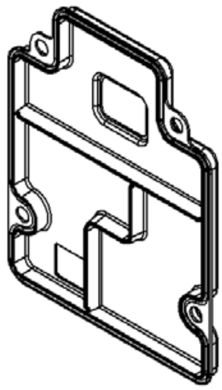
THE COMPASHIELD SHIELDING CAN FROM NOLATO

CONTENT

1. GUIDE LINE FOR DESIGN OF A COMPASHIELD SHIELDING CAN

The Compashield shielding can is a metal can over-moulded with conductive silicone gasket from Nolato. The purpose of this document is to summarise the experience gained by Nolato and to present a general guide line that could help designers to design the optimal shielding can in each application.

Picture 1
A Compashield shielding can.
This shielding can is a deep drawn and over –moulded Nolato standard can that is used in this document to demonstrate important design features.



2. EMI SHIELDING WITH CONDUCTIVE SILICONE RUBBER

EMI shielding of the components on a printed wire board (PWB) in a mobile phone is managed by a Faraday´s cage around the components with a conductive housing that is electrically connected to the ground path of the PWB. Traditionally the connection was arranged by soldering the housing to the PWB or with a metal finger gasket. A more flexible solution is to use a conductive silicone gasket to connect the housing and the PWB.

A silicone gasket is compared with a soldered shield can, easy to assemble and disassemble if needed for inspection or repair. A silicon gasket is also cost efficient and space saving in cases with many shielded chambers. Silicone has a better flexibility and offers environmental sealing compared to a metal finger gasket.

One method is to dispense the silicone onto the housing and cure it in place. This process is sometimes called form-in-place gasketing. The disadvantage with this process is that the design is limited due to the free forming process and that high compression forces are required.

A second method is to mould the silicone gasket onto the conductive housing. This method is called mould-in-place or over-moulding. It is used with good results in large volume production for components to mobile phones. Nolato has delivered over-moulded shielding cans to the mobile communication industry in a number of different programs since 1998.

3. OVER-MOULDED EMI SHIELDING CAN

Over-moulded shielding can are produced by inserting a supporting can into an injection moulding machine and mould a gasket of conductive silicone on top of the can for a flexible contact with the PWB. With this technology we can combine the properties of two materials and reduce the number of parts to simplify assembly and disassembly, improve quality and add functionality. The cost is low especially when several shielded chambers are required. There are three possible can types. Sheet metal cans and die-cast metal cans and cans of plastic.

Sheet metal shielding cans are made of a sheet metal that has been shaped by deep drawing or folding into a 5-sided can. The can is used to cover the components in one or several compartments on the PWB. The metal part can be made of most metals, such as stainless steel or nickel silver or aluminium. The metal part is apart from shielding also used to stiffen the total assembly.

In applications where a very stiff shielding can is required in the phone, or some designers prefer to use a die-casted or impact extruded part of aluminium, magnesium or zinc as the base for the shielding can. This type of metals is also very good for heat dispersion and heat removal from hot components. This part can be used as it is or surface treated depending on the material and application. A conductive gasket is moulded on top of this part.

Over-moulded can of plastic is the third possibility. To ensure the shielding function the plastic needs to be metallized or over-moulded by a conductive layer of silicone. Plastic cans are not used today due to the need of an expensive surface treatment or thick and expensive layer of conductive silicone as well as a low yield from the moulding process. One interesting alternative would be to use a three material shield can with metal for shielding, silicone for contacting the PCB and plastic for features as hooks, holders etc.

In this document we will focus on the most commonly used shielding can, the sheet metal can.

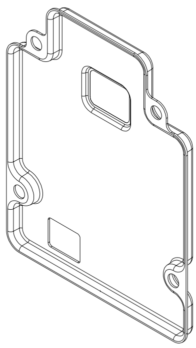
4. SHEET METAL CAN

4.1 Assembly

One of the first things to decide when designing a shielding can is how it should be assembled. For a proper shielding function the silicone gasket needs to be compressed to the PWB. In most cases screws can do this. It is then most common that the screws are used to fasten the can and the PWB in a cover with threads below the PWB. It is also possible to use screw inserts that is riveted to the can.

One could also use a cover to press the can down to the PWB. In this case the force comes from screws or snaps between front and back covers.

An alternative solution that could be used is to construct snaps on the shield can and to snap the can onto the PWB. This design requires a metal with high tensile strength for the snap function. This type of high strength metal is normally to stiff to be deep drawn. The steel could only be shaped by folding or used flat. This could be ok for some applications but this design with snaps do not offer the design freedom or the possibility to increase stiffness to the construction as deep drawing. In this document we will focus on the deep drawn metal can. If there are any questions on a folded can please contact us.



Picture 2.
A deep drawn shielding can design for four screws.

4.2 Metal selection

The most important parameters in metal selection are, shielding effect, ageing properties, stiffness, possibility for deep drawing, weight, price and cosmetics. Table 1 will give guidance in the selection.

Property	Stainless steel	Nickel silver	Aluminium	Copper, brass
Shielding effect	Good	Good	Good	Good
Ageing properties	Excellent	Excellent	Good	Poor
Stiffness	Excellent	Good	Poor	Good
Deep drawing	Good	Good	Excellent	Excellent
Weight	Good	Good	Excellent	Good
Cosmetics	Excellent	Good	Poor	Poor
Price	Good	Poor	Excellent	Poor

Table 1
Comparison of different metals for deep drawing of shielding cans.

