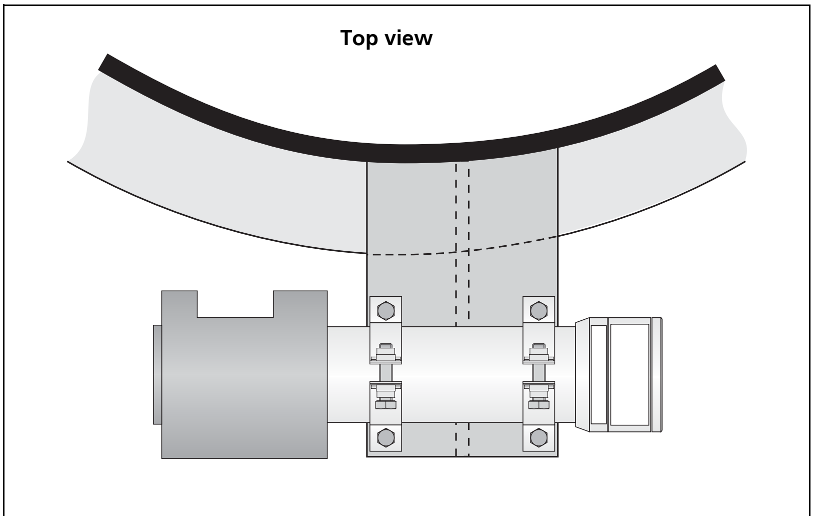
Alternative installations

Mounting procedure with clamps

- Manufacture a suitable bracket for the vessel.
- According to the drawing below, drill 4 holes (d = 11 mm) for the clamps into the bracket.
- Install the bracket either directly on the vessel or on a sturdy support.
- Mount the detector with the clamps on the bracket.



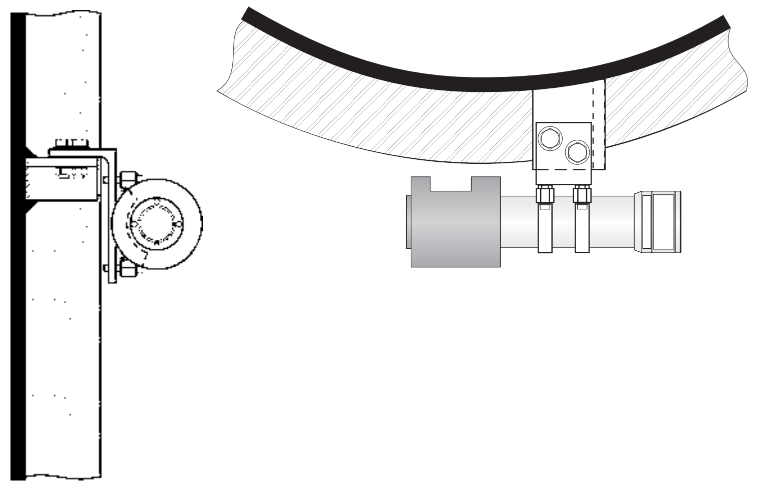
NaI-detector bracket



NaI-detector mounted on bracket

Mounting procedure with detector support

- Manufacture a suitable bracket for the vessel.
- If the support is not welded onto the bracket, drill 2 holes (d = 17 mm) for the support into the bracket, as shown in the drawing below.
- Install the bracket either directly on the vessel or on a sturdy support.
- Mount the support with the detector on the bracket.

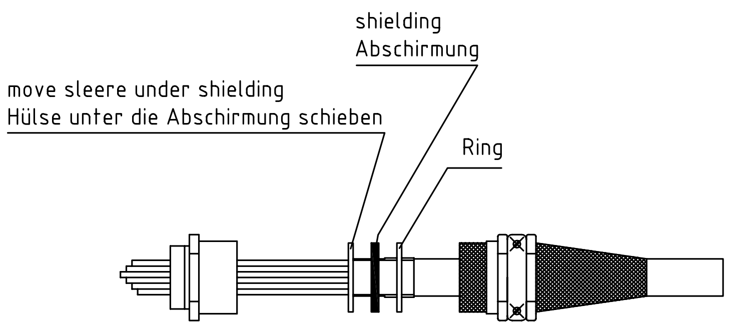


Installation proposal with detector support

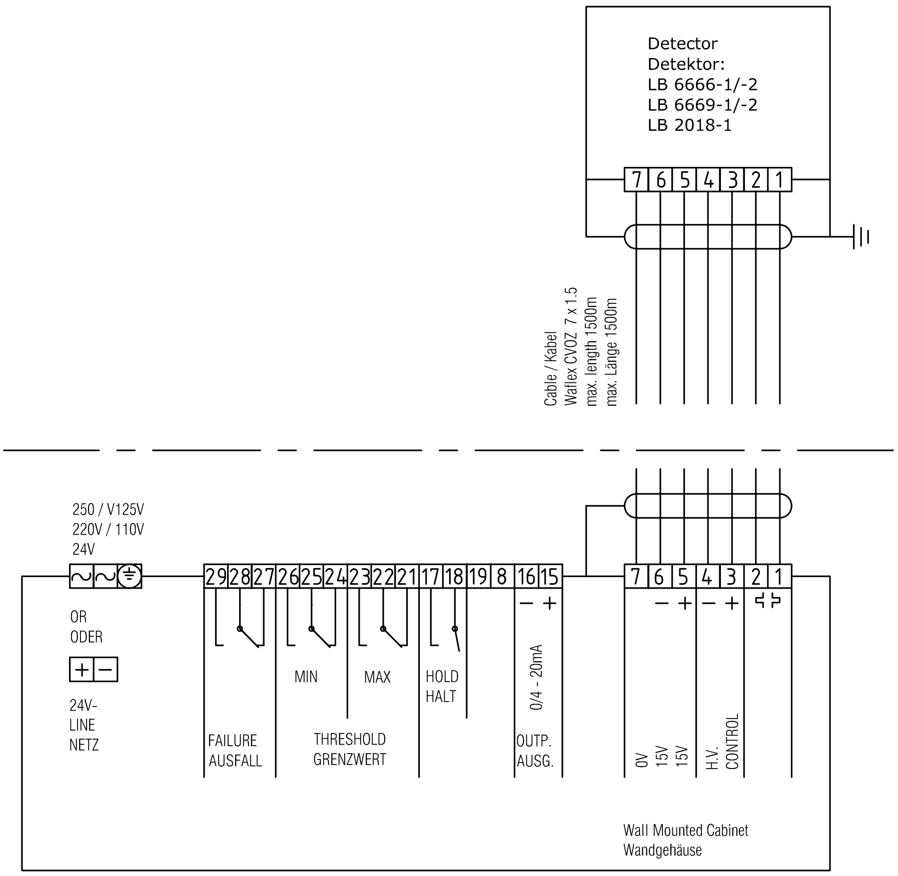
For the mechanical dimensions of the clamps and the detector support please see page 119.

4 Electrical Connection

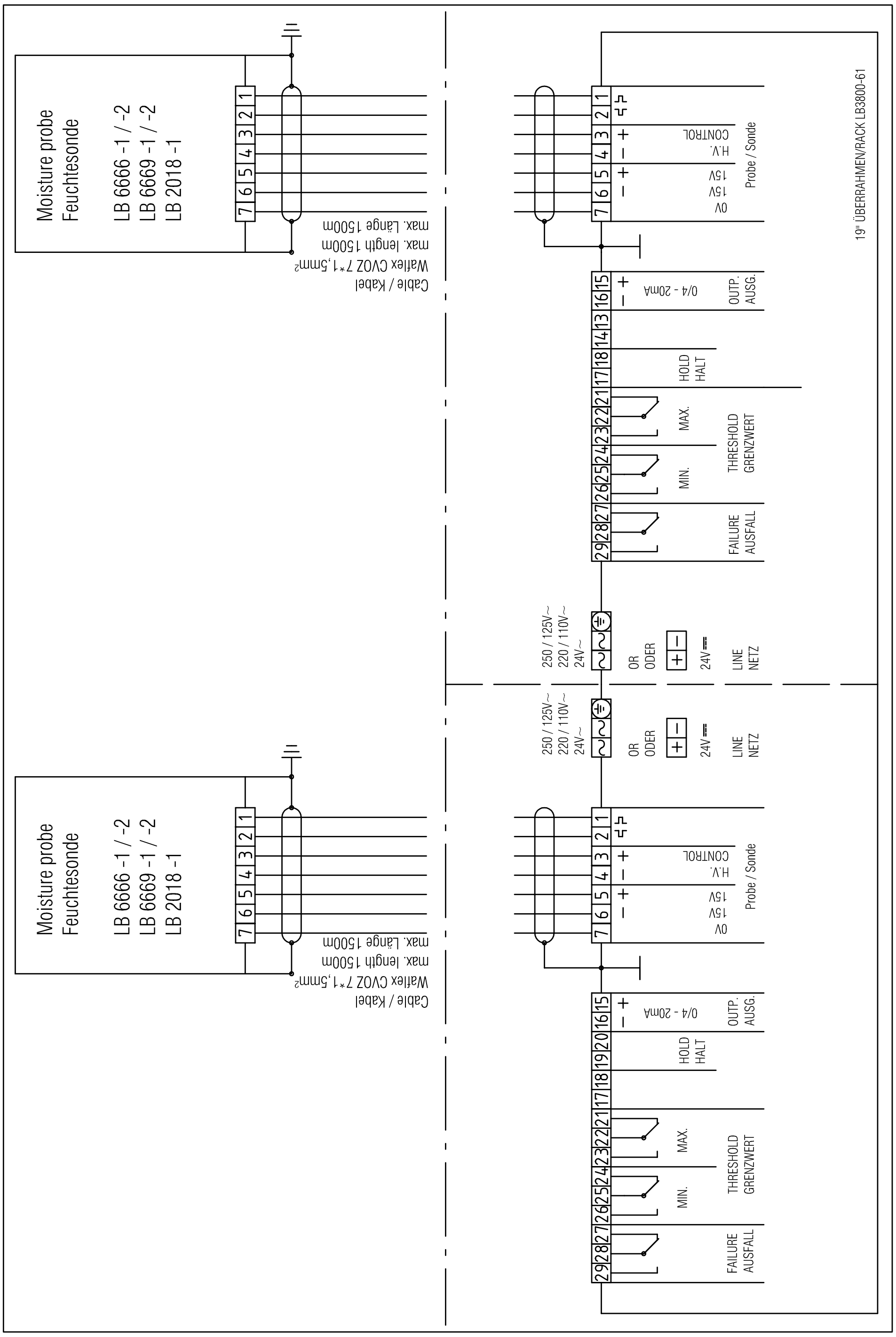
4.1 Wiring Diagram Wall Housing LB 350-1



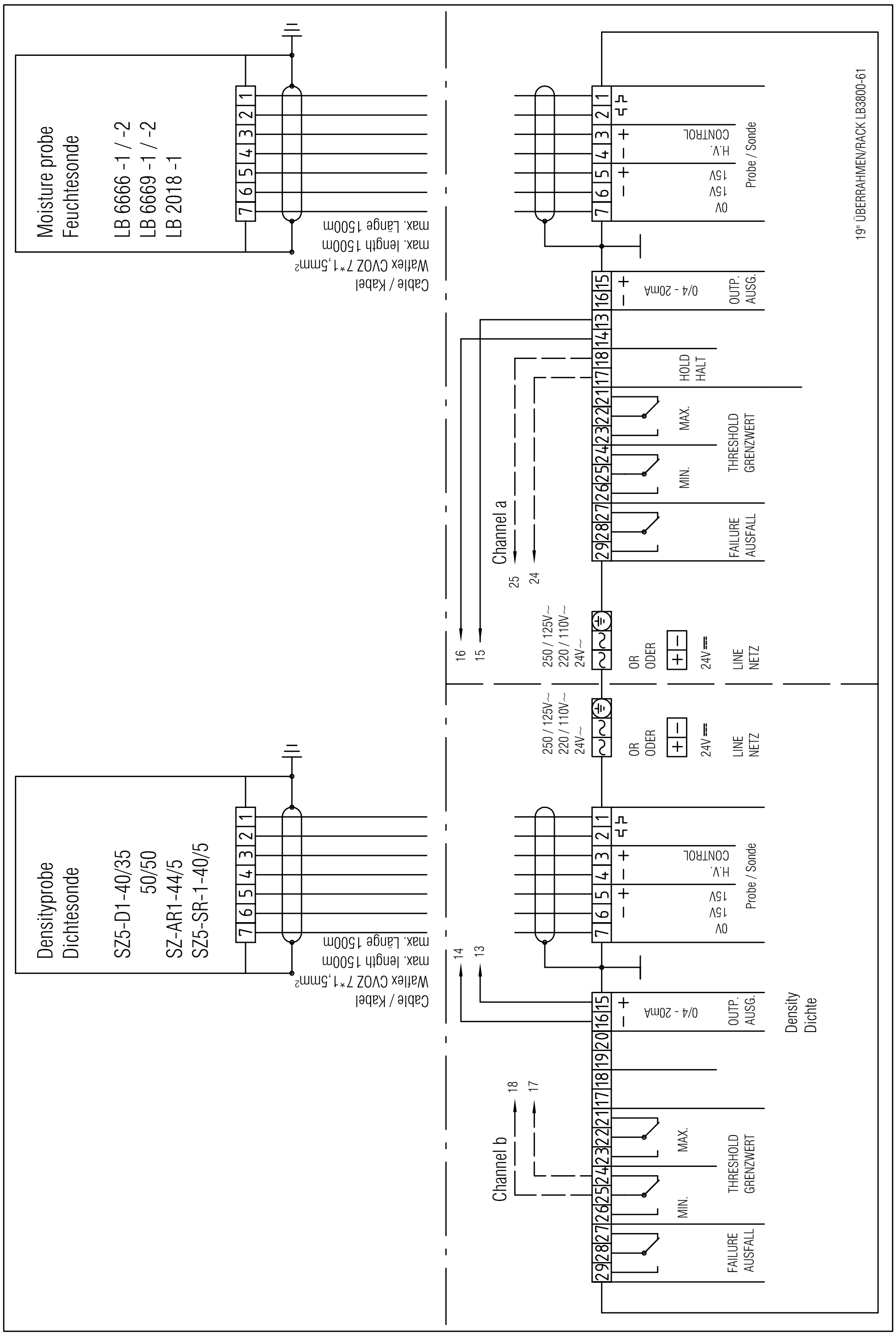
cable gland at the scintillation counter
Kabeldurchführung am Szintillationszähler



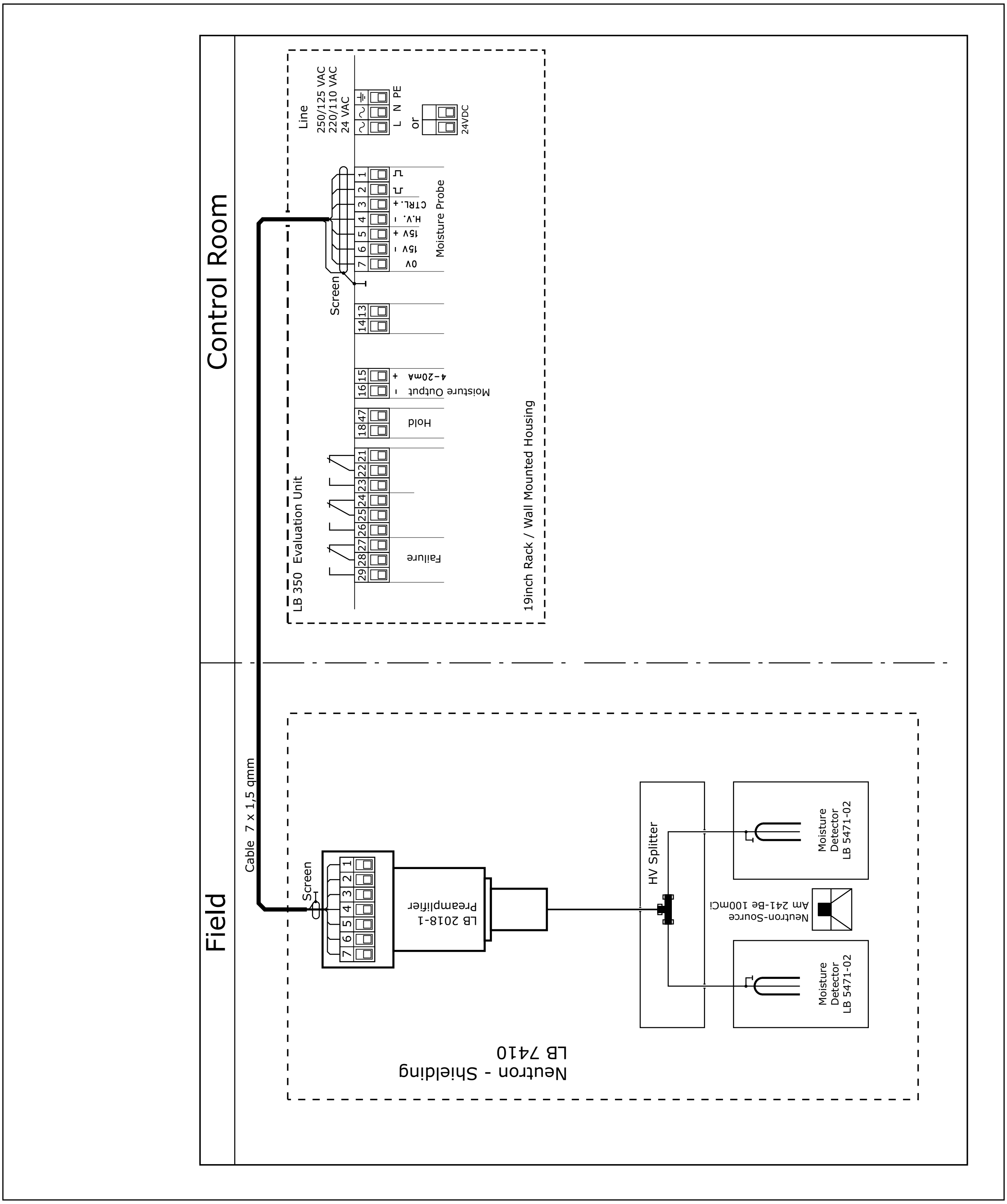
4.2 Wiring Diagram 19" Rack LB 350-2



4.3 Wiring Diagram 19" Rack LB 350-3



4.4 Wiring Diagram LB 7410 with LB 350-1/2



5

Measurement Amplifier LB 350

The measurement amplifier system LB 350 is a microprocessor-controlled evaluation unit for moisture measurements with bunker or surface probes. In addition to its function as evaluation unit, it also supplies the required operating and control voltages for connection of the probes, detectors and scintillation counters.

Depending on the measurement tasks or configuration, the measurement amplifier system LB 350 is available in a compact wall housing or in a 19″-rack (1- or 2-channels).

Wall-mounted housing

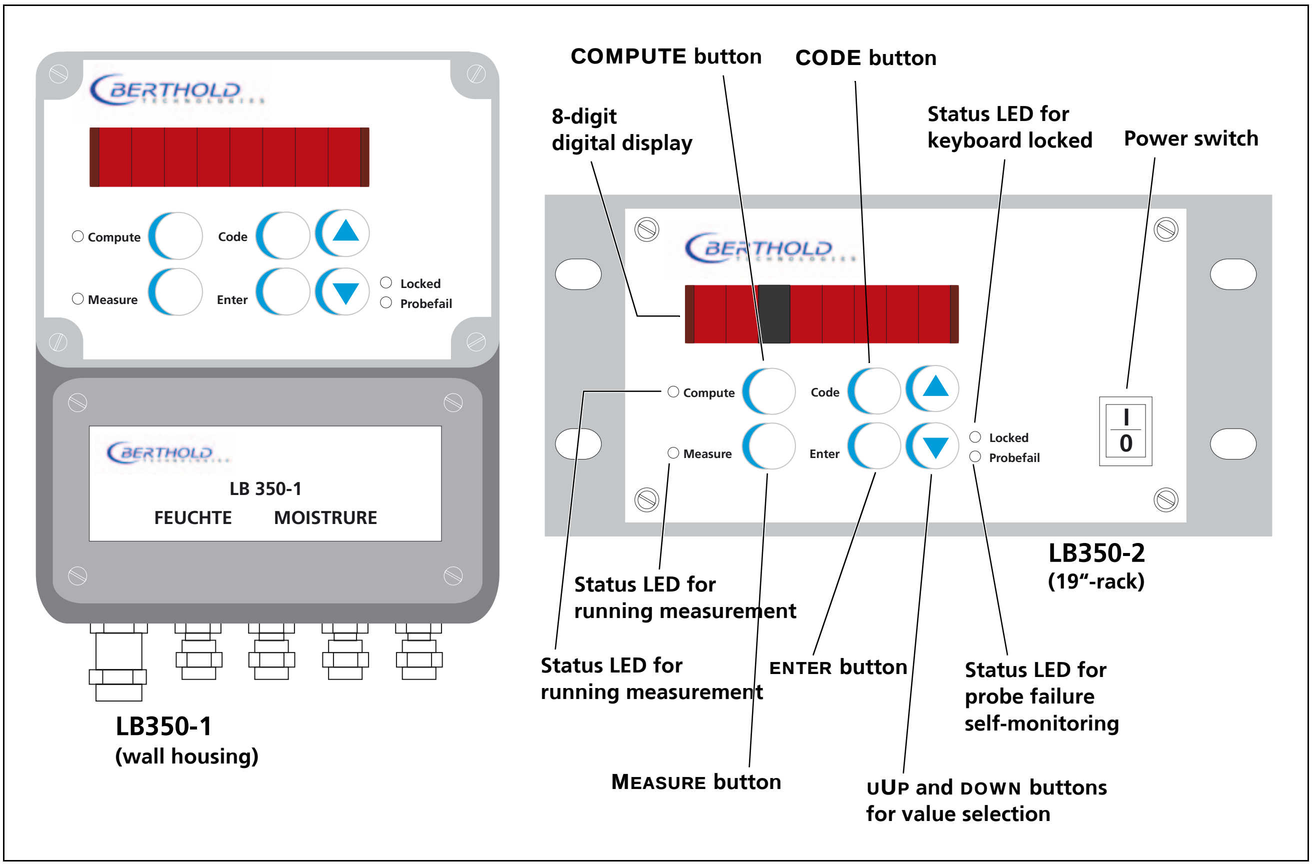
19″ housing

All standard parameters have already been specified by the manufacturer, which simplifies commissioning and calibration of the device.

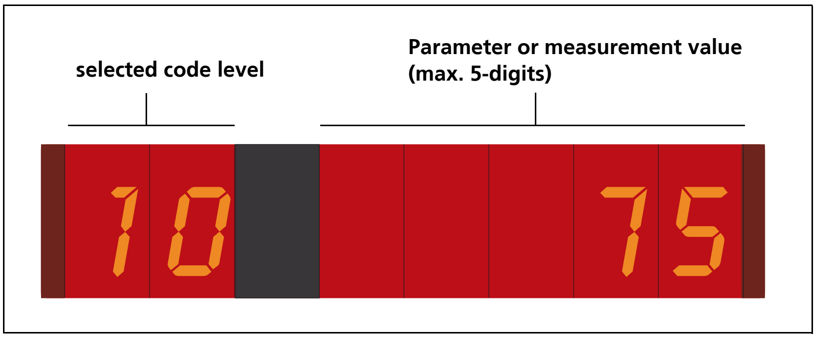
For special measurement tasks, all major parameters can be changed as required within broad limits, so they can be adapted optimally to each customer's specific needs.

Various parameters are stored in the device on code levels which can be selected in a simple manner (see page 45).

5.1 Operating and Display Elements



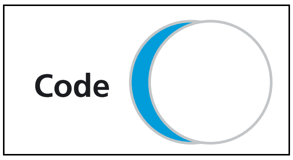
5.1.1 Display



The device comprises a 7-digit digital display. The first two digits show the selected code level, the last 1-5 digits the set function value or the current measurement value.

5.1.2 Button Functions

The device is operated via a clearly-arranged membrane keypad with six push buttons.



CODE: Selection of the code level

All parameters are stored on code levels which can be selected via the **CODE** button.

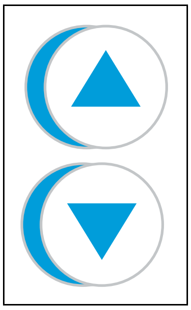
The selected code level is displayed via the first two digits of the digital display.

If you push the button briefly, the next higher level is selected. If you keep the button pushed down, you will scroll through all levels in rising order and with increasing speed, starting again at zero after the last level.

Counting backward is possible if the **CODE** button is pushed together with the **DOWN** button .

The code level is displayed permanently to avoid false interpretations. The function of the **CODE** button is activated when the measurement mode is enable or disabled.

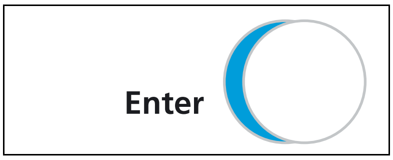
For a description of the code levels please refer to chapter 5.2.



UP and DOWN: Set parameter value

Briefly push the **UP** button to increment and the **DOWN** button to decrement the value on the display by one.

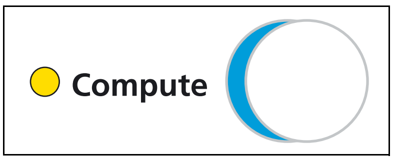
If you keep the buttons pushed down, the value changes continuously with increasing speed. Starting with the last decade, the program counts up to the full decade and then automatically goes to the next decade and the same process is started.



ENTER: Various functions

With the **ENTER** button, the following functions are carried out:

- Take over changed parameter values. Then automatic switchover to the next higher code level.
- Start reading in the pulses by pushing the **MEASURE** and the **ENTER** buttons at the same time.
- Acknowledge and delete error messages.



COMPUTE: Calibrating the device

The calibration curve is determined by the value pairs in codes 20 to 29 and 30 to 39:

During calibration, the Compute LED is on.

MEASURE: Start and stop measurement

With the **MEASURE** button, the following functions are carried out:

- Turning the measurement mode on and off.
- Start reading in the pulses with the **ENTER** button.

If you push the button **MEASURE** alone after the last input, the device automatically switches directly to the measurement and display mode.

IMPORTANT

*The functions of the **ENTER**, **COMPUTE** and **MEASURE** buttons are available only if the keyboard has been unlocked (see chapter 6.3). All parameters can also be changed in the measurement mode.*

Power switch: Turns the device off and on

ATTENTION

The device must be turned off before connecting and disconnecting the probes!

Although all device parameters are stored in an EE-PROM and the clock is also battery-buffered, you should not turn off the device for a longer period of time.

If the operating voltage has been interrupted for more than one month, the clock has to be set new and after more than one year all parameters have to be checked and entered new, if necessary.

Any time the device is powered up, it takes a few seconds until it is ready for operation, since a test program is running during this time. Any possibly occurring error will be displayed (see chapter 12).

In the 19"-rack version, the power switch is located on the front panel of the device and in the compact system behind the cover of the connection box on the wall housing.

5.2 Description of the Code Levels

Password (00)

You can choose any number comprising up to 6 digits to protect the device against unauthorized modification of parameters.

Year (01)

The last two digits (YY) of the current year are displayed. The correct year is important for the automatic correction of the activity decay of the source.

Date (02)

The current date is displayed in the format month/day (MM.DD). The correct month is important for the automatic correction of the activity decay of the source.

Time (03)

The current time information confirms the correct function of the clock. Time deviations, however, have virtually no effect on the correction of the activity decay of the source.

Level (10)

The current moisture is displayed in the measurement mode.

Pulse rate (11)

The pulse rate currently counted by the detector is displayed for function control. The value set in *Code 12* is used as time constant. The displayed values fluctuate owing to the statistical distribution of the radiation quanta, relative to the size of the pulse rate and the time constant.

