

Ultrasonic Level Measurement DU 44 Z and DU 46 Z Sensors

**Sensors for continuous,
non-contact level measurement
in very high bulk solids silos.
For dust explosion hazardous areas**



DU 46 Z:
Measuring range
approx. 60 m.
(approx. 200 ft)



DU 44 Z:
Measuring range
approx. 40 m.
(approx. 130 ft)

Advantages of Ultrasonics

- Non-contact level measurement
- Measurement accuracy unaffected by product properties such as specific weight or conductivity
- No recalibration necessary on change of product

Application

- Non-contact, continuous level measurement in very high bulk solid silos
- Measuring range:
DU 44 Z up to 40 m (130 ft),
DU 46 Z up to 60 m (200 ft)
- Operating temperature: $-20\dots+60\text{ }^{\circ}\text{C}$
($0\dots140\text{ }^{\circ}\text{F}$)

Principle Sensor Features

- The DU 46 Z operates at a very low frequency to significantly increase the measuring range
- Increased accuracy using a newly developed emitting principle
- Connection by commercial multi-core installation cable
- Approval for dust Ex Zone 10
- CSA approval

Endress + Hauser

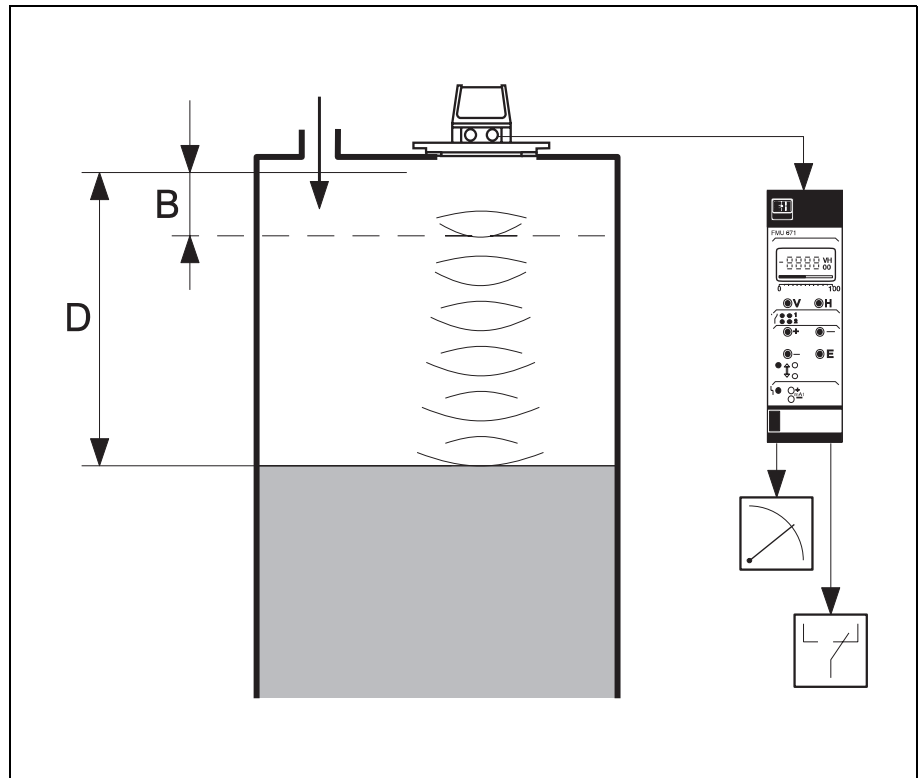
Nothing beats know-how



Measuring Principle

Ultrasonic measuring principle

D= Distance sensor - product surface
B= Blocking distance



Ultrasonic Measurement

An ultrasonic emitter (sensor) mounted above the product is excited electrically and then directs an ultrasonic pulse through the air towards the product surface.

The product surface partially or fully reflects the pulse back to the sensor. This echo is detected by the same sensor, now acting as a directional microphone, and converted into an electrical signal.

The time between transmission and reception of the pulse - *the run time* - is directly proportional to the distance between the sensor and the product surface. The distance D is determined from the velocity of sound c and the run time t by the formula:

$$D = c \times t / 2$$

For c = 340 m/s, a run time of 10 ms corresponds to a transmission path of 3.4 m and thus to a distance of 1.7 m.

Measuring Range

Due to the attenuation characteristic of the sensor, there is a zone immediately below it from which returning echoes cannot be detected. This so-called *blocking distance* determines the start of the measuring range.

The end of the measuring range is determined by the attenuation of the ultrasonic pulse by the air as well as by the strength of the reflection from the product surface.

Requirements

The primary requirement for good ultrasonic measurement is reflection at the product surface:

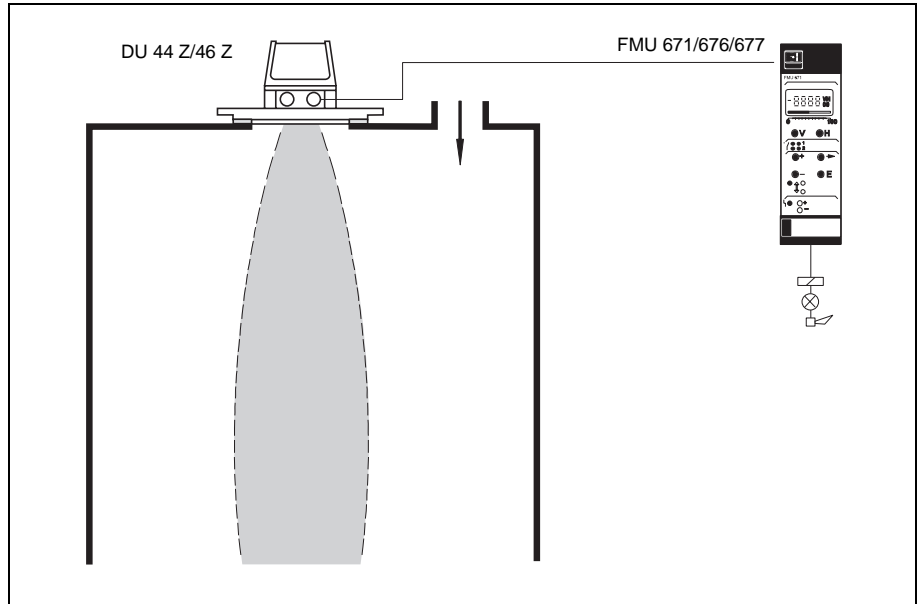
- Granular and lumpy bulk solids, such as crushed stone, gravel, ore, coal, glass cullet, etc.