Each metal type can be supplied with different tensile strength. To minimise risk for scratches and damages during handling it is recommended to use a matt surface and as high tensile strength as the deep drawing allows with the given material and design. Nolato can advice the correct strength classification for each application.

To improve corrosion resistance and surface conductivity the sheet metal could be plated with silver or gold. This plating is normally not recommended due to the cost and risk for micro cracks during deep drawing. Tin plating can not be used due that the melting temperature is to low for the over-moulding.

We have found that in many applications a can of stainless steel SS 2333-02 with matt surface is the best compromise that offers excellent shielding properties after ageing, high stiffness and the best cosmetics. SS2333-02 is equal to annealed EN 1.4301 and ASTM 304.

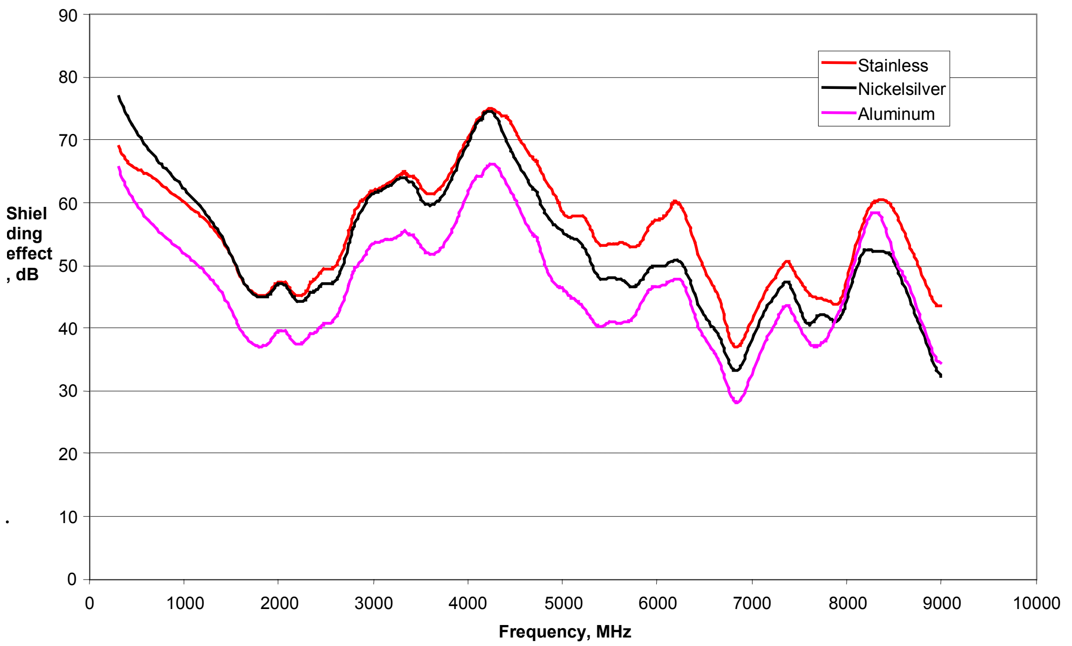


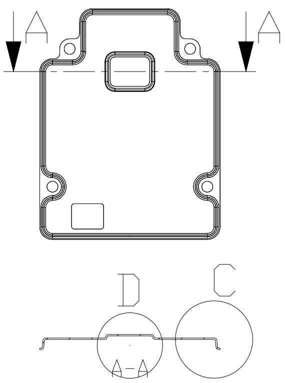
Diagram 1
Comparing shielding effect of cans made of different metals. Measurements are made on Nolato standard shielding can after ageing in acid gases according to IEC 60068-2-60, method 2.

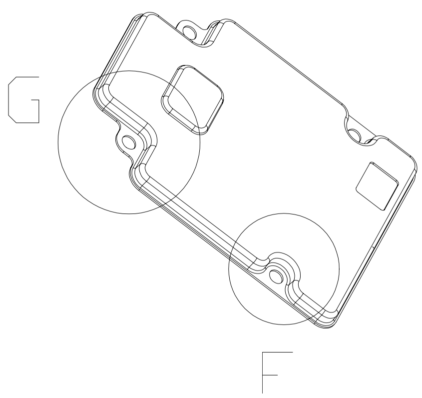
Deep drawing of this type of products can be made in material thickness from 0,2 to 0,3 mm. In designs with very simple deep drawings thickness down to 0,15 mm may be used. If cans of 0,10 mm is required, deep drawing is not possible, cans must be folded.

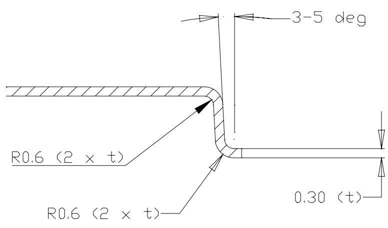
With thicker sheet metal, space consumption, weight and price increases. On the other hand the stiffness, planarity and possibility to deeper drawings also increases. In many projects we have found that a thickness of 0,25 or 0,3 mm is the best compromise.

