Life Energy Motion

LEM TRANSDUCERS
GENERIC MOUNTING RULES

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1 INTRODUCTION

This document explains the rules for mounting LEM transducers in customers' applications. Following these rules will guarantee good mounting of the product in its environment and good behavior over time.

This document only concerns mechanical mounting of the transducers using screws and various threaded parts assemblies. For example, rules concerning electrical connections, electromagnetic environment… etc. are not described here.

Instructions for both metal and plastic housing transducers are given, even though the document is mainly concerned with problems encountered when fixing transducers with a thermoplastic housing.

2 REMINDER CONCERNING STRESS AND TORQUE

When tightening a screw, the pinched material of the transducer is compressed between the screw head (or the washer surface) and the support surface which the transducer touches locally in front of the screw head.

Following tightening, forces are balanced inside the screw, with the total transducer material force compression equal to the tension force inside the screw.

The link between the torque applied on the screw and the corresponding tension force inside is quite complex and depends on for example:

- Thread type *(metric or other standard, pitch…etc.)*
- Different materials of the system *(screw, washer, threaded part in which screw is tightened, transducer materials)* => local friction coefficient depends on each pair of material types
- Different materials' roughness and surface hardness
- Interface type *(dry or with more or less lubricant)* => impact on local friction coefficients between materials
- Tightening speed => impact on friction

Focusing on material properties, the mechanical limit reached by the transducer housing material which will be pressed locally by the screw head pressure on the customer support is in reality a maximum compression stress.

As this maximum recommended stress value would not be convenient and far from the realistic values expected by customers when designing their mounting support, LEM datasheets recommend a torque corresponding to a precise standard configuration.

If only one parameter differs from the previous configuration, the customer must adapt the tightening conditions corresponding to the constraints of their own support design. Most of the time, modifications will consist of slightly decreasing applied torque or using wider washers than the ones LEM uses in tests, for example. The chosen torque remains the customer's responsibility.

3 MECHANICAL THEORY - MOUNTING METHOD CHOICE

When a solid object must be mounted perfectly *(no possible remaining motion)*, the user need only to constrain **six possible movement modes**, called **DOF** *("degrees of freedom")*. For example, defining one precise point position *(three translations)* and orientation *(three angles)* enables the position of an object in space to be known exactly.

Theoretically speaking, when less than six DOFs are blocked, the system is **hypostatic** and some possible motion modes remain. If more than six DOFs are constrained, this is known as a **hyperstatic** fixing mode, that is to say that you have applied more constraints than necessary to mount your part, and there is a **risk of over-stressing** it while mounting.

In order to avoid hyperstatic problems, it is recommended to mount LEM transducers with only one mounting system. Indeed, some transducers can be mounted horizontally or vertically, using housing brackets or primary bar mounting holes, but in each case **both mounting systems shall never be used together** as shown below.