With these bulk solids, a grain size greater than 10 mm (0.4 in) allows measurement to be carried out using diffuse reflection which is independent of the slope of the material or the outlet funnel.

- With fine-grained or powdery bulk solids e.g. quartz sand, cement, powdered plastics, raw meal etc. operation is dependent on the contours of the material (mirrored reflection).

Measuring System

The ultrasonic sensor is connected to the transmitter Nivosonic FMU 671/676/677 in Racksyst design.



Nivosonic FMU 671/676/677

The ultrasonic sensor is powered by the Nivosonic FMU 67. transmitter. The sensor provides the Nivosonic with information which is converted to a level or content value. A temperature sensor, located behind the diaphragm, measures the temperature of the air above the product.

The Nivosonic FMU 67. performs the following functions:

- Measured value display
- Linearization of the vessel characteristic
- Temperature correction
- Suppression of spurious echoes caused by fixtures etc. within the silo.

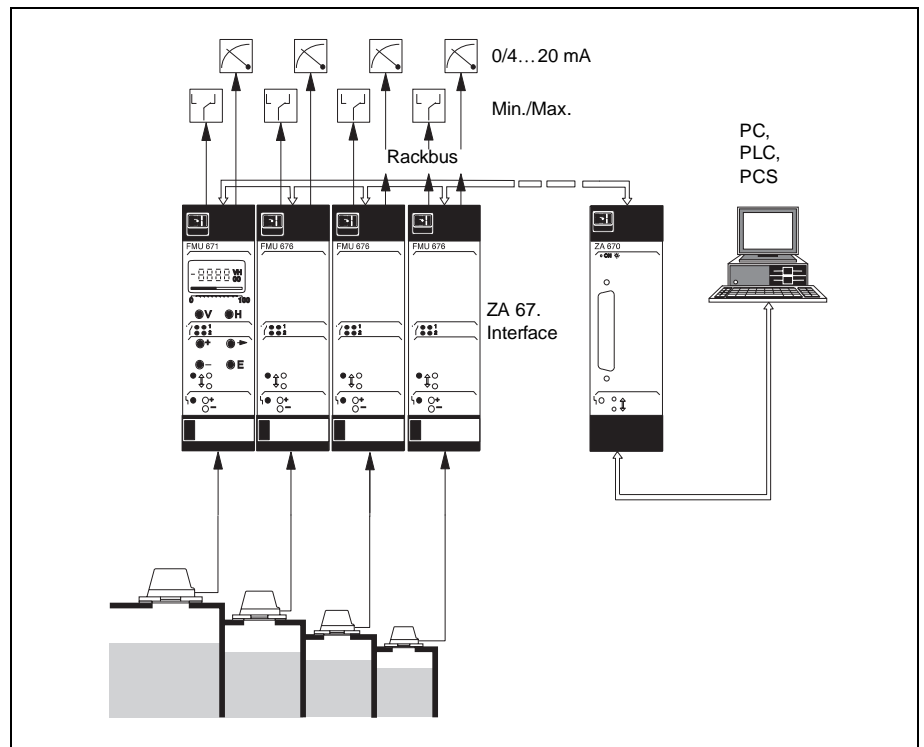
Measurement Accuracy

Measurement accuracy is unaffected by the differences in strength of the reflected signal.

- The effect of pressure changes $p_e = -0.5 \dots +0.5$ in air or nitrogen is $\leq 0.1 \%$.
- A constant temperature and velocity of sound in the measuring path gives accuracies of $\leq 1 \%$ of the measuring range.
- The resolution of the measurement is 1.7 cm for a sound velocity of 340 m/s.

The velocity of sound (331.6 m/s at 0°C) and the temperature correction ($0.6 \text{ ms}^{-1}/^\circ\text{C}$ or $0.17\%/^\circ\text{C}$) are calibrated in the factory. The values are freely selectable and can be adjusted for other gas mixtures.

In addition to the features listed below, the Nivosonic FMU 671/676/677 can be integrated via the Rackbus and ZA 67. interface into a process control system.



Planning

Maximum Measuring Range

The measuring range depends upon:

- The strength of the reflection from the product surface (grain size of the product).
- The attenuation of the signal between the sensor and the product (by air temperature and dust).
- The level of background noise from fixtures, coarseness of the silo wall and the filling curtain.
- With large measurement ranges, marginal effects are larger than with smaller measuring ranges.