4.3 Design details

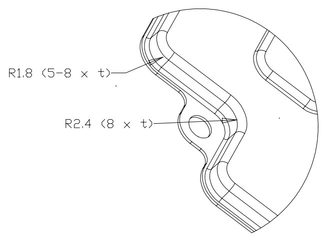
If holes or slots are to be introduced on the can for ventilation or other purposes it is preferred to have a minimum diameter of 1,0 mm from a yield point of view. In the detailed design of the can it is important to consider need for draft angels and bending radius as shown in picture 3.



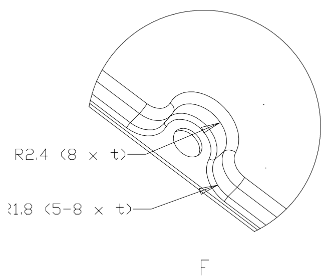




C



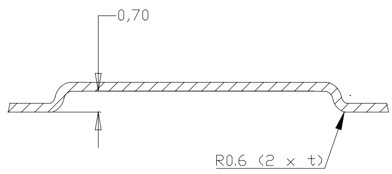
G



Picture 3
The picture shows Nolato standard can with a material thickness of 0,3 mm.
General requirements for deep drawing of shield cans of other design and material thickness t = 0,15 to 0,30 mm is indicated within brackets. The larger radius allows less complicated tooling..

4.4 Space requirements
The total height requirement of a shielding can is the height of components plus a safety margin for component clearance of 0,2 – 0, 4 mm plus the material thickness. Recesses can be made if needed for extra high components. Shielding cans typically has a height of 1,8 to 2,5 mm and requires a ground trace of 1,5 mm width on the PWB around the periphery of the can.

Picture 4
Example of a recess. With a recess height of max 0,7 mm the requirement of the deep drawing outer radius is the same as in picture 3. Higher recesses will require a larger radius.



D

5. CONDUCTIVE SILICONE
The high-quality conductive silicone rubber used for the shielding can is developed and manufactured by Nolato Silikonteknik. To produce it, silicone rubber, conductive particles and additives are mixed together.

The mixes can be optimised for every product in terms of shielding requirements, raw material cost, production efficiency and mechanical properties as hardness and compression set.

5.1 Nolato 8630
For demanding applications we suggest to start with using our standard material Nolato 8630. It is easy to process, shields well and has passed ageing test of several mobile phone manufacturers as well as survived the lifetime of real phones on the market.

Based on low density silvered glass particles with sizes up to 100 my, Nolato 8630 was specially developed for shielding cans to offer lower cost than the traditionally used silvered copper (Nolato 8604). The shielding performance of Nolato 8630 on cans made of stainless steel, nickel silver or aluminium is also better than silvered copper thanks to a lower contact resistance.

	Test method	Unit	8630	8604
Conductive filler			Ag / Glass	Ag / Cu
Volume resistivity	Mil-G-835388	mOhmcm	2	1
Density	ISO 2781	g/cm^3	1,9	3,4
Hardness	ISO 7619	Shore A	75	75
Tensile strength	ISO 37	Mpa	1,5	1,8
Elongation at break	ISO 37	%	90	430
Tear strength	ISO 34-1C	N/mm	11	10
Compression set, 72 hours, 100 C 168 hours, 70 C	ISO 815	%	20 20	40 30
Average shielding effect, 0,3 – 9 GHz Gasket on SS2348 can Gasket on Nickel silver can Gasket on Aluminium can	Nolato, modified MIL STD 285 as in chapter 8	dB	 >57 >53 >52	 >50 >46 >41
Flammability	UL 94		HB	HB
Compression modulus, 10% strain 20 % strain	ISO 7743	MPa	9,2 9,8	8,9 9,0

Table 2, Typical material data for two standard materials from Nolato .

Nolato 8630 and 8604 are high temperature cured silicone system. In environmental tests the material has proved none or only slights deterioration of conductivity or shielding effect. Silicone rubber can easily withstand heat, cold, moisture, UV ozone and pressure over long time. Operating temperature is at least from – 30 C to +125 C.

