Design Guide

Introduction

This guide provides basic design rules and information needed to help designers during initial stage of design.
It also shows various technologies used in keypad manufacturing to serve the various needs of customers.
ESI, Early Supplier Involvement, this programme allows San Teh Manufacturing (STM) to assist customers in their early stage of development. It helps to improve product design and resolve any queries the customer might have.

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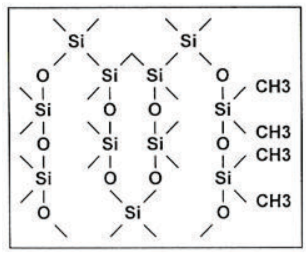
1.0 MATERIAL
Silicone rubbers have various excellent characteristic features not obtained in any organic rubbers so that they playa very important role in almost all industries including the electrical and electronic business machines, automobiles, food, medical supplies, household commodities, articles for sports and hobbies, etc.

1.1 General Properties of Silicone Rubber

1.1.1 High Bond Energy
The polymeric molecular structure of silicone rubbers has a main chain formed of siloxane linkages Si-O. The bond energy of the siloxane linkage Si-O is 106.0 kcal/mole which is much higher than the bond energy 84.9 kcal/mole of the carbon-to-carbon bond C-CO This difference in the bond energies explain the outstanding stability of silicone rubbers in comparison with other organic rubbers. In general, silicone rubber have much better heat resistance, electrical insulation, chemical stability, etc. than organic rubber.

-Si-O-Si-O-Si-

1.1.2 Low intermolecular force and strong coil-forming
Dimenthylpolysiloxane, a typical polymeric constituent of silicone rubbers, has a helical or coiled molecular configuration with a small intermolecular force so that it has high resilience, large compressibility and excellent cold resistance. Furthermore, the outwardly directed methyl groups are able to rotate freely resulting in the unique surface properties of silicones such as water repellence and surface-releasability.



1.2 Characteristic Features of Silicone Rubbers

1.2.1 Heat Resistance
Compared to organic rubbers, silicone rubbers in general have incomparably high heat resistance.

Silicone rubbers can be used semi-permanently at 150C (302F) with almost no change in the properties and can withstand more than 10,000 hours of continued service at 200C (392F). With this excellent heat resistance, silicone rubbers are widely used in application requiring excellent heat resistance.

Heat resistance of general purpose silicone rubbers may differ considerably depending on the formulation of the ingredients, selection of the curing agent, etc.

1.2.2 Cold Resistance
Silicone rubbers have excellent cold resistance.
In contrast to brittle point of most organic, silicone rubbers can retain their elasticity, where most of other organic rubbers lose their elasticity and become brittle.

1.2.3 Weatherability

Silicone rubbers have excellent weatherability. While rapid degradation is unavoidable in most organic rubbers under the influence of ozone, produced by corona discharge, silicone rubbers are virtually unaffected by ozone. Moreover, physical properties of silicone rubbers are stable and little changed even by prolonged exposure to ultraviolet light and over weathering conditions.

1.2.4 Electrical Properties

Silicone rubbers have extremely high electrical resistance, 10 14 to 1016 ohm-cm, which is stable over a wide range of temperatures and frequencies. The electrical insulation of silicone rubbers is little affected by moisture and immersion in water and therefore widely used as a material for electrical insulation.

Silicone rubbers are highly resistant against corona discharge under high voltage and arc discharge so that they are also used as an electrical insulating material under high voltage conditions.

1.2.5 Electrical Conductivity

Silicone rubbers can be electroconductive by compounding with a filer such as carbon black. Several grades of electroconductive silicone rubber are available.

Applications of electroconductive silicone rubbers include contact points of keyboards, parts in electrical heater elements, parts in antistatic devices, and shielding of high voltage cables.

1.2.6 Radiation Resistance

Although the radiation resistance of dimethyl silicone-based general-purpose silicone rubbers is not particularly high compared to most organic rubbers, methyl phenyl silicone rubbers, formulated from a silicone gum having phenyl groups introduced into the polymer molecules, have greatly improved radiation resistance and are useful as a material for electrical insulation of cables and connectors in atomic power plants.