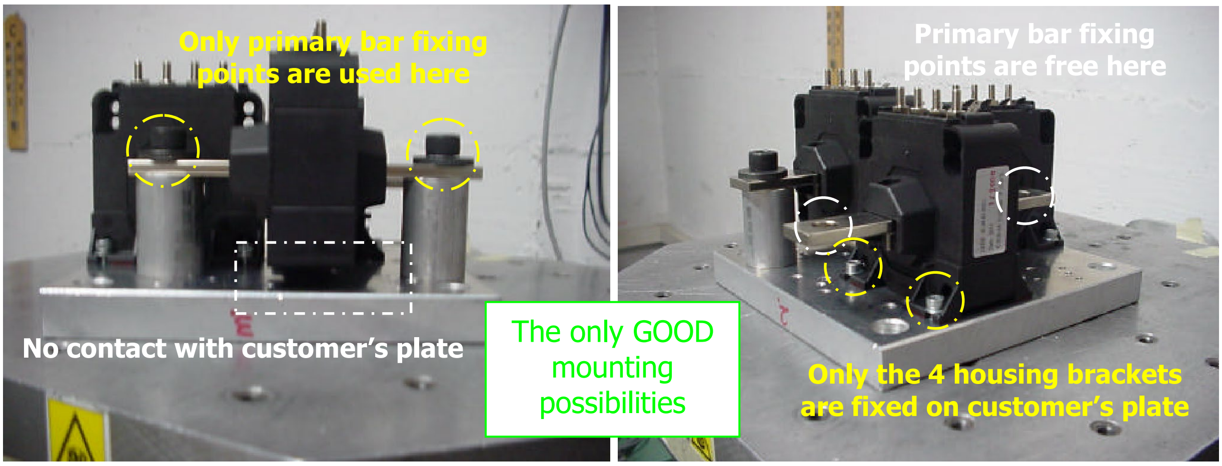

FIGURE 1: TRANSDUCER MOUNTED ON THE PRIMARY BAR OR USING HOUSING BRACKETS

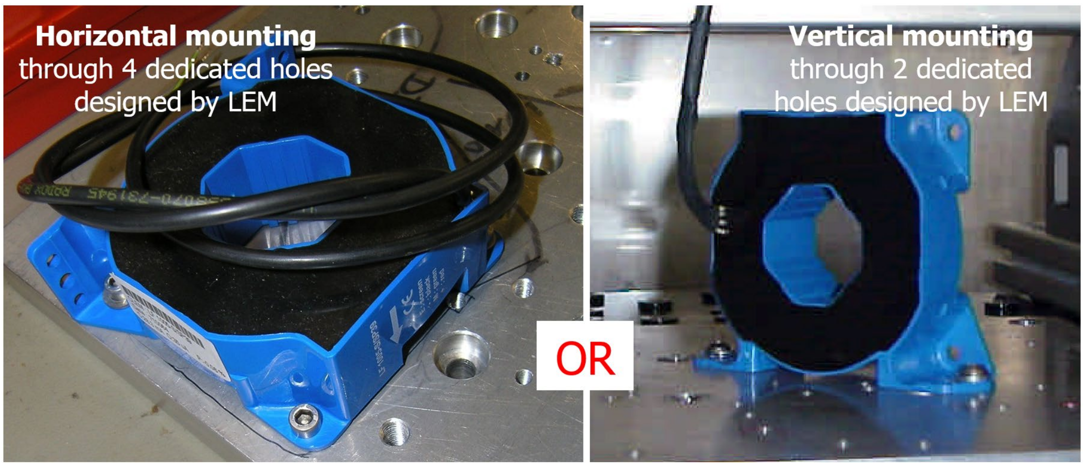

FIGURE 2: TRANSDUCER MOUNTED HORIZONTALLY OR VERTICALLY

LEM transducers have only electrical functions and **shall not be considered as a structural reinforcement or stressed member in any case**.

4 DESIGN RULES FOR CUSTOMER'S SUPPORT

The aim of this section is to provide generic rules enabling customers to achieve a proper design of the support on which the LEM transducer will be mounted and to avoid some pitfalls.

Although the content of this chapter refers to any housing material, sensitivity to stress is obviously more important for plastic fixing brackets. This means that most of the problems listed here will most commonly affect products with a plastic housing.

The main rule is to **maximize the volume of plastic directly compressed** while tightening in order to smooth stresses. The higher the stresses, the greater the risk of experiencing creep, which causes mounting screws to loosen over time.

First of all, the support has to be **as flat as possible** and the contact with the transducer has to be located **primarily around the mounting screw zones**. Some interferences in other regions before screw-tightening would cause damage on mounting brackets as shown below *(mounting bracket bending before compression due to screw tightening)*:

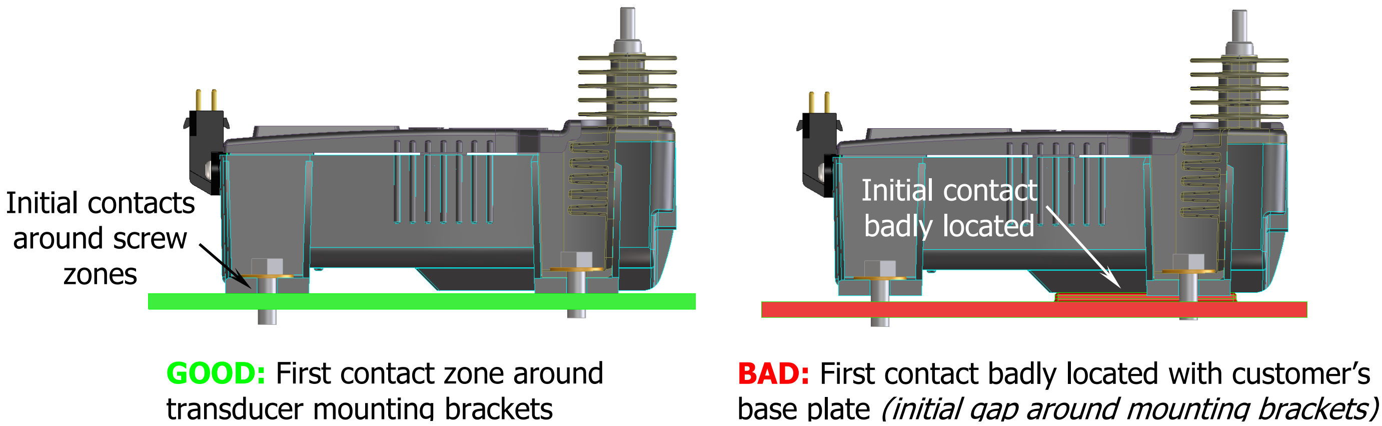

FIGURE 3: FIRST CONTACT ZONE BETWEEN LEM TRANSDUCER AND CUSTOMER'S IMPROPERLY LOCATED

Most of the time, transducer mounting consists in making a plane defined by different zones of the transducer (below fixing brackets) match with a reference plane of the customer application. The previous customer support reference plane must be fully flat. If the customer support is not sufficiently flat, the LEM transducer could experience significant deformation during fixing. Significant stress could then be applied to transducer during the mounting, possibly resulting in instantaneous failure of the housing (or of internal parts) during screw tightening.

Another principle concerning customer's support design is to **maximize the first contact zone between support and LEM transducer's bracket around screw pressure zone**. The following view shows what can happen applying LEM recommended torque when using a local insert instead of general flat support contact surface.

