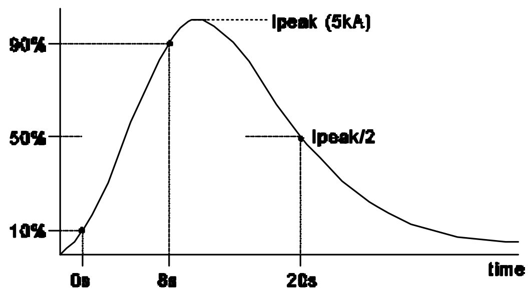
LIGHTNING PROTECTION

SCOPE

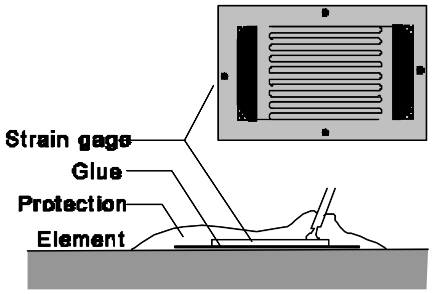
Modern weighing systems rely heavily on high performance electronic components, but the features that make this possible also makes these components more vulnerable to the disruption and damage that can be caused by lightning or over voltage in general.
Together with Telematic Ltd (a member of the MTL instruments Group plc), Revere Transducers has studied specifically the problem of lightning damage to weighing systems. This application note sets out the principles of lightning protection and covers the installation of a lightning protection system.

LIGHTNING

Movements of air might be generated by heat coming from hillsides in full sun or by cold air masses pushing underneath warmer air in a frontal weather system. As the warm air rises, it progressively cools and forms a cloud consisting of water droplets and, at greater heights, ice crystals. A thunder cloud is such a system in which the air velocities are much greater than normal. The violent up-draughts and down-draughts in the cloud centre generate static charges, which result in positively charged ice crystals in the upper region and negatively charged water droplets in the lower region of the cloud.
The intense field which is generated between the charge centres causes ionisation of air molecules to take place and a conducting channel is opened which permits charge neutralisation to occur, ie, a lightning stroke. Most lightning are actually cloud-to-cloud strokes. Something like 15% are cloud-to-ground discharges.
Local charge concentrations tend to be greatest at high or sharp points, so a cloud to ground stroke is most likely to hit tall objects such as masts, towers, trees etc. Once the ionised channel between cloud and ground is complete, a conducting path is formed short circuiting the charged centres and the main current or return stroke can flow so as to neutralise the charge imbalance. This current can induce voltages onto structures commonly associated with electrical distribution such as long (underground) cable runs parallel to the earth.
Tests and investigations indicate that a lightning strike within a 300m radius of the geometrical centre of the site will definitely have a detrimental effect on the weighbridge. Nor is such damage confined only to earth strikes, since cloud-to-cloud strikes are equally capable of producing an electromagnetic pulse (EMP) of sufficient strength to cause damage.
Lightning strikes are bursts of current and voltage, well in excess of normal level. Designers of lightning protection units use "standard" waveforms to evaluate their equipment. A lightning-induced surge waveform is simulated by using equipment with a short-circuit current output of typically 5 or 10 kA giving 8/20µs pulses (ie rising to peak value in 8µs and decaying to half that value in 20µs).



DAMAGE BY LIGHTNING STRIKES



Modern load cells are produced utilizing foil type resistance strain gages. The strain gages are produced by laminating thin foil to an epoxy or polyamide backing. A load cell has normally four (or a multiple of four) strain gages placed in a wheatstone bridge configuration. Several resistors are placed in series with the excitation lines of the wheatstone bridge.
The resistors compensate for temperature effects and are used to calibrate the load cells output. The strain gages as well as the resistors are only capable of handling low voltages usually up to a maximum of 15 or 25 volts. The dielectric strength of the foil backing is approximately 400 to 500 volts. An overvoltage or current which is caused by a lightning strike can destroy a load cell by:

damaging the resistors or strain gages.
damaging the foil backing, which will connect the bridge to the housing.

The damage in both cases might result in a complete burn out of the component, but this is not absolutely necessary. It is possible that only a part of the load cells circuit or one of the strain gages glue layer is damaged. As a result the scale starts to drift and/or will not hold its return to zero. Sometimes these problems appear weeks after the actual lightning strike!