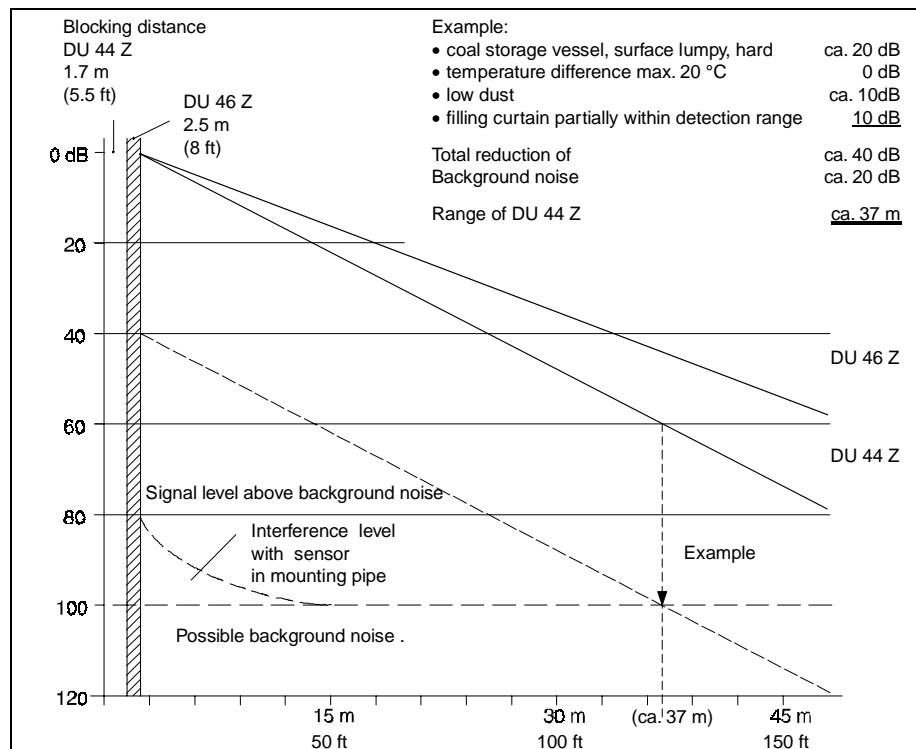
Careful planning of the installation point and correct sensor mounting are decisive factors for accurate measurement.

Attenuation

The diagram shows ideal attenuation curves for the DU 44 Z/46 Z sensors:

- Check the factors affecting your measurement using the table below.
- Shift the ideal attenuation curve down by the sum of their reduction values.
- Check the background noise level (in the diagram 20 dB) and subtract it from the theoretical detection limit of 120 dB.
- The intersection of the curve and background noise gives the maximum measuring range - see example -.

Echo attenuation as a function of distance (with ideal reflection and atmosphere).



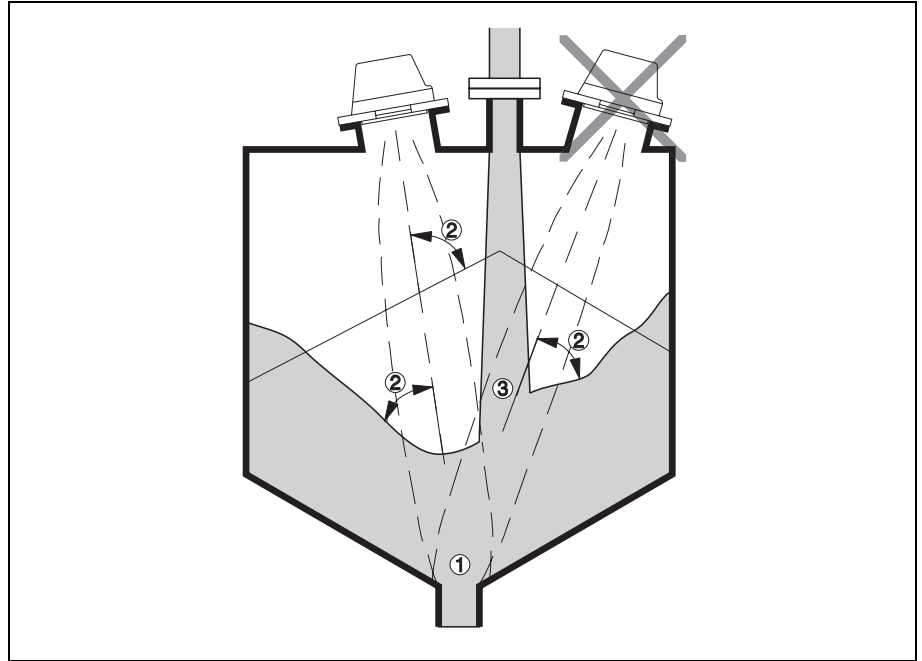
Attenuation in dB with interference in silo

$$* x \text{ }^{\circ}\text{C} = (x \cdot \frac{9}{5} + 32) \text{ }^{\circ}\text{F}$$

Effects in bulk solid silos	Attenuation dB
Temperature layering * Difference in air up to 20 °C temperature between sensor and product up to 40 °C surface up to 60 °C	0 5...10 10...20
Filling curtain Outside detection range Small amount inside detection range Large amount inside detection range	0 5 ...10 10...20
Dust No dust Light dust Heavy dust	0 5...10 10...20
Solids surface hard, rough soft e.g. peat, dust-covered clinker	20 20...40

Recommendations

- Direct the sensor to the centre of the outflow funnel ① so that an echo is received when the silo is empty.
- An angle tending to 90° ensures a strong echo.
- To ensure accurate readings, keep away from the side walls and select the largest angle possible ② to the filling mound or outflow.
- Avoid measuring through the filling curtain ③.



Recommendations for mounting.

Coarse-Grained Bulk Solids

A strong working echo is produced by diffuse reflection from the surface of coarse-grained solids or from the uneven surface of fine-grained solids. The installation point is therefore unimportant.

Fine-Grained Bulk Solids

The smooth surface of a very fine-grained or dust-forming material produces no significantly diffuse reflection. The sonic beam is reflected like that of light (angle of incidence = angle of reflection). The installation point is therefore of critical importance for correct measurement.