FIGURE 4: EFFECT OF CUSTOMER'S SUPPORT DESIGN ON LEM TRANSDUCER'S BRACKET

The problem shown previously has been seen using a torque value lower or equal to the one recommended in LEM product datasheet. This can be explained in the following figures:

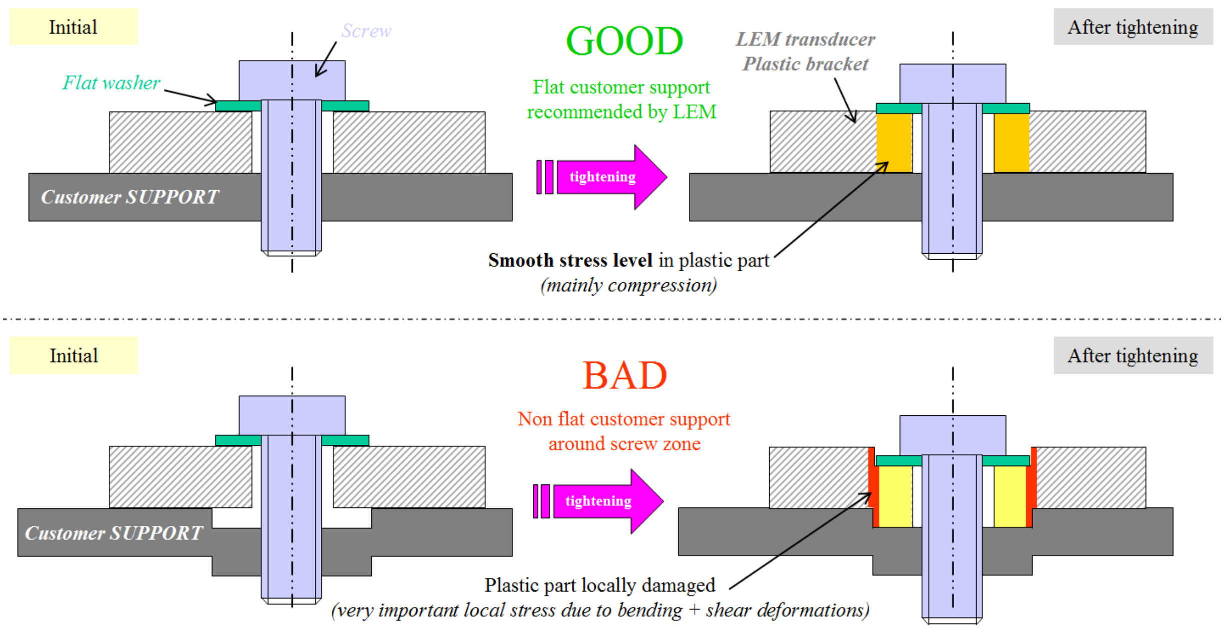

FIGURE 5: LOCAL INSERT EFFECT ON CUSTOMER'S SUPPORT AROUND SCREW HEAD

The latter configuration corresponds to a customer fixing zone built with a metal sheet and a **welded** or a **caged nut** *(see Figure 7)*. In both cases, the direct surface of contact between the LEM transducer's plastic bracket and the nut is lower than the general metal sheet surface.

The surface of the customer's support in direct contact with the transducer's mounting bracket should be **at least as wide as the washer** used for tightening *(see Figure 6)*. In case of using for example a "Rivkle" pierce nut *(see Figure 7)*, the following problem could appear:

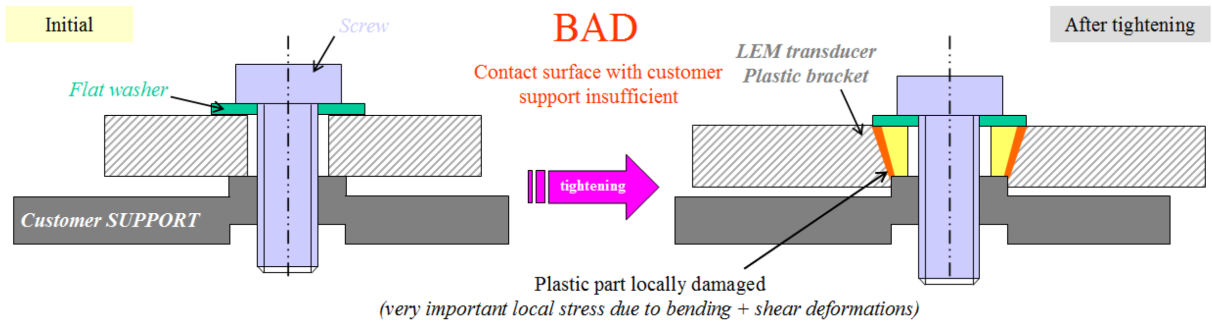

FIGURE 6: INSUFFICIENT CONTACT ON CUSTOMER'S SUPPORT AROUND SCREW HEAD

Even if customer support has a reasonable global flatness, very small local flatness variations of the order of only 0.1 mm can cause problems. These can create initial stress concentrations in the plastic during its compression, decreasing its ability to be smoothly compressed. With such vertical support discontinuities, the torque supported by the plastic bracket must be decreased compared to the perfectly flat configuration.

The different fixing elements below are not forbidden but they must be used with care when integrating LEM products. For example, using these elements means that LEM datasheet recommended torque can no longer be applied. Indeed, these features prevent maximized flat surface contact below the fixing bracket used in LEM fixing tests.