Time constant (12)

The time constant for the moving average calculation is specified in this code. The largest permissible time constant should be used, so that the display is fairly steady.

Additional remark!: The natural statistical fluctuations of the output signal **I** around a mean value depend on the selected time constant τ and the measured pulse rate **n**. The average reading fluctuations (ΔI) correspond to the 1 sigma value and are calculated as follows:

$$\Delta I / I = \pm \frac{1}{\sqrt{2 \times n \times \tau}}$$

The 2 sigma value corresponds to the statistical error, and the maximum statistical fluctuations are specified by the 3 sigma value.

See also „Time constant and reaction of measurement value“ on page 12.

Rapid Switch (13)

The automatic rapid switchover is not effective for the standard input "0". The use of the function "rapid switchover" is advisable only for special applications. If the moisture changes suddenly and significantly, the time constant changes the value to 1/10.

Example: If the time constant is set to 20s, then the time constant will temporarily be reduced to 2s if significant moisture changes do occur. Thus, the measurement value follows the final value very quickly. If the measurement value has reached the final value, the device automatically switches back to 20s.

If the rapid switchover is used, the digit entered in *Code 13* - which corresponds to a multiple value of the Sigma value - should be so high that statistical fluctuations do not trigger the switchover of the time constant too often. Therefore, you should enter at least the value "3" or better "4". It is advisable to determine the optimum input during everyday operation.

0/4 mA (14)

Starting point of the current output, typically 0 for the start of the measurement range of 0% moisture.

20 mA (15)

Final point of the current output, typically 15 mA for the end of the measurement range of 15% moisture.

Current output (16)

Switchover of the current signal from 0 ... 20 mA to 4 ... 20 mA.
Input value 0 for 0 ... 20 mA.
Input value 1 for 4 ... 20 mA.

Min.-Alarm (17)

Switchover point for "Limit value min".
If the moisture value set here is not reached, then the relay triggers a "Limit value min" alarm.

Max.-Alarm (18)

Switchover point for "Limit value max"
If the moisture value set here is exceeded, then the relay triggers a "Limit value max" alarm.

Switchover hysteresis (19)

The relays are deenergized only after the measured value has changed corresponding to the hysteresis entered in %, relative to the difference between the set thresholds (MAX/MIN). The hysteresis should not be selected too small, as otherwise the relay may switch several times in the course of a slow moisture change due to statistical fluctuations. A value of 2% is useful in most cases.

(20) to (29) Comparative moisture values are entered in *codes 20 to 29* for which pulse rates have been measured in *codes 30 to 39*. Please keep in mind that *code 20* and *code 30*, and *code 21* and *code 31*, etc. each make up one value pair.

The comparative moisture values are entered after they have been determined in the laboratory. The values have to be entered into the respective code with rising moisture content.

Note: A new curve is calculated only when the Compute button has been pushed, using the calibration values in *codes 20* to *39*. The slope and the offset of this characteristic curve are output in *codes 40* and *41*.

(30) to (39) The comparative pulse rate is determined while a sample is being taken. The respective moisture value determined in the laboratory is then entered in the corresponding *codes 20* to *29*.

Example: If a pulse rate of 120 cps has been determined in *code 30* for sample A, then the moisture value of sample A, e.g. 4%, has to be entered in *code 20*. For *code 31* the lab value has to be entered in *code 21*, etc. Thus, it is possible to enter up to 10 lab samples.

a 0 (40) This value is used for information purposes. It indicates the position of the curve and is calculated new on the basis of the calibration data in *codes 20* to *39* every time the **COMPUTE** button is pushed.

$$F_V = a1 \times I + a0$$

a0 = value in code 40
a1 = value in code 41
I = currently measured pulse rate
F_V = resulting moisture measurement value

Using this formula, the respective moisture is calculated during the measurement process.

If the values in code 40 and 41 are changed, this has a direct effect on the measurement value.

a 1 (41) This value is used for information purposes. It represents the slope of the curve and is calculated new on the basis of the calibration data in *codes 20* to *39* every time the **COMPUTE** button is pushed.

Factor F (42) For special cases, you may here enter the intentional change of the slope of the straight characteristic curve. For each new calibration, this value is automatically set to "1". If the value is set, for example, to 1.1, then all measurement values are displayed multiplied by 1.1.

Constant K (43)

For special cases, you may here enter the intentional change of the position of the straight characteristic curve. For each new calibration, this value is automatically set to "0". If you enter, e.g. 2, here, then the value is always displayed increased by 2%.

Test Generator (45)

For function control and simulation, you can enter an arbitrary pulse rate simulating a certain moisture. The pulses arriving from the detector will be suppressed and become ineffective. Please keep in mind that entries will be taken over only if you push **ENTER** and become effective after you have pushed **MEASURE**.

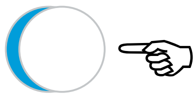
IMPORTANT

At the end of the test, the value must be reset to "0" to clear the system again for the detector pulses.

6 Functional Processes

6.1 Selecting a Code

Code

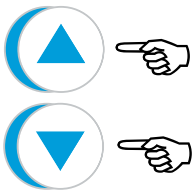


▶ Push the **CODE** button until the desired code number appears in the first two digits of the digital display (see also page 39).

6.2 Entering Parameters

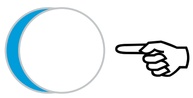
Code

▶ First, select the desired code number via the **CODE** button.



▶ Enter the desired parameter value via the **UP** and **DOWN** buttons (see also page 39).

Enter



▶ Push the **ENTER** button to conclude your entry.

As soon as you push **ENTER**, the display jumps to *code 0*.

IMPORTANT

When the keyboard is locked, no input is possible, except in code 0 (password). That means, the UP and DOWN buttons do not have any effect.

6.3 Password

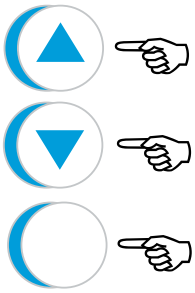
The keyboard can be protected against unauthorized use by entering a password. If the keyboard is locked, all entries, except for the input of the password are locked and the LED **LOCKED** lights up. The **ENTER**, **COMPUTE** and **MEASURE** buttons are also locked.

Enter the password to lock the keyboard and enter it again to unlock the keyboard again.

6.3.1 Changing the Password

Initial input

When the device is turned on for the first time, the keyboard is unlocked and on the display you see *code 0* (Password).



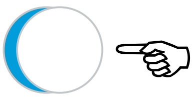
Enter

- Using the **UP** and **DOWN** buttons, enter the desired password (see also page 39).
- Complete the entry with **ENTER**.
  The password is now stored and the display jumps to *code 1*.

Change password

The password can be changed any time via *code 0*.

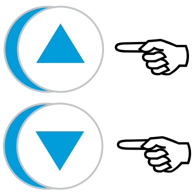
Code



- Push the **CODE** button to select *code 0* (password).

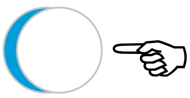
IMPORTANT

To change the password, you have to unlock the keyboard by entering the current password.
If you have forgotten the password and you cannot operate the device any more, please contact Berthold Technologies or your local representative. If worst comes to worst, you may also reset the device. Then the password is also disabled.



- Using the **UP** and **DOWN** buttons, enter the desired password (see also page 39).

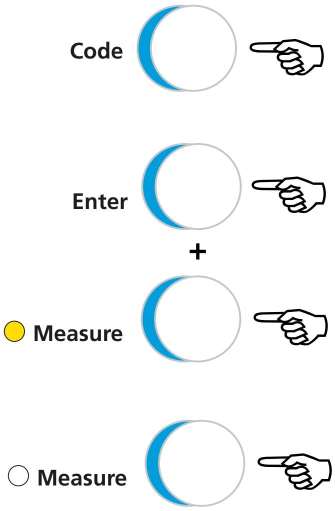
Enter



- Complete the entry with **ENTER**.
  The new password is now stored and the display jumps to the next higher code level.
- To lock the keyboard now, select *code 0* again and enter the new password (see above).

6.4 Reading-in Pulse Rates

In *codes 30 to 39* you can read in pulse rates. Please proceed as follows:

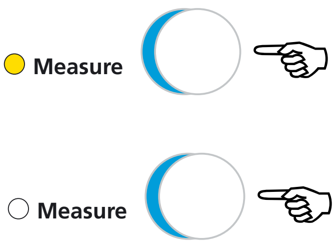


- First, select the code level via the **CODE** button (e.g. *code 31*).
- Push the **ENTER** and **MEASURE** buttons *at the same time*.
  The Measure LED lights up indicating that pulse rates are being read in. During the reading-in process, the arithmetic mean of the read-in pulse rates is calculated.
- If the pulse rate on the display has become stable (after approx. 30 s), stop the reading-in by pushing the **MEASURE** button one more.
  The Measure LED goes off.

6.5 Calibration

See chapter 7 ff.

6.6 Measurement Start



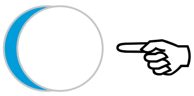
- Push the **MEASURE** button.
  During the measurement, the Measure LED lights up and the display jumps to *code 10* (current measurement value).
- Push **MEASURE** to stop the measurement again. The Measure LED goes off.

IMPORTANT
Start and stop of the measurement is possible only with the keyboard unlocked.

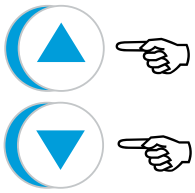
6.7 Entering Test Pulse Rates

In *code 45* you can enter a test pulse rate. If *code 45* contains a numerical value greater than zero, the measurement program works with this pulse rate as input pulse rate. This allows you to control the device for test purposes to a certain measurement value.

Code

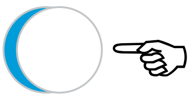


▶ Select *code 45* via the **CODE** button.



▶ Using the **UP** and **DOWN** buttons, enter the desired test pulse rate (see also page 39).

Enter



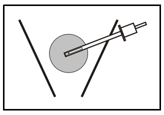
▶ Push the **ENTER** button to conclude your entry.

IMPORTANT

Upon completion of the test, enter zero again in code 45. If the value is not reset to 0, the same measurement value will be displayed all the time.

7

Commissioning the Moisture Measurement with Bunker Probe



7.1 Preliminary Setting

Assumed application values

To make this manual easier to understand, we have proceeded from the following example:

Material:	Coarse coke
Bulk density:	approx. 0.5 - 0.8
Absorption coefficient for Cs-137:	0.066
Moisture measurement range:	0 - 15%
Measurement device for moisture measurement:	LB 350

When using the measurement method with density compensation:

Measurement device for density measurement:	LB 350 or LB 376 for density transmission measurement

Numerical values that deviate from this example have to be taken into account accordingly in the parameter setting (Tables 10.4.1 and 10.4.2).

- ▶ Parameterize the density measurement according to the enclosed code list 5.2. You only have to enter the parameters listed in the moisture parameter column. Values identified by a question mark have to be adapted to the actual conditions.
- ▶ First, disable the density compensation. To do this, set *code 50* in the moisture measurement to "0".

7.2 Calibration

For preliminary setting, it suffices to have an empty bunker to set the zero point and a bunker filled with coke whose coke moisture has been determined.

- Enter the respective pulse rate in *codes 30 and 31* and the respective moisture values of the product (e.g. coke) in *codes 20 and 21*.

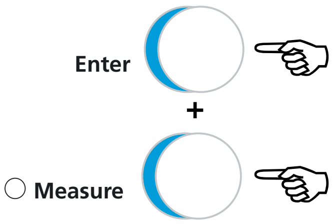
Example: Read in 50 cps in *code 30* with empty bunker. Thus, 0 (0% moisture) is entered in *code 20*.

For the bunker filled with coke, a pulse rate of 200 cps is entered in *code 31*.

A lab sample of this coke showed 5%. Thus, 5 is entered in *code 21*.

Reading-in the pulse rate:

Select *code 30* (or *31*) in the moisture measurement.



- Keep the **ENTER** button pushed and push the **MEASURE** button. Then release both buttons again.

The currently measured pulse rate appears on the display in *code 30* (*31*).

Initially, it fluctuates strongly and then levels off after about 30 seconds.

- Push the **MEASURE** button after approx. 30 seconds (max. 60s). This completes the determination of the pulse rate.

Start calculation of the moisture calibration curve

Push the **COMPUTE** button to calculate a calibration curve using the value pairs in *codes 20* to *29* and *30* to *39*, which is expressed in the values in *code 40* and *code 41*.

- Make sure that all unused value pairs will be set to 0. In our example, *codes 22* to *29* and *codes 32* to *39*.

- For the following calculation of the characteristic curve you have to stop the measurement with the **MEASURE** button, so that the Measure LED is off.

- Push the **COMPUTE** button. The evaluation unit calculates the coefficients a0 and a1. The moisture measurement device is ready for operation.

- Push the **MEASURE** button to start the measurement device, the measurement is activated. The LED indicates that the measurement is active.

The moisture measurement is now working according to the following function:

$$F_V = a1 \times I + a0$$

a0 = value in *code 40*
a = value in *code 41*
I = currently measured pulse rate
F_V = resulting moisture measurement value (always negative for the moisture measurement)

First measurement values of the moisture measurement

The measurement device is now ready for measurement and measures the current moisture. If the calibration process was completed properly, a reasonable value has to appear on the display. If this is not the case, check the parameters once more.

7.3 Fine Adjustment

Several samples have to be taken for calibration which are representative for the moisture measurement values at the measurement location. Parallel to each sampling step, the pulse rate value of the moisture and the density measurement are read off (procedure see above). Please enter the numerical values in the table in chapter 10.5.

Sampling

To rule out calibration errors, you should take about 5 to 15 samples. Each sample has to be taken from a new bunker filling. The laboratory moistures must cover a fairly large moisture range (at least 3%). Please enter the lab values in the table sheet in chapter 10.5.

IMPORTANT

Samples that are determined at constant moisture are useless.

Artificial moistening

In order to obtain different moistures, the product can be moistened with water before it is filled into the bunker. If necessary, the moistening can be carried out on a conveyor belt that transports the product to the bunker. To avoid pockets of moisture, it would be helpful to have several hand-over points where the product can be mixed thoroughly once more. A hand-over point is, for example, when the material on a conveyor belt drops onto another conveyor belt.

Samples can be taken in the following situations:

- during the filling process
- with filled vessel
- during emptying

Please make sure that samples are taken from that material which is being measured later or has already been measured.

Sampling

When taking probes during the filling or emptying process, the samples should be taken in small amounts (typically 5 kg), until the product comes from the environment of the measurement volume.

As a rule, this can be roughly estimated. Altogether, the sample quantity should be approx. 30 kg.

We recommend taking double or even quadruple samples from these approx. 30 kg, in order to be able to identify outliers and to obtain a sample mean value of the lab analysis. This can be done by dividing the sample several times.

The samples have to be packed in plastic bags to avoid loss of moisture prior to the analysis.

The laboratory will then, as a rule, take only small amounts from these samples for analysis.

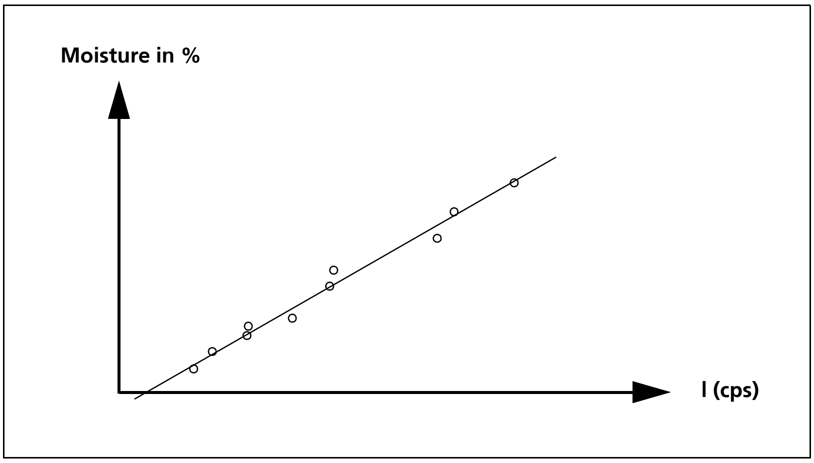
It is not unusual that several analysis values of the same sample may vary significantly. Therefore, it is always advisable to determine a mean value from these analyses.

Single analysis values which deviate significantly from the mean value, so-called outliers, can be discarded. In these cases, one can assume that either the respective sample was not representative (e.g. pocket of moisture), or that an analysis error has occurred.

Calculation of the moisture calibration coefficients

Using the table values you can now create an x/y graphic.

- On the y-axis, enter the moisture lab value, and
- on the x-axis the pulse rates.
- Now add a trend line by hand or by means of a PC with a regression line in the graphic. This trend line is then the characteristic curve of the measurement.

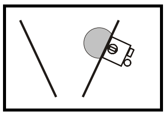


Using the characteristic curve, you can read off the pulse rate at 0% moisture.

- Enter the pulse rate for 0% in *code 30* of the moisture measurement and set *code 20* to the value 0 (0% moisture).
- In *code 21*, enter a high moisture value (e.g. 10%). Now enter the pulse rate measured at this moisture value in the characteristic curve in *code 31*.
- Make sure that *codes 32* to *39* and *codes 22* to *29* are set to "0".
- Push the **COMPUTE** button to calculate the characteristic curve for the moisture measurement.

The measurement device is now completely calibrated.

8 Commissioning the Moisture Measurement with Surface Probe



8.1 Mechanical Installation

8.1.1 Optimum Installation Site and Preparation

- At low moisture, one has to expect a measurement volume of approx. 60 cm radius. This means that even at lowest filling level the probe has to be covered by at least 60 cm material. If this is not the case, this will result in incorrect measurements.
- Inside the bunker the distance of the measurement to the next wall must be at least 60 cm, otherwise the calibration characteristic curve will be nonlinear.
- Inflowing material must not fall directly onto the measurement location, as otherwise the protection ceramic of the mounting frame will be destroyed prematurely.
- No deposition of material must occur at the planned measurement point; the material must drain off completely.
- Ceilings, floors, supports and other installations which may prevent or disturb the assembly have to be taken into account prior to assembly.
- The electrical installation of the abrasion detection has to be taken into account.
- A representative sampling location has to be foreseen for calibration (options: e.g. while filling, emptying or in the filled bunker).

8.1.2 Mounting Frame

- When installing the mounting frame in the bunker you always have to see that the surface of the wearing plate and the inside lining of the bunker form a level area.
- If the inside of the bunker wall juts out further than the wearing plate, projecting wall parts (stone, rubber or ceramic linings) inside the bunker and around the wearing plate have to be sloped. This prevents that cavities can be created around the measurement location or that the measurement location is clogged by fine grained material.
- A jutting out of the wearing plate into the inside of the bunker must be avoided, as otherwise the ceramic on the edges may get damaged (see page 26).

8.1.3 Optimizing the Measurement Display

If the turnaround time of the product in the bunker from filling to emptying is too short, or if you need to get a more accurate reading (minimization of the statistics), then the measurement should be started only with filled vessel. The time constant of the moisture and, if provided, the density compensation also have to be increased. Clearance is obtained by opening the HALT contact. This HALT contact must be insulated and come as a signal from the control of the bunker (see also under *Weighing hopper* on page 12).

Without this control, we need a turnaround time of at least 1.5 minutes for a time constant of 20s. Turnaround time also means that during this time the measurement site is completely covered by the product.

This means, by reverse conclusion, as long as the measurement site is not fully covered by material, the measurement must be halted by closing the HALT contact.

8.2 Preliminary Setting

Assumed application values

To make this manual easier to understand, we have proceeded from the following example:

Material:	Coarse coke
Bulk density:	approx. 0.5 - 0.8
Moisture measurement range:	0 - 10%
Measurement device for moisture measurement:	LB 350

Numerical values that deviate from this example have to be taken into account accordingly in the parameter setting (Tables 10.4.1 and 10.4.2).

- ▶ Parameterize the density and, if installed, the moisture measurement using the enclosed code list 5.2. You only have to enter the parameters listed in the moisture parameter column. Values identified by a question mark have to be adapted to the respective conditions.
- ▶ First, disable the density compensation. To do this, set *code 50* in the moisture measurement to "0".

8.3 Calibration

For preliminary setting, it suffices to have an empty bunker to set the zero point and a bunker filled with coke whose coke moisture has been determined.

- Enter the respective pulse rate in *codes 30 and 31* and the respective moisture value of the product (e.g. coke) in *codes 20 and 21*.

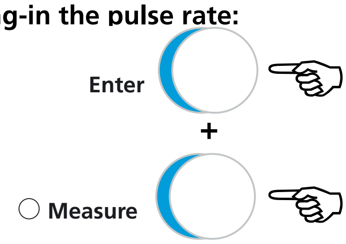
Example: Read in 150 cps in *code 30* with empty bunker. Thus, 0 (0% moisture) is entered in *code 20*.

For the bunker filled with coke, a pulse rate of 250 cps is entered in *code 31*.

A lab sample of this coke showed 5%. Thus, 5 is entered in *code 21*.

Reading-in the pulse rate:

Select *code 30* (or *31*) in the moisture measurement.



- Keep the **ENTER** button pushed and push the **MEASURE** button. Then release both buttons again.

The currently measured pulse rate appears on the display in *code 30* (*31*).

Initially, it fluctuates strongly and then levels off after about 30 seconds.

- After approx. 30 seconds (max. 60s) push the **MEASURE** button. This completes the determination of the pulse rate.

Calculation of the moisture calibration curve

Push the **COMPUTE** button to calibrate the measurement device.

- Before you push the **COMPUTE** button, check if all values in *codes 32 to 39* have been set to 0. Set values deviating from 0 to 0.

- For the following calculation of the characteristic curve you have to stop the measurement with the **MEASURE** button, so that the Measure LED is off.

- Push the **COMPUTE** button. The evaluation unit calculates the coefficients a0 and a1. The moisture measurement device is ready for operation.

- Push the **MEASURE** button to start the measurement device, the measurement is activated. The LED indicates that the measurement is active.

The moisture measurement is now working according to the following function:

$$fv = I \times a1 + a0$$

fv = volume moisture

I = pulse rate supplied by the detector

a0 = coefficient in *code 41*

a0 = coefficient in *code 40*

First measurement values of the moisture measurement

The measurement device is now ready for measurement and supplies the first results. If the calibration process was completed properly, a reasonable value has to appear on the display. If this is not the case, check the parameters once more.

8.4 Fine Adjustment

Several samples have to be taken for calibration which are representative for the moisture measurement values at the measurement location. Parallel to each sampling step, the pulse rate value of the moisture and the density measurement are read off (procedure see above). Please enter the numerical values in the table in chapter 10.5.

Sampling

To rule out calibration errors, you should take about 5 to 15 samples. Each sample has to be taken from a new bunker filling. The laboratory moistures must cover a fairly large moisture range (at least 3%). Please enter the lab values in the table sheet in chapter 10.5.

IMPORTANT

Samples that are determined at constant moisture are useless.

Artificial moistening

In order to obtain different moistures, the product can be moistened with water before it is filled into the bunker. If necessary, the moistening can be carried out on a conveyor belt that transports the product to the bunker. To avoid pockets of moisture, it would be helpful to have several hand-over points where the product can be mixed thoroughly once more. A hand-over point is, for example, when the material on a conveyor belt drops onto another conveyor belt.

Samples can be taken in the following situations:

- during the filling process
- with filled vessel
- during emptying

Please make sure that samples are taken from that material which is being measured later or has already been measured.

Sampling

When taking samples during the filling or emptying process, the samples should be taken in small amounts (typically 5 kg), until the product comes from the environment of the measurement volume.

As a rule, this can be roughly estimated. Altogether, the sample quantity should be approx. 30 kg.

We recommend taking double or even quadruple samples from these approx. 30 kg, in order to be able to identify outliers and to obtain a better mean value of the lab analysis. This can be done by dividing the sample several times.

The samples have to be packed in plastic bags to avoid loss of moisture prior to the analysis.

The laboratory will then, as a rule, take only small amounts from these samples for analysis.

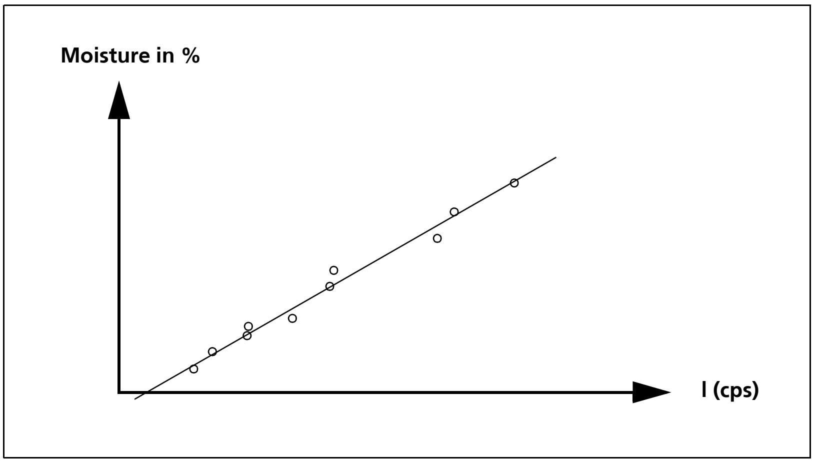
Is is not unusual that several analysis values of the same sample may vary significantly. Therefore, it is always advisable to determine a mean value from these analyses.

Single analysis values which deviate significantly from the mean value, so-called outliers, can be discarded. In these cases, one can assume that either the respective sample was not representative (e.g. pocket of moisture), or that an analysis error has occurred.

Calculation of the moisture calibration coefficients

Using the table values you can now create an x/y graphic.

- On the y-axis, enter the moisture lab value, and
- on the x-axis the pulse rates.
- Now add a trend line by hand or by means of a PC with a regression line in the graphic.



Using the trend curve, you can read off the pulse rate at 0% moisture.

- Enter the pulse rate for 0% in *code 30* of the moisture measurement and set *code 20* to the value 0 (= 0% moisture).
- For *code 21*, enter a high moisture value (e.g. 10%). Now enter the pulse rate measured at this moisture value in the graphic in *code 31*.
- Make sure that *codes 32* to *39* and *codes 22* to *29* are set to "0".
- Push the **COMPUTE** button to calculate the characteristic curve for the moisture measurement.

Now the zero pulse rate is calculated in *code 30*.

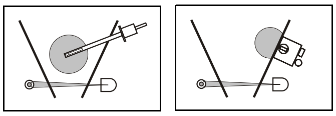
The measurement device is now completely calibrated.

9

Density Compensation with Transmission

Assumed application values

Density measurement device:	LB 350
Absorption coefficient for Cs-137:	0.066



9.1 Preliminary Setting

- With a full bunker and an average bulk density, enter a pulse rate in *code 40*.
- In *code 50*, enter the mean value of the density measurement range. Starting from our original values, we will get a mean value of 0.65 g/cm³ for a measurement range of 0.5 to 0.8 g/cm³.
- In *code 36*, enter the measurement path (in cm) of the radiation through the material. For this type of pre-calibration, this value must be entered very accurately, i.e. down to the centimeter, if possible.

IMPORTANT

Do not enter any further pulse rates in codes 41 to 49 for this calibration.

- Push the **COMPUTE** button and the evaluation unit calculates the zero pulse rate in *code 30*.

Thus, the measurement is ready for operation and can be started by pushing the **MEASURE** button (LED lights up when measurement is active).

9.2 Calibration

The following step has to be carried out in the evaluation unit of the density measurement LB 367. The preliminary setting of the density measurement has already been completed.

In this step you determine the pulse rate for the average bulk density.

The pulse rate of the density measurement is entered in *code 40*.