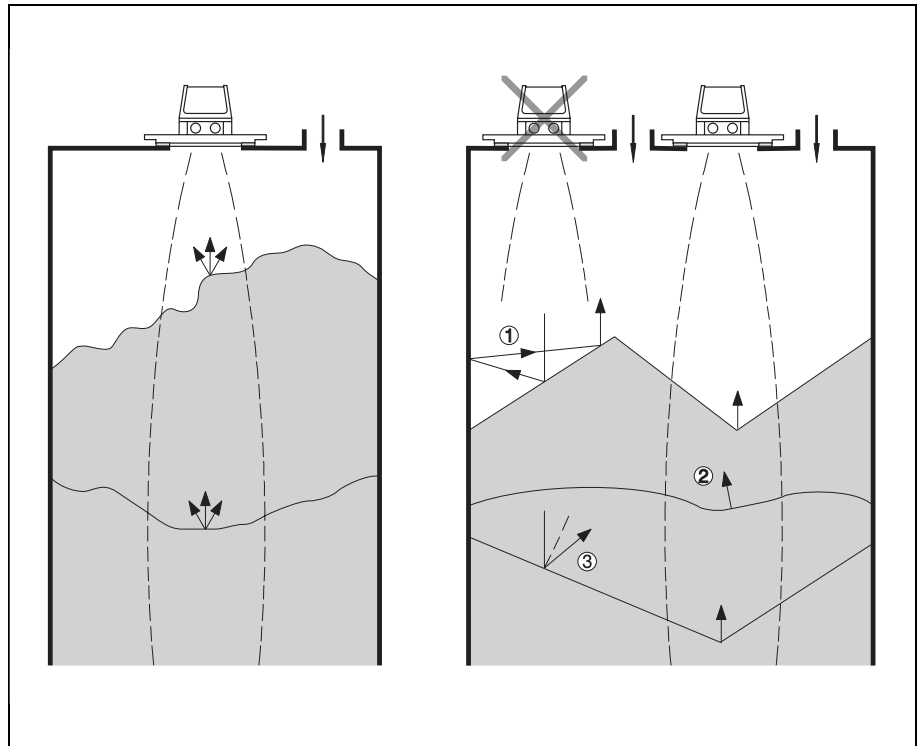
Left:
With diffuse reflection, the installation point is not critical.

- The material must not flow through the detection area
- Detection area is directed at the outlet so that an echo also returns when the silo is empty

Right:

No diffuse reflection produced with a smooth surface

- ① Level is shown lower than actual level due to the material-wall-material reflection
- ② Slightly sloping surfaces with mounds up to 5° easily detected
- ③ Reflection to the side. No echo is received

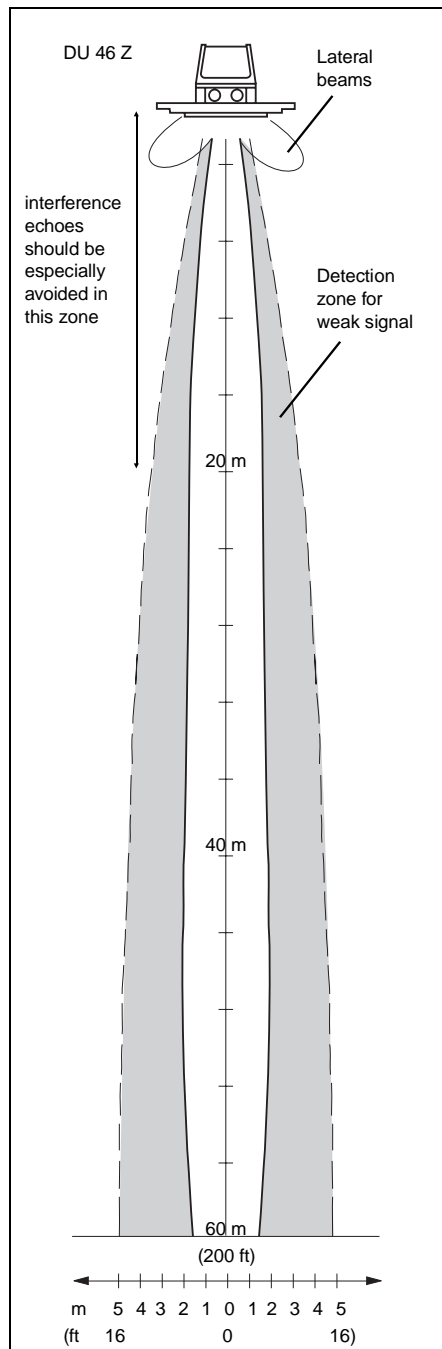


Internal Fittings

Detection Zone and Interference

- Check that the ultrasonic pulse arrives unobstructed at the product surface.
- If struts and internal fittings are present in the silo, then careful positioning of the sensor is important in order to keep background noise as low as possible.
- If the silo wall is within the detection zone, then the characteristics of the wall (rough, smooth, edges) significantly affect the level of background noise.
- Lateral beams are created in the immediate vicinity of the diaphragm. Please refer to Page 8 for sensor installation.

Measuring range and detection zone DU 46 Z.