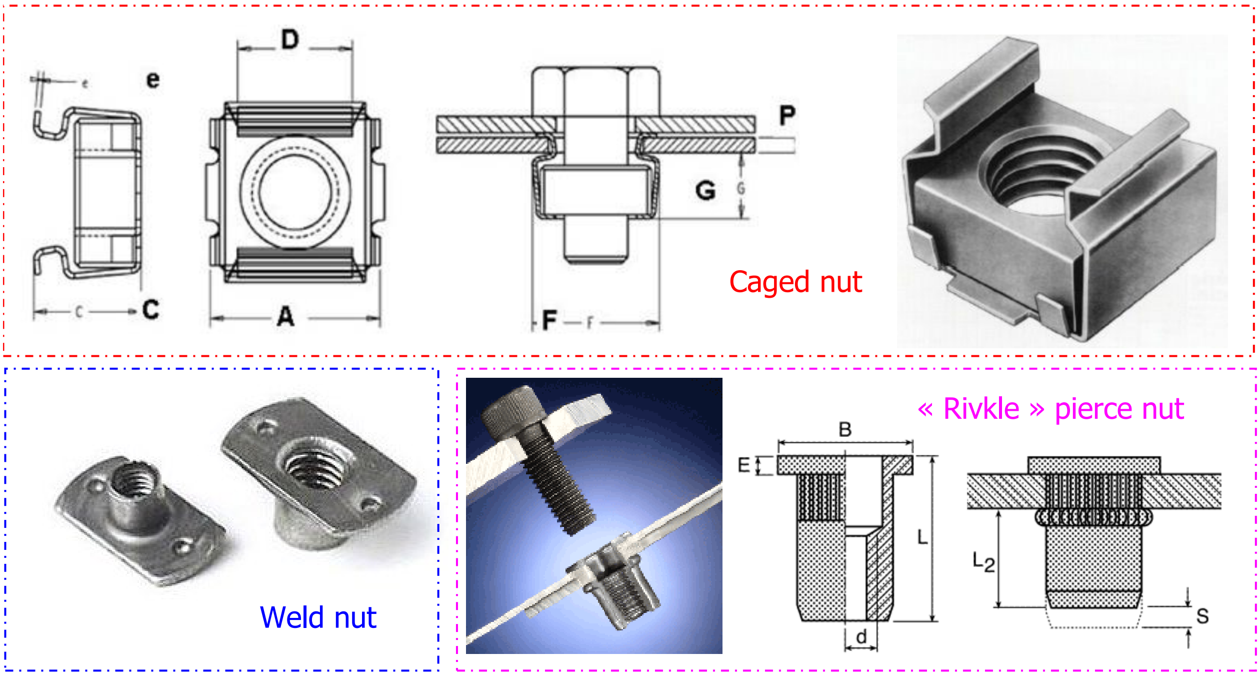

FIGURE 7: EXAMPLES OF NON-FLAT CUSTOMER SUPPORT DESIGN AROUND SCREW ZONE

The last thing to avoid when designing the customer support is to have a **screw axis not perpendicular to the contact surface**. In this case, stress will be very different around the screw hole and the plastic will be damaged.

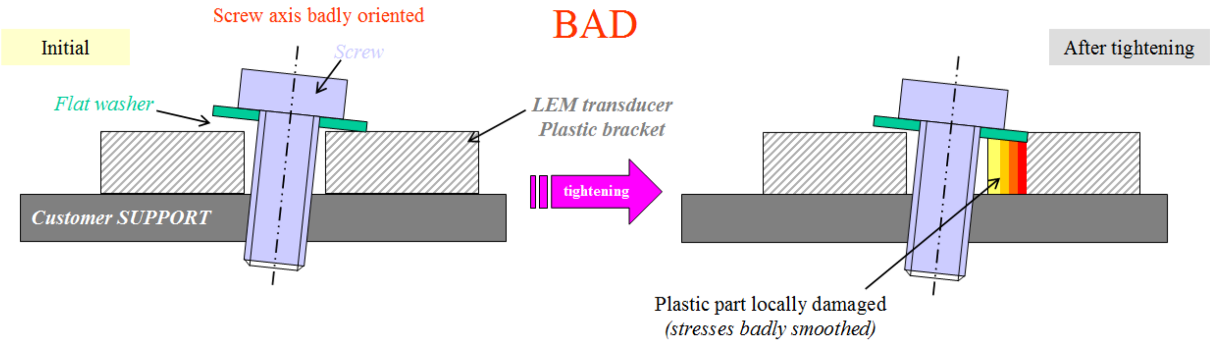

FIGURE 8: SCREW AXIS NOT PERPENDICULAR TO CONTACT SURFACE ON CUSTOMER'S SUPPORT

To conclude, we can emphasize the fact that a **totally flat customer's support design should be used if possible**. If not, local nut function should be implemented very carefully in order to limit non-flat impact on plastic brackets under screw pressure.

5 CHOICE OF FASTENING HARDWARE

Choosing good fastening hardware will allow mounting LEM transducers without damaging the plastic brackets and smoothing as much as possible the stress around the screw zone in order to limit creep risks.

First, in order to minimize stress below screw heads, it is important to maximize compressed plastic surface. So, a **flat washer is mandatory**; standard screw head dimensions are not wide enough.

Concerning the washer type: its aim is to smooth stress while tightening, so any aggressive shape **in direct contact with plastic brackets** *(cutting edges…)* should **not be used** and only flat plain washers are recommended to tighten the transducer's plastic mounting brackets (minimum recommended size: according to standard NF E25-514 "M" series).