As a rule, we do not know if the density is an average density value; therefore, this process has to be repeated with each new filling. This can be done parallel to the acquisition of the moisture pulse rates. From the pulse rates measured, one then has to calculate the mean value.

- Overwrite *code 40* with this mean value.

IMPORTANT

Codes 41 to 49 must not contain any further pulse rates for this type of calibration, unless another type of calibration is performed than the one described here.

▶ Push the **COMPUTE** button to calculate the characteristic curve for the density measurement.
Now the zero pulse rate is calculated in *code 30*.

IMPORTANT

After the calibration, you should write down and archive the values of all parameters.

Enabling the density compensation

▶ To enable the density compensation, set *code 50* of the moisture measurement to "1".

9.3 Fine Adjustment

Further optimization of the density compensation can be obtained through trend evaluation of the moisture as compared to the density reading. It would be ideal if no effects on the moisture would be apparent despite varying density.

Recalibration is possible by inclining the density calibration curve around the center. You can do this by changing the density absorption coefficient, followed by a one-point calibration in the density range mean value (in our example at a bulk density of 0.65 g/cm³).

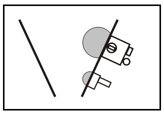
The smaller the coefficient, the lower the influence of the density compensation.

Push the **COMPUTE** button to enable this change in the device.

10 Density Compensation with Backscatter Chamber

Assumed application values

Density measurement device: LB 350



10.1 Preliminary Setting

The following procedure is valid if the density measurement range is between 0 and 1 g/cm³. For a bulk density above 1 g/cm³ please note the default setting described below.

- With an empty bunker, enter the pulse rate in *code 30* and a density value of 0 in *code 20*.
- With a full bunker and an average bulk density, enter the pulse rate in *code 31*.
  In *code 21*, enter the mean value of the density measurement range. Starting from our original values, we will get a mean value of 0.65 g/cm³ for a measurement range of 0.5 to 0.8 g/cm³.
- Push the **COMPUTE** button. The evaluation unit calculates the coefficients a0 and a1.

Compute 

The measurement is now ready for operation and can be started by pushing the **MEASURE** button (LED is on if measurement is active).

IMPORTANT

Using these values for calibration results in a fairly small coefficient a1 in ***code 41****, i.e. about 0.0001. Thus, the resolution of this coefficient is low. A better resolution can be obtained if we multiply all density parameters in the density measurement by 100. The decimal point for coefficient a1 moves to the right by 2 digits and thus permits a higher resolution.*
Example:

Measurement range:	*0.5 – 0.8g/cm³*
Input in code 14:	*50*
Input in code 15:	*80*
Density calibration points 20 + 21:	*Bulk density x 100*

If the bulk density is higher than 1 g/cm³, e.g. for sinter 1.5-2 g/cm³, then you should make the following basic setting, which deviates from the above setting:

- *Code 14*: 15
- *Code 15*: 20
- *Code 20*: 15 (for 1.5 g/cm³)
- *Code 21*: 20 (for 2.0 g/cm³)
- *Code 30*: 47000
- *Code 31*: 39370
- At the end, push the **COMPUTE** button.

IMPORTANT

In this case you can multiply the density value only by 10 to increase the display resolution, since the input range of the density in codes 20 to 29 is limited to a value of max. 100.

10.2 Calibration

The following step has to be carried out in the evaluation unit of the density measurement LB 350. The preliminary setting of the density measurement has already been completed.

In this step you determine the pulse rate for the average bulk density.

The pulse rate of the density measurement is entered in *code 31*.

As a rule, we do not know if the density is an average density value; therefore, this process has to be repeated with each new filling, parallel to the determination of the moisture pulse rate. From the pulse rates measured, one then has to calculate the mean value.

▶ Overwrite *code 31* with this mean value.

IMPORTANT

Codes 32 to 39 must not contain any further pulse rates for this type of calibration, unless another type of calibration is performed than the one described here.

For bulk densities above 1 g/cm^3, the pulse rate in *code 30* also has to be adapted. The value in *code 30* is obtained by multiplication of the pulse rate in *code 31* with the factor 1.2.

Example: If *code 31* contains a pulse rate of 36000cps, then you have to enter the value 43200 in *code 30*.

▶ Push the **COMPUTE** button to calculate the characteristic curve for the density measurement.

The evaluation unit calculates the coefficients a0 and a1.

The moisture measurement device is ready for operation and can be started by pushing the **MEASURE** button (LED is on if measurement is active).

IMPORTANT

After the calibration, you should write down and archive the values of all parameters.

Enabling the density compensation

To do this, set *code 50* in the moisture measurement to "1".

10.3 Fine Adjustment

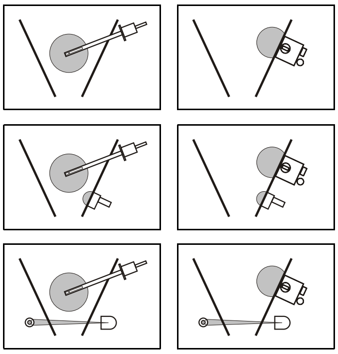
Further optimization of the density compensation can be obtained through trend evaluation of the moisture as compared to the density reading. It would be ideal if no effects on the moisture would be apparent despite varying density.

Recalibration is possible by inclining the density calibration curve around the center. You can do this by changing the pulse rate (*code 30*) for the density value 0.

Example:
The longer the distance *pulse rate at density 0 and pulse rate at average density*, the lower the compensation influence of the density measurement.
The following setting causes a bigger compensation influence:
Code 30: 41000
Code 31: 44000
as compared to the following setting, which causes a smaller compensation influence:
Code 30: 38000
Code 31: 44000
Prerequisite: *Codes 20* and *21* are unchanged for both settings.

Push the **COMPUTE** button to enable this change in the device.

10.4 Code Table

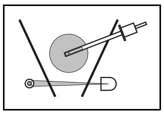
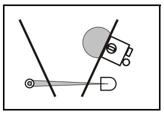


10.4.1 Start Values for Moisture Measurement with Bunker Probe

Berthold moisture measurement LB 350 with density compensation

Tag:		Product:	
Code	Designation	Range	Moisture parameters
00	Password	0-999999	
01	Year	YY	Current year
02	Month / Day	MM.DD	Current date
03	Hour / Minute	SS.MM	Current time
10	Moisture reading		
11	Current pulse rate		
12	Measurement time	s	20
13	Rapid switchover	0/1	0
14	Lower measurement range limit	0-100	0
15	Upper measurement range limit	0-100	Level (10)
16	0-20 mA / 4-20 mA	0/1	0*
17	Lower limit value	0-100	
18	Upper limit value	0-100	
19	Hysteresis	0-10	
20	Moisture 0	0-100	0
21	Moisture 1	0-100	
22	Moisture 2	0-100	
23	Moisture 3	0-100	
24	Moisture 4	0-100	
25	Moisture 5	0-100	
26	Moisture 6	0-100	
27	Moisture 7	0-100	
28	Moisture 8	0-100	
29	Moisture 9	0-100	
30	Pulse rate 0	0-99999	
31	Pulse rate 1	0-99999	
32	Pulse rate 2	0-99999	
33	Pulse rate 3	0-99999	
34	Pulse rate 4	0-99999	
35	Pulse rate 5	0-99999	
36	Pulse rate 6	0-99999	
37	Pulse rate 7	0-99999	
38	Pulse rate 8	0-99999	
39	Pulse rate 9	0-99999	
40	Coefficient a0	0-99999	-25
41	Coefficient a1	± 1.9999	0.1
42	Factor	0-10	1
43	OFFSET	-10 to +10	0
44	(not used)		
45	Test pulse rate	0-99999	0
50	Density compensation?	0 / 1	0
51	Lower measurement range limit		0.5*
52	Upper measurement range limit		0.8*
53	Density measurement value		

*** These values are guide values only and have to be adapted to the respective measurement situation.**

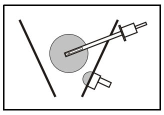
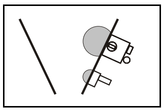



10.4.2 Start Values for Density Compensation with Transmission Method

Berthold density measurement LB 367

Tag:		Product:	
Code	Designation	Range	Moisture parameters
00	Password	0-999999	
01	Year	YY	
02	Month / Day	MM.DD	
03	Hour / Minute	SS.MM	
04	0-20 mA / 4-20 mA	0/1	0
06	Measurement unit	0-3	0
09	Program version		
10	Density reading		
11	Current pulse rate		
20	Time constant	s	20
21	Rapid switchover	0/1	0
22	Lower measurement range limit		0.5*
23	Upper measurement range limit		0.8*
24	Lower limit value		
25	Upper limit value		
26	Hysteresis		
27	Density of carrier liquid		
28	Solids density		
29	Error routine	0	0
30	Background		14000
31	Absorption coefficient		Cs: -0.066 / Co: 0.044
32	Factor		1
33	Offset		0
34	Isotope Am=0 / Cs=1 / Co=2	1 / 2 / 3	
35	Test pulse rate	0-99999	0
36	Measuring path	cm	?
40	Pulse rate 0	0-99999	0
41	Pulse rate 1	0-99999	
42	Pulse rate 2	0-99999	
43	Pulse rate 3	0-99999	
44	Pulse rate 4	0-99999	
45	Pulse rate 5	0-99999	
46	Pulse rate 6	0-99999	
47	Pulse rate 7	0-99999	
48	Pulse rate 8	0-99999	
49	Pulse rate 9	0-99999	
50	Bulk density 0	0.000-5.000	0.65
51	Bulk density 1		
52	Bulk density 2		
53	Bulk density 3		
54	Bulk density 4		
55	Bulk density 5		
56	Bulk density 6		
57	Bulk density 7		
58	Bulk density 8		
59	Bulk density 9		

*** These values are guide values only and have to be adapted to the respective measurement situation.**

10.4.3 Start Values for Density Measurement with Backscattering Method

Berthold density measurement LB 350

Tag:		Product:	
Code	Designation	Range	Moisture parameters
00	Password	0-999999	
01	Year	YY	Current year
02	Month / Day	MM.DD	Current date
03	Hour / Minute	SS.MM	Current time
10	Moisture reading		
11	Current pulse rate		
12	Measurement time	s	20
13	Rapid switchover	0/1	0
14	Lower measurement range limit	0-100	0.5*
15	Upper measurement range limit	0-100	0.8*
16	0-20 mA / 4-20 mA	0/1	0
17	Lower limit value	0-100	
18	Upper limit value	0-100	
19	Hysteresis	0-10	
20	Moisture 0	0-100	0
21	Moisture 1	0-100	0.65*
22	Moisture 2	0-100	
23	Moisture 3	0-100	
24	Moisture 4	0-100	
25	Moisture 5	0-100	
26	Moisture 6	0-100	
27	Moisture 7	0-100	
28	Moisture 8	0-100	
29	Moisture 9	0-100	
30	Pulse rate 0	0-99999	0
31	Pulse rate 1	0-99999	
32	Pulse rate 2	0-99999	
33	Pulse rate 3	0-99999	
34	Pulse rate 4	0-99999	
35	Pulse rate 5	0-99999	
36	Pulse rate 6	0-99999	
37	Pulse rate 7	0-99999	
38	Pulse rate 8	0-99999	
39	Pulse rate 9	0-99999	
40	Coefficient a0	0-99999	
41	Coefficient a1	±1.9999	
42	Factor	0-10	1
43	Offset	-10 to +10	0
44	(not used)		
45	Test pulse rate	0-99999	0
50	Density compensation?	0/1	0
51	Measurement range lower limit		
52	Measurement range upper limit		
53	Density measurement value		

*** These values are guide values only and have to be adapted to the respective measurement situation.**

10.5 Data Table of the Lab Values for Determination of the Calibration Parameters

Sample number	Date	Laboratory moisture	Pulse rate of moisture measurement	Display of moisture measurement	Pulse rate of density measurement

11 Radiation Protection

11.1 Radiation Protection Guidelines

The neutron moisture measurement system LB 350 uses *radioactive sources*.

Local regulations controlling the use of radioactive sources must be followed. This is the law.

Installation, dismantling, relocation, maintenance, testing involving the radioactive source, or its shielding shall ONLY be performed by trained and specifically licensed persons.

11.1.1 Sources

The sources are part of the neutron moisture measurement system. Depending on the type of source, they are located in the:

- Neutron probe LB 6666 (*AmBe-241*)
- Neutron probe LB 6669 (*AmBe-241*)
- Shielding LB 7410 for surface moisture measurement (*AmBe-241)*
- Shielding backscatter chamber for density compensation (*Cs-137*)
- Shielding LB 744x for density compensation (*Cs-137* or *Co-60*)

Radioactive sources for industrial applications are always "encapsulated radioactive substances" which are tightly welded into a sturdy stainless steel capsule, so that the radioactive substance cannot leak out. Contamination is therefore ruled out. Moreover, any activation of the product being measured by the sources used is not possible for physical reasons.

The following radiation sources are used for moisture measurement:

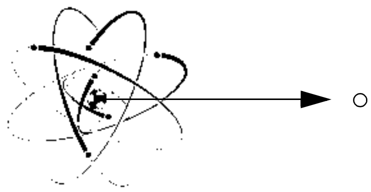
AmBe-241 emits neutrons and Gamma radiation. It is supplied as a point-shaped source. The half-life period is approx. 432 years.

Co-60 emits Gamma radiation with an energy of 1.17 or 1.33 MeV. It is supplied as a point-shaped source. The half-life period of Co-60 is 5.27 years.

Cs-137 emits Gamma radiation with an energy of 0.660 MeV. It is supplied as a point-shaped source. The half-life period is about 30 years.

11.1.2 Neutron Radiation (n)

Neutron radiation is a particle radiation, just like α- and β-radiation. In case of the sources used here, the fast neutrons are generated through bombardment by light nuclei (Beryllium) with α-radiation (consisting of Am-241) and the initial energy can be up to 12 MeV. Since these are electrically neutral nuclear particles, the interaction with other substances is lower and the radiation is more penetrating and harder to shield.



Neutron (n)
(nuclear particle)

The interaction with matter is dependent primarily on the energy (this corresponds to the velocity) and is based on the scattering on atomic nuclei and on the capture by absorption. In fast neutrons, scattering processes which proceed in accordance with the laws of elastic collision in mechanics dominate. The ionization processes do not occur immediately, but are generated by excitation states and exchange processes.

Since a neutron has about the same mass as a hydrogen nucleus, it is strongly scattered by heavy elements, without being subject to significant energy loss.

On the other hand, neutrons colliding with light hydrogen nuclei emit about half of their energy and, therefore, they are decelerated after a short time (after approx. 18 collisions) to slow (thermal) velocity, which corresponds to the Brownian molecular movement.

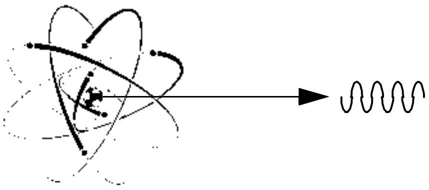
Materials with a high hydrogen content are needed as shielding material, for example water, paraffin or plastic materials, along with materials with high capture cross section for neutrons, e.g. boron or lithium.

The damaging effect of neutron radiation on living body cells can be caused either by external irradiation or by internal exposure after incorporation.

11.1.3 Gamma Radiation (γ)

Gamma radiation is not a particle radiation, but high-energy photons, i.e. electromagnetic radiation with a very high frequency. Like radiowaves and microwaves or light, it is emitted in energy quanta and has the same velocity of propagation and is subject to the same laws of propagation.

Contrary to particle radiation, one cannot specify a maximum range for electromagnetic wave radiation. Since photons have no electrical charge and no rest mass, they do not interact strongly with other materials. Therefore, they have a relatively large penetration power.



The interactions with other materials is the higher, the higher the atomic mass, so that materials with a high specific weight are particularly suitable as shielding material. Heavy metal, e.g. lead, is preferably used as shielding material for γ-radiation.

The interaction is caused by the superimposition of three effects:

Photo effect

The photo effect occurs especially for energies less than 0.1 MeV. An atom absorbs the photon by transferring all energy to an orbital electron which in turn looses its kinetic energy through excitation and ionization.

Pair formation effect

The pair formation effect occurs in the higher energy range at above 1 MeV and dissipates the photon in the electrical field of the atomic nucleus. Its energy is transferred to the absorber material.

Compton effect

The Compton effect occurs particularly in the medium energy spectrum and scatters the photon at the outer electron shell which, at the same time, results in a loss of energy. The process is repeated several times until in the lower energy ranges the energy is released by the photo effect. Interactions due to the Compton effect are - with the γ-sources that are typically used in technical applications - mainly relevant for the calculation of the shielding effectiveness.

On passage through matter, the photo, the Compton and the pair formation effect superimpose each other. The γ-radiation is absorbed or scattered as a whole and a consolidated attenuation coefficient (ϕ) can be given which at an absorber thickness (d) expresses the general law of attenuation as follows:

$$\phi = \phi_0 \times e^{-\mu \times d}$$

This formula includes the original and the attenuated radiation field. The relationships based on this law of attenuation are the basis for all calculations of the absorption of sources.

The damaging effect of γ-radiation on living body cells can be caused either by external irradiation or by internal exposure after incorporation due to its relatively high penetration power.

11.1.4 Installation of Shieldings

CAUTION

Very important! Please observe the radiation protection regulations applicable in your country and the radiation protection guidelines in this chapter.

CAUTION

Radiometric measuring devices utilize radioactive substances which are manufactured in compliance with federal regulations and which are protected by suitable shieldings. Careful conformance to these regulations ensures that no hazard exists for persons using the devices. Working with these measuring devices is, therefore, only permitted under the supervision of the Radiation Safety Manager. All other persons working with these devices have to be instructed accordingly.

CAUTION

The shielding with the radioactive source is delivered in a box in compliance with the regulations concerning the transportation of radioactive substances. Take the shielding out of the box just prior to installation. Up to that time, store it in a location that is guarded against unauthorized access.

CAUTION

Using the drawings of the shielding and taking into account the situation at the measuring site, carefully install the mounting brackets and supports. Make sure that the mechanical stability of the mounting devices matches the weight of the shielding. Damage to the shielding must be avoided.
The shielding has to be installed as close to the vessel as possible.
Control areas, if there are any, have to be identified and, if necessary, guarded off.

How to determine the radiation exposure during installation of the shielding is described on page 81 ff.

11.1.5 Source Disposal

In general, each country has a depot for receiving and disposing of radioactive material.

However, if you would like to return radioactive material to us for disposal, the international regulations for transport, labeling and dose rates of the radioactive material have to be complied with, as well as the regulations applicable in each country. It is the full responsibility of the sender to make sure these regulations are complied with. Please keep in mind:

- Dose rate on the surface of the packing:
  < 2000 µSv/h (for the US this value is 1000 µSv/h).
- Dose rate in a distance of 1 m from the surface:
  < 100 µSv/h (this value is valid worldwide).
- Attaching the UN number with the symbol for dangerous cargo on each package.
- Shipping documents with correct description of the contents and accident procedures sheet in conformance with the ADR regulations are required.
- Packaging must comply with the valid ADR regulations.

For all questions on source transport or source disposal please contact our source disposal and repair department at our Bad Wildbad headquarters:

Phone	+49 (0)7081 177 228
Fax	+49 (0)7081 177 330

Please indicate the source number to enable the respective person in charge to quickly identify the source.

In particular, we would like to emphasize the following:

- Radioactive materials and their shieldings must not be damaged in any way and must have a valid seal test certificate. The seal test certificate may not be older than six months at the time of arrival in Germany. An exception is possible if a PTB certificate is available which confirms that the validity of the test dates has been extended.
- If you plan to return radioactive sources with isotope Am-241 or Cm-244, you have to include the *Special Form* certificate.
- It is indispensable that radioactive material that is returned to us is adequately labeled with your name and address.
  If you have received a quotation from us, please include our quotation number as well.
- Radioactive material can be returned only after you have received permission from Berthold Technologies. We would be happy to send you a quotation on the disposal costs to be expected.

- The radioactive material has to be shipped to Bad Wildbad carriage paid. Berthold Technologies does not take over any costs for customs clearance or transport.
- Berthold Technologies has to be informed in advance about the return transport. Radioactive material that is shipped to Berthold without prior notice will not be accepted by Berthold Technologies. Any warehouse expenses will be charged to the supplier.
- A copy of the enclosed notification form sheet and the seal test certificate has to be attached on each shielding. The original has to be included with the shipping papers. The documents have to be send in advance via telefax to our source disposal and repair department.

On the following page you find a form sheet you may use to return sources or shieldings to the manufacturer.

Notification Form

FOR DISPOSAL OF RADIOACTIVE MATERIALS

Company / Sender:	Person responsible:
Complete address:	Telephone no.:
Postal code / Town:	Country:

Source No.	Isotope	Activity mCi	Activity MBq

- ❑ Source will be returned for disposal
- ❑ Other instructions (please complete).

……………………………………………………………………………………………….

……………………………………………………………………………………………….

……………………………………………………………………………………………….

- ❑ Shielding may be disposed off
- ❑ New sources to be inserted in the shielding(s) according to sender's order no: ………………………………/ Our order confirmation no.
- ❑ Shielding to be returned empty to sender

❑ Shielding to be returned to sender after repair
Sender's repair order no: ………………………………/ Our order confirmation no.

❑ Return of a shielding on loan from sender
Sender's order no: ………………………………/ Our order confirmation no.

❑ Any other instructions or remarks:

…………………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………

The sender hereby declares that:	a) Sources and shieldings are not contaminated.
	b) The material to be returned has been packed and labeled according to the regulations (see ADR)

Place and Date:	*Signature and Title:*

11.2 Radiation Protection

11.2.1 General Information and Guidelines

In order to prevent adverse health effects caused by working with radioactive substances, limits for the maximum permissible radiation exposure of operating personnel have been agreed upon on an international level. Appropriate measures in designing the shieldings and arranging the measuring system at the measuring site will ensure that the radiation exposure of the personnel will remain below the maximum permissible value of 1 mSv (100 mrem) per year.

To ensure safe operation and compliance with the legal regulations, the company has to appoint a Radiation Safety Manager who is responsible for all questions relating to radiation protection. He will monitor handling of the radiometric measuring system and, if necessary, formalize the safeguards and any special precautions applicable to a given establishment in formal procedural instructions, which in special cases may serve as a basis for radiation protection guidelines. These may stipulate that access to the vessel shall only be permitted after the useful beam is shielded. Radiation protection zones outside the shielding must be - if they are accessible - marked and guarded. These instructions should also include checks of the shutter device of the shielding and actions in case of accidents - such as fire or explosion. Any special event has to be reported to the Radiation Safety Manager immediately. He will then investigate any damage and immediately take suitable precautions if he detects defects that may adversely affect the safe operation of the system.

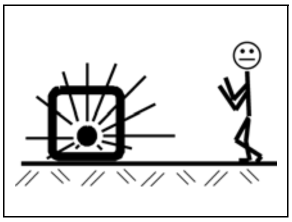
The Radiation Safety Manager has to make sure that the provisions of the Radiation Protection Regulations are observed. In particular, his duties include instructing the staff on the proper precautions when working in the vicinity of radioactive substances.

Radioactive sources that are no longer in use or have reached the end of their service life must be returned to the national radioactive waste disposal center or to the manufacturer.

Generally, every member of staff should endeavor to minimize any radiation exposure - even within the permissible limits - by careful and responsible action and by observing certain safety standards.

The total sum of the radiation dose absorbed by a body is determined by three factors. On the basis of these factors, certain fundamental radiation protection rules can be derived:

1. Distance

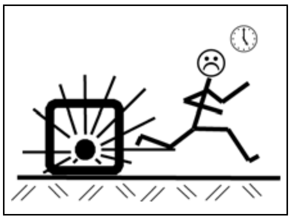


This means the distance between the radioactive source and the human body. The radiation intensity (dose rate) decreases - like light - in proportion to the square of the distance, i.e. doubling the distance to the source reduces the dose rate to one quarter.

Conclusion:

When handling radioactive substances, maximum distance to the source should be maintained. This is especially true for persons that are not directly involved in this work.

2. Time

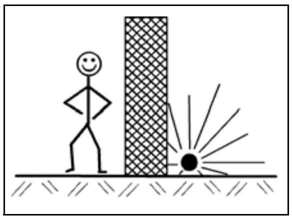


The total time a person stays in the vicinity of a radiometric measuring system and the body is exposed to radiation. The effect is cumulative and increases, therefore, with the duration of the radiation exposure.

Conclusion:

Any work in the vicinity of radiometric measuring system must be prepared carefully and organized such that it can be carried out in the shortest time possible. Having the proper tools is of particular importance.

3. Shielding



The material surrounding the source provides the shielding effect. As the shielding effect depends, following an exponential function, on the product of thickness multiplied by the density, it follows that material with a high specific weight are used for shielding purposes. The device designer usually calculates suitable dimensions.

Conclusion:

Before mounting or dismounting the shielding, make sure that the radiation exit channel is *locked* in the closed position.

DANGER

Do not remove the source from the shielding!

11.2.2 Installation of the Shielding

Safety instructions

To keep the radiation exposure of the assembling personnel as low as possible, only licensed personnel who have been trained on how to handle radioactive substances are allowed to assemble or disassemble the shielding with the source. The work is performed according to the instructions and under the supervision of the Radiation Safety Manager. It has to be ensured that the lock of the shielding is closed and secured, so that no unshielded radiation can exit. Make sure the shielding is not modified or damaged.

IMPORTANT

Depending on the operation conditions, the function check has to be repeated at appropriate intervals, and at least every six months.

Radiation exposure during installation of the shielding

The shieldings of measuring systems are usually designed such that the limit of the control area is in a given distance (in most cases less than one meter) around the shielding, and it does not matter whether point or rod sources are being used and how high their activity is. A simplified calculation of the radiation exposure during installation of the shielding is possible with sufficient accuracy using the dose rate data printed on the type plate, measured in 1 m distance from the shielding. The radiation exposure D can be calculated according to the following formula:

D (µSv) = DR (µSv/h) x t(h) x 4

D = accumulated dose during installation
DR = dose rate on the type plate of the shielding
t = time needed for the installation with shielding
4 = safety factor

If the work process is prepared well, you may expect a working time of less than 20 minutes to perform work such as installation of the shielding or operating the shutter.

Calculation example

DR = 3 µSv
t = 20 min (1/3h)

D = 4 x 1/3 x 4 = 3 µSv/h

If we compare this dose with the permissible annual dose of 1 mSv for persons who are not exposed to radiation on their job, this work may be carried out 250 times per year by one and the same person.

see also chapter 14.2.2.

11.2.3 Radiation Dose Calculations

When preparing work on radiometric measuring systems, it is important to pre-calculate the radiation exposure to be expected, since this has consequences on the required safety precautions.

The expected radiation exposure can be calculated quite easily and with sufficient accuracy, provided you know the isotope and the activity of the source used. You can take this information from the source documentation, or from the type label on the shielding.

11.2.4 Calculation of the Radiation Exposure for Gamma Sources (Cs-137, Co-60)

The radiation exposure to be expected for a shielded source is calculated as follows:

Formula

$$\text{Dose } D = \frac{A \times k \times T}{r^2 \times s}$$

A is the activity of the source and k the respective specific Gamma radiation constant (see table below). The distance from the measuring point to the source is r and the duration of stay at this point is T; s is the shielding factor of the shielding used. It is listed in the shielding brochure or can be calculated. It is listed in the shielding brochure or can be calculated. s = 1 when calculating the dose rate for work with an unshielded source.