Ultrasonic Beam

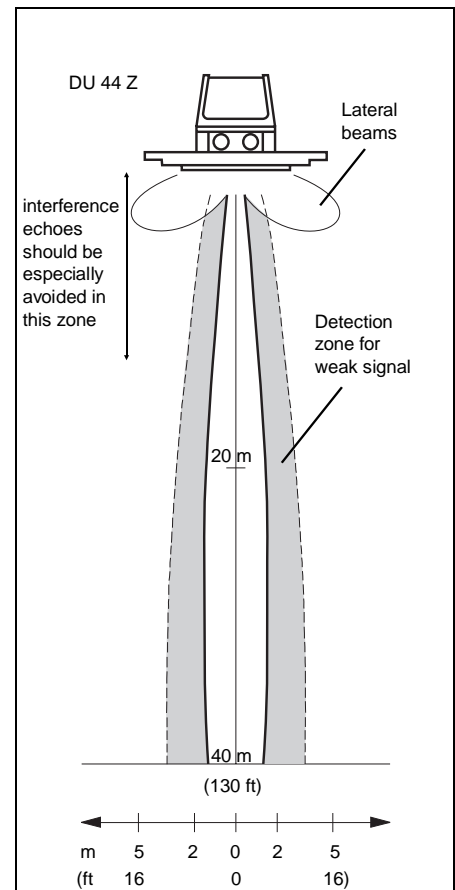
The ultrasonic pulse leaves the sensor as a narrow beam which slowly widens as it travels towards the product surface. Any object lying within the beam will produce an echo which may be received by the sensor.

- Edges, internal fittings etc. within the sound cone in the first third of the measuring range are critical since the sonic energy is still highly concentrated here, small reflecting surfaces causing very strong echoes.
- In the last third of the selected measuring range the sonic energy is spread across a much larger area. Reflections from internal fittings and edges are much less critical.

Two detection zones can be defined across the beam:

- Any object within the central detection zone (continuous line in the illustrations) will produce a strong echo.
- Echoes from the sensor zone (dotted line) are important to measurement only when the signal from the surface of the product is relatively weak.

Measuring range and detection zone DU 44 Z (Lines of equal attenuation)

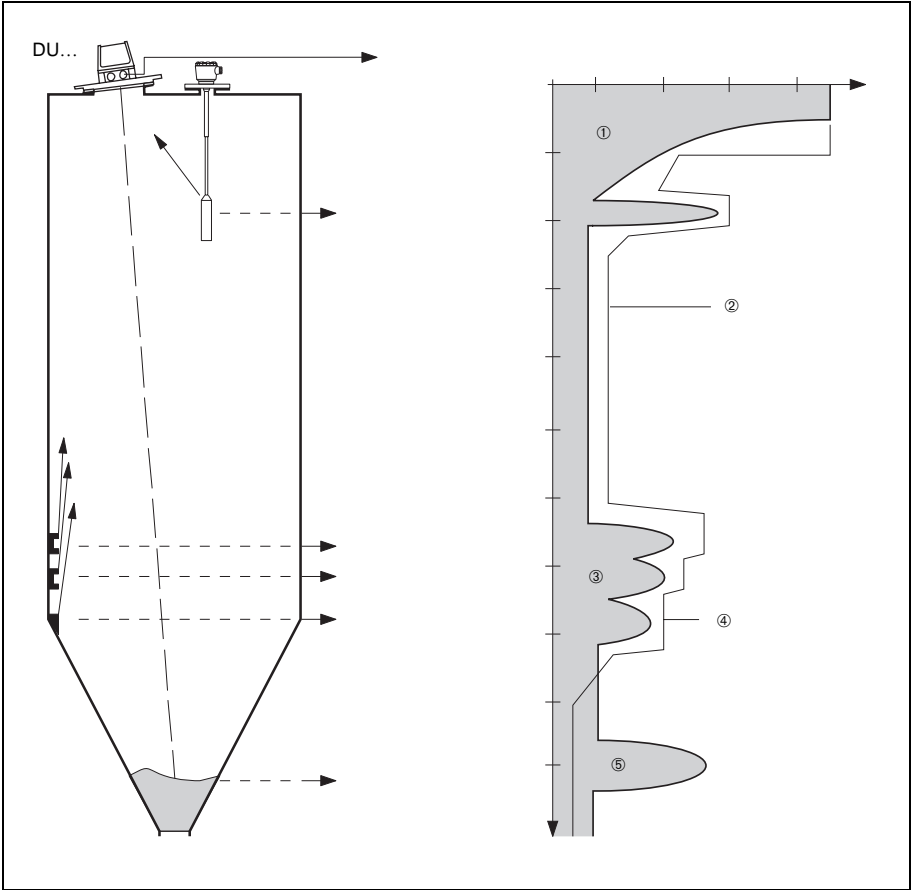


Echo Suppression

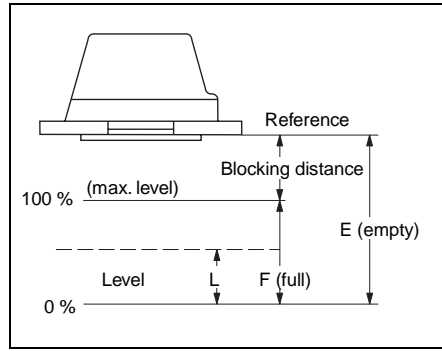
Using echo suppression, an analysis is carried out on all interference echoes sent to the material. The detection threshold is automatically matched to the echo profile so that these signals are no longer registered and processed.

Note that adjusting the detection threshold to the echo profile results in a reduction in the working range. This is especially important with weak working signals (cement silos etc.) where the interference threshold should be minimised by correct mounting and positioning of the sensor before the echo suppression function is activated.