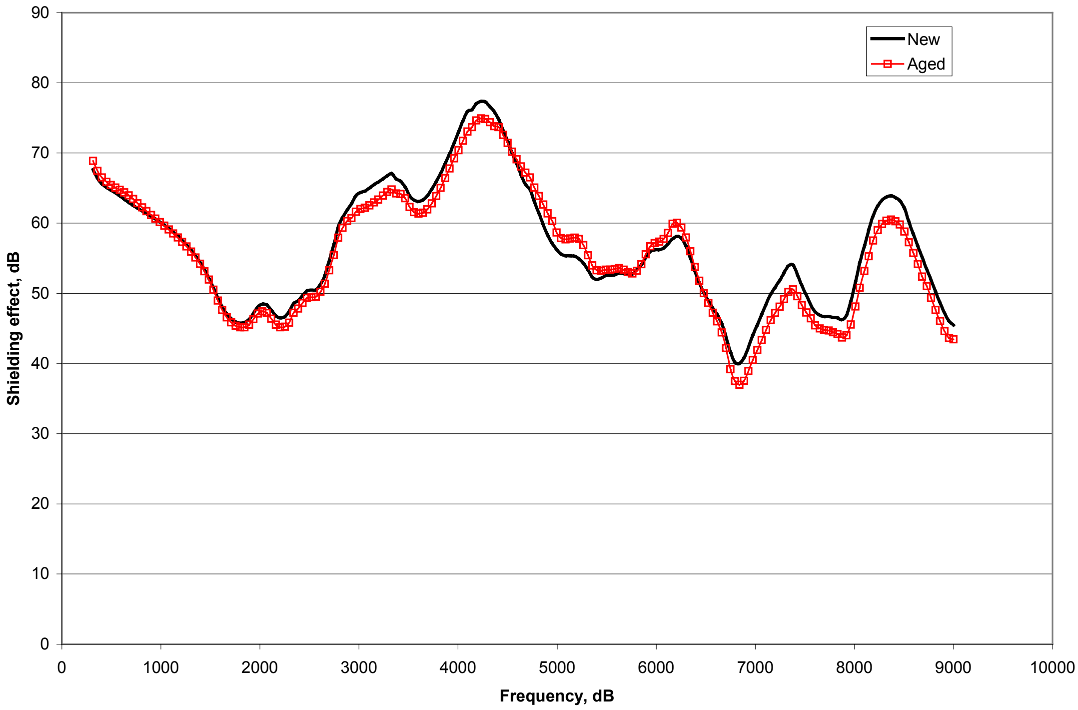


Diagram 2.
Example of aging effect of a shieldcan made of stainless steel and Nolato Ag/glas. Measurements are made on Nolato standard shielding can. Aging is a corrosion test with acid gases according to IEC 60068-2-60, method 2.

For adhesion to a metal surface a primer is used for any conductive rubber. This is also true for Nolato 8630 and 8604. The Primer is a solution of silanes and a solvent. The primer is applied through dipping or rolling and the solvent is then evaporated in air. On the metal can there is remaining a very thin layer of the adhesive. This adhesive is used during the over-moulding for chemical bonding to the rubber.

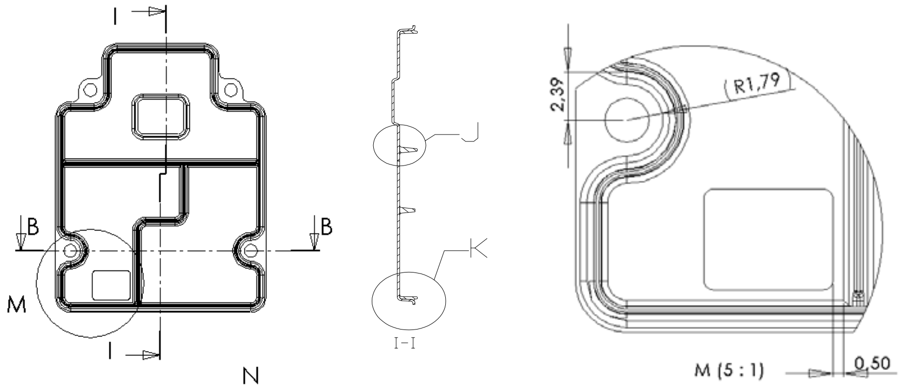
The primer layer is so thin that the electrical contact between the can and the conductive particles in the rubber is not disturbed. The primer will however increase the surface resistivity of the metal can. If a direct electrical contact to the metal is required one could make silicone bulbs for the contact or use more costly, selective priming.

6. GASKET DESIGN

6.1 Gasket location

A gasket has to be designed on both outer walls along the periphery of the can and on partition walls. The need for and location of the partition walls used to separate different chambers is decided in the PWB design. To avoid leakage and excessive flash it is important to have a sealing area of minimum 0,25 mm from a hole to the gasket. If screw inserts are to be assembled after over-moulding a distance of minimum 0,25 mm should also be kept from the area that will be covered by the insert.

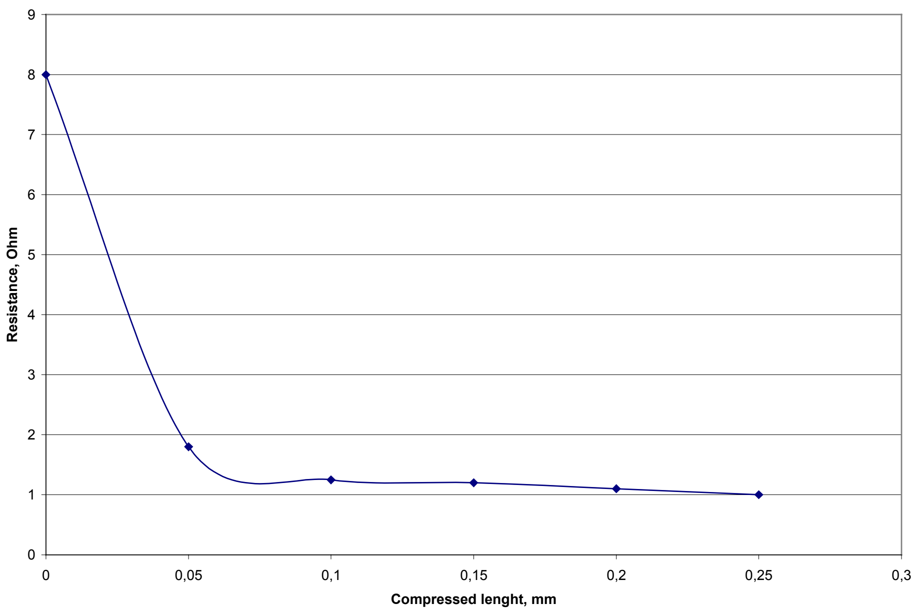
Picture 5
A shield can with three shielded chambers. A minimum distance of 0,50 mm from a hole to a gasket is required for sealing.