Nuclide	K	Dimensions
Co-60	0.35	$\frac{\mu Sv \times m^2}{h \times MBq}$
Cs -137	0.09	

Calculation example

The dose in a distance of 50 cm of a Co-60 source with an activity of 350 MBq and a time of 30 minutes in this distance has to be calculated. The source is installed in a shielding with a shielding factor of 30:

$$D = \frac{350 MBq \times 0.35 \mu Sv \times m^2 \times 0.5 h}{(0.5 m)^2 \times h \times MBq \times 30} = 8.2 \mu Sv$$

11.2.5 Calculation of the Radiation Exposure due to Neutron Sources (AmBe-241)

Shielding of neutron radiation

Neutron radiation is shielded by hydrogen-containing products, e.g. water, paraffin or polyethylene; the fast neutrons are decelerated to thermal energy by the elastic collisions with the hydrogen nuclei.

The thermal neutrons then have to be shielded by additional material, such as cadmium or boron, which have a high capture cross section for thermal neutrons.

Today, shielding and storage containers for neutron probes are typically filled with boron treated polyethylene (addition of boron approx. 2%) and they are dimensioned such that no accessible radiation protection areas are created outside the shielding.

Calculation of the maximum neutron dose rate:

From the neutron emission N_e, the neutron flow density F_D for the distance a [cm] is calculated as follows:

$$F_D = \frac{N_e}{4\pi \times a^2} \quad [n/\ cm^2 \times sec]$$

If we proceed from the assumption that the highest relative biological efficiency has to be expected for all neutrons emitted by an Am-241-Be-source, then we can give the following neutron flow density F_d from derived measurements for a dose rate of 1 µSv/h:

$$F_D = 0,\ 44 \left[\frac{n/\ cm^2 \times sec}{\mu Sv/\ h}\right]$$

Thus, the max. possible dose rate D_I of an AmBe-241 source is:

$$D_I = \frac{F_D}{F_d} \quad [\mu Sv/\ h]$$

Example:

Neutron source: AmBe-241
Activity: 3.7 GBq
Neutron emission: 2.2 * 10^5 n/sec
Searched for dose rate in 1 m distance (100 cm)

$$F_D = \frac{2.2 \text{ ¥ } 10^5}{4\pi \text{ x } 100^2} = \frac{2.2}{1.257} = 1.75 \text{ [n/cm2 x sec]}$$

$$D_L = \frac{F_D}{F_d} = \frac{1.75}{0.44} = 4 \mu Sv/h$$

The control area limit (3µSv/h) would be in a distance of 115 cm around the *unshielded* source.

11.2.6 Mandatory Shutter Test

This procedure ensures that the shutter mechanism is operating correctly and that when the Closed condition is indicated by the device handle or cylinder, the shutter is closed and the source is completely shielded. This is very important to avoid exposures to radiation if for some reason (such as a broken shaft in a point source shielding) the shutter indication is Closed but the shutter remains open. The USNRC and Agreement States make this a mandatory test to be done at intervals not to exceed 6 months. You may be asked to provide documentation of previously performed tests and a schedule for the next set of tests on your devices.

- ▶ Make sure that the control room has been informed that process information will be interrupted during the test.
- ▶ Measure the pulse rate (via the evaluation unit LB 350).
- ▶ Write down the reading.
- ▶ Move the shutter to the *Closed* position. Write down the reading.
- ▶ Repeat the sequence 5 times, noting the readings each time.
- ▶ Ensure that the shutter moves freely, without binding or sticking.
- ▶ If everything is OK, then archive this test.
- ▶ If there is a failure or you have doubt, notify the Berthold Technologies service department.
- ▶ Document the test, including the date of test, the device model and serial number, test conclusions and your name. A government inspector may ask you for this information.

11.2.7 Leak Test

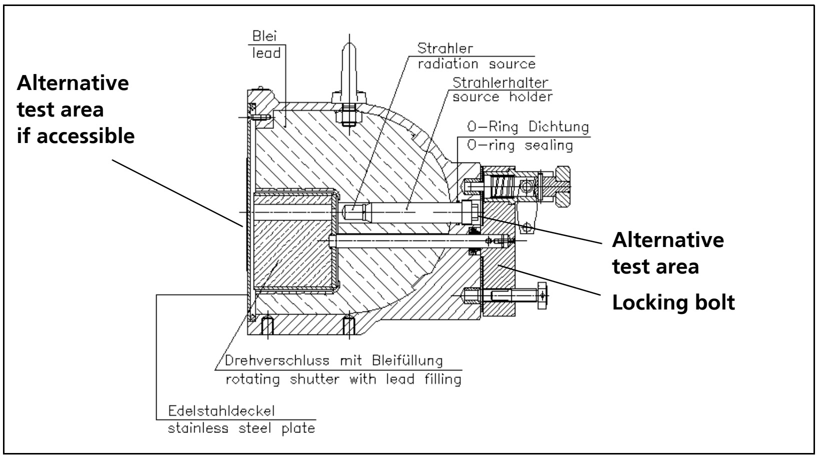
Regardless of the regulatory authority responsible for the sources employed in their territory, regularly recurring leak tests have to be carried out. These tests are usually carried out by the TÜV. The appropriate documents on the source have to be provided in order to carry out this test.

Required Documents

- Inventory of the sources to be tested with information on the previous leak tests
- Source certificate including the following information:
  - Nuclide, activity, purchase date, physical-chemical form
  - Description of capsule and type of sealing
  - Resistance against mechanical and thermal influences or classification of the source design
- Information on location, intended use as well as on the typical operational max. mechanical and thermal stress.
- If the sources are installed in an appliance, a drawing has to be enclosed which clearly shows the position of the source and of all parts that are essential for its protection against external influences. Proposals for the best test method should be available, e.g. through information on alternative test areas and, if necessary, the required manipulations, how the test can be carried out without adversely affecting the workability of the system or appliance.
- Certificate on an acceptance test by the manufacturer.

Wipe test on LB 744X

The head of the source holder and, if accessible, the front sheet metal, may be used as alternative test areas.



Wipe head of source holder:

- ▶ Turn locking bolt to horizontal position.
- ▶ The alternative test area is the head of the visible edge of the source holder.

Wipe sheet metal:

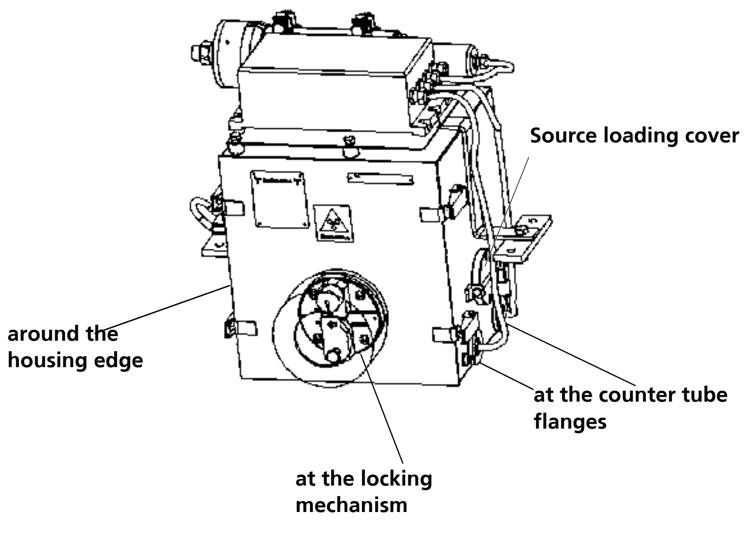
- ▶ Wipe the countersunk screws and around the edge of the plate.

Wipe test on lockable neutron shielding LB 7410

The „interrupted“ housing edges and recesses in the housing are used as alternative test areas. They have to be wiped all around. This is valid for the types delivered up to the year 2005.

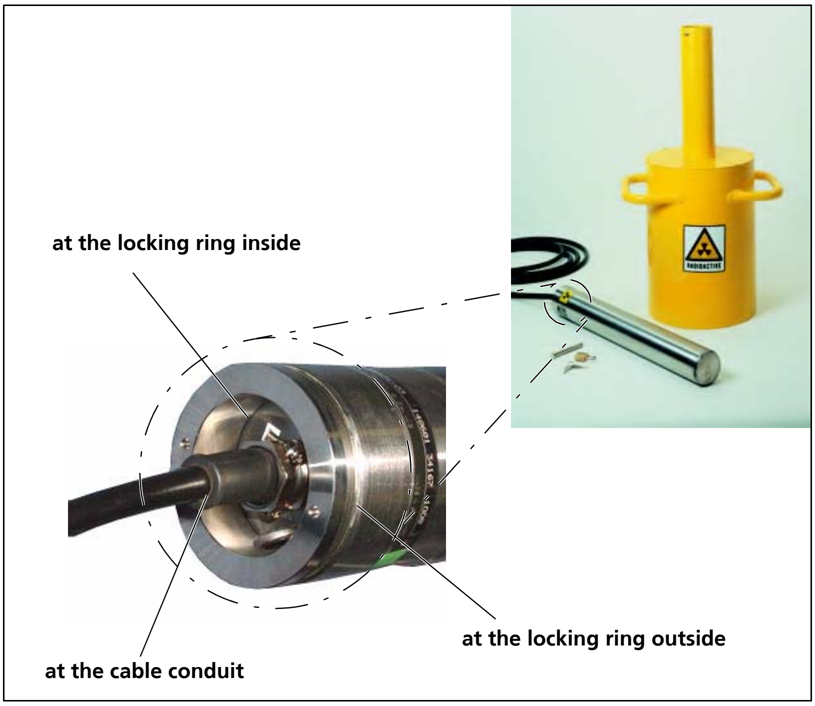
For newer types, which are equipped with a source loading, you have to wipe directly at the source or at its cover. To to this, you have to take off the source loading cover as follows:

- ▶ Turn the locking bolt of the locking mechanism to position closed.
- ▶ Open the lock of the source loading. The source loading is located on the outside above both counter tubes.
  - Open padlock and take it off.
  - Take locking pin out on the side.
  - Unscrew 2 Allen screws M5 at the sealing plug.
  - Pull out sealing plug
- ▶ Turn the locking bolt by 90 degrees in clockwise direction. The round metal cover of the source becomes visible inside the shielding.
- ▶ Wipe around the outer edge of this metal cover.
- ▶ After you have finished wiping, turn the locking bolt back to the *Closed* position again and close the source cover again.



Wipe test on neutron probe LB 6666 and LB 6669

The locking ring at the housing and the cable conduit can be used as alternative test areas.



11.2.8 Safety Measures

When designing the installation of radiometric measuring systems, the possibility that a fire breaks out must be considered. Flammable substances must not be stored in the proximity of radioactive substances. They should be covered and protected properly to prevent a possible spreading of the fire to the radioactive sources. It is mandatory to coordinate all preventive measures against fire with the local authorities, primarily with the fire department, which must be informed about the type, scope and place of application of the radioactive substances used, in order to be prepared in the event of fire.

When devising alarm plans, possible special features of the radiometric measuring systems have to be mentioned; the Radiation Safety Manager to be notified in the event of an emergency has to be included in those plans as well, and also the address and phone number of the regulatory authority.

11.2.9 Protection against Theft

Radioactive substances or facilities containing radioactive substances must be secured against unauthorized use. Fixed installations are, by their nature, protected against unauthorized use.

If facilities working with radiometric measuring systems are taken out of service for a longer or indefinite period of time, the radioactive sources together with their shieldings should be dismantled and secured until the facility is taken into operation again.

Portable measuring systems, on the other hand, have to be protected by keeping them under constant supervision, or, if they are not in operation, by keeping them in a locked room or container which can be guarded against unauthorized access.

This is especially true for low activity test sources which are used, for example, to check the function of dose rate measuring instruments.

In the event that radioactive substances are lost, the Radiation Safety Manager and the regulatory authority have to be notified immediately.

In case of theft, the police must be informed as well.

11.2.10 Accidents, Loss, Damage, Fire, Theft

Remember the principles of health and safety in such situations: time, distance and shielding. In case of one of the above situations:

- Limit access to the area
- Report to BERTHOLD TECHNOLOGIES who will advise what further immediate precautions to take and arrange for quick support from a licensed person.

In case of loss or theft, notify the regulatory authority.

If the sealed radioactive substances are no longer contained, the supervisory authority must be notified immediately and steps taken to ensure that the contamination cannot be dispersed.

Proper handling and disposal of possibly leaking radioactive sources or contaminated parts of the equipment must be coordinated with the supervisory authority.

11.2.11 Malfunctions and Accidents

The Radiation Protection Regulation defines malfunction as an event which for safety reasons prohibits continuation of the operation of the facility.

Malfunction means, that a device necessary to guarantee safe operation of the facility, e.g. the seal of the active radiation beam of the shielding, no longer functions properly.

An accident is an event which could expose persons to a radiation dose which exceeds the permissible limits, or could cause contamination by radioactive substances.

In terms of safety, malfunctions and accidents are very serious events and appropriate steps must be taken immediately to prevent hazards to persons as well as facilities, or to reduce them as much as possible.

It is therefore important that the personnel is aware of preventive measures and is prepared for possible accidents or malfunctions of the facilities, so that dangerous consequences can be ruled out as far as possible by a proper reaction of the personnel.

In any case, the Radiation Safety Manager who checks the situation at site and takes all necessary steps to prevent unnecessary radiation exposure of the personnel must be notified immediately.

The Radiation Safety Manager will then take appropriate measures and will inform the official authority concerned, and, if necessary, get further information from the manufacturer.

The necessary steps should be taken in the following order:

- ▶ Locate source.
- ▶ Check function of shielding.
- ▶ Check effectiveness of shielding by measuring the dose rate.
- ▶ Guard and mark controlled areas.
- ▶ Secure source and shielding.
- ▶ Document the incident and assess possible radiation exposure of personnel.

In case the source capsule is damaged, the following points have to be considered:

- Avoid contamination.
- Handle source with tools (e.g. pincers or tweezers) and put both (source and tool) in a plastic bag.
- Stay behind auxiliary shielding (e.g. concrete, steel, or lead plate).
- Check if vicinity is free of contamination
- Secure radioactive waste properly (deposit at governmental collection site or return to manufacturer).

If the source is leaking and the dose rate might possibly be exceeded, the regulatory authority (e.g. trade board) has to be notified immediately.

In case of an accident or malfunction or any other event which affects the safety, the regulatory authority has to be informed and also, if necessary, the authority in charge of public safety. Please contact Berthold Technologies if you need any further information.

12

Maintenance / Service

⚠ CAUTION

During installation of and service work on the Moisture Meter LB 350, the system and also the relay contacts have to be disconnected from power to ensure that contact with live parts will be avoided.

⚠ CAUTION

The Moisture Meter LB 350 may be installed, serviced and repaired only by trained personnel. Only install fuses which match the rating specified by BERTHOLD TECHNOLOGIES.

The moisture meter LB 350 does not have any parts requiring special maintenance. Only the shutter unit on the shielding of the radioactive neutron source has to be checked for correct function.

12.1 Checking the Shutter Locking Mechanism

To ensure continuous radiation protection, it is very important to check the general condition of the shielding and the shutter locking mechanism at least every six months (see also chapter 11.2.6 on page 83).

⚠ CAUTION

A jammed shutter or other damage to the shielding preventing the proper function have to be reported to the Radiation Safety Manager immediately.

12.2 Checking the Evaluation Unit LB 350

12.2.1 Error Messages

After power on, an automatic self-test is carried out. If an error is detected, the following messages may be displayed:

- Error A ROM error
- Error b RAM error
- Error C RAM decoder error
- Error 5 detector error
- Error 8 clock error

After an error has been indicated, all inputs are blocked until you have pushed the **ENTER** button.

FAULT A, b, C

ROM or RAM faults require replacement of the CPU card LB 3940. These error messages cannot be reset by pushing the **ENTER** button.

ERROR 5

Detector error

This message appears if:

- no pulse rate is displayed, or
- the wrong HV reference value has been displayed.

The fault relay is energized in both cases.

If the error message is acknowledged, but the error is unremedied, then the error message is displayed again after one minute.

ERROR 8

If ERROR 8 is displayed, the measurement is aborted. Check the buffer battery and replace it, if necessary. This fault can also be indicated if the date in *code 02* is entered via the keyboard and it deviates by more than one year from the previous date.
If this fault occurs, the device has to be reset and the parameter data have to be checked and, if necessary, entered again.

12.2.2 Other Errors

Power failure

If the system does not respond when powered up, then you have to check the power supply and the main fuse. In a 19"-rack, the fuse is located on the rear panel, in compact systems inside the connection box.

Check the power supply at the power supply unit. The measurement points can be tapped on the front plate of the power supply unit. To do this, you have to unscrew and flip down the front panel with the display in the 19"-rack. If the device is accommodated in a wall housing, you have to unscrew the 4 screws and take off the front panel with the display.

The following voltages must be available:

0 /+10$V_{ref.}$ ± 2%

+ 5V ± 5%

+ 15V ± 10%

If one of these voltages is not correct, you have to replace the entire power supply.

Reset

If the device is blocked, proceed as follows to reset it (the calibration parameters will be retained):

- Turn the power supply off and wait for approx. 5 seconds.
- Keep the **ENTER** button pushed and turn on the power supply. Wait for "00" to appear on the display.

IMPORTANT

*For a complete reset you have to push the **ENTER** and **CODE** buttons and turn on the power supply at the same time.*

IMPORTANT

All calibration parameters will be lost and have to be entered again.

12.2.3 Malfunctions in the Preamplifier or in the Counter Tube in the LB 7410 or LB 6669

Malfunctions in the preamplifier and the counter tubes can be caused by excessive mechanical or thermal stress. Heavy vibrations or blows and temperatures exceeding 60°C have to be avoided. If necessary, use shock absorbers or a heat insulation.

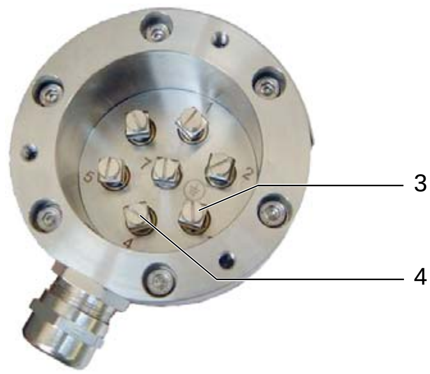
The table below helps you to identify faults in the preamplifier or in the counter tube.

Fault	Probable Cause	Process described in ....
Measurement value drift	Malfunction in the preamplifier or in the counter tube	Measurement of HV reference voltage on page 93 Plateau measurement on page 95
Pulse rate too low	A counter tube is damaged or a cable has bad contact	Check the pulse rate on page 94
No pulse rate	Cable, preamplifier or counter tubes are damaged	Check the preamplifier and the counter tubes on page 98

Measurement of the HV reference voltage

This voltage is generated in the preamplifier LB 2018 or in the LB 6666 probe. The value lies outside the limits if the preamplifier, the counter tube or the HV-cable are faulty. The voltage between detector terminals 3 and 4 typically lies between +3.8V and +4.8V.

The fluctuation must not exceed +/- 0.1V.



Detector terminals

Checking the pulse rate at the LB 7410

If the pulse rate is too small, one of the counter tubes may be damaged, so that only one counter tube will supply pulses. Normally, both detectors have to supply nearly the same pulse rate. To find out which counter tube is faulty, you have to check the pulse rates of each single counter tube.

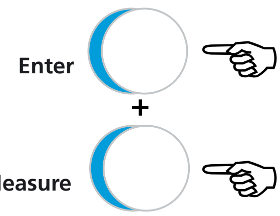
- ▶ Disconnect one of the counter tubes from the HV-divider to get the pulse rate of one counter tube only. To do this, open the HV-divider housing and disconnect one of the counter tubes from the HV-connector (the connector is screwed on using a bayonet mount). Check if the pulse rates of both counter tubes are identical. To avoid measurement errors caused by the product, make sure that the level in the bunker does not change during the measurement.

HV-divider, only a single detector is connected (see also illustration on page 100).

To measure the pulse rate, operate the evaluation unit LB 350 as follows:

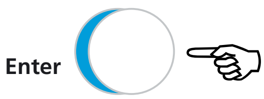
- ▶ Select *code 30*.
- ▶ Push the **MEASURE** button.

The LED goes off and the device is ready to read the counting pulses.



- ▶ Push the **ENTER** and **MEASURE** buttons at the same time.

The "Measure" LED is on and the respective pulse rates are read. Wait for approx. 60s.



- ▶ Stop the pulse rate measurement by pushing the **ENTER** button. Now read off the pulse rate on the display.
- ▶ Repeat this step with the second counter tube and compare both pulse rates.

Plateau measurement

If no pulse rate is available yet, but the measurement value is drifting, you have to check the function of the preamplifier and the counter tubes by means of a plateau measurement.

To this end, you have to record a plateau curve. You have to record the pulse rate at different reference voltages.

IMPORTANT

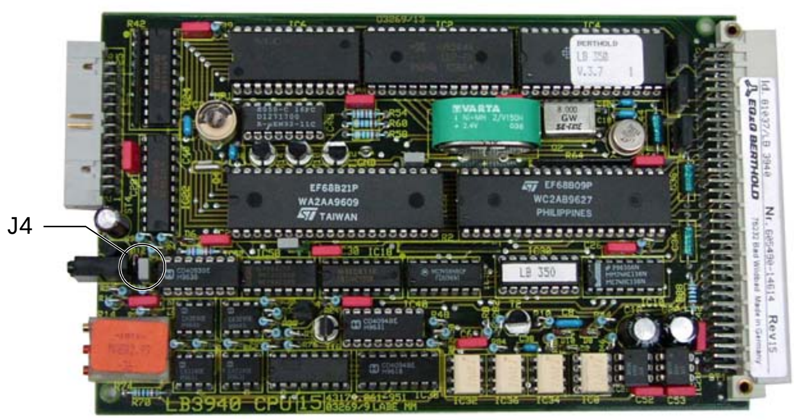
Make sure the level in the bunker does not change during the plateau measurement.

Preparation

- ▶ Remove the front cover of the evaluation unit LB 350.

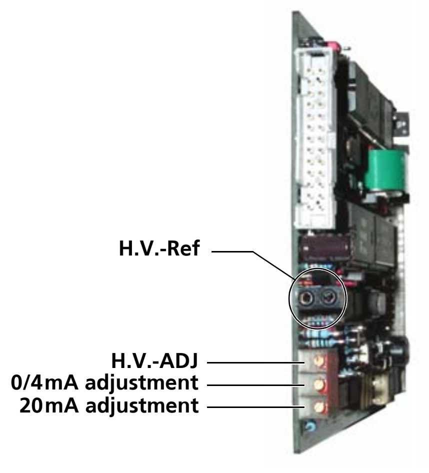
LB 350 with open front cover

- ▶ Close the jumper J4 on the CPU card LB 3940. This will set the HV control to manual voltage.



CPU card LB 3940

- Connect a DC voltmeter to the test socket identified as H.V.-REF in the illustration below. There, you measure a HV reference voltage between 2 to 5 VDC. This HV voltage can be changed using the potentiometer H.V.-ADJ.
- Disconnect one of the counter tubes by disconnecting the HV-connection of the respective counter tube in the HV divider housing from the Y-connector.

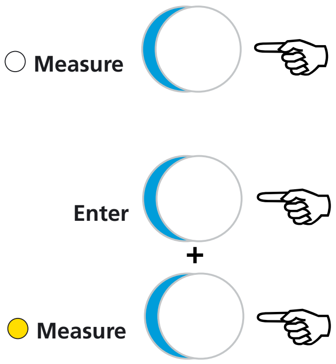


CPU card LB 3940

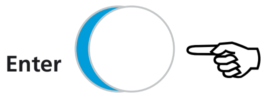
Recording the plateau

- Set the measurement device to *code 30*.

Recording the measurement values



- Push the **MEASURE** button, so that the LED next to the button is off.
- Now change the reference voltage to 3V using the potentiometer H.V.-ADJ.
- Push the **ENTER** and **MEASURE** buttons at the same time. The **MEASURE** LED is on, the pulse rate is read in and averaged. Wait for measurement value to become stable (approx. 60 s).

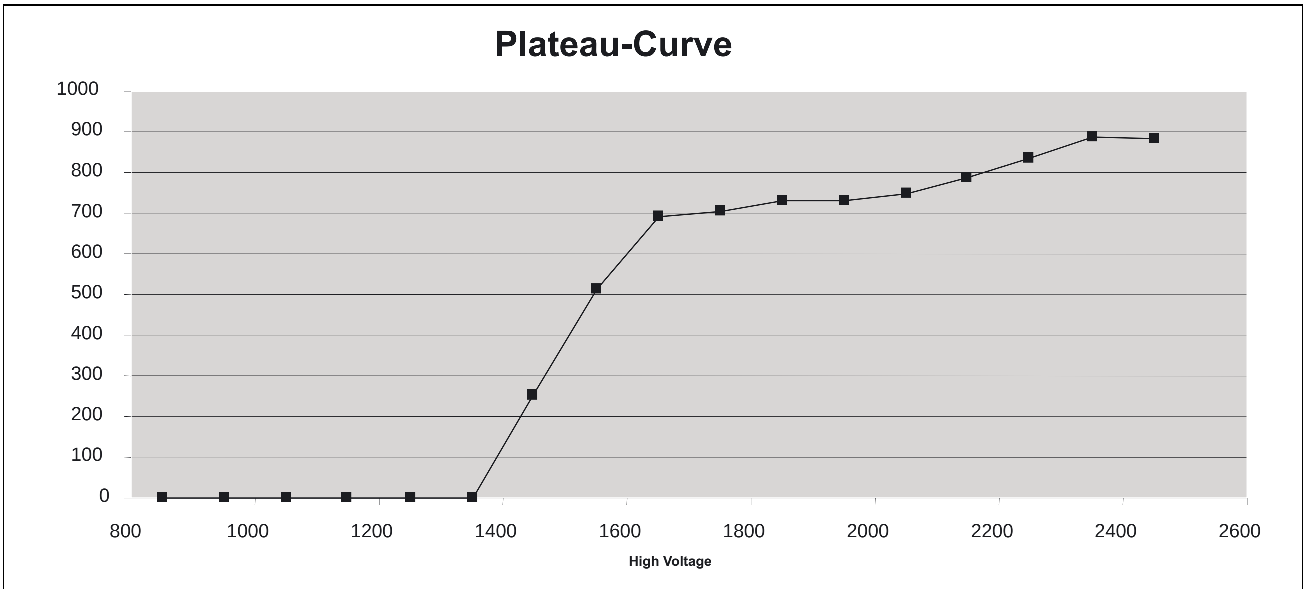


- Stop the reading-in by pushing the **ENTER** button.
- Read off the pulse rate on the display and draw the curve as a function of the HV-reference voltage.
- Using the potentiometer H.V.-ADJ., change the reference voltage in steps of 0.2V (left turns means increasing voltage).
- Repeat the process described starting with „Recording the measurement values“ until you have reached 5V.

The curve drawn onto an x/y graphic must have a clear plateau. The pulse rate in the plateau may deviate by max. 5% in the range of 0.5V. The operating voltage during automatic operation (jumper J4 open) must lie in the middle of the plateau.

Repeat this process also with the second ^{3}He counter tube.

If the plateau is either too short or too steep, the counter tubes or the preamplifier have to be replaced.