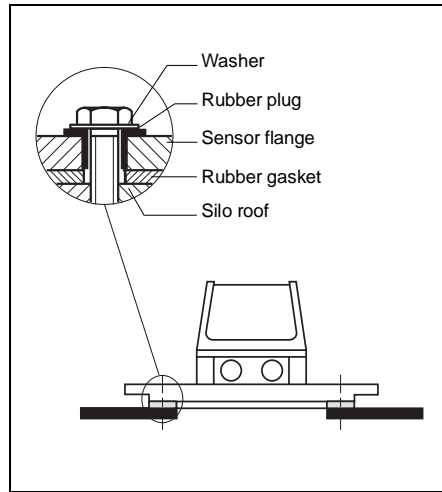
- Suppression of spurious echoes from fixtures:
- ① Signal decay of the sensor
 - ② Time-dependent threshold which an echo signal must exceed for the evaluating unit to register.
 - ③ Interference echo
 - ④ Echo suppression
 - ⑤ Working echo from product surface



Sensor Mounting



The sensor is supplied with rubber plugs for the flange bore holes and a rubber gasket for sonic decoupling. Note the torque (approx. 35...40 Nm) when tightening. If the torque is too great, then the rubber is compressed so tightly, that sonic decoupling can no longer be guaranteed.



Blocking Distance

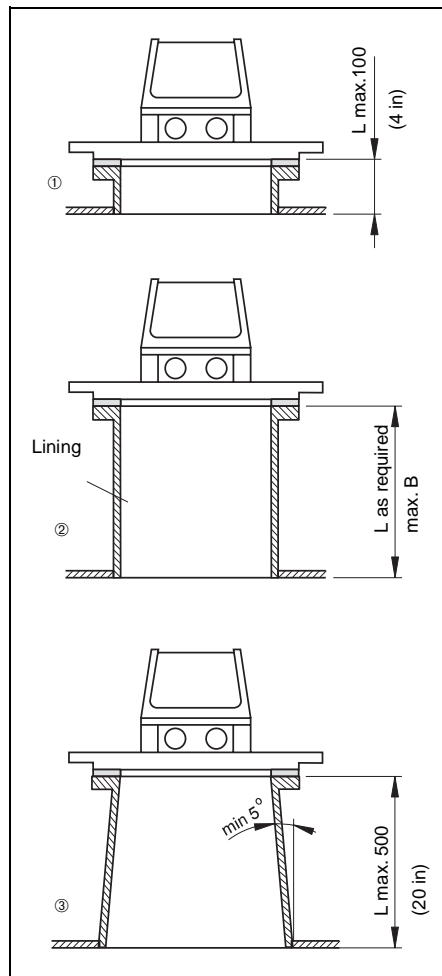
The sensor requires a ringing time after the ultrasonic pulse has been emitted before the returning echo can be detected. This means that the material must not rise up to the sensor. Even at the maximum level (overflow greater than 100 %) the blocking distance must not be overstepped.

The blocking distances are 1.7 m (5.5 ft) for DU 44 Z and 2.5 m (8 ft) for DU 46 Z.

Mounting on a Silo Roof

The sensor is best mounted on the roof of closed vessels which contain bulk solid materials.

A dust removal system should be used when filling the vessel. The sensor flange on the silo roof must be airtight. If this is not the case then suction of the air can lead to hissing, which under certain circumstances can cause incorrect measurement.



When mounting with a collar only:

- ① cylindrical collar, nominal width to suit sensor flange*
 - ② cylindrical collar, nominal width to suit sensor flange*, lined with sound absorbing material
 - ③ tapered collar, min. aperture 10°.
- *see dimensions, page 11

Mounting on a Collar

Besides the main sonic beam, which is directed downwards, the sensor also has lateral beams which spread out sideways (refer to Page 6). With long vertical collars the sonic pulses ricochet back and forth for long periods of time creating strong continuous interference echoes.

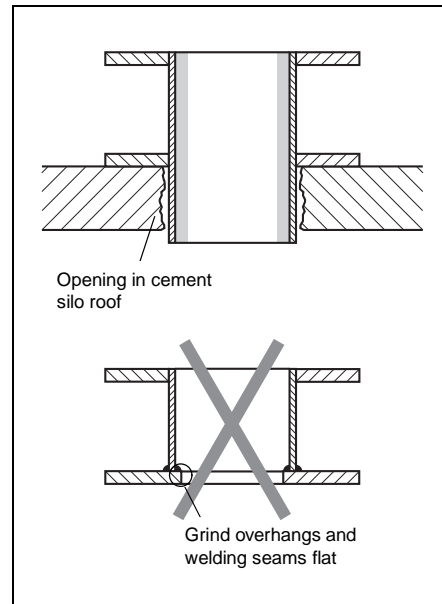
If the sensor can only be mounted on a collar, then a few important points must be noted in order to ensure correct measurement.

- If the cylindrical collar is not higher than 100 mm (4 in), then the lateral beams generate no interference echoes to falsify the measurement.
- A cylindrical collar can be of any height up to the blocking distance as long as it is lined with a sound absorbing material. This lining can be carpeting, e.g. needled felt or foam such as Plano 10 mm. Insulating material such as anti-boom matting is not suitable. A properly lined collar absorbs all laterally produced signals and optimises the directional range of the sensor.
- A tapered collar, either round or stepped, with a min. aperture of 10° can be up to 500 mm high.

Collars

When mounting a collar also take into account unevenness and overhangs which can produce interference echoes. Even a surface roughness of ≥ 0.5 mm can be a source of interference echoes.

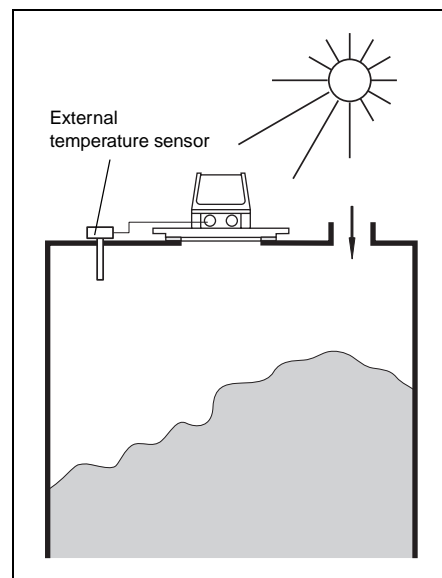
When openings are made in concrete silo roofs for the sensor, then the end of the collar must project completely into the vessel. Check the collar has no overhangs or welded seams.



