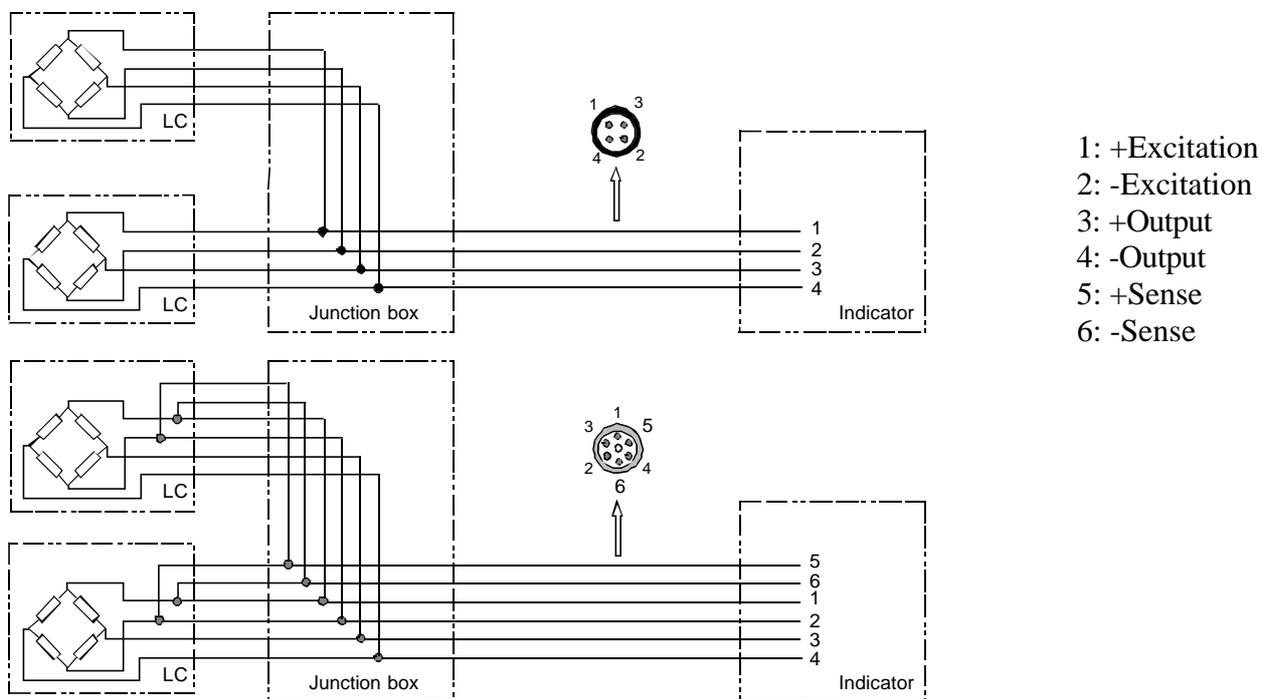


# LOAD CELL CABLING

## GENERAL

Most industrial load cells are used in multiple load cell weighing systems. Load cells should be electrically connected in such a way that the signal (output) lines, excitation (power supply) and sense (when present) lines are in parallel. Usually the connection is not made at the indicator, but in a separate housing, a so called junction box, located adjacent to the weighing system.



The above figures represent the two basic configurations, using four- or six-wire ( sense ) load cells. With 4-wire extension cables the load cell output should be connected to pairs of diagonally opposite wires.

Sometimes it is necessary to trim the output of each individual load cell to avoid corner load differences, which are caused by:

- # the parallel connection. Each load cell will be loaded with the resistance of the other load cells. As a result, the individual load cell output tolerances will be increased by the individual output resistance tolerance.
- # unequal load distribution.

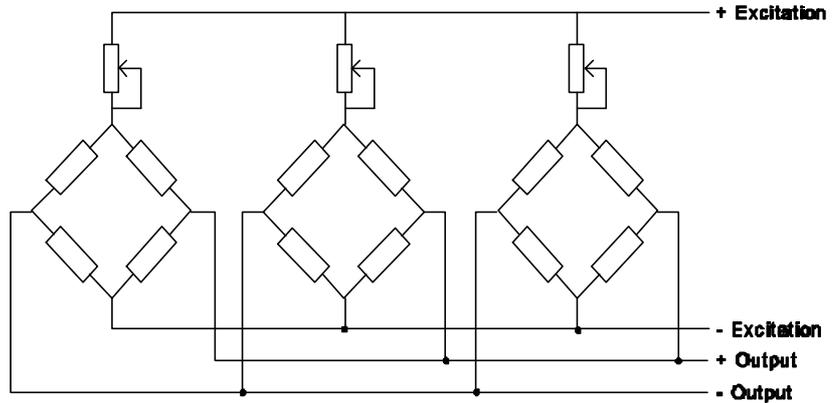
Trimming can be done by placing resistors or variable resistors into the excitation (Excitation trim) or output (signal trim) lines. **All load cells should be placed on the same horizontal level. Check for mechanical unequal load conditions before trimming the load cells!**