The following figures show examples of non-appropriate washer types, **not to be used directly on LEM plastic parts.**

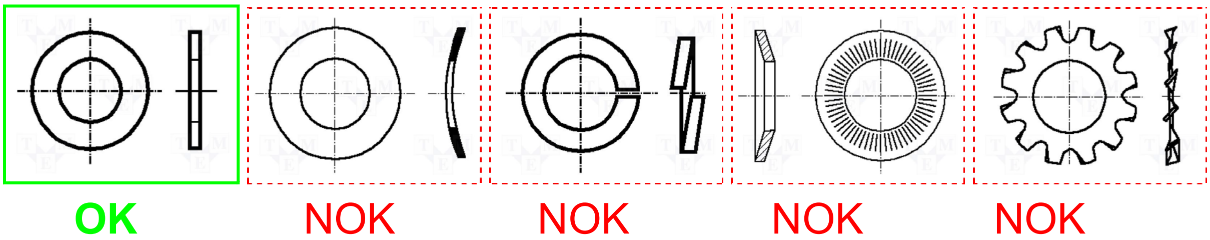

FIGURE 9: WASHER TYPES ALLOWED FOR DIRECT CONTACT WITH LEM TRANSDUCER'S BRACKETS

We can notice that the flat plain washer function can be included by using a large head screw as shown below. However, it's **better to keep these two functions separately** *(screw + flat washer)*; in the case of one single part, the friction forces are directly applied on the transducer's bracket *(torque effect)*.

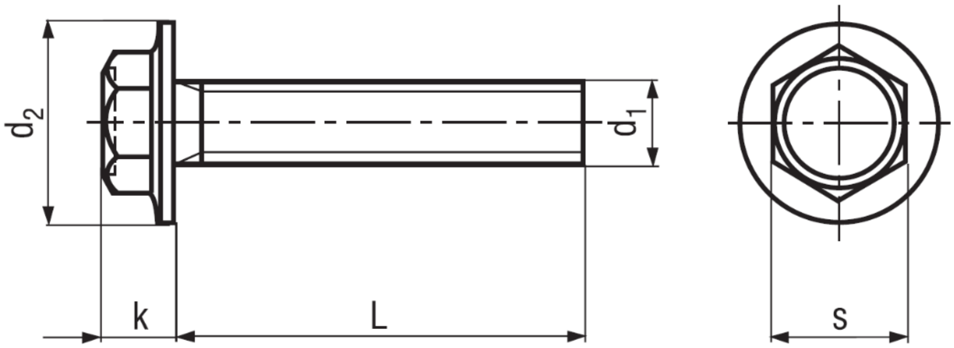

FIGURE 10: LARGE HEAD SCREW EXAMPLE INTEGRATING WASHER FUNCTION

Adding a split or locking washer to the flat plain one is sometime used to prevent loosening, mainly on steel or cast-iron parts for example. This technique is generally successful for transducers with a metal housing, but it is **at best useless**, at worst dangerous, with plastic housed transducers as shown below:

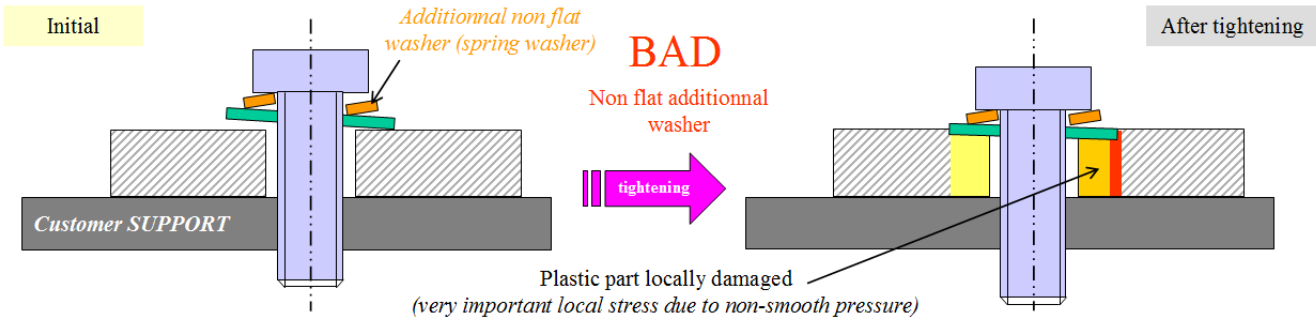

FIGURE 11: POTENTIAL RISK DUE TO THE USE OF DOUBLE WASHER MOUNTING

Moreover, the locking effect is based on the fact that tensile force, directly linked to the loosening torque, remains the same over time. This is true while tightening metal, but creeping is much more important for plastics. Therefore, **even with the additional locking washer**, loosening torque will decrease over time. We do not advise the use of locking washers as they are not very efficient for plastics *(see Figure 11)*.

Another way to prevent loosening is to use **safety self-locking** nuts or screws. In this case, an anti-loosening system consists in adding a high friction material located in the thread zone. Even if plastic creeps, the necessary torque needed to loosen the screw remains higher than with a lock washer solution.

The following graph shows the loss of tightening torque when tightening a typical LEM transducer mounting bracket at two different initial torques *(1 or 3 N.m)*:

- With only "standard" NF flat plain washer,
- With NF flat plain washer and lock washer,
- With NF flat washer + safety self-locking nut.