6.2 Gasket height

The second thing to consider in the gasket design is the gasket height. It should be high enough to reach over the edge of the can and to take up tolerances and close the gap between the can and the PWB but not too high to avoid excessive compression forces. To ensure a good electrical contact with the PWB it is enough with compression of 0,05 mm. A higher compression does not improve the contact considerably as can be seen in diagram 3. Typical gasket heights are 0,2-0,4 mm over the metal can. We would recommend starting with a gasket 0,25 mm higher than the metal shield can. If found necessary to close the gap the gasket height can easily be increased at a later stage.

Diagram 3
Resistance versus compression length on a typical shielding can

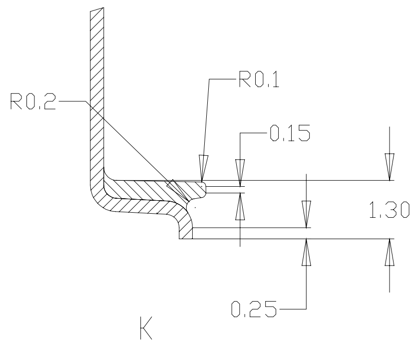


6.4 Design of the gasket on outer walls

The gasket on the outer periphery is supported by the metal walls and can be made thinner than the free standing partition walls. The cross section must however not be too thin to assure a good flow and well distributed conductive particles. This is important to assure a good and repeatable electrical contact.

The preferred dimensions are shown in picture 6. A sealing area of 0,25 mm around the periphery is required for sealing. A sealing area of the same width is required also on the inside of the can. The sealing areas must be supported from the backside of the can during over-moulding. This sealing will not take any space but it will be visible on the backside of the can as minor pressure marks. The total width including the sealing area is 1,3 mm. The lip of the gasket that sticks out about 0,25 mm over the metal surface has a width of about 0,35 mm. No release angel is required for the silicone on the inside of the wall. On the outside of the wall is a release angel of 10-15 degrees recommended.

Picture 6
The profile of the gasket on the outer walls with the recommended dimensions.



6.5 Design of the gasket on partition walls

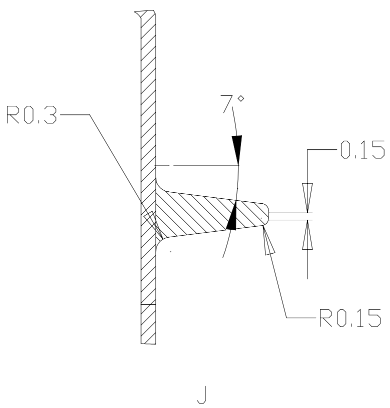
The gasket in the partition walls is standing on its own and it needs to be thicker than the gasket on the outer walls to not risk that it flips off the ground path during assembly of use. A wide base also improves the electrical contact between metal and gasket. A wide top of the gasket improves the contact with the PWB. The preferred dimensions are shown in picture 7.

The width in the sealing area is about 0,45 mm. At bottom the width is determined by the height of the gasket as discussed earlier. A normal gasket height is 2,0 - 2,8 mm. This height gives a bottom width of about 1 mm

A ground path of minimum 1 mm width is recommended on the PWB.

Sealing areas of 0,25 mm is required on both side of the partition wall just as on the outer walls.

Picture 7
The profile of the partition walls with the recommended dimensions.



6.6 Split line and gating

The over-moulding tool is normally designed so that one of the halves fully support the metal can and that the rubber is formed in the other half. The split line will follow the inside of the can.

The gating is normally through a cold channel nozzle with a hole of 1 mm in the top. The gating is preferably from the back of the can, through a small hole and into the bottom of a partition wall. In this construction it will be easy to remove the gate mark and there will be less tear on the primer layer. The disadvantage is that the gate mark on the back of the can may conflict with visual requirements.

Alternative gating is from the inside of the can. Gating could be on the top of one partition wall. Disadvantage is the difficulty to remove the gate mark exactly in line with the wall height. A second possibility is to go down on the inside of the can but close to partition wall and use a side gate. This will leave rubber on an area of approx. 2,5 x 2,5 mm with a height of 0,5 mm.

The positioning for the gating must be discussed with Nolato in every application to assure a smooth flow and minimise risk for space conflicts.