Silicone rubbers can be used as a radiation-resistant material even at high temperature as high as 200C (392F) to 300C (572F), where most organic rubbers such as natural rubber can no longer be used due to thermal degradation.

1.2.7 Thermal Conductivity

Silicone rubber have a thermal conductivity of about 0.5 x 10-3 cat/cm-see C. this value is higher than that of most organic rubbers.

Thermal conductivity property of silicone rubbers are used in heat-radiator sheets, EMI gasket and heating rollers.

1.2.8 Steam Resistance

Silicone rubbers absorb a maximum of about 1 % of water even after prolonged immersion in water. Mechanical and electrical properties of silicone rubbers are little affected by immersion irrespective of water temperature.

Although no degradation is seen in silicone rubbers in contact with steam under normal pressure, pressurised steam may have considerable influences on the properties of silicone rubbers. High pressure steam at 150C (320F) or higher causes breakage of the polymeric main chain of the organic polysiloxane so that the properties of the silicone rubber are reduced. This problem can be solved by the improvement in the formulation of the silicone rubber and selection of the proper curing agent and post curing conditions.

1.2.9 Chemical, Oil, and Solvent Resistance

At temperature below 100C (212F), the oil resistance of silicone rubber is somewhat inferior to that of nitrile and chloroprene rubbers. At temperature above 100C (212F), the oil resistance of silicone rubber is superior to all types of organic rubber.

Silicone rubbers are chemical and solvent resistant as well. Polar organic compounds such as aniline, alcohol, dilute alkaline and acid solutions only slightly affect the properties of silicone rubber exhibiting a maximum swelling of 10 - 15%.

Silicon rubber swells when contacted with non-polar solvents such as benzene, toluene, and gasoline but he original properties are quickly restored when the solvents are removed.

Silicone should not be used with highly concentrated strong acid and alkaline solutions because they permanently damage silicone rubber.
Other solvents affect the properties of silicone rubber in different ways so it is important to thoroughly test silicone rubber before using it in areas where solvents are being used.

1.2.10 Compression Set

Compression set is critical when rubber is used as a packing material in pressure cookers and other high pressure applications. The compression set of silicone rubber is very low and varies little in temperature from -60C (76F) to 250C (482F). On the other hand, organic rubbers are not suitable for use as packing materials at this extreme temperature.

1.2.11 Bending Fatigue

Conventional rubbers are generally not as resistant as organic rubbers against dynamic stress such as fatigue by repeated bending.
Compounded rubbers which are 8 to 20 times as resistant against fatigue by bending compared to conventional grades of silicone rubbers.
These silicone rubbers products are used in keyboards in office automation instruments, rubber-made parts of transportation machines, and other applications where repeating flexing and bending are required.

1.2.12 High Tear Strength

General purpose silicone rubbers have a tear strength of about 15 *kgf/cm.* This relatively low tear strength can be substantially increased by improving the chemical structure of the organopolysiloxane and selecting the proper curing agent and tiller.
Several high-strength grades with a tear strength of 30 -50 *kgf/cm* are available and are widely used for moulding intricately shaped, reverse-taper, and large-sized articles.
Although silicone rubber generally has a lower strength than organic rubber, at high temperature silicone rubber retains its strength whereas organic rubber's strength gradually deteriorates.

1.2.13 Gas Permeability

Thin films of silicone rubbers have somewhat larger permeability to gases and vapours than organic rubber and plastic resin films. Relatively high selectivity of permeability among different gases is also one of the characteristic features of silicone rubber films. By virtue of these unique features, silicone rubber films are promising as a membrane for the separation of gases and liquids.
For example, heart-lung machines and oxygen enrichment equipment are now being developed using silicone rubber films as the gas exchange membrane.

1.2.14 Vibration Absorption

General purpose silicone rubbers have a small loss factor so that they are not recommended as a vibration-proof material. However, several vibration-proof silicone products are available which serve as a vibration-proof material with stability over a temperature range from -50C (-58F) to 100C (212F).