Besides load cells, also the measuring device (indicator/computer) and peripheral equipment such as printers, barcode-readers etc can be damaged, especially when nearby ac power lines have been struck. As with load cells it is possible that only parts of the electronics are damaged, such as RS-232 ports or even just some small tantalum capacitors. Small damage which might not be noticed directly after the lightning strike might cause the indicator to drift. Printed circuitboard should be checked carefully for physical damage or residues from burnt out components.

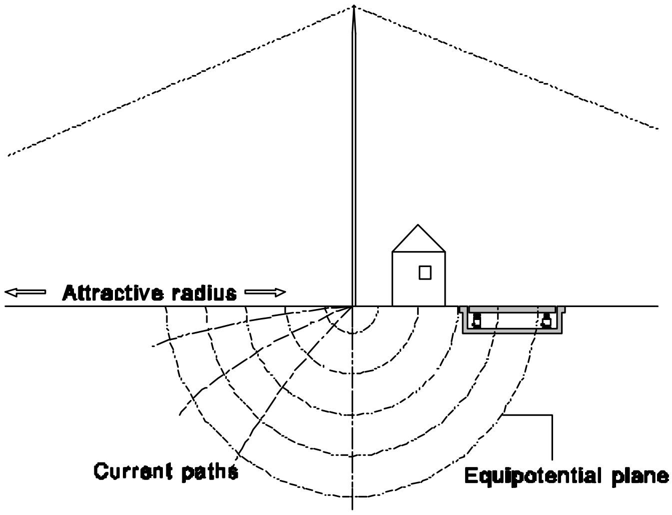
LIGHTNING PROTECTION

It is obvious that a high level of protection against lightning strikes can only be established if the complete system is protected. The decision to protect a system or part of a system should be based on:

the location (urban area or open field).
the average ground flash density (ask for statistics at the appropriate national institute).
the costs incurred during a breakdown period.
the expenses for the replacement of parts and workmanship.
the insurance company requirements (or premiums!).

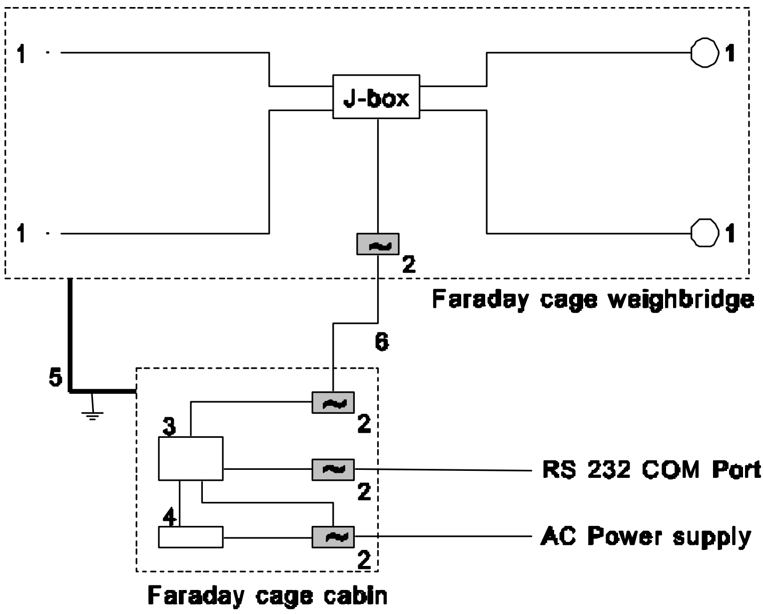
Protection can be considered in two stages; external and internal. Normally, **external protection** entails bonding the steel roof of the cabin where the indicator is located or any nearby structure or a high protection mast in such a matter as to provide a preferential point of discharge and safely conduct the surge to earth via conductors.
In fact considerable controversy surrounds such external protection. A weighbridge or in general a scale is not an attractive point for lightning to strike, but a 20m mast has an attractive radius of 81m. Lightning which might otherwise have struck a building or tree 60m or more away will now be captured to produce a current surge to ground within the very neighbourhood of the weighbridge! Unless very stringent precautions are taken such a surge will produce an electromagnetic induced pulse which will undoubtedly cause severe damage to the weighbridge.