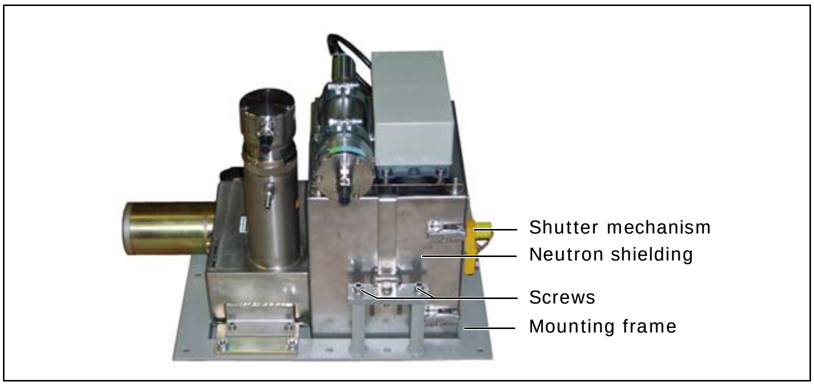
Checking the preamplifier and the counter tubes

If no pulse rate is available, this may have the following cause:

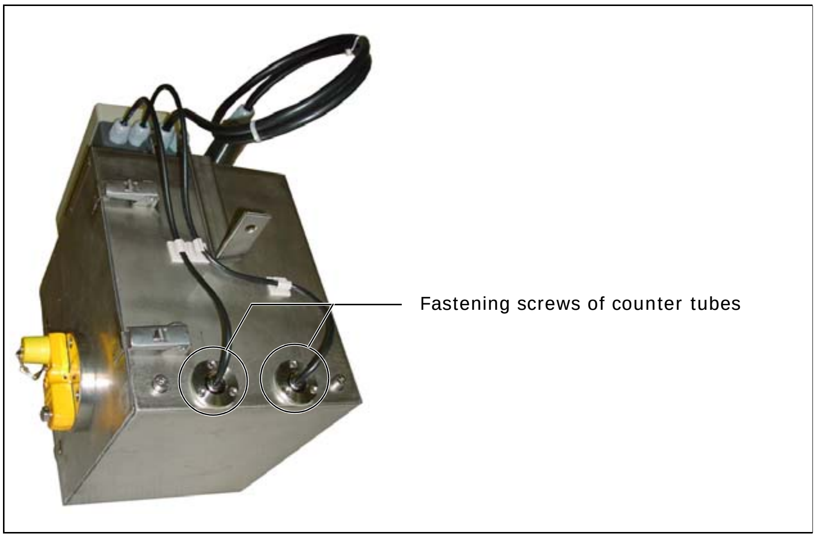
- the power supply of the preamplifier is missing.
- the preamplifier is faulty.
- the detectors are faulty.
- the high voltage is shorted or there is a contact error in one of the high voltage cables or the high voltage cable connector.

Proceed as follows to locate the possible cause:

Preparation Dismantle the counter tubes:



- ▶ Connect the shutter mechanism to the neutron shielding.
- ▶ Remove both fastening screws of the shielding.
- ▶ Remove the neutron shielding from the mounting frame.



- ▶ Open the 6 screws around the counter tube flange and pull the counter tubes from the shielding.

Check The following check is valid for the LB 2018 preamplifier and also for the LB 6666 probe.

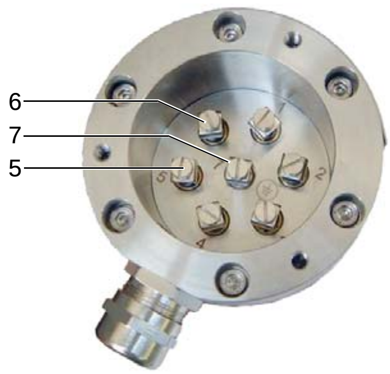
However, with respect to the LB 6666 probe, measurements can be carried out only on the evaluation unit, since it does not have a separate connection box.

- ▶ Connect the 7-wire cable from the evaluation unit to the pre-amplifier.
- ▶ Turn the power supply of the evaluation unit LB 350 on.

The HV setting of the evaluation unit has to be set to manual high voltage 4V.

- ▶ Plug the jumper J4 onto the CPU card LB 3940. Set the HV-Ref. to 4V (see also plateau check on page 95).

Check the supply voltages on the preamplifier:



Connection housing of the preamplifier without cable

The following voltages have to be measured:

between terminal 5 and 7: +15V DC +/- 10%

between terminal 6 and 7: -15V DC +/- 10%

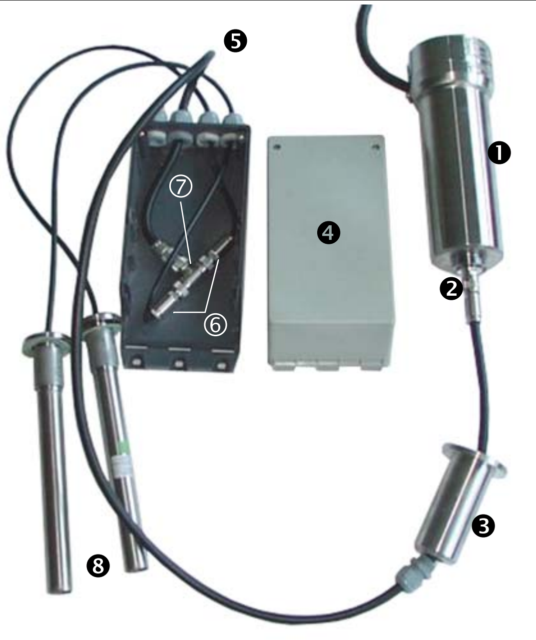
Check the high voltage on the preamplifier:

⚠ **CAUTION**

The preamplifier generates a high voltage of 2000V.

IMPORTANT

Do not dismantle the parts shown in the illustration below from the LB 7410 shielding for these measurements.



❶ Preamplifier LB 2018 (part no.: 80139)

❷ HV connection

❸ Coupling ring

❹ Cover for HV-divider

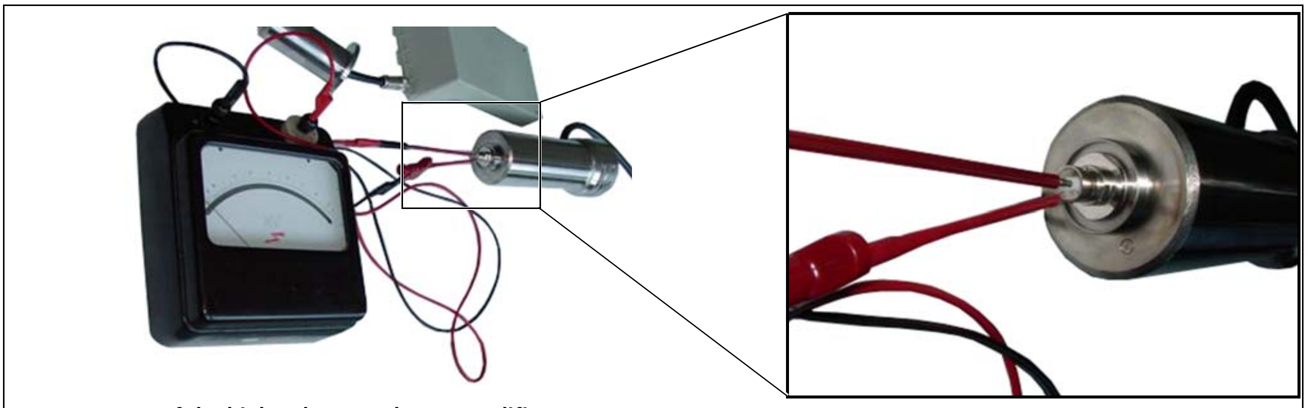
❺ HV divider

❻ HV counter tube connections

❼ HV-Y connections

❽ Counter tubes

- ▶ Disconnect the preamplifier from the power supply.
- ▶ Disconnect the high voltage connection from the preamplifier.
- ▶ Establish the power supply to the high voltage amplifier again.
- ▶ Measure the high voltage at the preamplifier output. The voltage must be 2000VDC ± 10%.

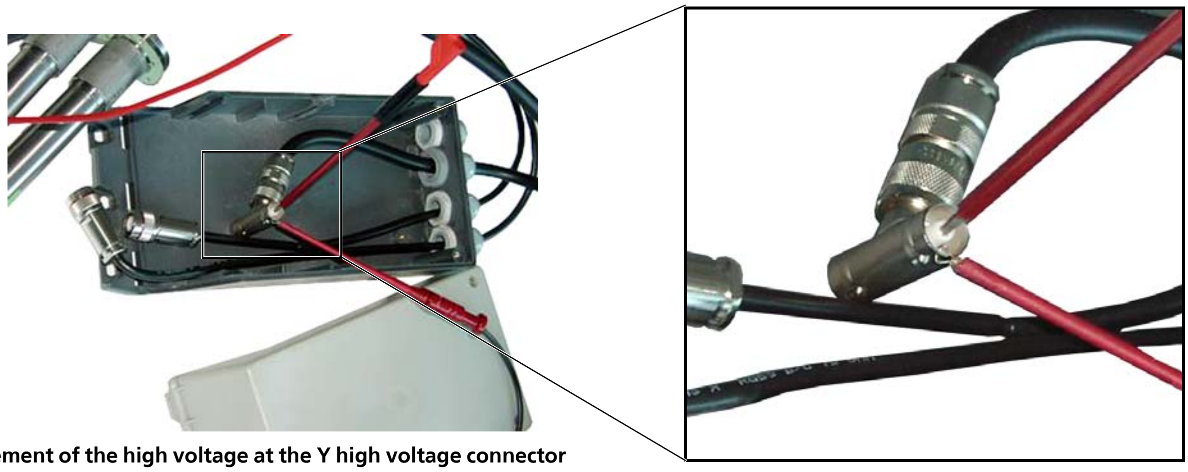


Measurement of the high voltage at the preamplifier output

If no voltage or a different voltage is measured, the preamplifier is faulty and has to be replaced.

Check the supply voltage at the high voltage divider:

- Disconnect the preamplifier from the power supply.
- Connect the high voltage connector again to the preamplifier.
- Disconnect the counter tubes from the Y-HV connector.
- Establish the power supply to the high voltage amplifier again.
- Measure the high voltage at the Y high voltage connector. The voltage must also be 2000VDC ± 10%.

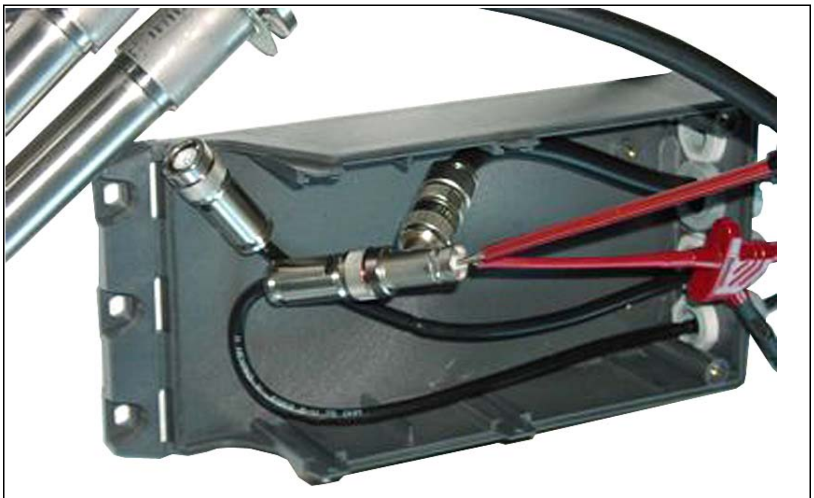


Measurement of the high voltage at the Y high voltage connector

If no voltage or a different voltage is measured, the Y high voltage connector is faulty and has to be replaced.

Check the supply voltage with connected counter tube:

- Disconnect the preamplifier from the power supply.
- Connect a counter tube to the Y-connector.
- Establish the power supply to high voltage amplifier again.
- Measure the high voltage at the Y high voltage connector. The voltage must also be 2000VDC ± 10%.
- Disconnect the preamplifier from the power supply.
- Disconnect the counter tube and connect the other one.
- Establish the power supply to high voltage amplifier again.
- Measure the high voltage at the Y high voltage connector. The voltage must also be 2000VDC ± 10%.



Measurement of the high voltage with connected counter tube

If no voltage or a different voltage is measured at one of the counter tubes, the counter tube is faulty and has to be replaced.

Dismantling the electronics from the LB 6666 probe

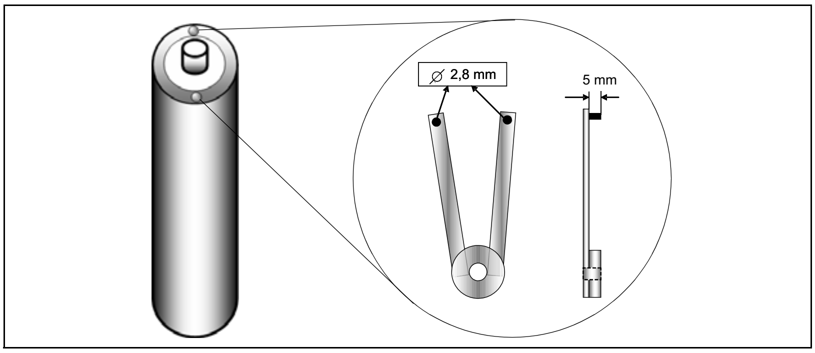
If a fault in the probe is detected, you have to return the probe electronics to BERTHOLD TECHNOLOGIES for repair. Please do not return the source, which is also included in the probe.

Proceed as follows to dismantle the electronics from the probe:

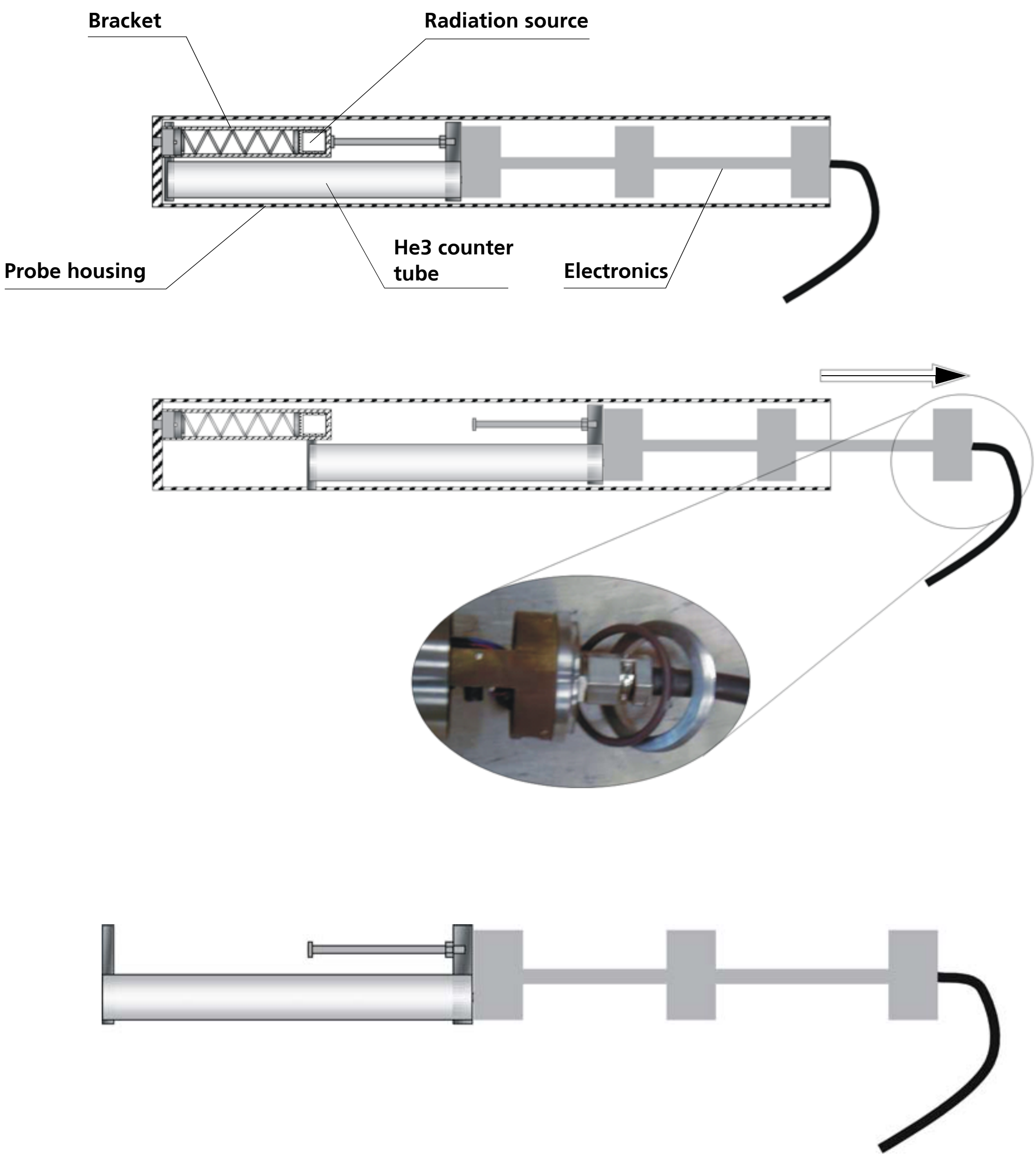
ATTENTION

During dismantling, leave the probe in the shielding container to ensure radiation protection.
After you have dismantled the electronics, leave the probe housing in the shielding and keep the shielding in a locked room.

- To be able to open the locking ring on the probe, you have to raise the probe slightly by means of the cable in the shielding.
- Open the probe using a face spanner.



▶ Pull the electronics out of the probe.



Dismantling the electronics from the LB 6666 probe

Adjusting the current output on the evaluation unit LB 350

With the potentiometer 0/4 mA you can adjust the lower and with the potentiometer 20 mA the upper value of the current output on the CPU card LB 3940 (see illustration on page 96).

You have to use the test pulse generator *code 45* for the adjustment. In the test pulse generator you have to enter the respective pulse rate to simulate the upper or lower end of the measurement range.

The pulse rates can be calculated using the following formula:

$$I = \frac{F - C40}{C41}$$

I: Pulse rate
F: Moisture reading
C40: Offset of code 40
C41: Factor of code 41

Example:

Measuring range: 0 ... 10%

Code 40: -10

Code 41: 0.1

After application of the above formula, we calculate the following pulse rates:

at 0%: 100 cps

at 10%: 200 cps

If you enter 100 cps in *code 45*, 0% moisture is displayed.

If you enter 200 cps in *code 45*, the measurement device indicates 10% moisture.

To reduce the display inertia, you can stop the measurement and then start it again.

Thus, the measurement value will be displayed correctly right away, without having to approach the final value slowly via the time constant.

IMPORTANT

After the adjustment, make sure to turn off the test pulse generator again by entering "0".

13 Technical Data

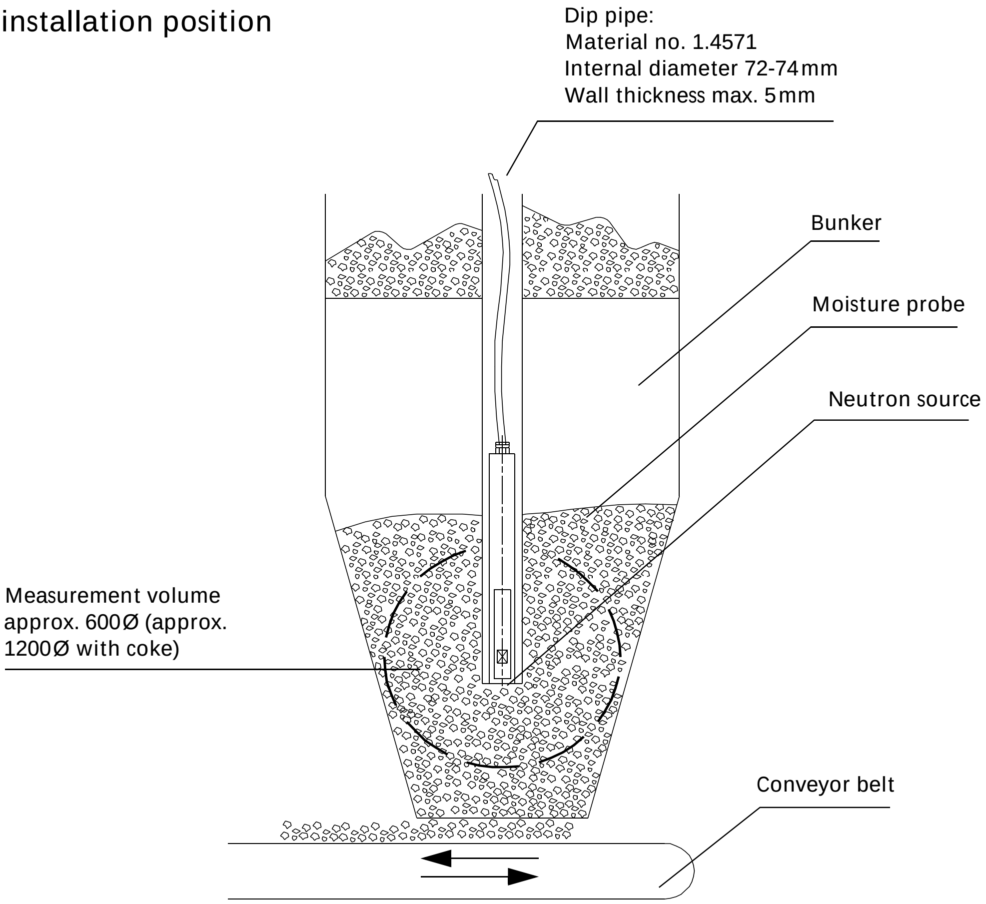
Evaluation unit LB350	
Version LB 350-1	Aluminium wall housing, IP 54, weight approx. 10 kg
Version LB 350-2	19'' rack, 3 rack units, weight approx. 14 kg
Version LB 350-3	19'' rack, 3 rack units, accommodating 2 measurement channels for moisture-density-compensation, weight approx. 19 kg
Power supply	AC voltage: 250/230/125/24 VAC DC voltage: 24 VDC (18 - 36 VDC)
Power consumption	max. 25 mA
Operating temperature	0°C to +50°C (273K to 323K)
Storage temperature	-40°C to +70°C (233K to 343K)
Analog output	Moisture signal: 0/4 - 20mA, insulated, load max. 500Ω
Detector connection	7-wire, supply (±15VDC) and pulse line on separate wires
Digital input	Measurement value „Halt“ through external contact closure
Digital outputs	3 relay contacts for: collective error message, limit value Max, limit value Min., load capacity max. 250VAC/2A non-inductive
Parameters	Setting via code numbers
Operation	Membrane keypad with 6 push buttons
Display	Max. 5 digits
Detectors (General Data)	
Counter tube	^{3}He-counter tube, automatic drift stabilization
Operating temperature	-20 to +50°C (253K to 323K)
Storage temperature	-40 to +70°C (233K to 343K)
Housing	Stainless steel
Cable	7x1.5 mm^2, screened, max. cable length: 1400 m
Moisture bunker probe LB6666	
Type LB 6666-1	3.7 GBq (100mCi) AmBe
Type LB 6666-2	11.1 GBq (300mCi) AmBe
Protection type	IP 65
Moisture bunker probe LB6669	
Type LB 6669-1	3.7 GBq (100mCi) AmBe (counter tube and preamplifier separate)
Type LB 6669-2	11.1 GBq (300mCi) AmBe (counter tube and preamplifier separate)
Protection type	IP 65
Surface moisture probe LB7410	
LB 7410-13	Lockable surface neutron shielding with 2 counter tubes, housing: stainless steel, weight approx. 50 kg
LB 7410-24	same as LB7410-13 but with pneumatic lock, weight approx. 55 kg
LB 7410-44	same as LB7410-13, in fire-proof version, weight approx. 90 kg
LB 7410-55	same as LB7410-44 but with pneumatic lock, weight approx. 95 kg
Source for LB7410	3.7 GBq (100mCi) AmBe or 11.1 GBq (300mCi) AmBe
Density compensation for transmission	
Detector	Sz5 D1 50/50 scintillation counter with crystal 50x50
Source	Cs-137 or Co-60, depending on version
Shielding	LB7440 or LB7442
Density comp. for backscatter radiation	
Detector	Sz AR 1 44/5 scintillation counter with crystal 50x50
Source	Cs-137 (30mCi)
Shielding	Lockable shielding with stainless steel housing