1.2.15 Transparency and Coloration

In contrast to most organic rubbers coloured in black due to the formulation of carbon black as a reinforcing filler, silicone rubbers can be highly transparent when the filler compounded for the reinforcement is a finely divided silica filler which only slightly affects the transparency inherent in organopolysiloxane gum.
Several high-transparency, high-strength silicone rubber products are used to make various shaped articles such as tubes for and food-processing machines.
High-transparency silicone rubber compounds can easily be coloured by adding a pigment. Vividly and brilliantly coloured silicone rubber articles can be manufactured.

1.2.16 Non-Stickiness and Corrosion Resistance

Silicone rubbers are chemically inert and as such are non corrosive to most metals and other materials. Silicone rubbers also have excellent release properties making them ideal for use as fixing rollers in copying machines, rollers in printing presses, sheets, and lostwax processes.

1.3 Silicone Rubber Applications

Field Of Industry	Suggested Applications
Household Electric Appliances	Anode Caps, Wedges, Defrosters in refrigerators Hot air brushes, Front door gaskets, Turn belts of microwave oven
Electric Wires	Lead wires, Heater wires in heating jars, ignition wires
Business Machines	Rubber contacts in pocket electronic calculator and keyboards EMI gaskets Rubber rollers in PPC copying machines Platen rollers in printers and telecopier machines
Machines	Hot stamp machines, Solar hoses, Vibration absorbing rubber
Automobiles	Diaphragms, Plug boots, Water connectors Radiator hoses, Turbo charger hoses
Food Industry Products	Gasket of pressure cookers, packing of vacuum bottles Gaskets of electronic-controlled jars, Nipples of nursing bottles
Hobby Goods	Goggles, snorkels, mouthpieces, goggle bands Swimming caps

2.0 Raw Silicone Rubber

Major raw silicone material suppliers are:
Shinetsu, Dow-Coming, Toray, Toshiba, GE, Wacker and Bayer.

One major parameter used to define silicone rubber is material hardness/durometer. This can be defined in both Shore or JIS value.
Below is a conversion table for Shore and JIS

Shore A	JIS
30	29
32	30
35	33
38	35
40	37
43	40
45	42
49	45
50	46
54	50
55	51

Shore A	JIS
59	55
60	56
64	60
65	61
69	65
70	66
74	70
75	71
80	75
85	80
90	85
95	90

Range of hardness for Silicone rubber is between 30JIS to 90 JIS.

For remote control keypads. the general hardness used is between 50 JIS and 60 JIS.

2.1 Material General Specification

Silicone Rubber Product	
Operating temperature	-15C to 80C
Storage temperature	-30C to 85C
Operating force (Grams)	50 to 450
Cycle life	100,000 to 20Millon
Contact resistance	<100 Ohms
Contact rating @ 5mA 12VDC/0.5sec/20 million cycles	
Contact bounce	<12m seconds
Insulation resistance	>10^{12}Ohms @ 500VDC
Break voltage	>25~30 KV/mm
Key colour	Optional
Key size	Optional
Key Shape	Optional
Tactile feedback	Optional
Printing Colour	Optional

Conductive Rubber		**Insulative Rubber**	
Specific gravity	1.06~1.18	Specific gravity	1.10~1.40
Hardness JIS	70	Hardness JIS	30~90
Tensile strength kg/sm^2	58	Tensile strength kg/sm^2	50~95
Elongation %	170	Elongation %	100~650
Compression set %	21	Compression set %	10~24
Vol. resistivity Ohm-cm	25	Vol. resistivity Ohm-cm	>10^{12}Ohms

3.0 Moulding Processes

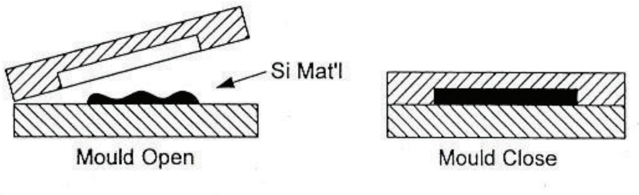
Most common rubber moulding processes are