Effective height of structure (m)	Attractive radius (m)
5	30
10	50
15	67
20	81
25	95
30	108
40	132
50	155



The table above is representing the attractive radius of a structure versus its effective height for downward strikes. Masts, which are designed to protect the weighbridge are of little more use than had the lightning struck the structure of the weighbridge directly. Further the mast's attractiveness now serves to actually increase the risk of damage.

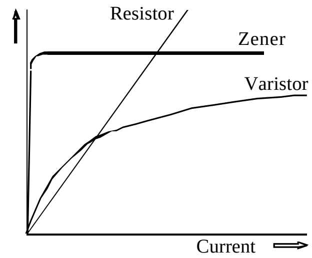
Internal lightning protection sets out to <u>provide potential equalisation throughout the whole system</u> by the use of protection devices and the creation of a Faraday cage out of the weighbridge structure. A Faraday cage is also created around the control room or cabin. If the distance between the two cages is relatively short, then they should be linked by an earth wire so that the whole system rises and falls at the same potential.
Any external connection such as ac power lines, communication ports and the signal/excitation cable is a potential source of surges and transient overvoltages. Central to the provision of lightning protection is therefore the installation of an overvoltage protection device at the entrance of the Faraday cage for each input or output cable.



1: Load cell
2: Protection device
3: Indicator
4: Printer
5: Potential equalisation cable with earth connection ($ 16mm^2)
6: Signal/Excitation cable

SURGE PROTECTION DEVICES

No single component can combine all the necessary features of virtually instantaneous operation, high current capability, accurate voltage control and operation stability. Therefore, multi-component networks (Surge Protection Devices or Units) utilising the best features of several components, are used in practice. An SPD incorporates combinations of gas-filled discharge tubes for high current surge diversion and zener diodes for secure voltage clamping with minimal leakage. For ac power applications, varistors are often used because of their higher power absorption capability.



Most SPDs are connected in series, similar to shunt diode barriers for intrinsically safe systems. By using this kind of SPDs, additional resistance is introduced into the circuit, which will restrict the operating voltage. Further, introducing SPD's into a weighing circuit creates the introduction of a temperature effect:

1) The end-to-end resistance of the SPD will change with any change of ambient temperature.

2) The leakage current to earth will change with any change of ambient temperature.

These effects which appear to be very small, will cause no problems for ac power lines and digital communication lines, but they introduce a considerable error to the weighing system, especially if SPDs are placed on each end of the cable between the J-box and indicator.

The LC30 surge protection device made by Telematic Ltd is specially designed to protect load cells and weighing system installations without affecting the accuracy claims of the system supplier. The device (**verified to IEC 801.5**) is connected in series with the signal, sense and excitation lines and imposes little impedance (1Ω). It is recommended for use at both weighbridge and weighing cabin ends of the circuit.

The LC30 clamps incoming transients immediately without causing undue leakage losses under normal conditions. Once the transient has passed, the device automatically resets to the passive state, allowing normal operations to continue. Specifications LC30 unit:

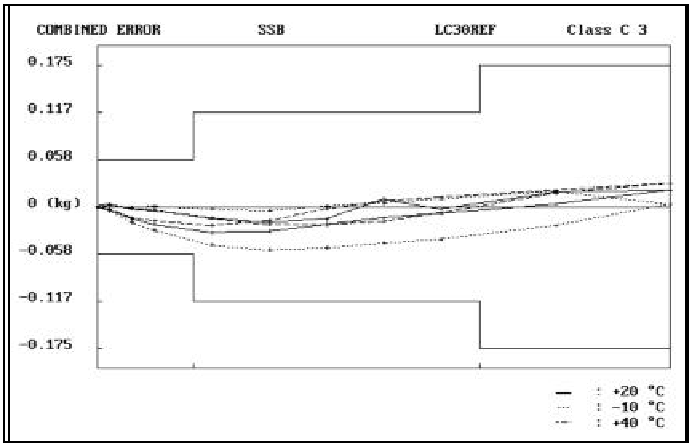
Nominal excitation voltage	V ac/dc	10...15
Maximum excitation voltage	Vac	20
Maximum excitation voltage	Vdc	28
Leakage current at 28 Vdc	µA	<10
Peak impulse current (8/20µs)	kA	10
Protection to IEC44	IP67 (enclosure)	
Connections Input and Output	6-wire + screen + earth	

For ac power lines we recommend the MAO5/D/2. This device incorporates a unique three stage protection: first - Surge Clipping Devices to absorb spikes that could damage equipment, or the internal filter; second - a filter to supress noise in the system; third - ring supression.