7. COMPRESSION FORCE

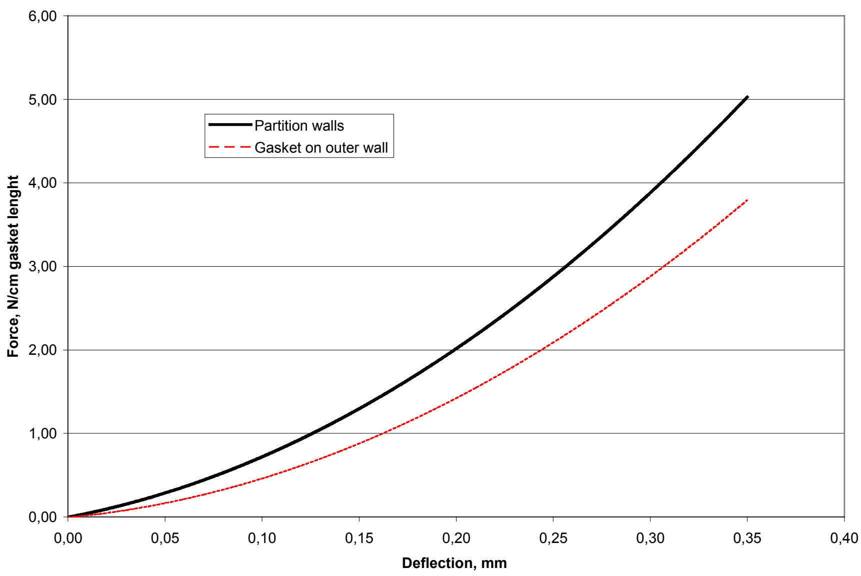
A compression and deflection characteristic of the gasket is an important parameter in the design. During assembly the metal can should be compressed down to the PWB to close the gap and to assure a low resistance electrical contact.

The closure force required to achieve this deflection is a function of length and shape of the gasket, compression percent as well as the modulus of the silicone. Generally speaking the closure force for moulded gaskets for EMI shielding of mobile phones is in the range of 2 to 3 N/cm gasket length.

The closure force can be calculated by FEM or measured directly on the gasket with a compression testing equipment that is capable of measuring the force – deflection relationship. Measurements on the assembly force of the standard gasket is shown in diagram 4.

After compression of the rubber there is an internal rearrangement of the molecular structure in the rubber. This is seen as a stress decay that will reach equilibrium within one hour after the compression. A rule of thumb is that the relaxed force is 75 % of the initial force.

Diagram 4
Initial compression force versus deflection given as N/cm gasket length for the standard gasket on the outer wall and on the partition walls.



8. QUALITY CONTROL IN PRODUCTION

8.1 The production process

The quality is assured by quality control in all steps of the production that includes four main steps:

Metal can preparation
Deep drawing of metal can from sheet metal, washing of cans, dimensional inspection, delivery in bulk to Nolato Silikonteknik, priming of cans.

Rubber mixing
Mixing of rubber, silver and additives. Test of volume resistivity and shore hardness.

Over-moulding
Insertion of metal in injection moulding machine, over-moulding with rubber, ink marking, post-curing, bulk packaging, inspection of electrical resistance and visual appearance.

Deflashing and packaging
Deflashing and 100 % visual inspection, packaging, visual sample inspection and delivery to customer.

In each application it is important to define the demands and specifications at an early stage for dimensional tolerances, electrical resistance and visual requirements.

8.2 Dimensional tolerances

Dimensional tolerances for a shielding can are preferably defined according to ISO 2768-m. The height of the gasket can be tightened to +-0,08 mm.

8.3 Requirements for electrical resistance

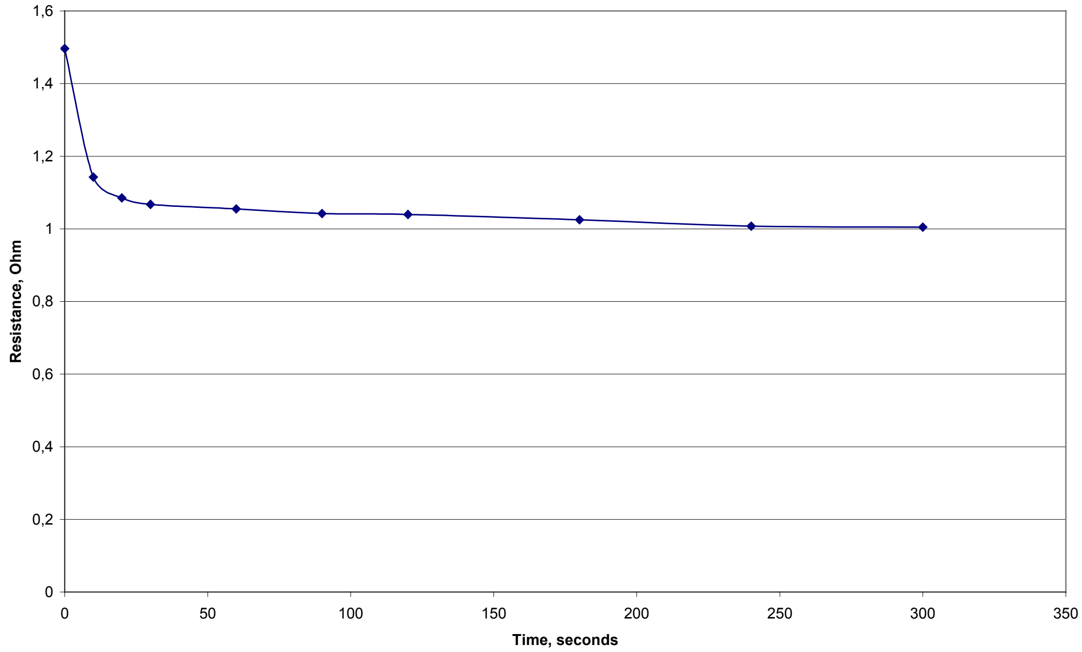
For a proper shielding effect it is important to have a low resistance from the rubber to the metal can. For the first prototypes resistance is checked by pressing a 10x10 mm flat electrode to the rubber lip and measure the resistance through the gasket to the metal can (Nolato standard method, R3). This test is done to assure that the new product is as expected and has similar resistance as other well-known products. Resistance values up to 3 ohms are normally found.