# EXCITATION TRIM

Excitation trim is the oldest and still most used method of trimming each individual load cell. The output is trimmed by placing series resistance into the supply circuit to reduce the excitation voltage, resulting in the reduction in sensitivity of the individual load cells to equal the lowest one.

The figure opposite shows a diagram of three excitation trimmed load cells.

A temperature-independent variable resistor or potentiometer of typically 10Ω is inserted in the + excitation lead of each load cell.



There are two methods of trimming with excitation. The first method is to adjust the potentiometers by trial and error whilst moving calibration weights around from corner to corner.

All potentiometers should be adjusted to have zero ohm resistance at the start of this procedure. Then once the lowest output corner is located, the other cells are trimmed to match this lowest output.

This method can be very time consuming, particularly for high capacity scales, or vessel scales where the use of test weights at the corners is not practical. In these cases the second and best method is "pretrimming" the potentiometers with the use of a sensitive voltmeter ( at least 42 digit ). The following procedure can be used:

- 1) Determine the exact mV/V rating of each load cell, which can be found on the load cell's calibration certificate.
- 2) Determine the exact excitation voltage supplied by the indicator by measuring this voltage with the voltmeter ( for example 10.05 V ).
- 3) Multiply the lowest mV/V-value ( step 1 ) by the excitation voltage ( step 2 ).
- 4) Divide the trimming-factor found in step 3 by the mV/V-value for the remaining load cells.
- 5) Measure and adjust the excitation voltage of the three remaining load cells with each respective potentiometer. Verify the results and make the final adjustment while moving a testload from corner to corner.

LC	Output	step 3	step 4	step 5
#1	2.995	2.995 * 10.05		Do not adjust
#2	3.001		30.10 / 3.001	10.030
#3	3.003		30.10 / 3.003	10.023
#4	2.998		30.10 / 2.998	10.040

**WARNING:** The reduction of sensitivity of one load cell will cause a change in zero of all load cells. Therefore adjust in small steps and always verify the results of each adjustment!

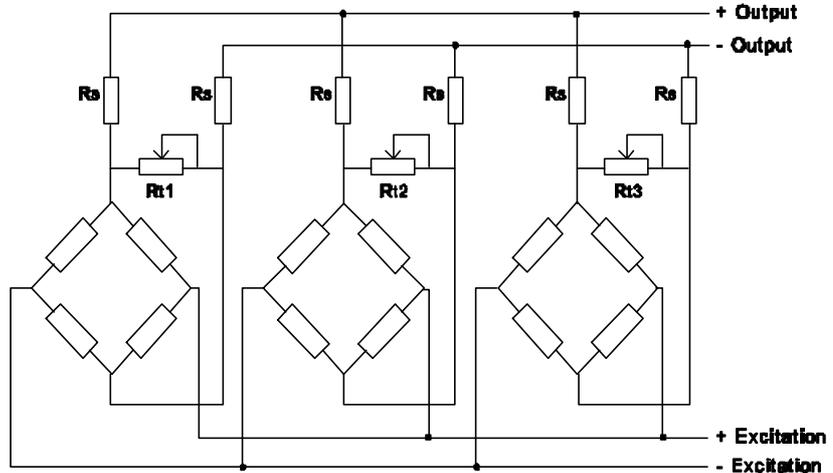
# SIGNAL TRIM

The principle of signal trim is based on placing a relatively high parallel resistance (476220 K $\Omega$ ) between the two output leads of each load cell, to shunt a small part of its signal. Because of the low voltage and current values in the signal circuit, it takes a large resistance change to accomplish a small output change. The main benefit of signal trim is a neglectible interaction between span and zero and excellent temperature stability.

The figure opposite shows a diagram of three signal trimmed load cells.

To avoid an interaction problem between cells in a multiple load cell system, a series resistor ( $R_s$ ) of typically 2500 $\Omega$  is placed in each of the output leads.