Accessories

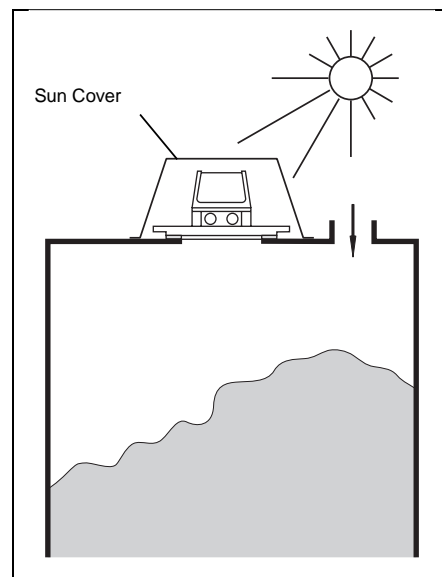
External Temperature Sensor

A temperature sensor to correct the ultrasonic run time is mounted on the diaphragm of the sensor. If the sensor is subject to strong sunlight, then heating within the sensor housing may occur. The temperature sensor will then not be measuring the actual temperature in the silo and a false run time compensation may result giving incorrect measurement. An external temperature sensor should then be used. This is available from Endress+Hauser and is connected to the terminals assigned to it.



Sun Cover

Warming up of the sensor due to sunlight can be prevented by constructing a sun cover rather than by using an external temperature sensor. Check when mounting that sonic decoupling is still possible. The cover should not be in contact with the sensor flange on the silo roof or with the mounting screws.



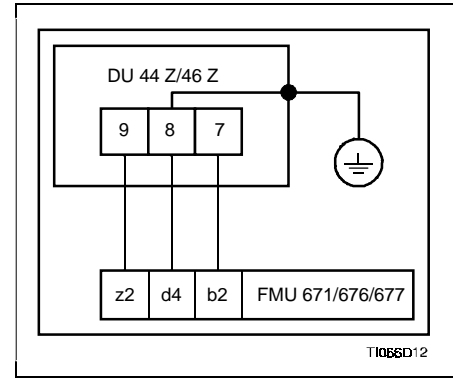
Sun cover as required, e.g. steel plate.

Electrical Installation

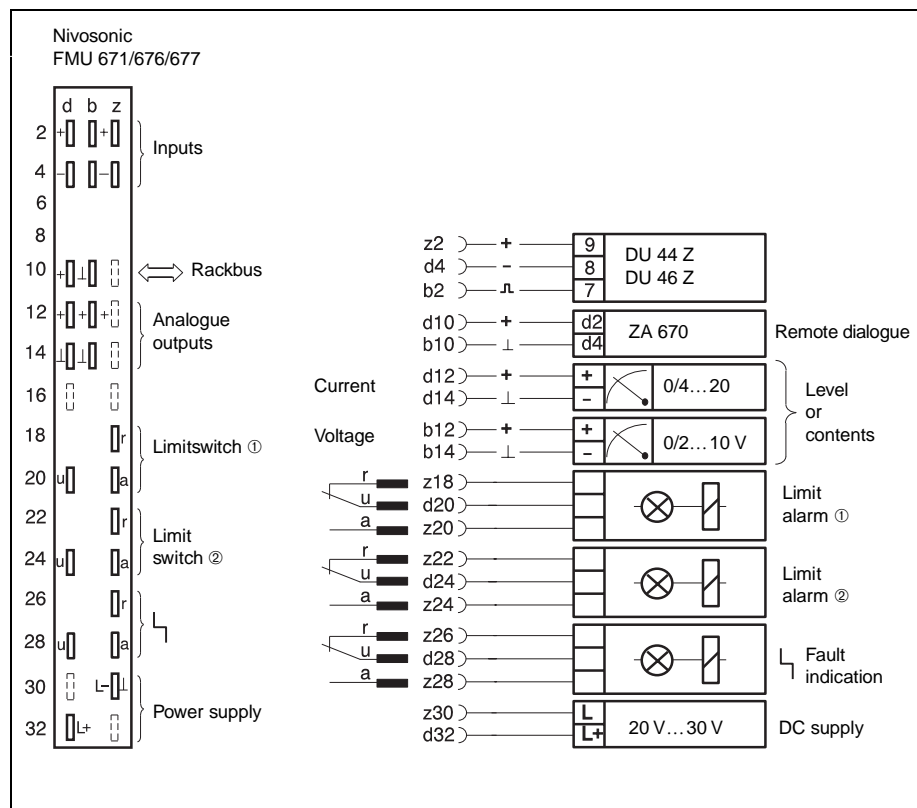
Sensor Connection

- Power is supplied by the Nivosonic FMU 67.
- Use commercial 3-core installation cable.
- Use screened, transposed cable if electromagnetic interference is to be expected.
- Max. line resistance. 25 Ω/core.
- Connect screening of the cabling to the sensor, not to the FMU 67..
- Terminal 8 in the sensor is to be grounded.

With the Nivosonic FMU 67., the sensor circuit is electrically isolated so that no interference occurs with the output current circuits.



Connection diagram
Sensor DU 44 Z/46 Z -
Nivosonic FMU 67.



Connection diagram
Nivosonic
FMU 671/676/677.