A) Compression Moulding
B) Transfer Moulding
C) liquid Injection Moulding

San Teh Manufacturing only uses Compression Moulding and Injection Moulding

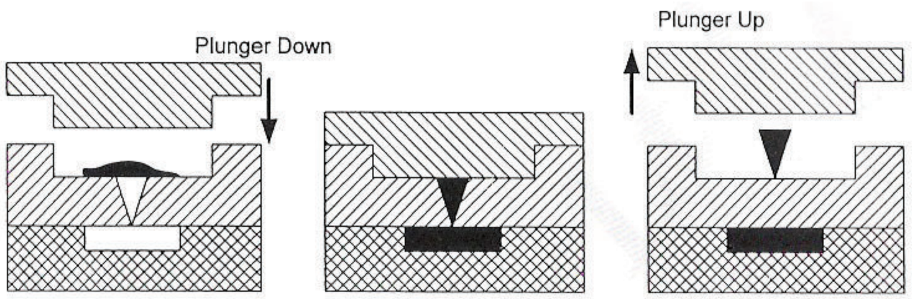
3.1 Compression Moulding

A piece of uncured rubber of the right weight is placed between two halves (-150C) of a mould.
This mould is closed in a press and the rubber is forced to fill up the cavities in the mould.
The rubber gains heat from the heated mould and cures.
After a certain cycle time, the part can be removed.



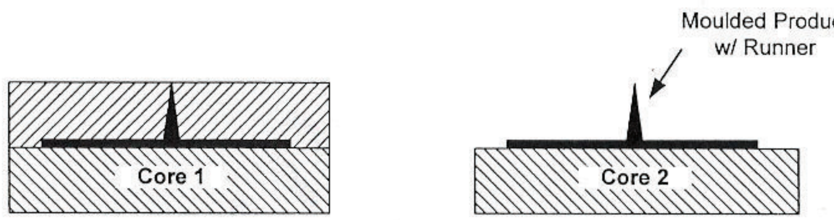
3.2 Transfer Moulding

Uncured Rubber is forced through a "runner system" mould with small gate point by a plunger. The rubber then fills the cavities of the and the rubber begins to cure in the heated mould. Once cycle time is reached, the part is removed from the mould.



3.3 Liquid Injection Moulding

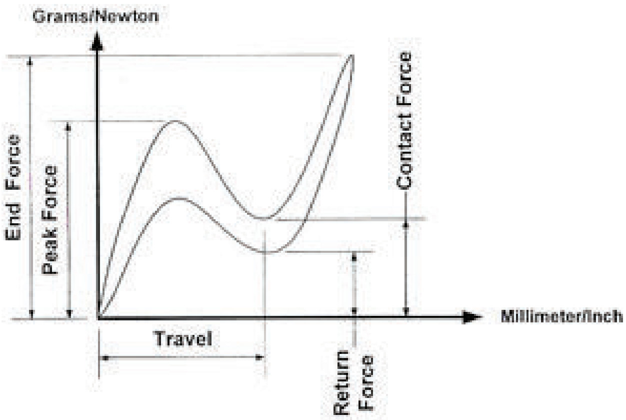
Low viscosity liquid silicone material is injected into the cavity in the mould much similar to that of plastic injection.
To increase yield in the production process.1 cavity mould and 2 core mould are built.
As one core is used, the injected product is removed from the other core.