Conversely to excitation trim; the larger the shunt resistor ( $R_t$ ), the more signal will be available.



The following procedure should be followed for "pretrimming" of the potentiometers:

- 1) Determine the exact mV/V rating of each load cell, which can be found on the load cell's calibration certificate.
- 2) Measure the output impedance of each load cell with a sensitive ohmmeter ( at least 42 digit ).
- 3) Calculate the trimming-factor (TF) for each cell by dividing the lowest output value by each of the others.
- 4) Calculate the appropriate parallel resistance values ( $R$ ) for each cell by dividing the load cell output impedance by (1-TF).
- 5) Connect only the load cell output lines.
- 6) Remove the output leads from one of the load cell signal inputs and measure the resistance across those inputs with an ohmmeter, adjusting the trim potentiometer until the resistance equals the value of " $R$ " calculated for that particular cell.

When finished, replace the load cell output leads and repeat the process for each load cell except for the one with the lowest output, for which trim should be disabled.

LC	Output	Output impedance	step 3	step 4
#1	2.995	350.1 $\Omega$		Disable
#2	3.001	350.4 $\Omega$	2.995 / 3.001	175258 $\Omega$
#3	3.003	350.3 $\Omega$	2.995 / 3.003	131493 $\Omega$
#4	2.998	350.5 $\Omega$	2.995 / 2.998	350266 $\Omega$

Verify the results and make the final adjustment whilst moving a testload from corner to corner.

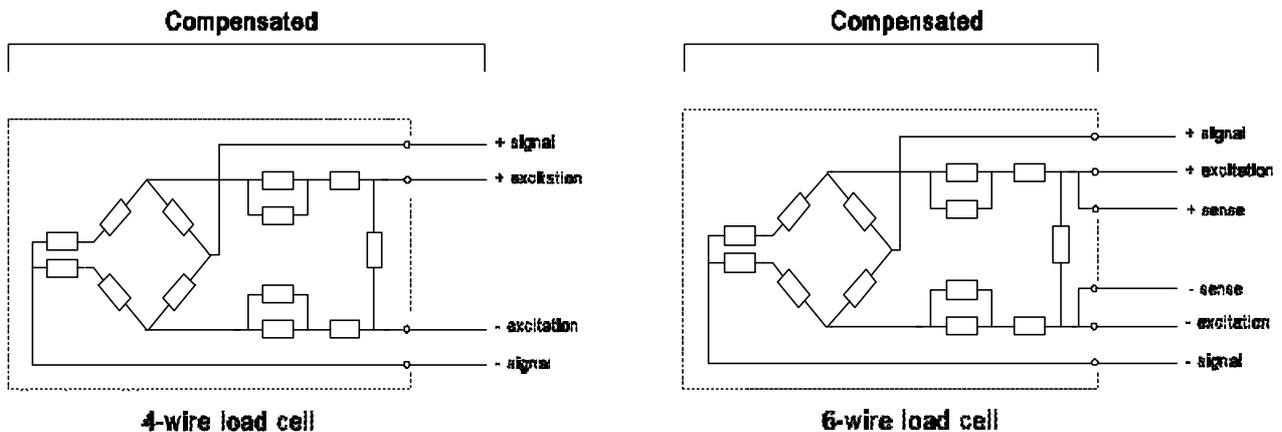
**WARNING:** The resistors " $R_s$ " should be very well matched (" 0.1%) and should have a small temperature coefficient (#10 PPM), else the system will be non-linear!

## 4-WIRE / 6-WIRE LOAD CELLS

A load cell may have a cable with four or six wires. A six-wire cable, besides having +/- excitation and +/- signal lines also has + and - sense lines. It is a common misconception that the possibility to sense the actual voltage at the load cell is the only difference between 4-wire and 6-wire load cells.

A load cell is compensated to perform within specifications over a certain temperature range ( usually -10 to +40 EC ). Since cable resistance is a function of temperature, the cable response to temperature-changes must be eliminated. The 4-wire cable is part of the temperature compensating system of the load cell. The load cell is calibrated and compensated with a certain amount of cable attached. **Never cut a 4-wire load cell cable.**

The 6-wire cable is not part of the temperature compensating system of the load cell. The sense lines are connected to the sense terminals of the indicator, to feed back the actual voltage at the load cells. The indicator either adjusts its output voltage or adjusts its amplifier to compensate for any resistance change in the cable. The advantage of using this "active" system is the possibility to cut ( or extend ) the 6-wire load cell cable to any length. **A 6-wire load cell will not perform within specifications if the sense lines are not used.**