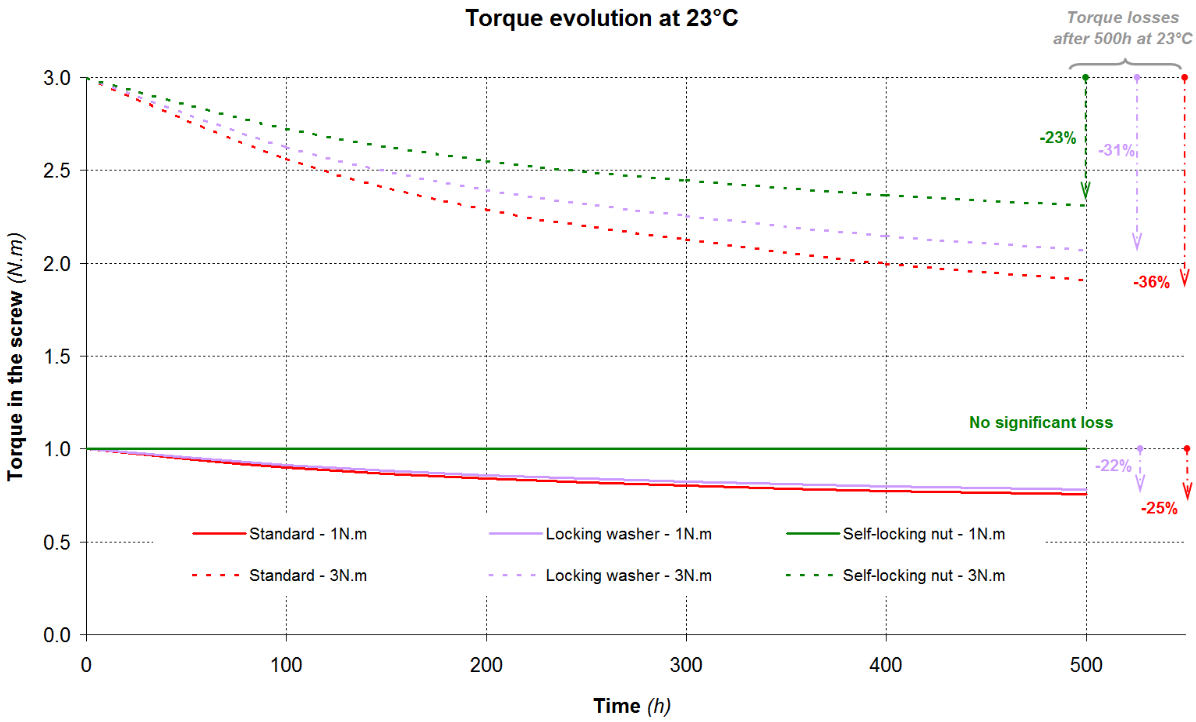

FIGURE 12: LOOSENING TORQUE AFTER 500 H @23°C WITH SELF-LOCKING SYSTEM OR ELASTIC WASHER

As we can see above, "Nilstop" **self-locking nut is a better way to prevent loosening** on plastic parts than a lock washer. The lock washer uses plastic reaction below the screw head to prevent loosening, but loosening is due to the fact that plastic creeps: its stiffness decreases over time. Adding a lock washer has a very low impact on loosening risks. Self-locking nuts don't work the same way: it adds a new friction torque due to the contact with elastomeric coating in the thread zone that is not directly impacted by bracket-plastic creeping.

Finally, we can state that **the wider the contact surface area between washer and plastic, the more important maximum torque is**. The simplified one-dimension approach even shows that maximum torque is nearly proportional to this surface area. So, one way to improve acceptable torque by 50% is to increase the compressed surface area *(surface of contact between plain washer and the plastic bracket…)* by the same percentage.

6 SCREW TORQUE

The aim of this section is to explain the **recommended fastening torque given in LEM datasheets**. First, we can state that the torque must be lower than a maximum value in order to ensure that plastic or metal bracket does not get damaged after mounting but it also has to respect a minimum value in a way that the transducer is tightened enough on the customer's support. For metal parts, most of the time, maximum torque limit is given by the screw's own mechanical resistance itself: the screw system breaks first.

For plastic fixing brackets, the limit is given by maximum plastic acceptable stress. This value depends directly on the thermoplastic used for the transducer's housing. In conclusion, the **maximum torque** given in the datasheet corresponds in fact to a **maximum acceptable pressure below the screw head**.

The **recommended torque value given in the datasheet** corresponds to approximately 90% of the limit value of stress accepted by the plastic perfectly respecting LEM tests conditions both in terms of support geometry and threaded hardware *(see chapter 8 for description of this configuration).*

The torque applied on the screw must respect the specified recommended value of the torque in the transducer's datasheet. Indeed, the **real value applied on the screw must not exceed recommended value in any case**. When using power tools with a tolerance of ±20%, the tolerance on the torque must be taken into account. For example, if the recommended applied torque is 2.2 N.m *(±10%)* in the datasheet, the **nominal torque** of the tool should not exceed the maximum recommended torque, that is to say 2.42 N.m, divided by 1.2. In this case, nominal torque on the power tool must be **lower than 2.0 N.m**.

Effective fastening torque should obviously be lower than the maximum acceptable torque. Tightening screws using a very high torque with plastic parts is not useful because, as you can see below, as the screw is progressively tightened, torque loss becomes more significant.