For part verification it is recommended to simulate the assembly in the phone and measure resistance on the "assembled" part. For this purpose a special measurement fixture is built for each product. It is normally a manual knee-joint press used to compress the gasket to a PWB with a segmented ground trace. Resistance is measured from each of the 5-8 the segments and to the metal. Resistance values should be correlated to the result from functional test of final phones and a specification of the resistance should be defined.

For controlling the over-moulding process samples are on a regular basis taken from each cavity to assure that the rubber is conductive and properly cured. The production data is stored in our SPC system.

A rubber characteristic that makes measurement of resistance difficult is the fact that the resistance is dependent on time and history. The resistance is at its highest point just after being compressed in the measuring device. The resistance drops of fairly quickly in the first seconds and reaches an equilibrium level after about 1 hour. The reading is in practical measurements not taken before 10 seconds. The same phenomenon is seen if a shielding can is tested several times. The first reading is always the highest. By repeating the measurement the resistance drops in the same manner as if the gasket is kept under compression.

Diagram 5 Resistance versus time after compression.



8.4 Visual requirements
Visual requirements may differ from application to application. To increase yield it is advisory to agree on acceptance for minor defects that do not disturb the function of the phone.

8.4.1 Cosmetic requirements
In the production process a primer and high clamping force is required. This makes it difficult to achieve high cosmetic requirements on an over-moulded shield can. It is important in each project to early identify any area on the shielding can with cosmetic requirements so necessary steps can be taken to avoid yield losses.

Improvements in scratches can be made by using a high strength metal and by using trays in all handling. A matt metal surface will hides scratches more than a bright surface. Lowering the sealing support on the backside of the can to reduce pressure marks is possible if a thin flash is allowed on the inside of the can.

With strict cosmetic requirement it may be needed to cover the visible part of the can with a label or self adhesive tape. Painting or surface treatment of the can after over-moulding is not recommended due to risk for bad adhesion caused by silicone traces.

8.4.2 Flash
In the silicone moulding it is difficult to avoid flash. This can partly be handled with controlled leakage areas on the inside of the can but there is always a risk for thin flash on the inside of the can. It is our experience that this is in most cases no problem providing the silicone flash is thin (less than 0,05 mm) and adheres well to the metal.

8.4.3 Gate mark

The gate mark is in most projects on the backside of the can. The gate mark is removed after the moulding by hand. There should be an allowance of +- 0,25 mm for a remaining gate mark not exactly in the level of the metal.

8.4.4 Adhesion

There is no standardised test method for testing the adhesion of the rubber to the metal. In practice a "finger test" is performed. The gasket is moved gently in a sideways direction by a finger. During this test the rubber should adhere well to the metal surface and no gap should be seen.

8.4.5 Defects in the rubber

A defect in the rubber gasket causing a gap of a maximum length of 2 mm has normally no influence on the shielding effect up to 9GHz. It is recommended to allow such minor defects, that could occur in the moulding or handling, to increase the yield.

9. MEASUREMENT OF SHIELDING EFFECTIVENESS

In order to determine the shielding effectiveness of gaskets on shielding cans a special fixture was developed by Nolato. The fixture has two cavities, one with a transmitting antenna and the other one housing a receiver antenna. The two compartments are isolated by means of the test object, a shielding can with a shielding gasket. By studying the coupling between the two antennas, with and without the plate, the shielding effectiveness can be quantified.

With this measurement system one can compare shielding effect of different shielding cans to evaluate different material combinations, ageing effects etc. This is very useful information in designing a good shielding solution but since shielding requirement differs from application to application the results can not verify that a shielding can will works in the actual application. A final functional test on the assembled equipment should be done to verify that shielding effect is good enough for the actual application.

A sketch of the design can be seen on the next page. The fixture is divided in two parts, both constructed in solid brass. To ensure a low impedance connection of the gasket, the lower part has a gold plated surface where the test object is mounted over the receiving antenna.
In the upper part of the fixture a plastic support put a pressure on the test object giving a fixed compression of the gasket. This part also holds the transmitting antenna.
The antenna elements are circular plates appr. 20mm in diameter. They are connected to the inner conductor of semi-rigid coaxial cables terminated in type SMA connectors at the side of the fixture.