## TEMPERATURE EFFECTS ON EXTENSION CABLES

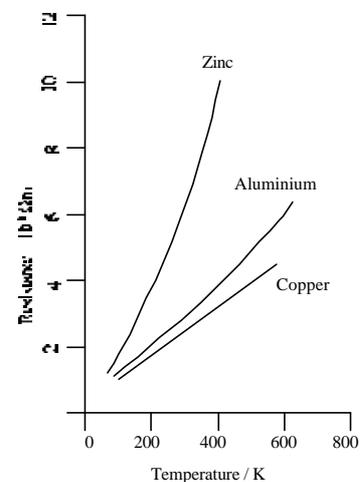
In many cases the degraded performance of a weighing system caused by temperature effects on the extension cable is very small. However, for long cable runs or high accuracy applications, this can be a significant factor.

The resistivity of any pure metal increases with its temperature. The figure opposite shows the effect of temperature on the resistivity of some metals. Over a limited range of temperature the graphs are approximately linear, hence a temperature coefficient of resistivity can be specified for the metal concerned.

If the resistance of a wire " $R_1$ " at a temperature " $T_1$ " is known then the resistance " $R_2$ " at temperature " $T_2$ " can be calculated by:

$$R_2 = R_1(1 + \alpha(T_2 - T_1))$$

where  $\alpha$  is the temperature coefficient of resistivity (  $K^{-1}$  )



The resistance of a wire at temperature  $T_1$  can be measured with an accurate ohmmeter or calculated with:

$$R_l = \sigma * l / A$$

- $\sigma$  Resistivity at 20EC ( $\Omega m$ ), for copper  $1,75 \cdot 10^{-8} \Omega m$
- $l$  Length (m)
- $A$  Cross-section ( $m^2$ )

The error to the system ( which is a typical span error ) caused by a temperature change of the extension cable can be calculated by:

$$1 - ((R_{ti} + 2R_1) / (R_{ti} + 2R_2)) * 100\%$$

where  $R_{ti}$  is the combined input resistance ( $R_i$ ) of multiple load cells ( $N$ ) placed in parallel.

$$R_{ti} = R_i / N$$

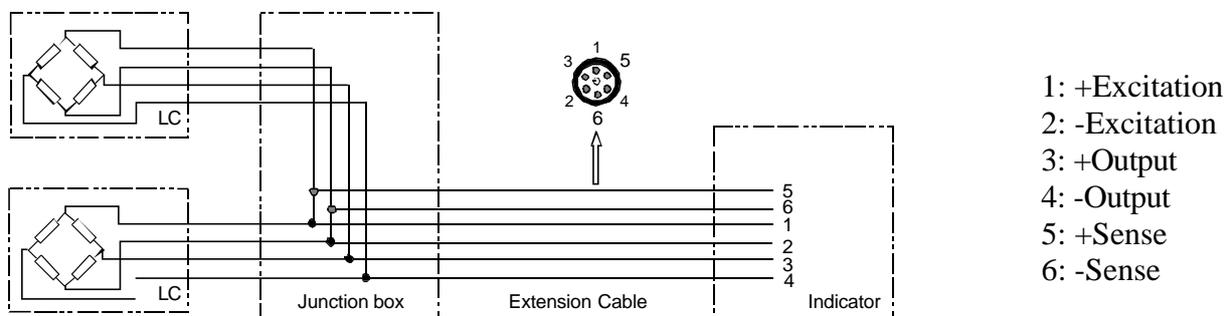
The current flow through the signal ( and sense ) lines is neglectable, therefore a small change in resistance in these lines will not effect the system. The calculations are only applied on the excitation part of the circuit.

**For example:**

Four load cells type SSB with an input resistance of  $350\Omega$  are connected in parallel. An extension cable with a length of 50m and a cross-section of  $0,75mm^2$  is connected between the junction box and the indicator. The cable is made of copper with  $\alpha = 4,3 \cdot 10^{-3} K^{-1}$ . The span-error over a temperature change of 30EC ( 20 6 -10 EC ) will be:

- 1)  $R_1 = 1,75 \cdot 10^{-8} * (50 / 0,75 \cdot 10^{-6}) = 1,167\Omega$
- 2)  $R_2 = 1,167 * (1 + 4,3 \cdot 10^{-3} * (-10 - 20)) = 1,016\Omega$
- 3)  $R_{ti} = 350 / 4 = 87,5\Omega$
- 4) Error =  $(1 - (87,5 + 2,334) / (87,5 + 2,032)) * 100\% = -0,34\%$

The figure below shows the correct diagram (for high accuracy or Weights and Measures applications) when 4-wire load cells are used in conjunction with an extension cable of considerably length. The sense lines are used to compensate for any change in resistance in the extension cable.