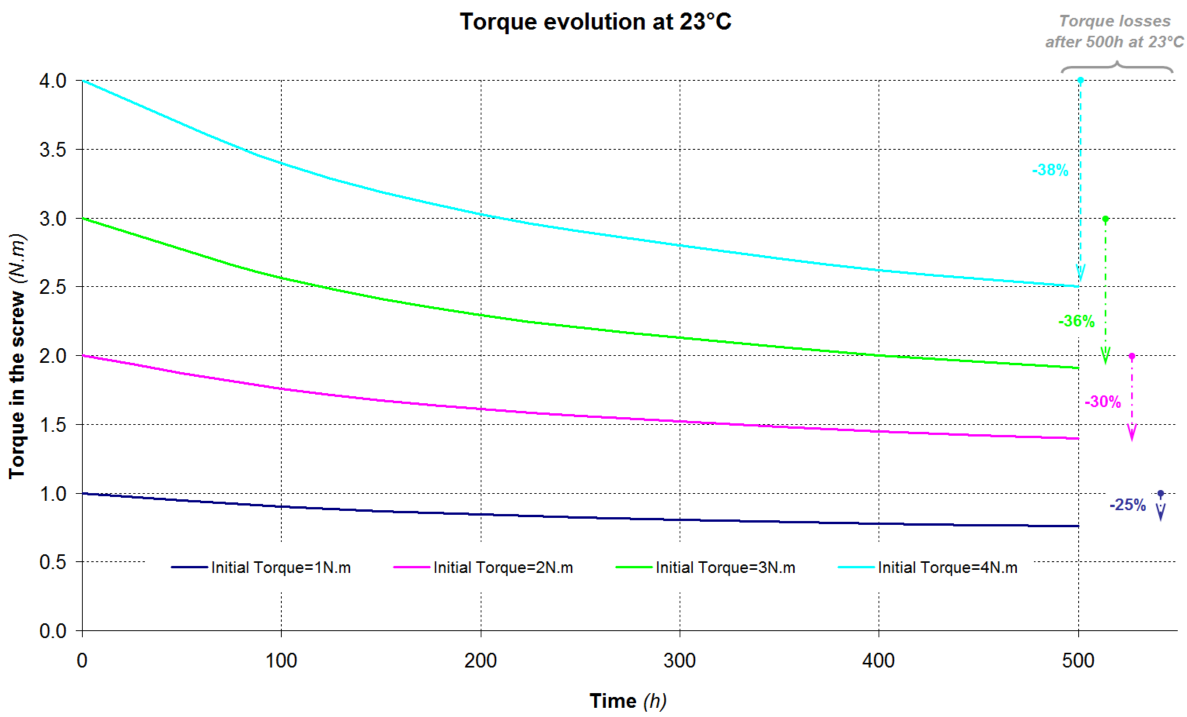

FIGURE 13: TORQUE LOSS WITH STANDARD ISO METRIC SCREW+FLAT PLAIN WASHER @23°C

Globally, tightening screws too much, close to the maximum plastic housing material stress limit, is not really significant because the torque loss is then more important and so residual torque remaining due to creep not greatly higher at the end than if initial tightening had been lower. Moreover, using high torque increases the risk of plastic failure due to possible deviations in the support process. These can include general geometry tolerances of the support shape, manual mounting deviations, bracket slotted hole more or less centered compared to the screw axis, etc.

Using different hardware *(nonmetric thread, other washer type, different hardware materials)* should be done by the customer very carefully. In such a case, the **maximum torque value given in the datasheet is no longer valid.**

Then, a method to choose the relevant torque to apply to mount the transducer on the support would be to **manually tighten** the different screws **slowly** to visually detect the start of washer marking on a plastic surface. This first value can be directly used in case of a low-speed manual tightening by operators. The use of an electrical screw-driving machine would require a study of the impact of rotation speed on the final tightening (affected by the materials used in the threaded system).

We can finally notice that some LEM transducers with plastic housings supporting very hard lifecycle conditions (wide temperature range conditions, very demanding vibrations resistance…) are equipped with metal compression limiter. Then recommended torques are higher and creep sensitivity (torque loss) nearly disappears.

Whatever happens, we firmly recall that a **torque must be applied only once** to a given screw. Once a screw has been tightened, it is completely forbidden, due to creep reasons, to return to it to re-apply the tightening torque *(even few seconds later only)*.

7 MATERIAL COMPATIBILITY

The use of different material for the different elements in a threaded joint may cause **galvanic corrosion problems**.

Indeed, each material has its own specific electrode potential. If two metals or alloys, with very different electrochemical potentials are in contact in an electrolyte, such as moist air, corrosion can occur as shown in figure 14.

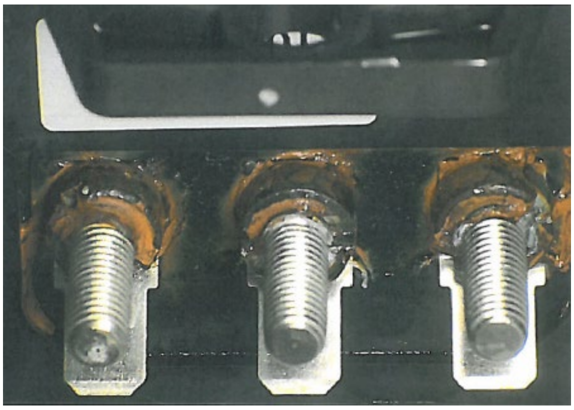

FIGURE 14: CORROSION EFFECT WITH WRONGLY CHOSEN NUTS

The test corresponding to the corroded parts shown in Figure 14 is salt mist *(containing NaCl 5%)*. This picture has been taken after only 4 days of test. All the fastening elements are in Nickel plated Brass, except the slotted round nuts which are made of Zinc plated blue Steel.