14 Technical Drawings

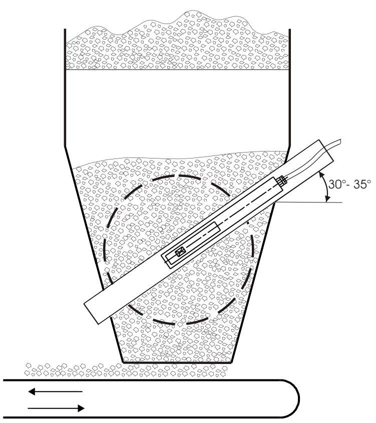
14.1 Bunker probe

14.1.1 Installation version 1

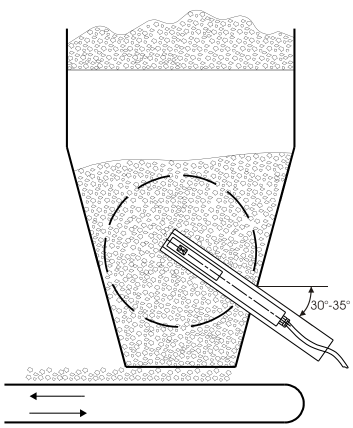
Vertical installation position



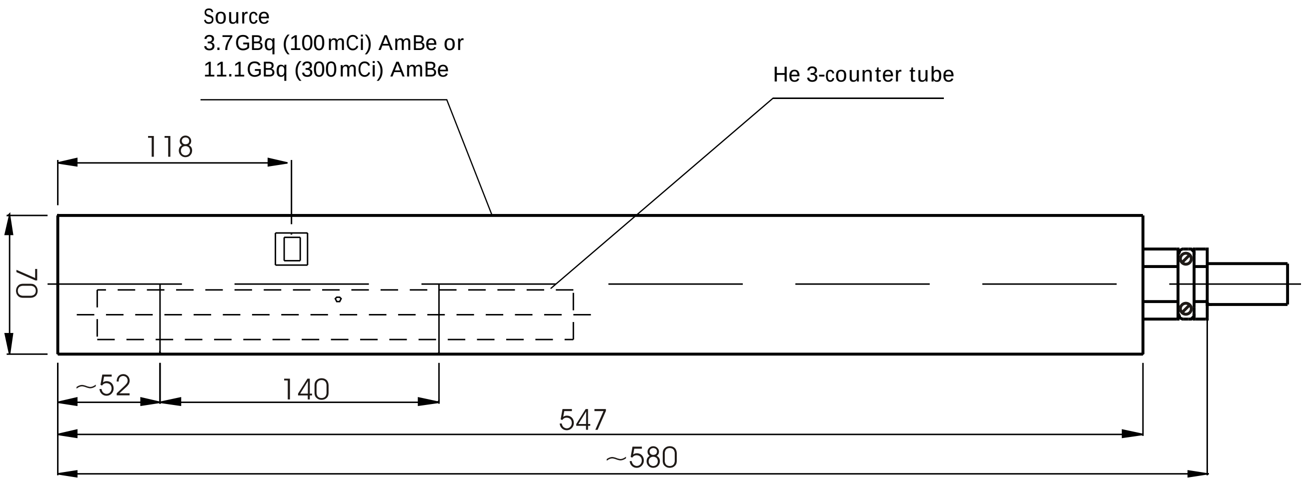
Moisture probe installed inclined



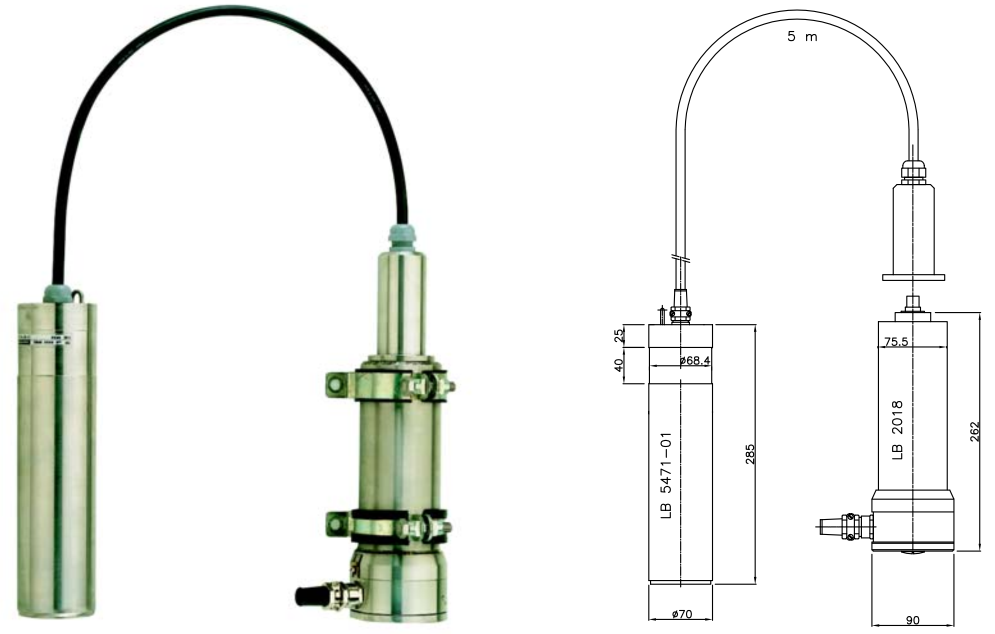
Installation with end-to-end dip tube



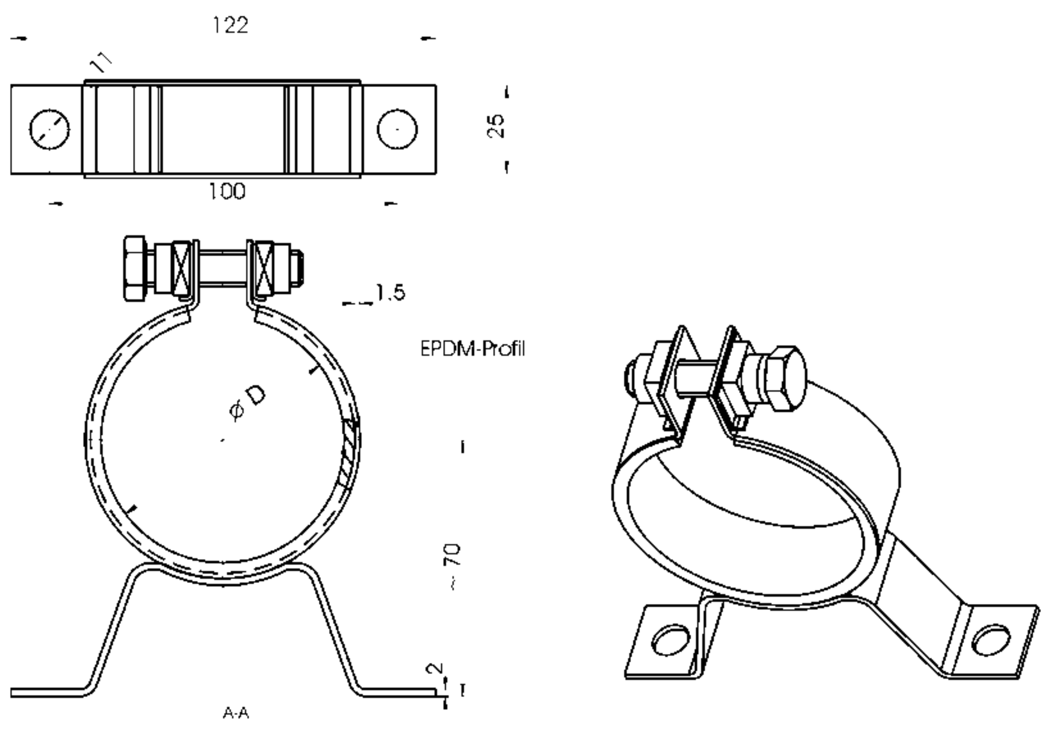
14.1.2 Moisture bunker probe LB 6666



14.1.3 Moisture probe LB 6669

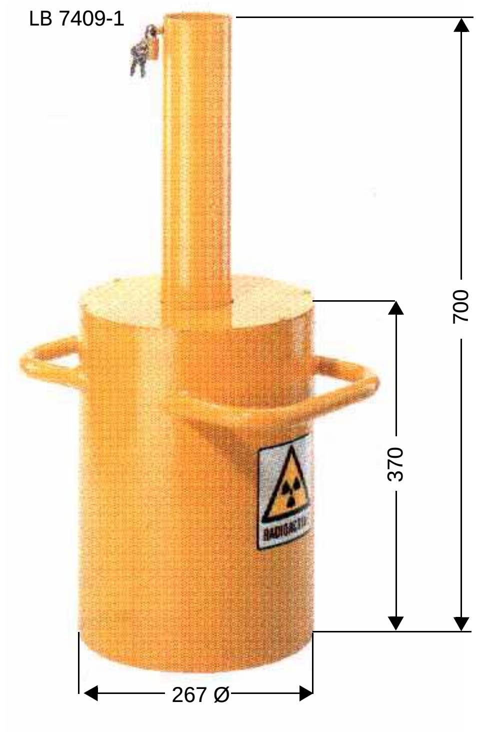


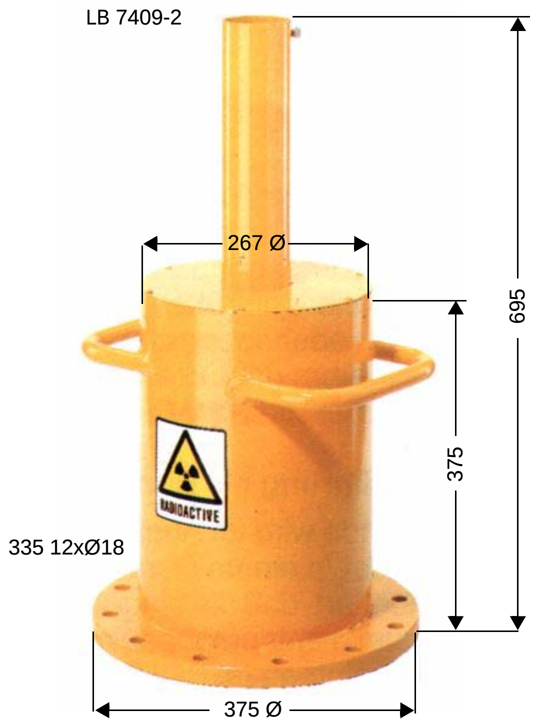
Fixing clamps for preamplifier LB 2018

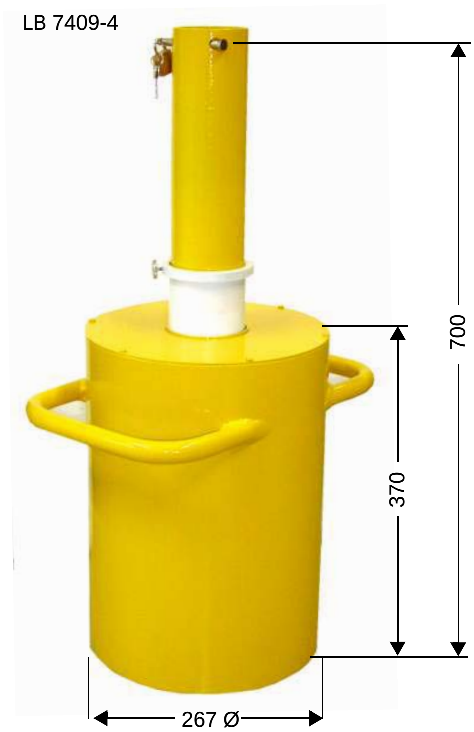


14.1.4 Shielding and transport vessel

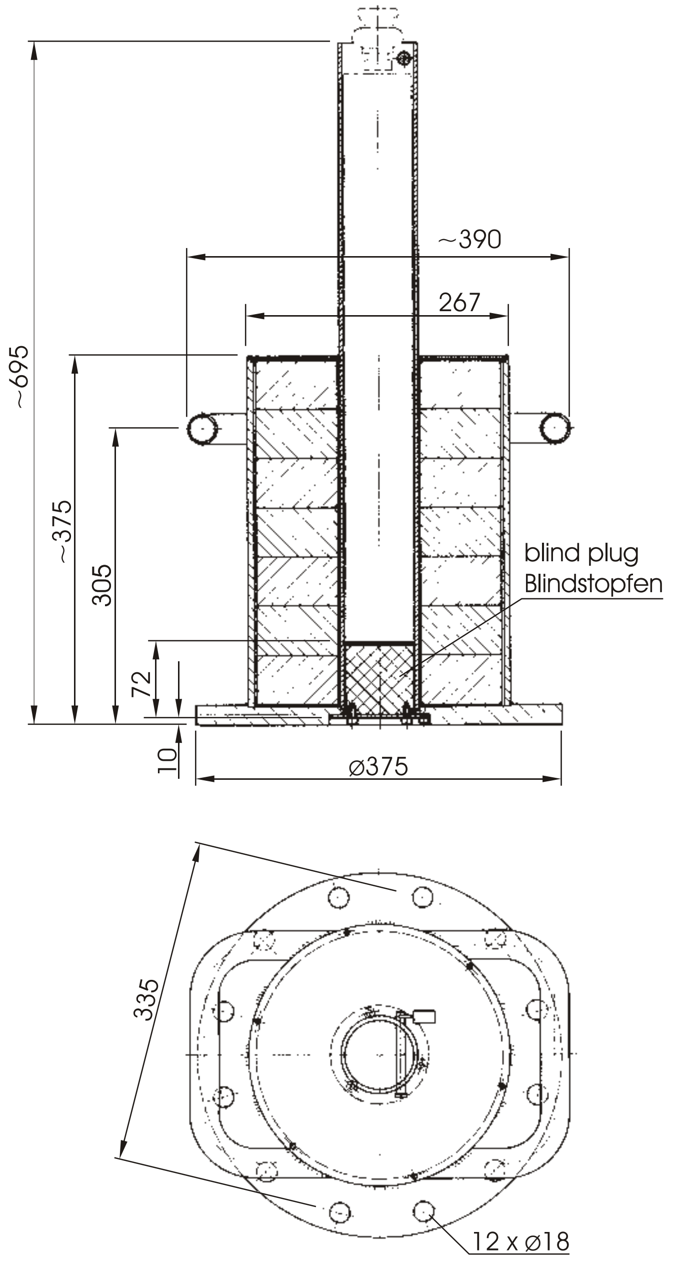
Dimensions



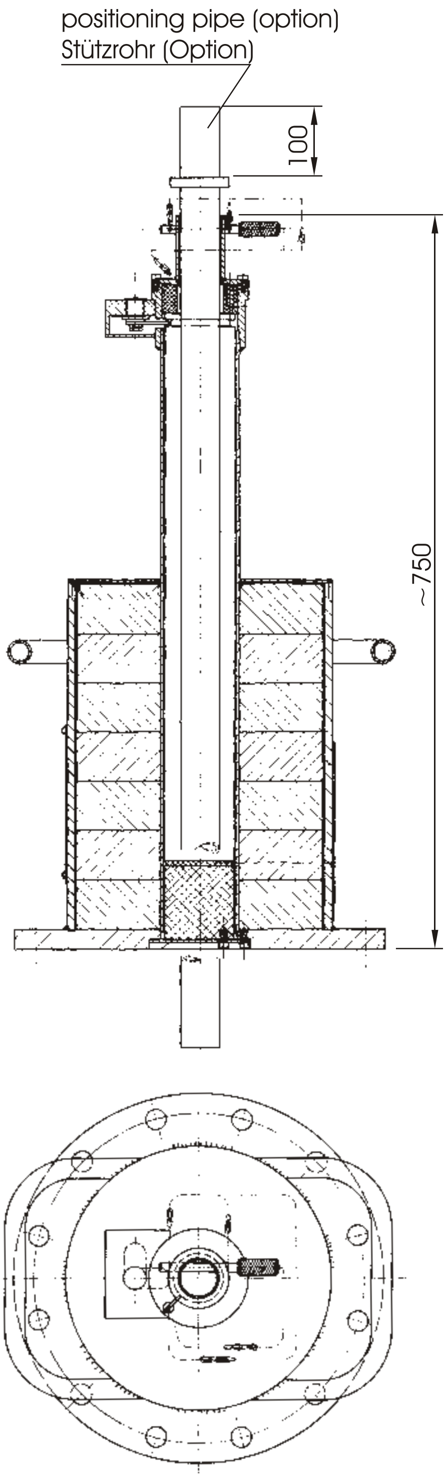




LB 7409-02

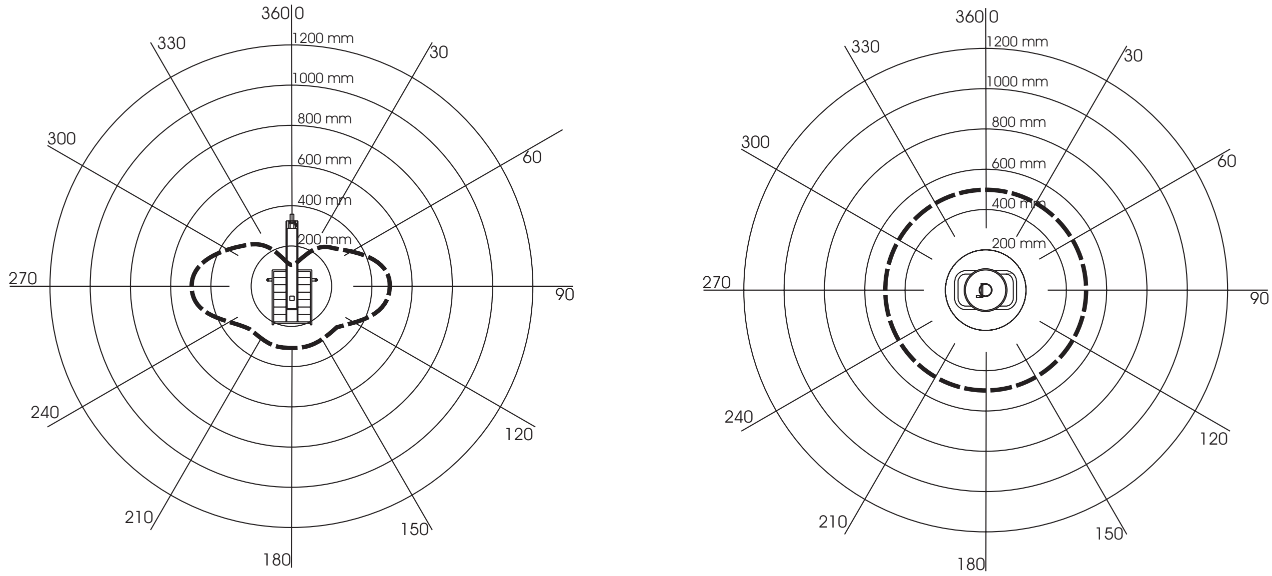


LB 7409-03

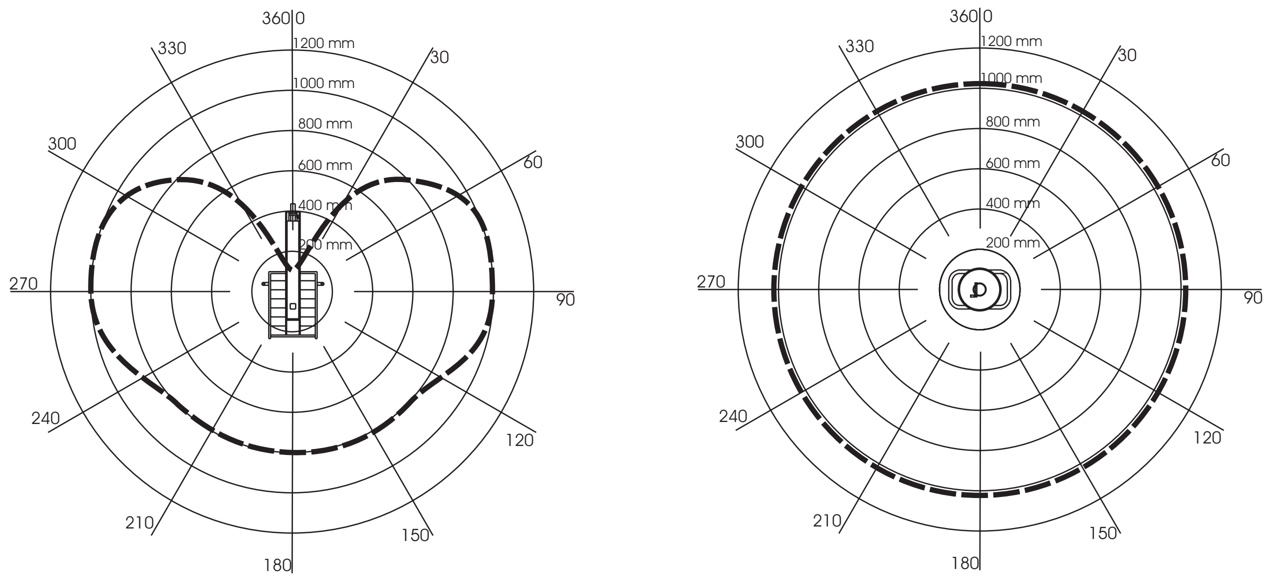


Isodose curves for shielding

100 mCi AmBe-241

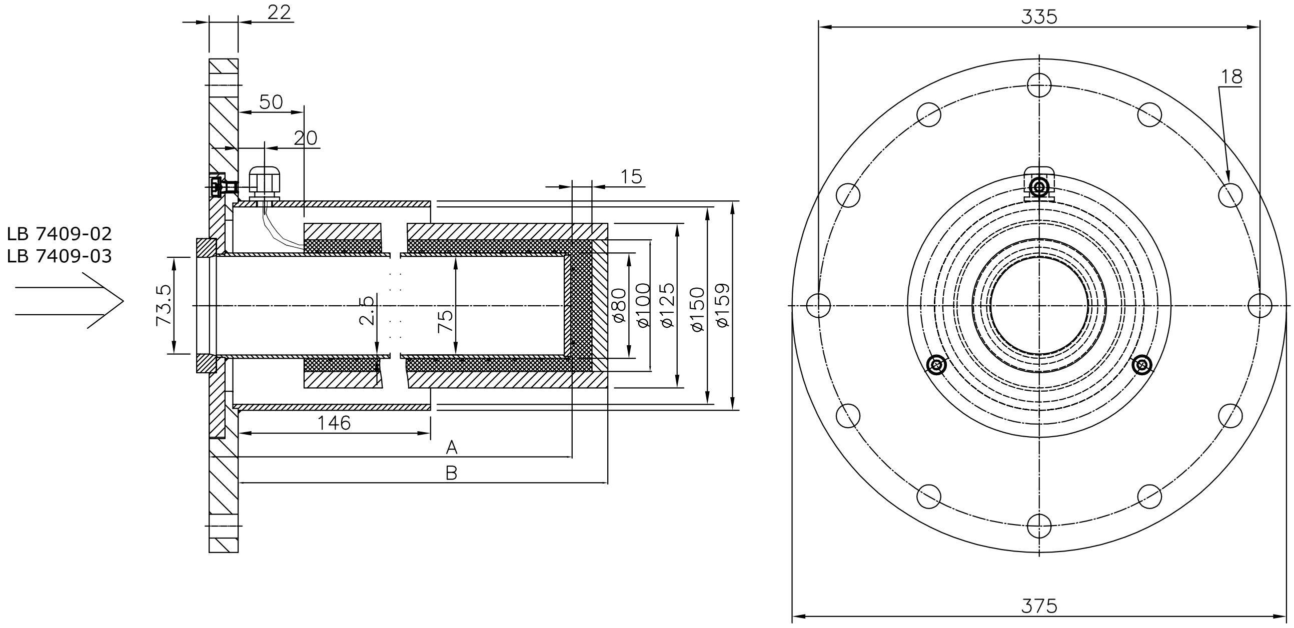


300 mCi AmBe-241



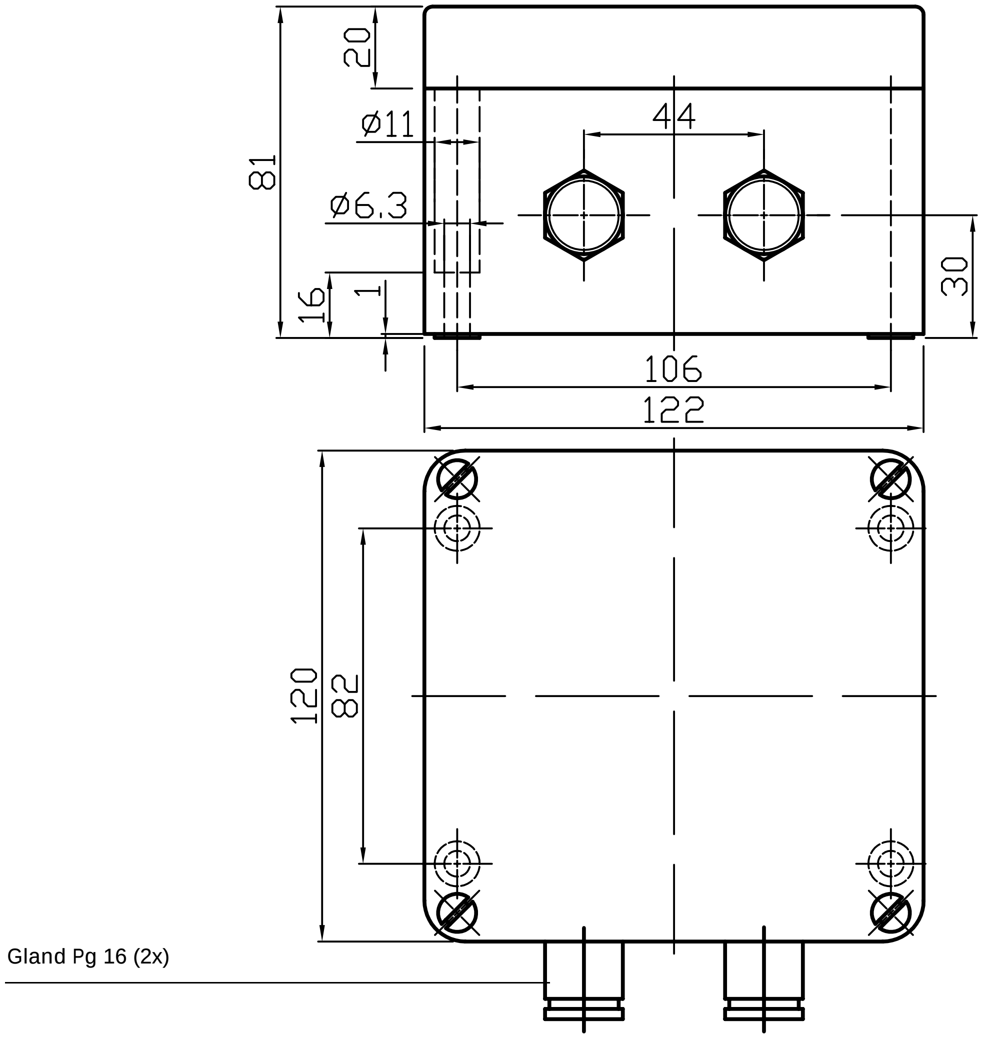
Distance indicated for 3 µSv/h
Distance information in mm from the surface of the shielding vessel

14.1.5 Ceramic dip pipe



Dip Pipe		
Part no.	A	B
34669-01	650	666
34669-02	950	966
34669-03	1250	1266

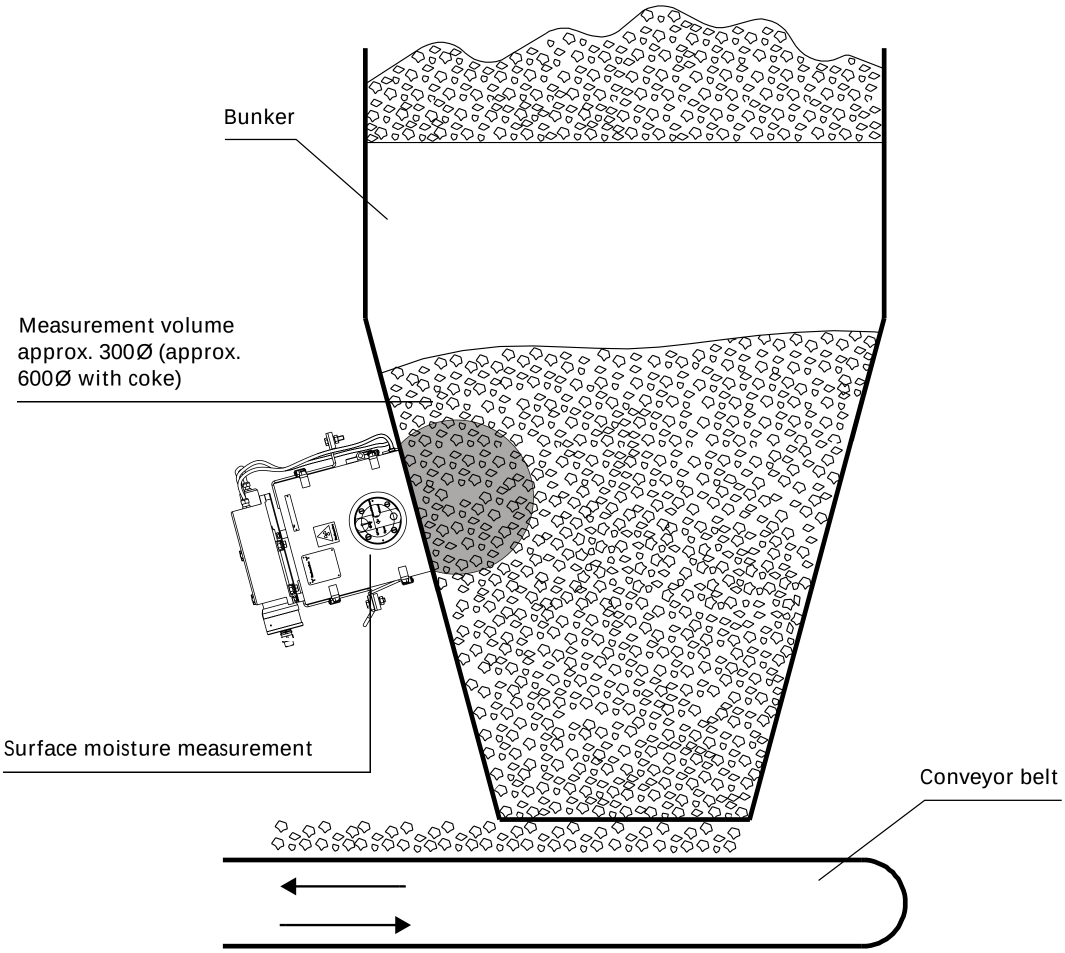
14.1.6 Terminal box for connection of the bunker probe LB 6666



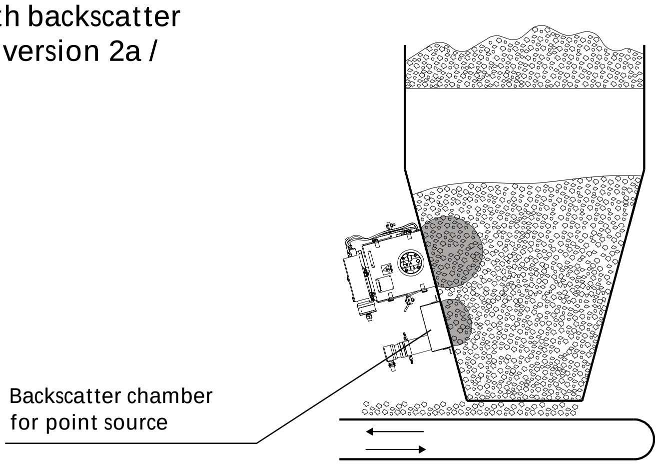
Weight: approx. 1150 g
Color: Structural varnish gray, similar to RAL 7001
Material aluminum pressure casting