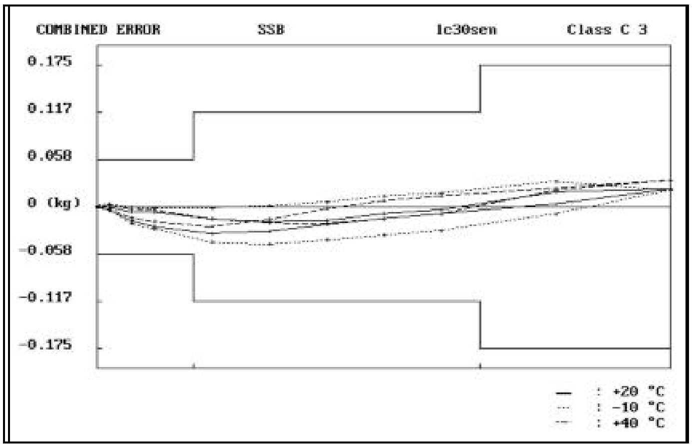
For RS232 communication lines we recommend the MTL377-16V. Specifications:

	Working voltage (V)	Max. operating current (mA)	Maximum resistance (Ω)	Leakage current (µA)	Let-through voltage (V)
MA05/D/2	240	5000		< 300	
MTL377-16V	16	300	12	5	26

TEMPERATURE TEST ON THE LC30



The graph opposite shows the result of a temperature test performed on an SSB type load cell, with an input resistance of 350Ω and a capacity of 500 kg. The load cell was connected to an HBM DK38 indicator, which supplies the load cell with an excitation of 10 Vac / 225 Hz.
According to OIML recommendation R-60, the limits of error shall refer to that error envelope as defined in the figure.



The 2nd graph shows the results of the same test with one LC30 connected in series between the DK38 and the load cell.
During this test the sense lines were used to effectively measure the leakage current in the sense and signal lines.

As shown in the accompanying table below, the readings for temperature effects on Zero Load Output and Sensitivity are hardly affected by the LC30 (S=Rated Output). The minor change in Zero Load Output and Sensitivy, together with the temperature stability allows an easy recalibration of the scale without affecting the overall accuracy.
We recommend to verify the calibration of the scale before and after the installation of the protection system with a reference weight (for example a loaded truck).

	Reference (mV/V)	LC30 (mV/V)	Difference (%S)
Zero uncompensated at 20 EC	0.00520	0.00496	0.012
Zero uncompensated at -10 EC	0.00505	0.00479	0.013
Zero uncompensated at 40 EC	0.00531	0.00506	0.012
Span compensated for zero at 20 EC	2.00313	2.00225	0.044
Span compensated for zero at -10 EC	2.00307	2.00223	0.042
Span compensated for zero at 40 EC	2.00317	2.00229	0.044

The trimming of each individual load cell (corner correction) will not be affected by the unit, when it is placed between the summing junction box and the extension cable.

EARTHING AND GROUNDING

Correct earthing is essential for successful protection. While normal wiring regulations or codes of practice give guidance on earth resistance to safeguard personnel and equipment or reduce interference, they generally have little to say about lightning and surge protection systems. The essence of any protection device for electronic or electrical equipment is to maintain a minimal potential difference between the circuit and the local earth/ground.
Surge protection devices are designed to control line-line and line earth voltages to levels acceptable to the equipment. Any device which works by diverting large currents to a local ground must have a low impedance connection to that ground. This means that the bonding connection must be of low resistance (well below 0,5Ω), short in length and as direct as possible without sharp bends.
Earthing in this context is about defining a central point about which all the electrical systems can float and is not necessarily about planting huge earth mats. Verify the earth connections at least twice a year and coat all connections with a good antioxidant grease.