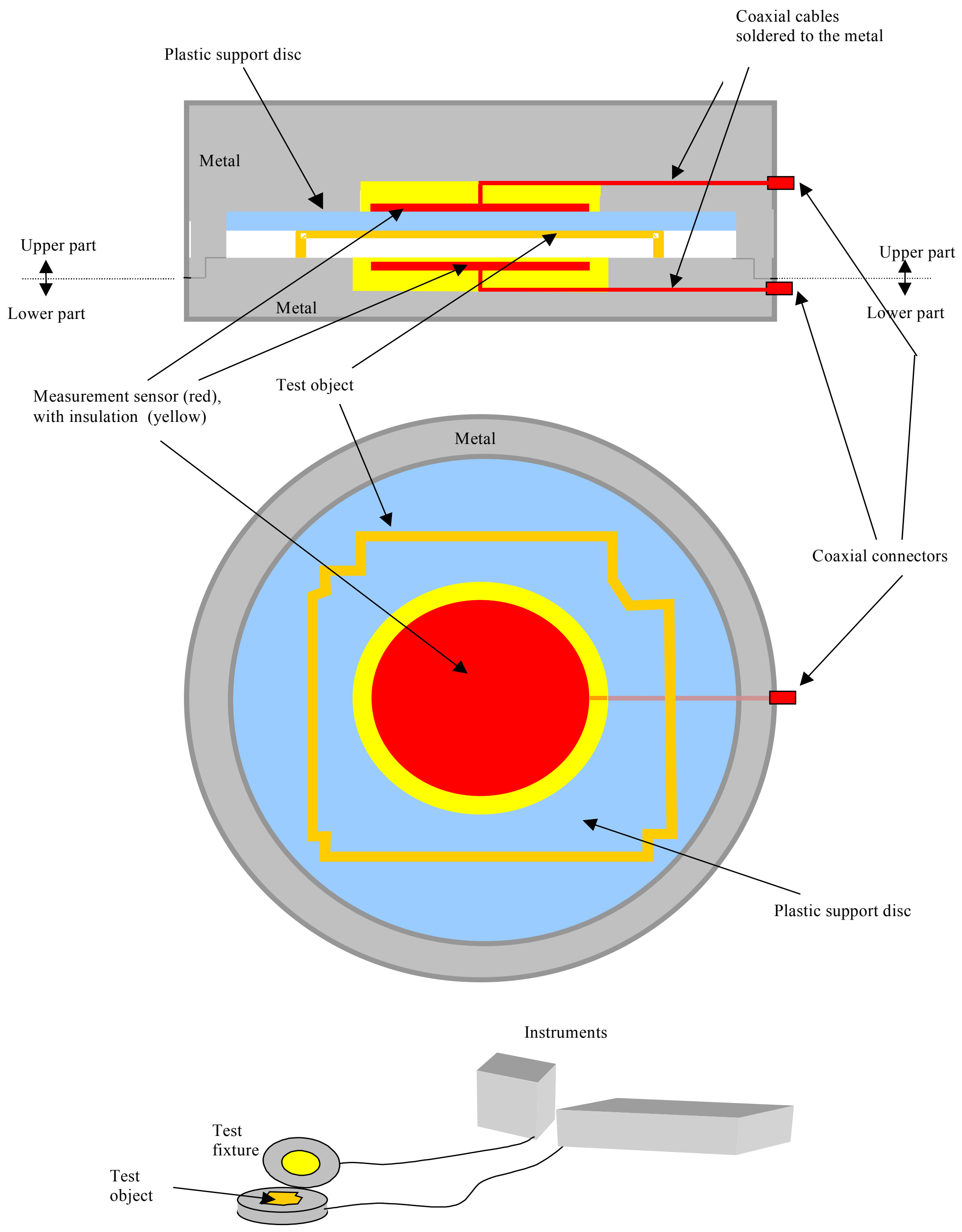
The test principle is a modified version of the shielding effectiveness measurement standard MIL STD 285. Modified in terms of antenna design and measurement distances to ensure possibilities to perform measurements at much higher frequencies. This test method allows measurements from 300 MHz up to 9 GHz.

The RF signal is generated and detected by a RF network analyzer E8358AR from Agilent.

The shielding effectiveness is defined as $se = 20 \cdot \log \frac{v_0}{v_1}$ [dB], where v_0 and v_1 is the receiver antenna voltage without and with gasket, respectively.

The shielding effect can be plotted against the frequency or presented as an average value over a given frequency range. Nolato normally reports the average shielding effect over the range from 0,3 to 9 GHz.

For measurements of over-moulded gaskets a standard deep drawn shielding can is used. It has a size of approx. 45x45x3mm and a wall thickness of 0,2 mm. A gasket is moulded on the edge. During the measurement is the gasket compressed to 2,7 mm.



Picture 8
Sketch of test fixture for Nolato shielding effect measurements

10. SCRAP AND RECOVERY

The over-moulded shielding can contains silicone rubber, silver and glass. No banned or restricted chemicals are used in the production or can be found on the final product. The gasket could after the lifetime be removed from the shield and sent for silver recovery but due to the low weight of each gasket this is normally not economical feasible.

The shielding can could after the lifetime of the phone be disassembled and sent for metal recovery by melting. The gasket will then leave traces of silica and silver in the melt that can be handled as normal impurities.

The shielding can with its gasket is not harmful to the environment and could if needed be deposited as normal industrial waste

11. ASSISTANCE

With the guidelines given in this document a standard shielding can could be designed. In project where there are design limitations it is in most cases possible to find satisfactory compromises but in those cases we advice that Nolato is contacted. Our experts will assist our customers in designing the best possible shielding can in each application. You could for instance send us your first CAD drawings and we design and add the gasket. Nolato is working with Solidworks and IDEAS. Other accepted file formates are Parasolid and STEP.

If there are any questions on how to design an over-moulded shielding can please, do not hesitate to contact your contact person at Nolato Silikonteknik or the Market department for assistance. Updated contact information can always be found on our web site www.nolato.se/silikonteknik.

12. EXAMPLE OF PRODUCED SHIELDING CANS

Picture 10
Two examples of modern Compashield shielding cans that has been designed according to this guidline..