14.2 Surface probe

14.2.1 Installation version 2

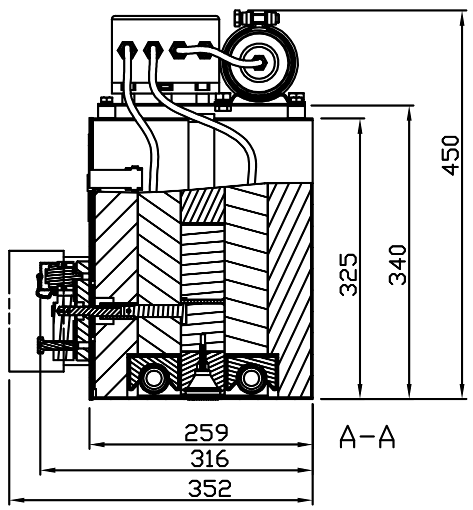


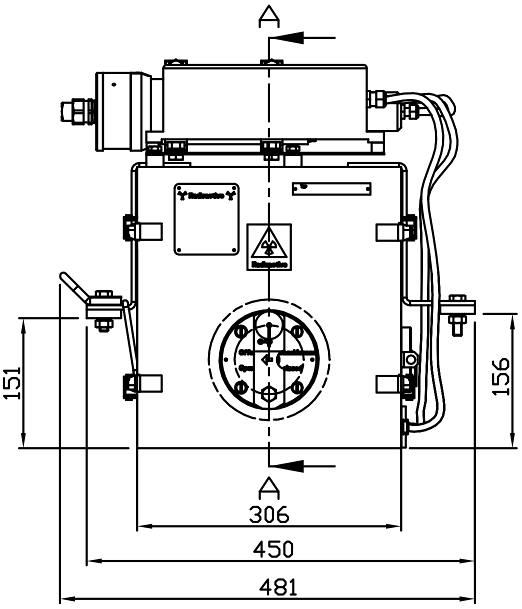
Surface moisture measurement with backscatter chamber as density compensation version 2a /

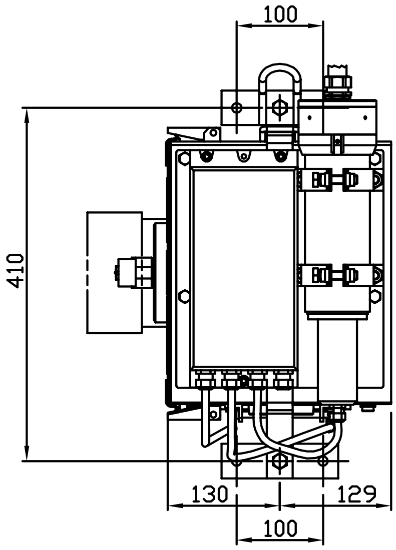


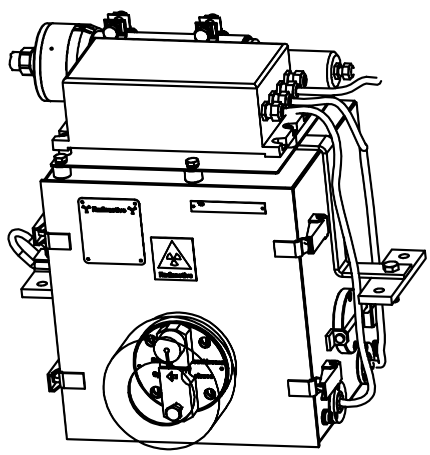
14.2.2 Shielding LB 7410

Dimensions



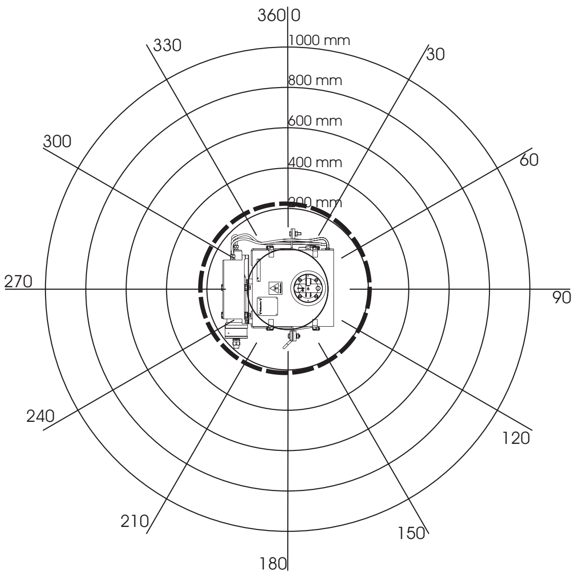


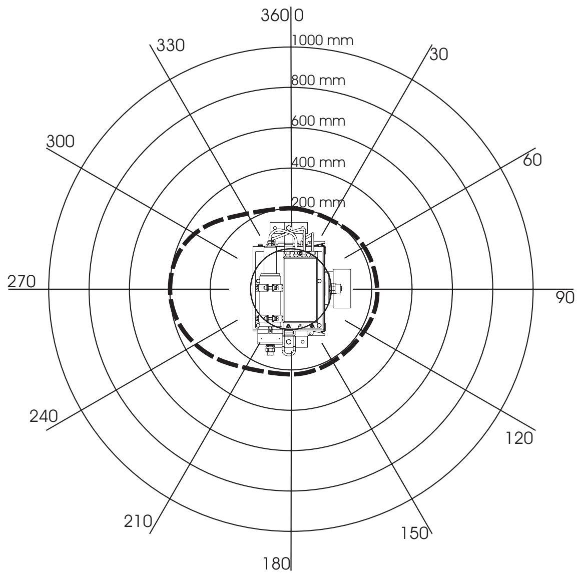




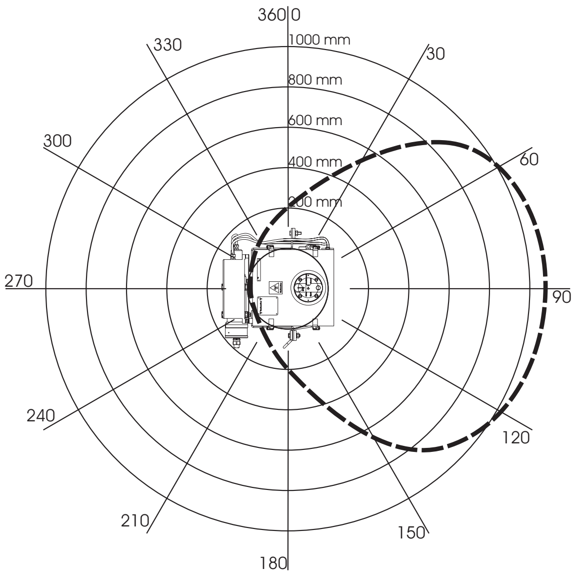
Isodose curves for shielding with 100 mCi

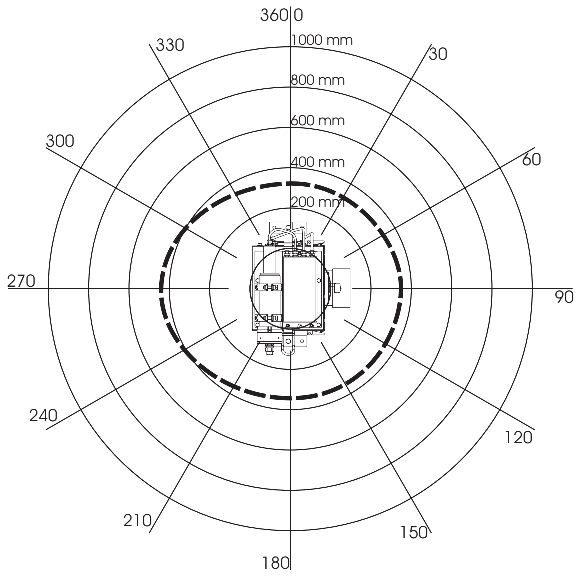
Radiation path closed





Radiation path open

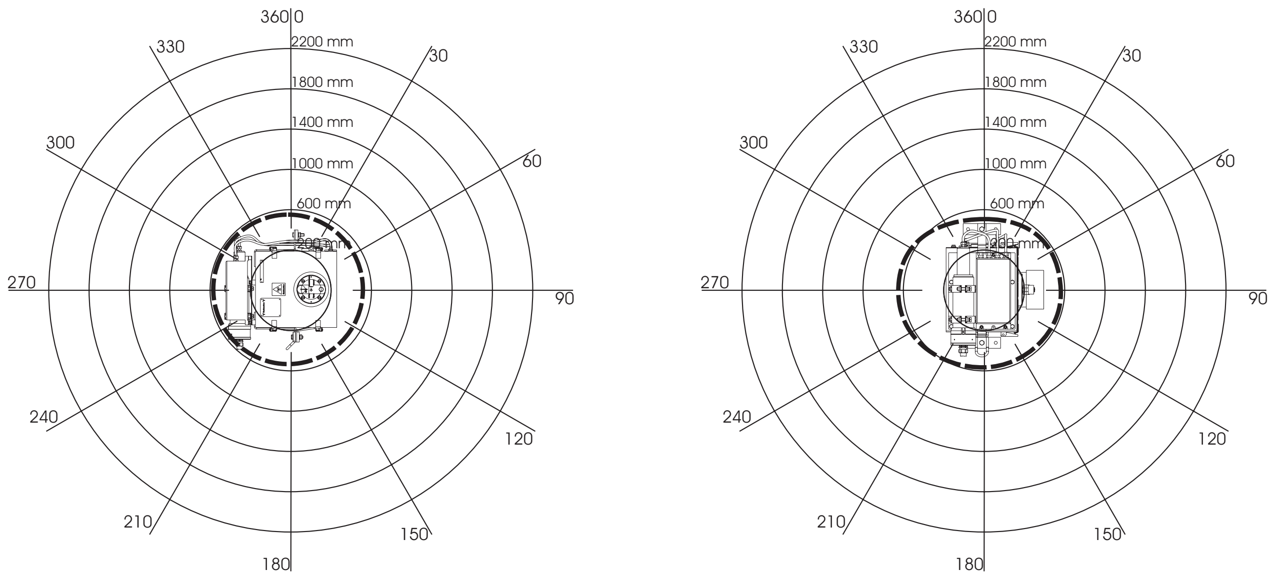




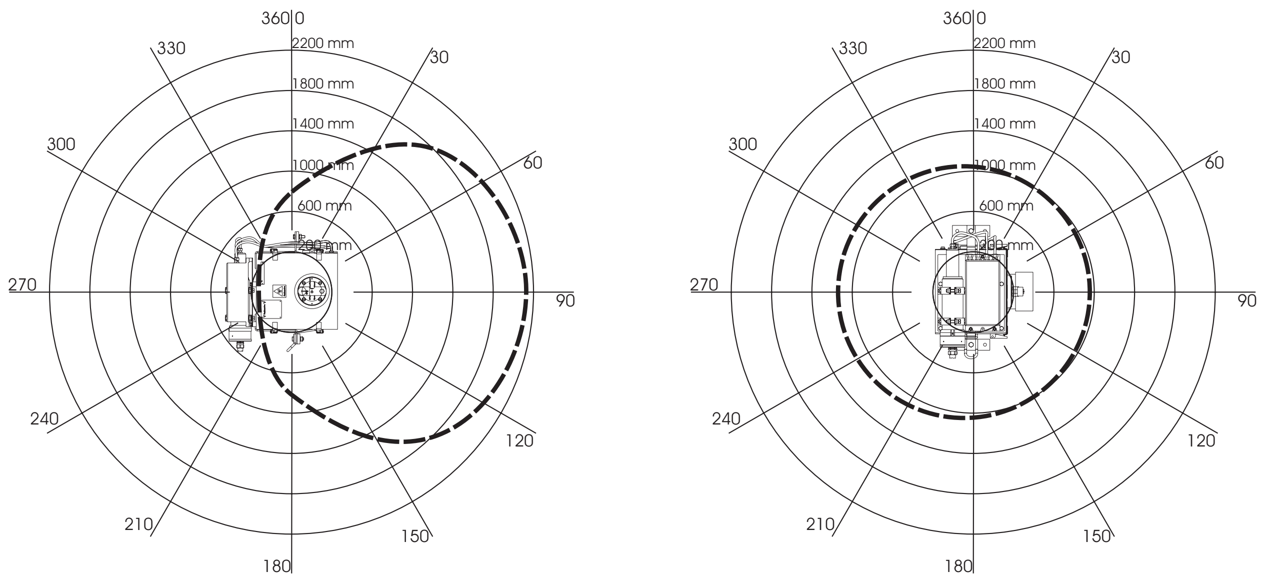
Distance indicated for 3 µSv/h
Distance information in mm from the surface of the shielding vessel
Source activity 100 mCi / 3700 MBq AmBe-241

Isodosenkurven für Abschirmung mit 300 mCi

Radiation path closed



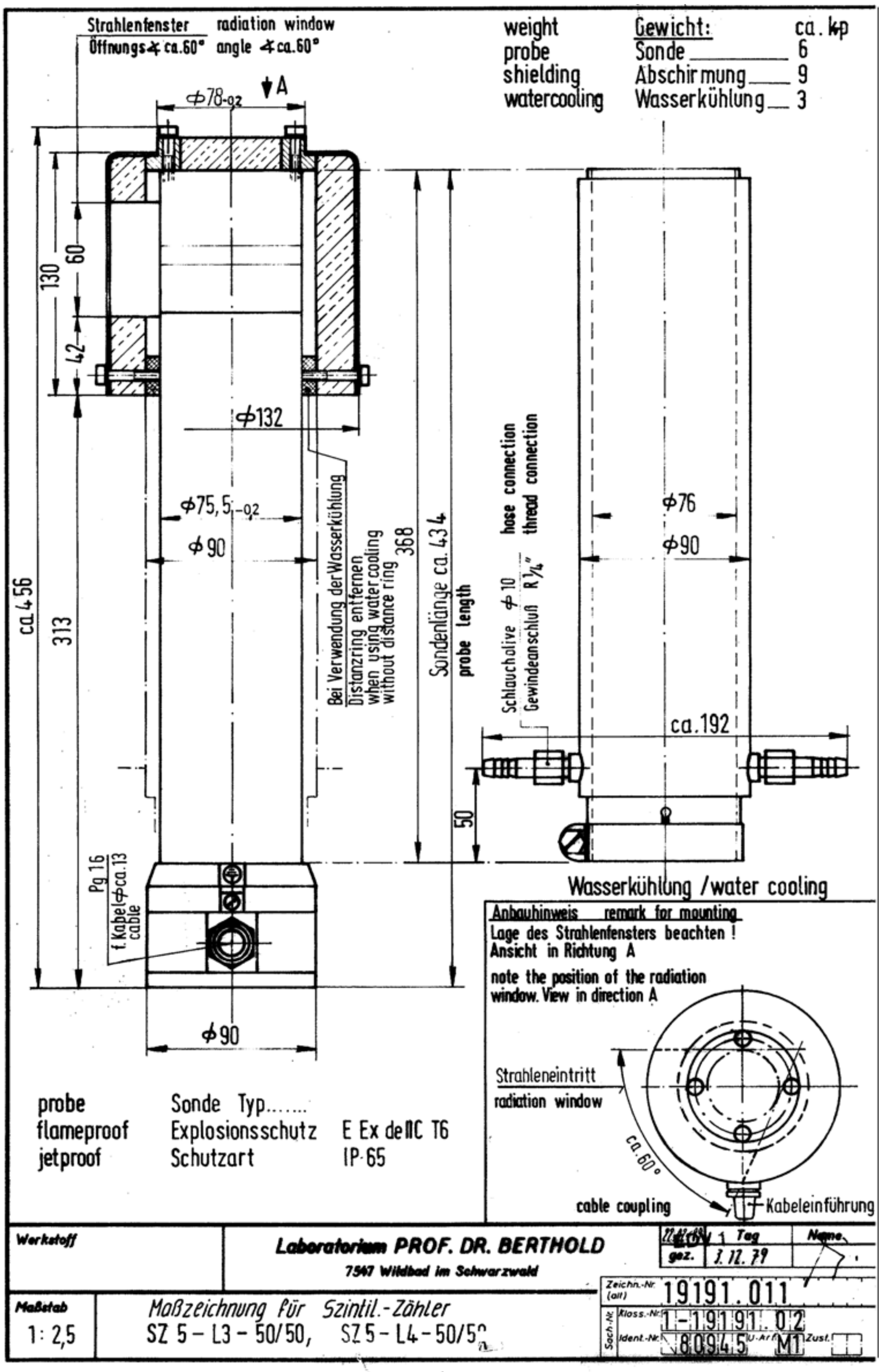
Radiation path open



Distance indicated for 3 µSv/h
Distance information in mm from the surface of the shielding vessel
Source activity 300 mCi / 11100 MBq AmBe-241

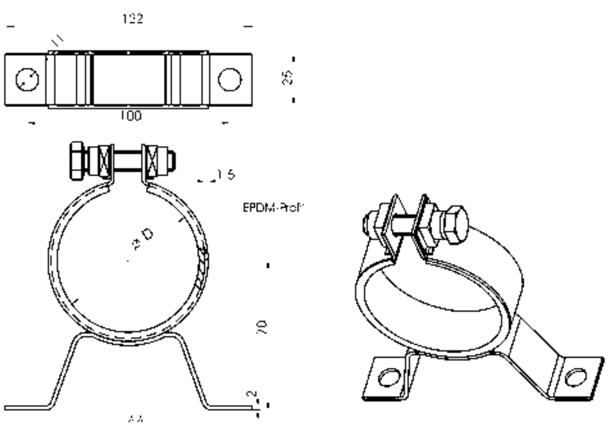
14.2.3 NaI-detector

Detector



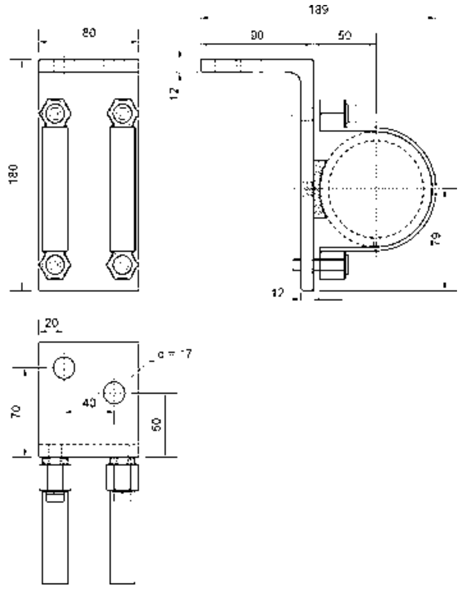
Fixing clamps for GM- and NaI-detectors

Standard clamps



Clamps for detector without water cooling D = 75	Clamps for detector with water cooling D=90
ID NO 31346 (1 set = 2 clamps)	ID NO 31347 (1 set = 2 clamps)

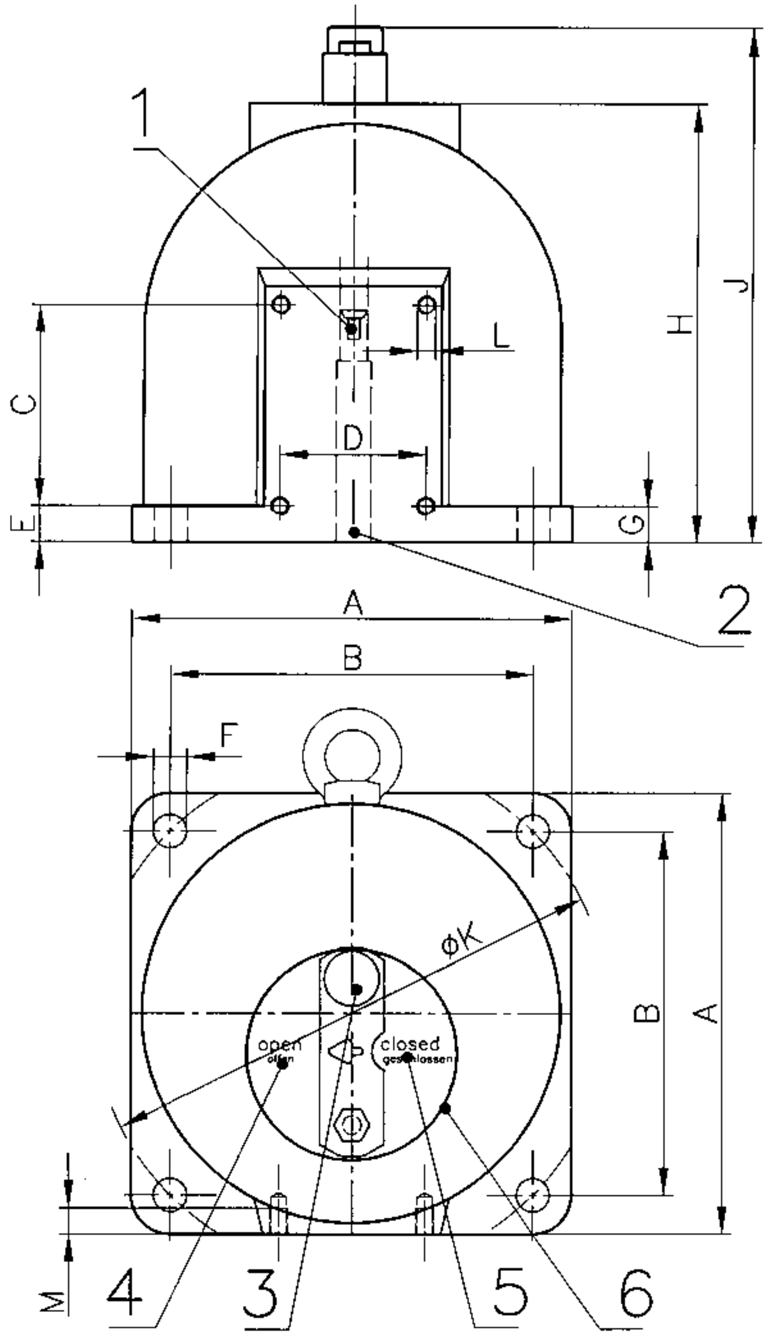
Detector support



Detector support for point detector without water cooling	Detector support for point detector with water cooling
ID NO 39247 (1 set = 2 clamps)	ID NO 39247 (1 set = 2 clamps)

This detector support consists of two clamps mounted on an angle. It may be used instead c the mounting clamps. The angle can be welded c screwed directly onto the bracket. Moreover, th detector support is very robust and can be usec where little space is available. All metal parts o this fixture are made of stainless steel.

14.2.4 Point source shielding

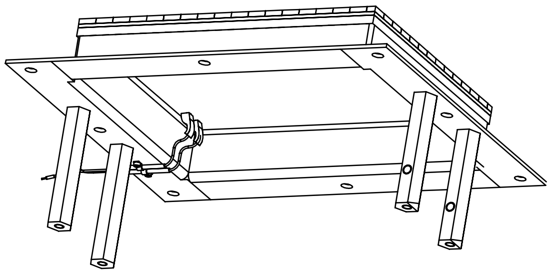


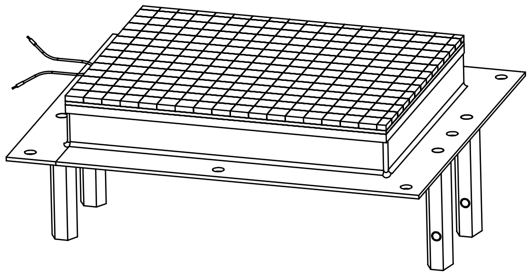
1 Point source
2 Radiation exit
3 Lock
4 Position Open
5 Position Closed
6 Type label

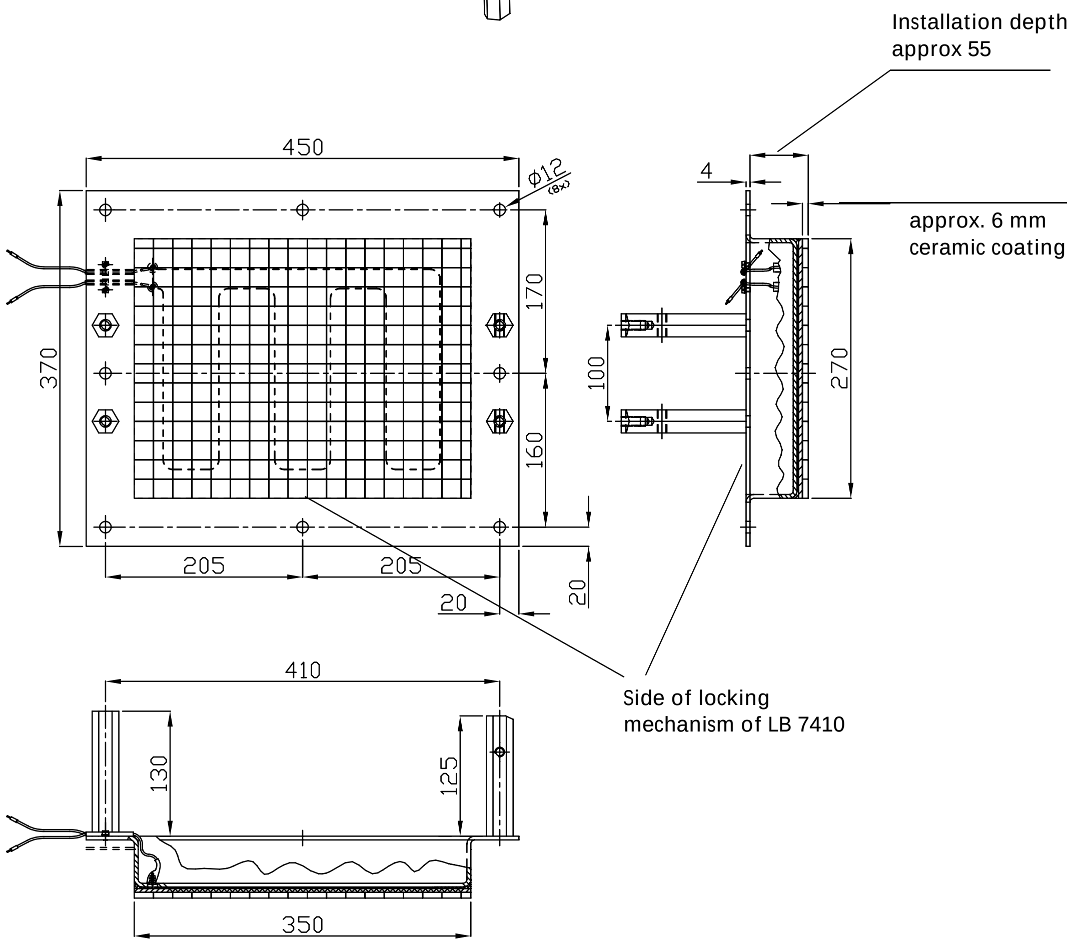
	A	B	C	D	E	F	G	H	J	K	L	M	Flange	kg
LB7440	180	142	60	60	15	18	20	173	238	200	M8	12	ND125/ PN6	31
LB7442	240	198	110	80	20	18	20	242	306	280	M10	14	ND200/ PN6	81