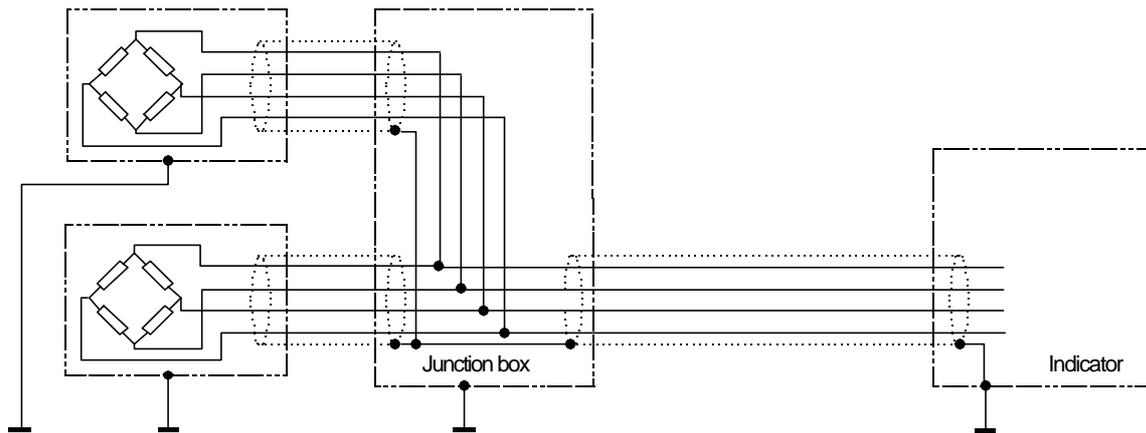


# GROUNDING AND SHIELDING

Proper grounding and shielding can be critical to the successful application of load cells which are generating low level signals (  $<5\mu\text{V}$  / scale division !). The basic rule:

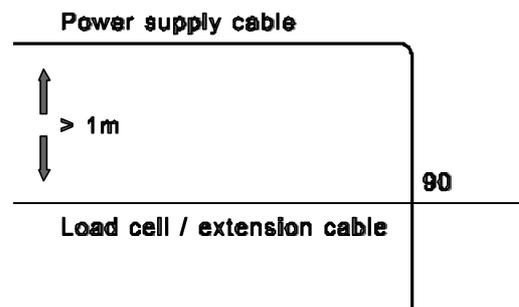
*Avoid continuous ground loops; a system should not be grounded at multiple points. This may occur, for example, if the shield of the load cell cable is connected to earth at both ends.*

Revere Transducers load cell cables are provided with a braided shield which provides protection from electrostatic interference when properly used. This shield is floating ( not connected ) at the load cell avoiding the inadvertent creation of a "ground loop". A basic system configuration is represented in the figure below:



The load cell case and junction box are grounded by mechanical attachment to the structure to which they are mounted. Usually this structure is grounded. The braided shield enclosing the load cell leads is grounded at the indicator, which is grounded through the power cord or housing.

In order to avoid interference, load cell cables and extension cables should be kept away from power circuits, with a recommended distance of at least one meter. Power supply cables should be crossed at right angles.



## CABLE REQUIREMENTS

The selection of a certain extension cable is frequently determined by the specific requirements of the installation. Not only the environmental conditions such as the presence of chemicals, sunlight, vibration etc. must be considered but also the cable's capacitance ( $\mu\text{F}$ ).

The cable's capacitance plays an important role with long extension cables and should be as low as possible!

# OUTPUT/INPUT CALCULATIONS

The total output signal of a multiple load cell system will be approximately the arithmetic mean value of the individual load cell outputs. The combined output can be calculated by:

$$U_o = ((DL + AL) / (E_{max} * N)) * S * U_e$$

$U_o$	Output voltage (mV)
DL	Deadload or tareweight
AL	Applied load
$E_{max}$	Load cell capacity
N	Number of load cells
S	Rated output (mV/V)
$U_e$	Excitation voltage