Corrosion problems shown on the previous example for electrical connections can also occur when using galvanically incompatible materials for transducer fixing features.

Quickly analyzing the following chart *(see Figure 15)*, it can be easily noticed that the potential difference between Nickel and Zinc, the two coating materials is important *(about 950 mV).* Indeed, the maximum acceptable difference commonly used is about 250 mV when salt mist exposure can occur.

	Anode										
Cathode	Magnesium	Zinc	Aluminum	Cadmium	Tin	Iron, Steel	Chromium	Brass	Copper, Bronze	Nickel, Monel	Stainless Steel
Zinc	0.50										
Aluminum	0.83	0.33									
Cadmium	0.80	0.30	0.02								
Tin	1.10	0.60	0.28	0.30							
Iron, Steel	0.90	0.40	0.08	0.10	0.20						
Chromium	1.15	0.65	0.33	0.35	0.05	0.25					
Brass	1.35	0.85	0.53	0.55	0.25	0.45	0.20				
Copper, Bronze	1.35	0.85	0.53	0.55	0.25	0.45	0.20				
Nickel, Monel	1.45	0.95	0.63	0.65	0.35	0.55	0.30	0.10	0.10		
Stainless Steel	1.40	0.90	0.58	0.60	0.30	0.50	0.25	0.05	0.05	0.05	
Silver	1.60	1.10	0.78	0.80	0.50	0.70	0.45	0.25	0.25	0.15	0.20

1. For units which will be subjected to salt spray or salt water, metal should be chosen where the potential difference is less than 0.25V.
2. Where it is possible the unit will be subjected to high humidity that is not salt laden, then the potential difference should not exceed 0.45V.

FIGURE 15: METALS GALVANIC COMPATIBILITY CHART

In conclusion, it is important to notice that all the **terminals and different fastenings mounted on LEM Transducers** are made of **Nickel-plated Brass**.

The fastenings mounted by the customers on LEM Transducers must respect galvanic compatibility with both Nickel and Brass *(if Nickel coating is locally damaged...)*, in order to avoid corrosion problems. The best way to be compatible is clearly to use directly Nickel-plated Brass components.

The choice of the different materials used for threaded hardware has a major impact on the friction existing inside the screwed assembly between each couple of materials. In this case, for a given torque, the pressing force applied by the screw can be very different. Logically, the same way, the same screw pressing force can correspond to very different torques.

8 LEM TIGHTENING TEST SET UP DESCRIPTION

- **Massive support** *(in “7075” (AZ5GU) aluminum alloy)* clean flat reference for different fixing bracket zones and directly threaded for receiving fixing screws
- First contact zones only around the LEM transducer brackets.
- Use of ISO metric threaded **screws** *(in A2 stainless steel)*.
- Use of standard plain **flat washers** *(size NF E25-514 “M” series; in A2 stainless steel)*.
- Temperature room close to 23°C and 50% relative humidity approximately (results would be different with significantly different ambient conditions).

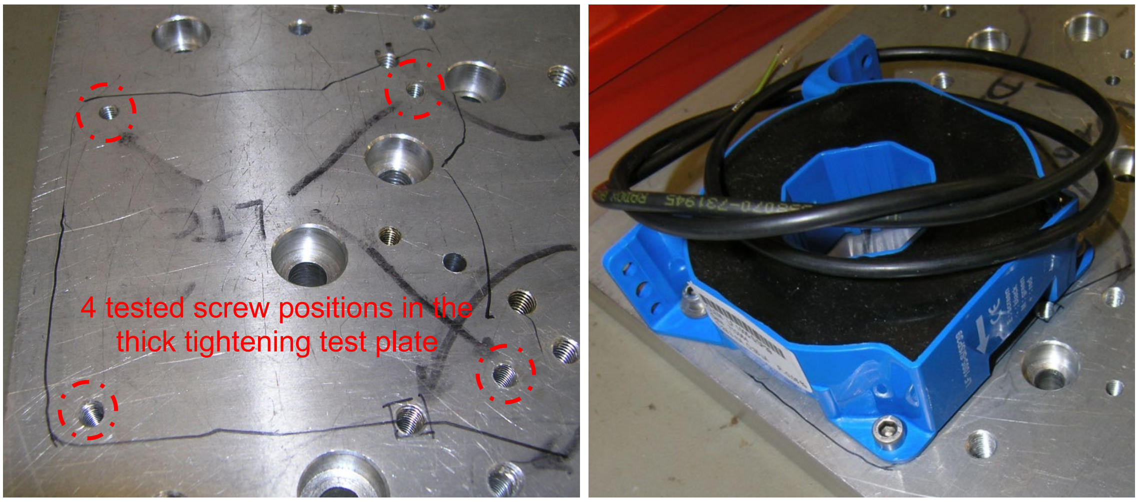

FIGURE 16: LEM CONFIGURATION FIXING SCREW TIGHTENING TEST EXAMPLE SETUP VIEW

An operator slowly tightens the screw with a tool measuring the torque until visually detecting a significant marking of the washer on the plastic surface of the fixing bracket. This torque value is the maximum torque accepted in this precise setup configuration that can support plastic material.

The **recommended torque value** given in datasheets corresponds to approximately 90% of the previous maximum torque value.

Out of this specific configuration, recommended tightening torque given by the datasheet is no longer warranted. The customer must validate the suitable torque corresponding to his own specific application support conditions.