14.2.5 Mounting frame for surface probe

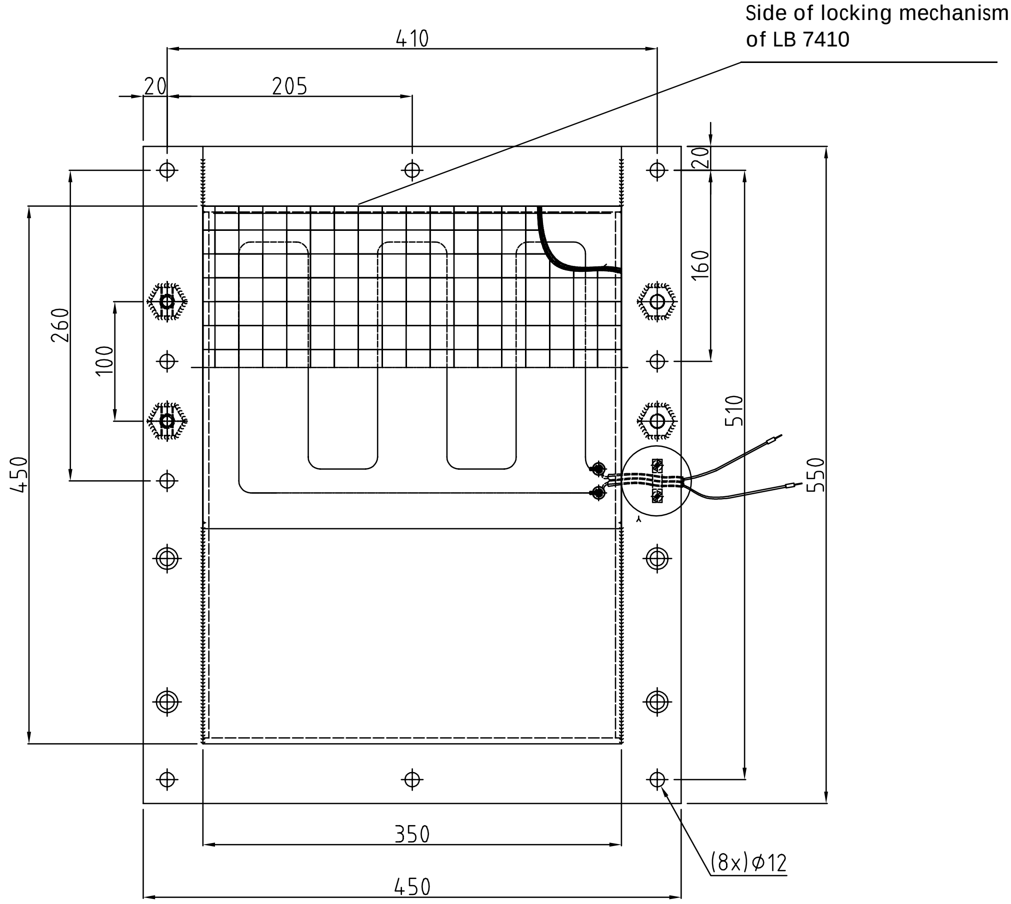
Mounting frame without density compensation

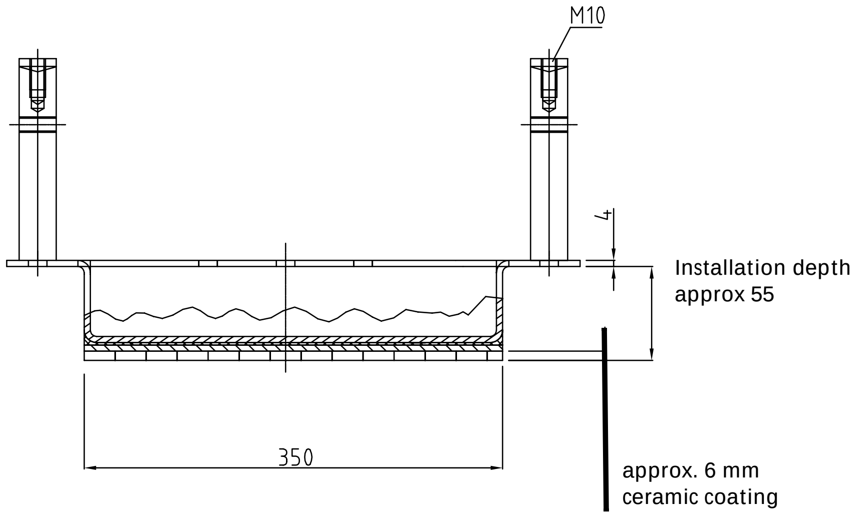




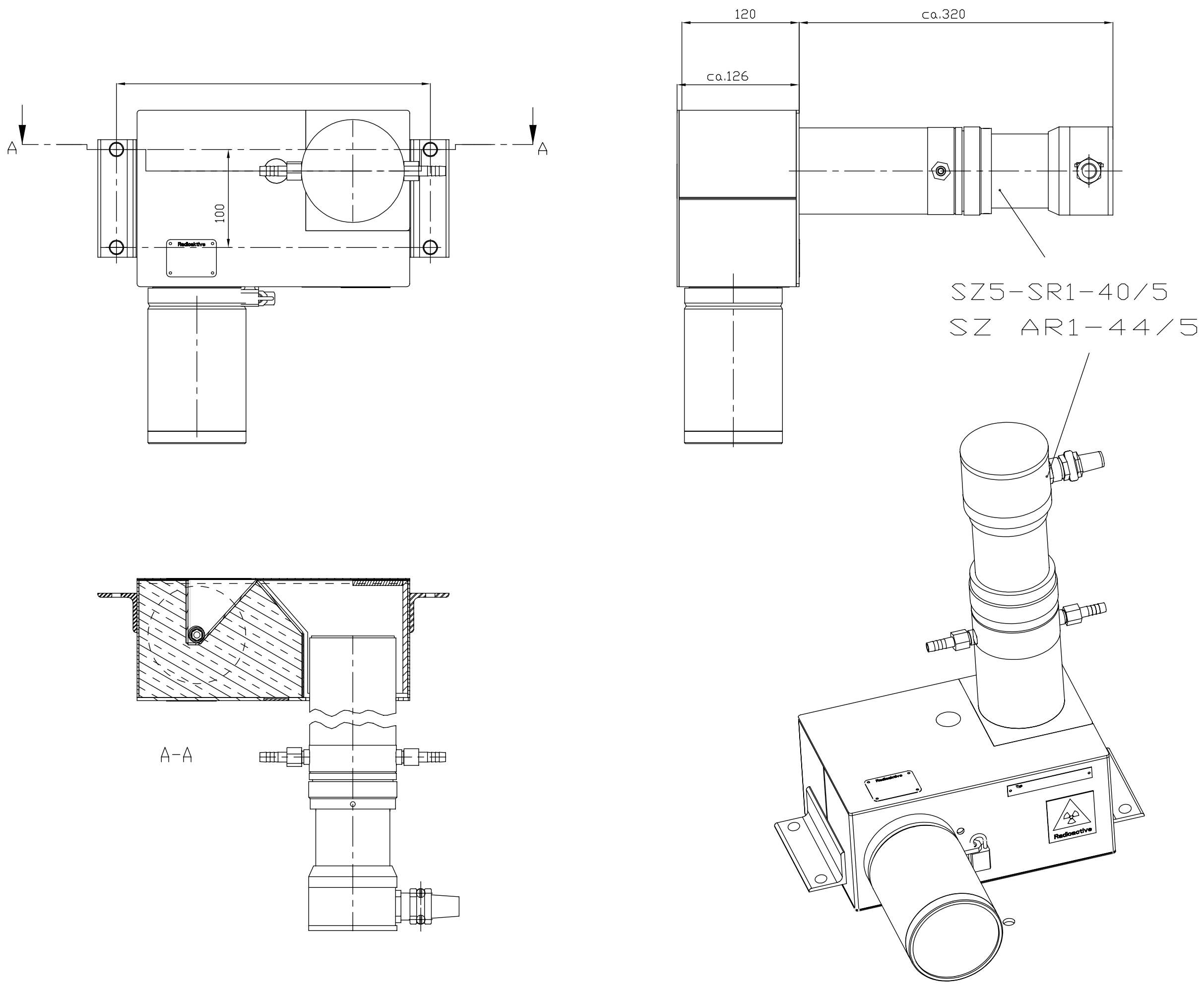


Mounting frame without density compensation





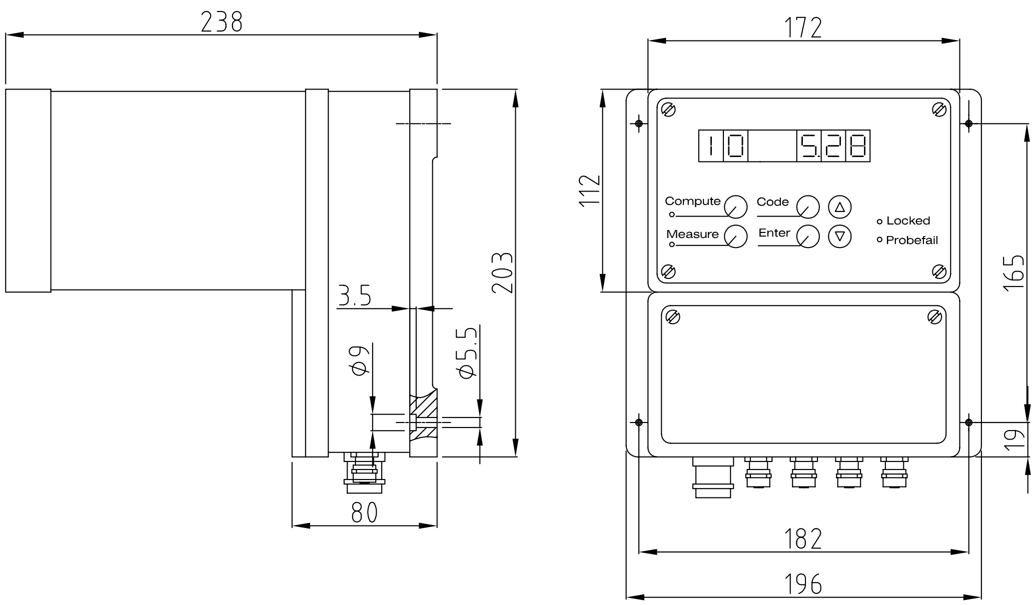
14.2.6 Backscatter chamber for density compensation



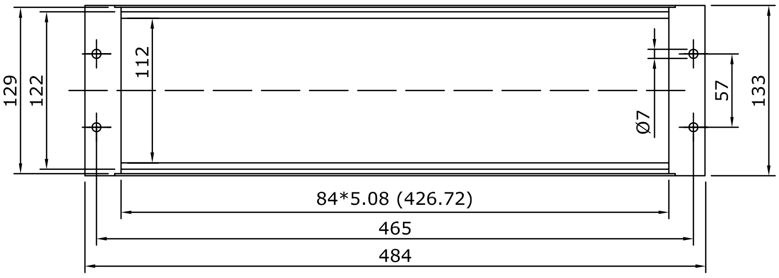
14.3 Evaluation Unit

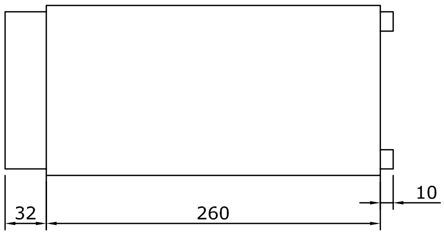
14.3.1 Housing

Wall mounted



In a 19 rack (for LB350-2 or LB350-3)

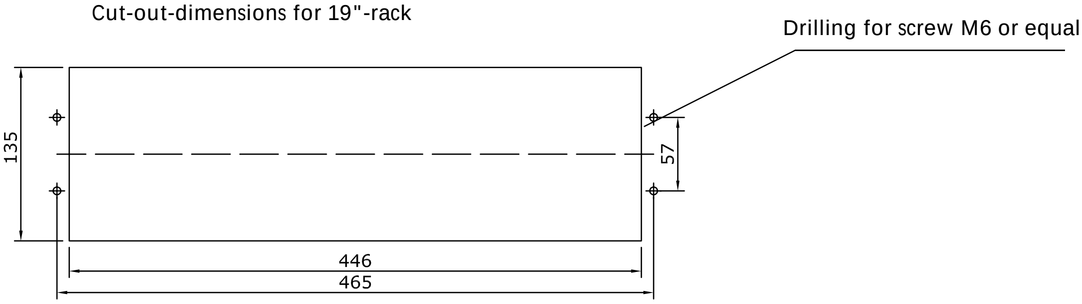




Projection: Fastening screws (front panel) = 10 mm
Cable holder (rear panel) = 32 mm

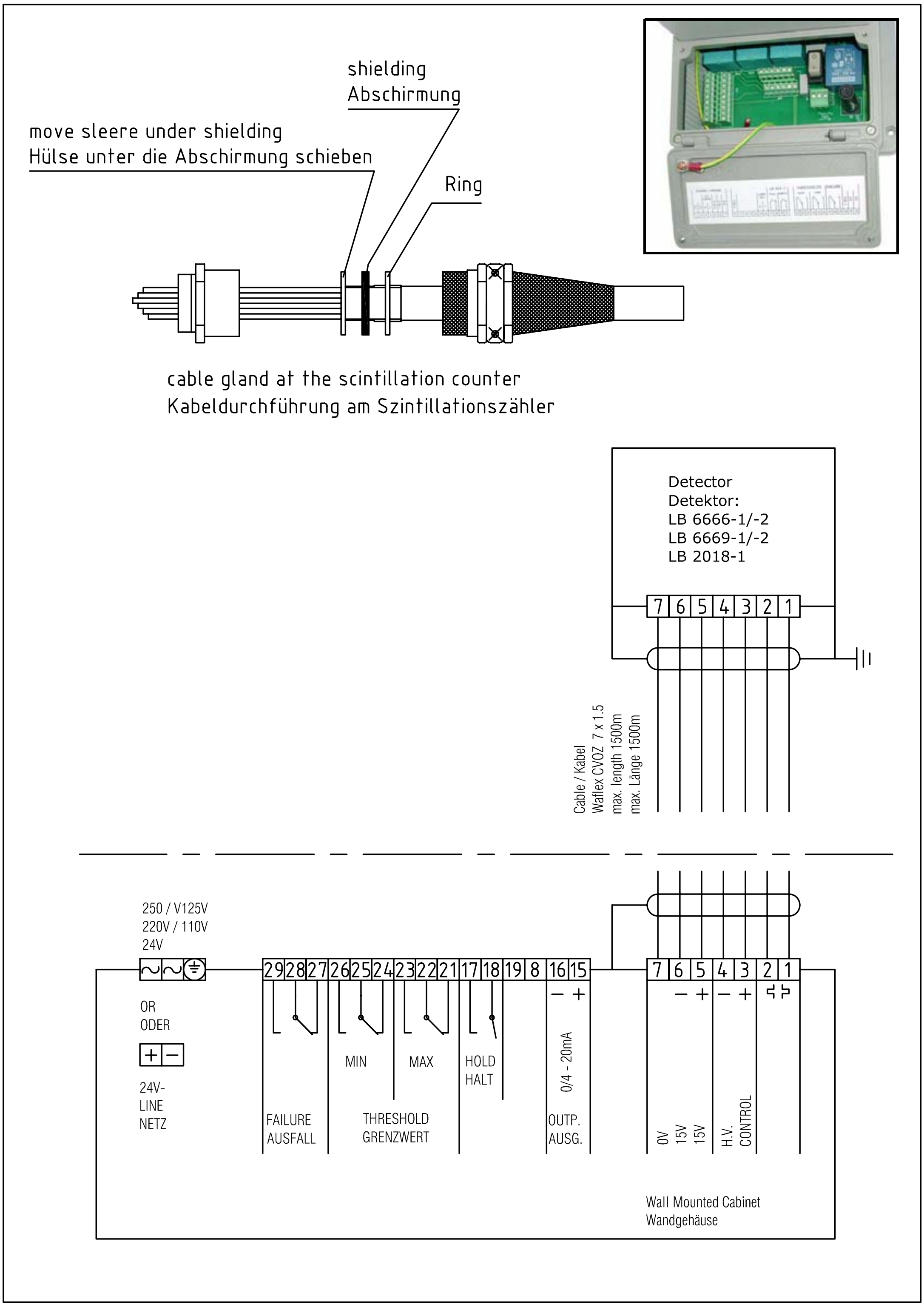
Additionally: Fasteners = 15 mm
Cable holder = 32 mm

Cut-out-dimensions for 19"-rack

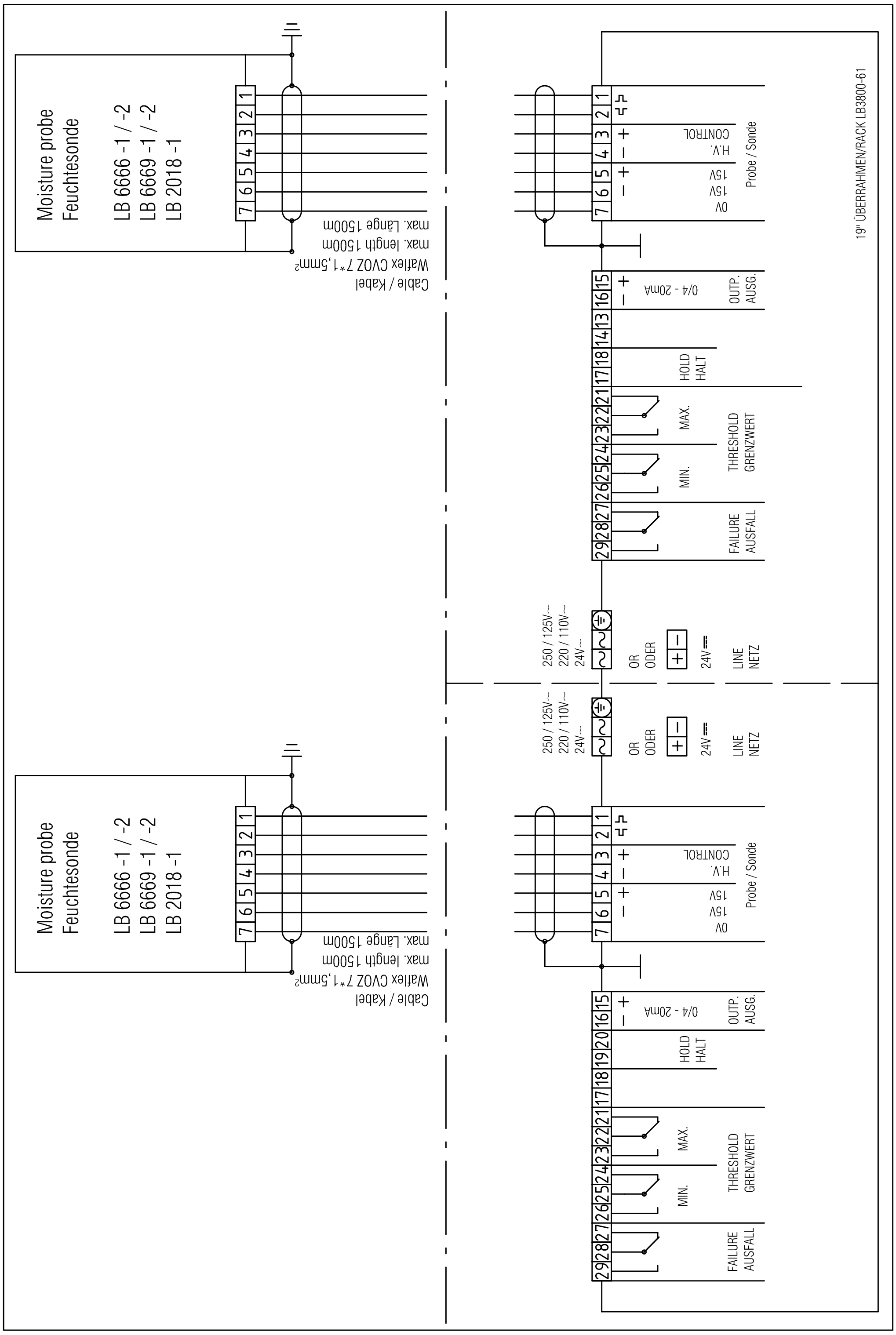


14.3.2 Wiring diagrams

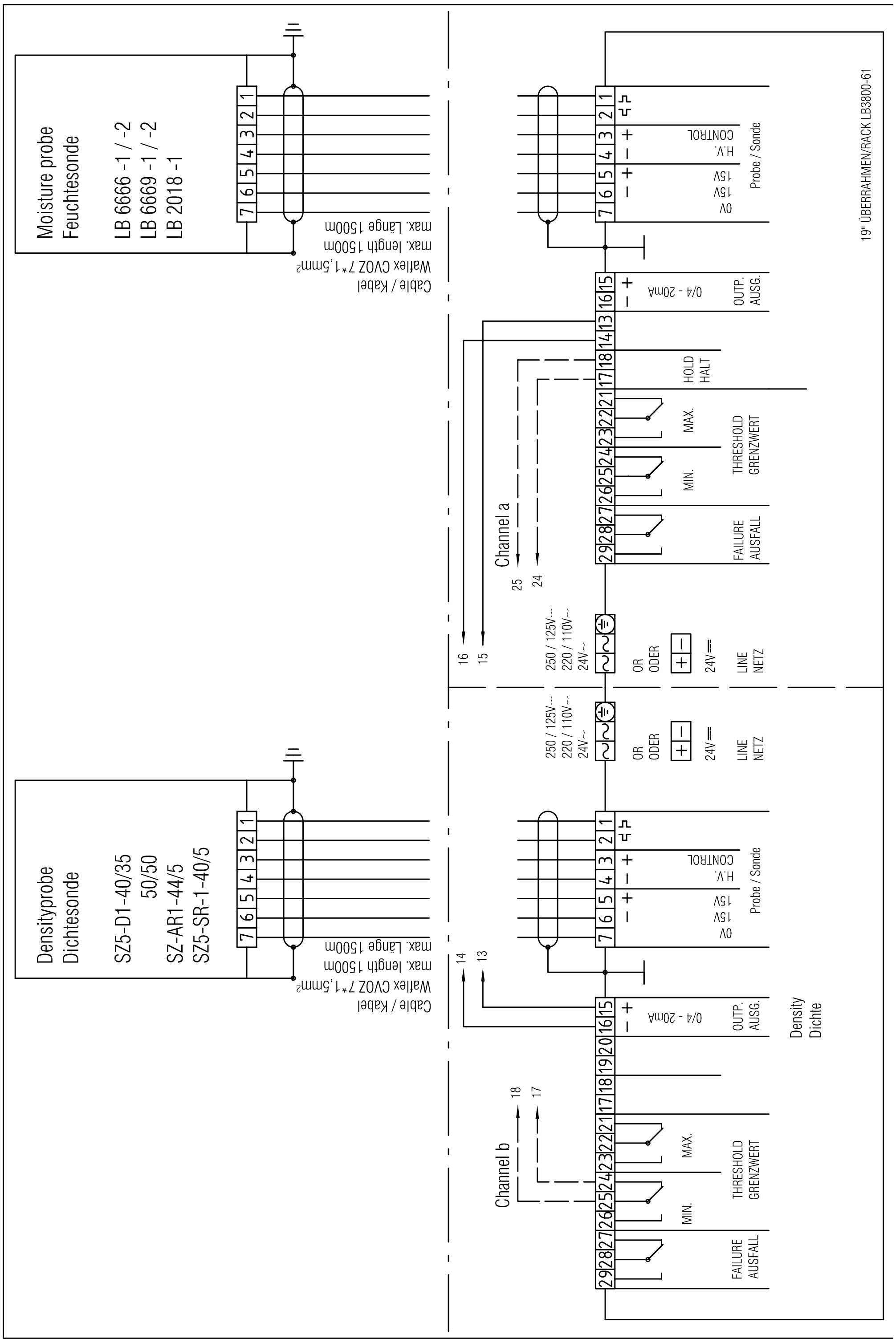
Wiring diagram wall housing LB350-1



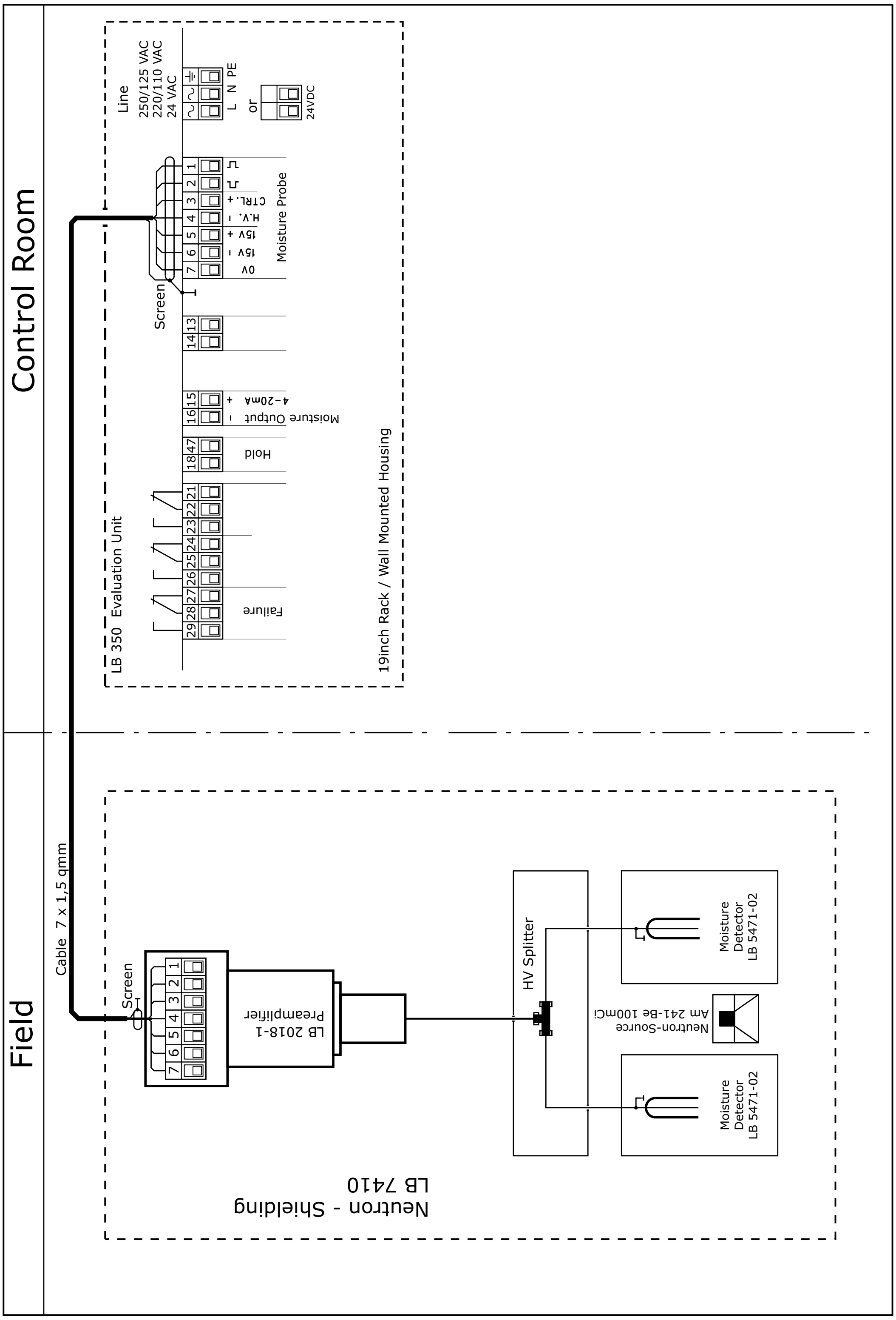
Wiring diagram 19" rack for 2-channel moisture measurement LB 350-2



Wiring diagram 19" rack LB 350-3 moisture measurement with density compensation



Wiring diagram 7410 with LB350-1/2



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