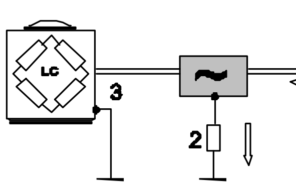


Fig.1

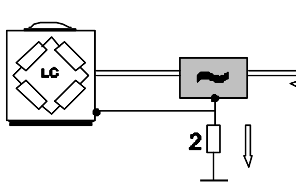
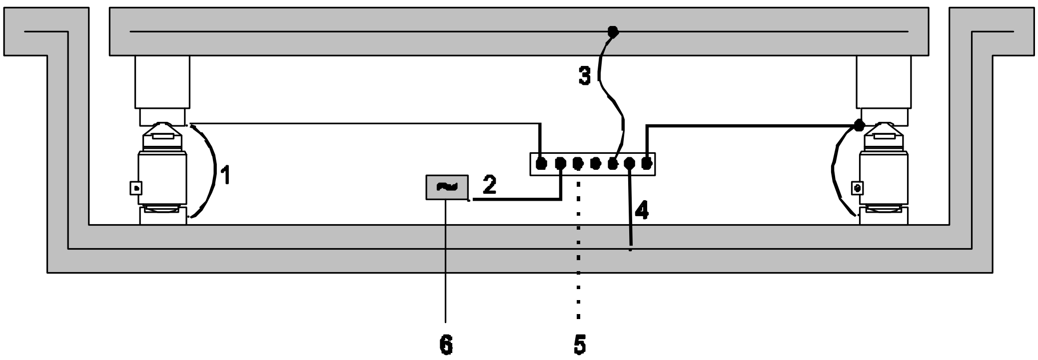


Fig.2

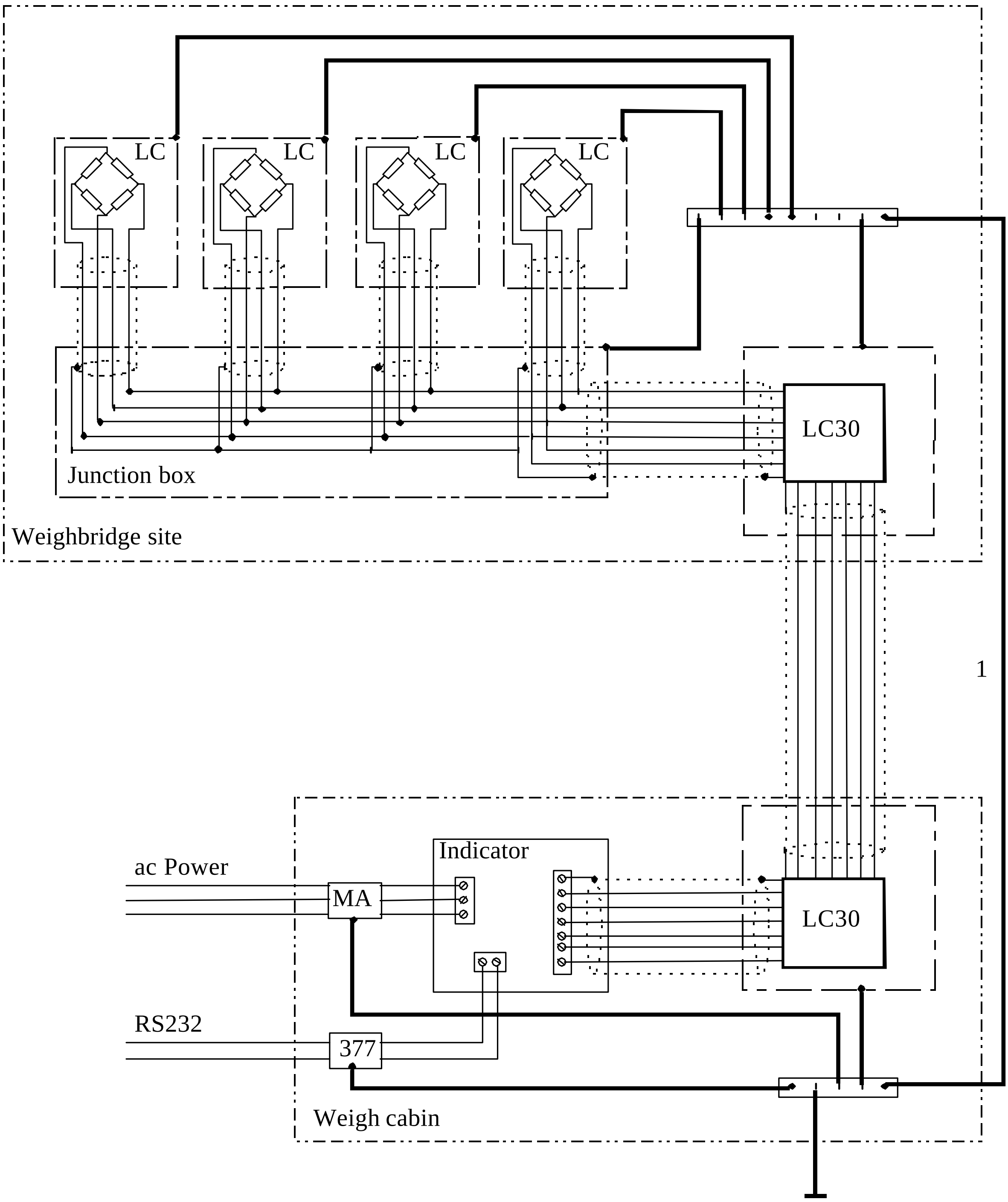
Figures 1 and 2 are showing an SPD connected to a load cell on a remote site. It is common for a nearby lightning strike to induce currents up to 500A (1). If this happened to the sys-tem, the gas-discharge tube in the SPD would conduct, and the current would flow to ground via the 0.2Ω ground cable (2).
Ignoring the cable inductance, this current would generate a 500*0.2=100V transient common-mode voltage across the ground conductor, which would appear in series with the input/output and ground terminal of the load cell (3, Fig.1), rendering the SPD ineffective.
This problem is easily overcome by using the **correct** grounding system shown in figure 2. By grounding the load cell and the SPD at the same point, they both rise to the same potential. If there are no other ground connections, the load cell no longer "sees" the transient voltage and is not damaged. The correct grounding system lay out can be as the figure below:



1 Bonding cable across load cell
2 Bonding cable connected to SPD
3 Bonding cable connected to concrete reinforcement of weighbridge deck
4 Bonding cable connected to concrete reinforcement of weighbridge pit
5 Bonding cable either to nearby earthing-bar in weigh cabin or to local earth
6 Shielded signal/excitation cable to indicator

Avoid additional grounding rods around the weighbridge (only one reference point!). The normal practice of connecting the load cell cable screens can be maintained.

SYSTEM LAY OUT



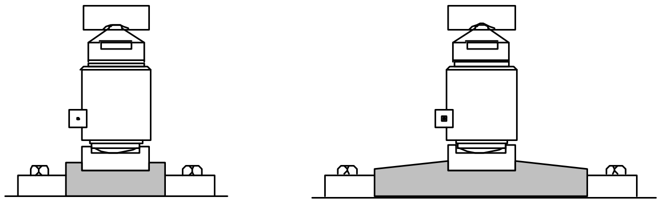
Notes:

The potential equalisation cable (1) should only be used if the distance between the weighbridge site and the weigh cabin is relatively short. Otherwise the weighbridge should be grounded at a local earth.

All earthing cables to load cells, j-boxes etc. should have a cross-section of at least 6 mm^2, but preferably 16 mm^2.
The main earth cable (1) should have a cross-section of 16 mm^2.

INSULATION PLATES

Some weighbridge manufacturers are using insulation plates between the load cell and the structure. Although some protection is established it should be realised that large lightning induced currents can still flow through the load cells circuit and damage it.
It is however unlikely that a potential difference strong enough to damage the foil backing between strain gages and housing will be built up. The insulation plates will only function if they are well protected against moisture; as soon as the plates are submerged the insulation resistance will drop dramatically.



It is of good practice to design the insulation plates to be as large as possible to establish a long insulation path as indicated in the drawing above.

This application note is written as a short guide in lightning protection. The concepts of protection are based on several MTL "Technical Papers" (available on request) as well as the experiences of our customers in the field.
Prices and more detailed information about Surge Protection Devices are available on request.

Customer support:

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

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