## For example

A scale is built with four load cells type SHBxM, capacity 200 kg and rated output 2 mV/V. The deadload or tare weight of the construction equals 75 kg and the maximum scale capacity equals 600 kg. With an excitation voltage of 5 V, the total load cell output at full load will be:

$$U_o = ((75 + 600) / (200 * 4)) * 2 * 5 = \mathbf{8,44 \text{ mV}}$$

The total load cell output in a non-loaded situation will be:

$$U_o = (75 / (200 * 4)) * 2 * 5 = \mathbf{0,94 \text{ mV}}$$

If the weighing range is divided in 3000 divisions of 0,2 kg each, then the output for each division will be:

$$(8,44 - 0,94) / 3000 = \mathbf{2,50 \text{ mV}}$$

The maximum current flow in the excitation or input circuit can be calculated by dividing the excitation voltage by the combined resistance of load cells and extension cable ( when present ):

$$I = U_e / (R_{ii} + 2R_l)$$

( see "Temperature effects on extension cables" to calculate  $R_{ii}$  and  $R_l$  ).

The above calculations can be used to verify the scale and indicator suitability. The resolution in microvolts per division is one of the most important features of a system which must be maximised for high accuracy applications ( Weights and Measures ).

# WELDING

Avoid electric welding after installation of the load cells. If welding is necessary and the load cells can not be removed then disconnect each individual load cell cable from the junction box or measuring instrument. Place the clamp earthing electrode of the welding apparatus in the close proximity of the weld to avoid a current path through the load cells. Further, connect a flexible copper lead of at least 16mm<sup>2</sup> cross-section between the vessel and foundation over each load cell.

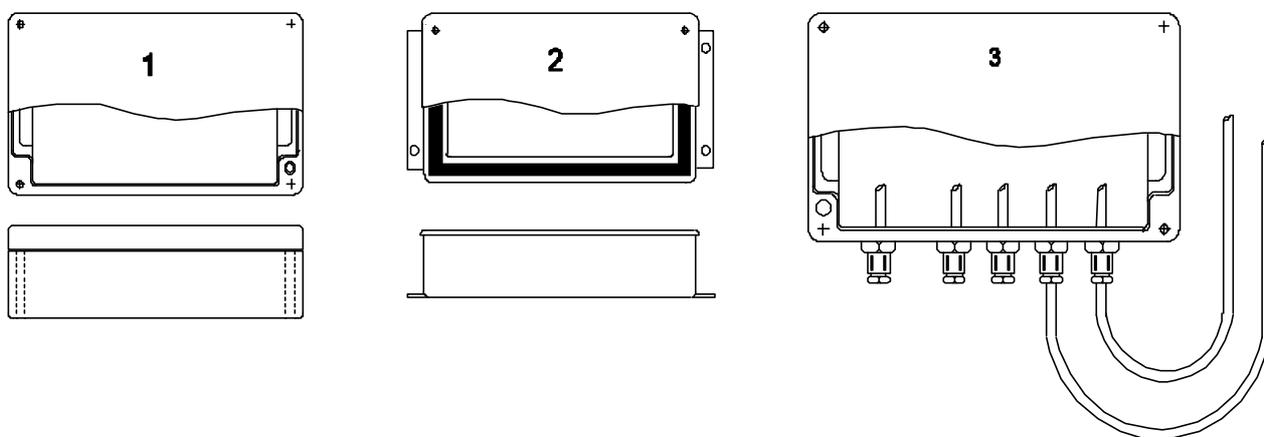
# CABLE JUNCTION BOXES

A junction box should be protected to at least IP54 ( DIN.40.050 ), but for outdoor use we strongly recommend a junction box protected to IP65. The degree of protection can only be achieved if the junction box is installed correctly:

- # Select the right location based on the environmental conditions, NOT on the ease of installation.
- # Put on the cover-screws according to the manufacturer's specifications.
- # Place the cable-entries downwards and provide a dripping-loop in the cable.
- # Avoid moisture during the installation, also ensure that no moisture enters the load cell cable before and during installation.

Moisture could decrease the insulation resistance of the circuit and might cause unstable readings. A bag with drying agent ( silicagel ) should be enclosed to absorb condensation. This bag should never make contact with any not-insulated wiring in the junction box.

For Weights and Measures applications the junction box must be provided with a sealing capability, for example two sealing screws with a wire and lead seal.



1: Glass fibre reinforced polyester junction box.

2: Stainless steel junction box.

3: Correct installation, with cable entries placed downwards and dripping loops.

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## Customer support:

The Revere Transducers group combines fifty years of load cell manufacturing with fifty years of application know how. For any further information, please contact our manufacturing operation or any one of our regional sales offices.

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