Technical Data

Housing

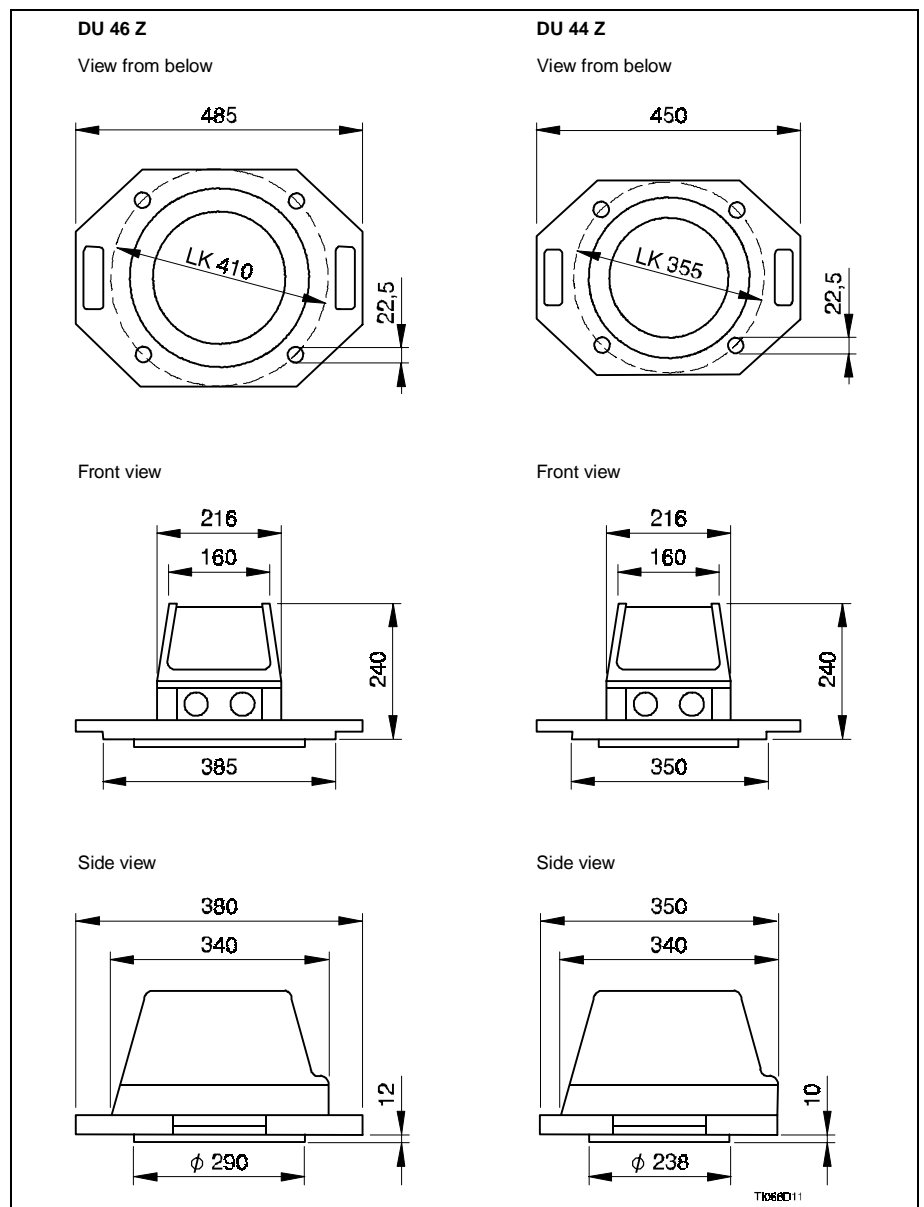
- Material: PU
- Flange: aluminium, coated
DU 44 Z: DN 250, PN 16, DIN 2501
DU 46 Z: DN 300, PN 16, DIN 2501
- Diaphragm: stainless steel 1.4571
- Grid in front of diaphragm: plastic
- Ultrasonic run time correction: silicon temperature sensor, integrated behind diaphragm
- Protection: IP 65
- Weight:
DU 44 Z approx. 13 kg
DU 46 Z approx. 15 kg

Operating Conditions

- Pressure p_e : max. 0.5 bar (7 psi)
- Temperature: $-20\text{ }^\circ\text{C} \dots +60\text{ }^\circ\text{C}$
(0 ... 140 $^\circ\text{F}$)
- Approval for dust Ex Zone 10
- CSA approval

Ultrasonics

- | | | |
|------------------------|---------------------|----------------------|
| | DU 44 Z | DU 46 Z |
| • Range : | ca.40 m
(130 ft) | ca. 60 m
(200 ft) |
| • Operating frequency: | 18 kHz | 12 kHz |
| • Pulse frequency: | 1 Hz | 1 Hz |
| • Blocking distance: | 1.7 m
(5.5 ft) | 2.5 m
(8 ft) |



Sensor DU 44 Z and DU 46 Z dimensions.

Dimensions in mm.
100 mm = 3.94 in
1 in = 25.4 mm

Ordering

Sensor DU 44 Z	
Order No.: 918706-0000	Order Code: DU44Z-S1

Sensor DU 46 Z	
Order No.: 918707-0000	Order Code: DU46Z-S1

External temperature sensor	
Order No.: 213239-0000	Order Code: Temperature sensor KTY

Supplementary Documentation

- Ultrasonic Measurement
System Information SI 005/00/e
- Nivosonic FMU 671/676
Technical Information TI 062/00/e
- Multipoint FMU 677
Technical Information TI 086/00/e
- Sensors DU 43 C, DU 43 S
for shorter measuring Ranges
Technical Information TI 145/00/e

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