Considerations for Injection Moulding

- only one colour moulding, either black or translucent
- on material hardn!:!ss is possible, ranging bewteen 40 - 60 ShoreA
- Key height maximun 10 mm.
- if conductive pill is to be used, there must be only Circular in shape
- prefarable for keymats with similar key shapes and heights
- preferably used in the production of rubbermat for computer keyboards

4.0 Force Specification Terminology



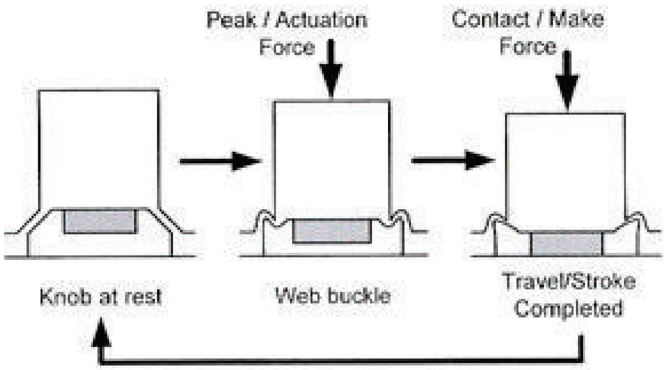
Above shows a typical force curve displacement when a knob of a keymat is depressed.

4.1 Peak force or **Actuation force** is the force to cause the web structure to buckle.

4.2 Contact force or **Make force** is the force level when the travel/stroke is completed.

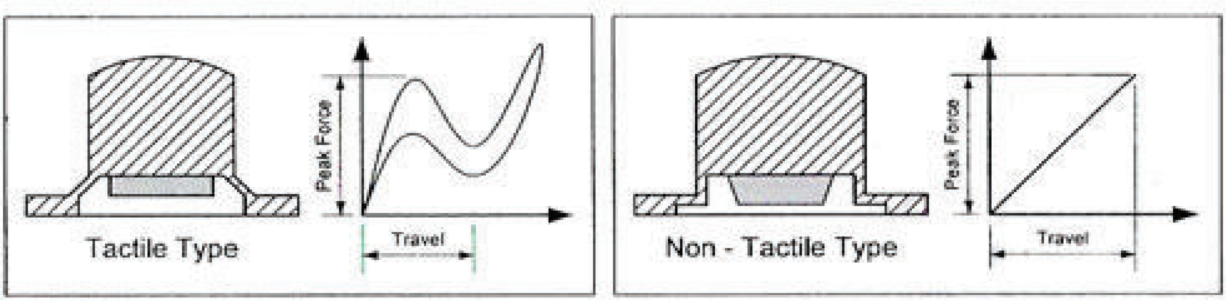
4.3 Return force or **Rebound force** is the amount needed to cause knob to return to original position. Return force is generally 10 grams **lower** than contact force.

4.4 Travel or **Stroke** is the distant the conductive layer make contact with PCB.



5.0 Force Specification Recommendation

5.1 Tactile and Non- Tactile Knobs



5.2 Actuation Force + Tolerances

Actuation Force	Tolerance (+/-)
50	10
70	15
90	15
100	20
120	20
150	25
170	30
200	30
350	35

5.3 Return/Rebound Force

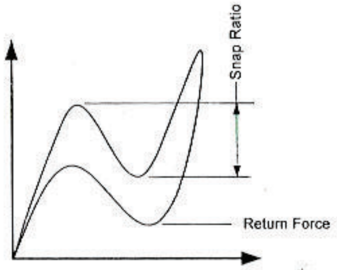
In order to prevent a "stuck" knob situation, San Teh Manufacturing recommend Return/Rebound force from 20 grams to 30 grams and above, depending on actuation force.

5.4 Snap Ratio / Tactile Ratio

This ratio is calculated: (Peak force - contact force) / Peak force
Recommended tactile ratio is between 0.4 - 0.6
For toggle / rocker button, we recommend ratio to be 0.3 - 0.5

5.5 Travel/ Stroke

Typical travel of a knob is 1.0 mm
Minimum travel shall be 0.8 mm



6.0 Dimensional Tolerance

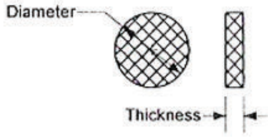
Dimension	L<10	11<L<20	21<L<30	31<L<50	51<L<10	101<L
Normal	+/- 0.1	+/-0.15	+/-0.2	+/-0.25	+/-0.5	+/-1.0%
Critical	+/- 0.05	+/-0.08	+/-0.1	+/-0.15	+/-0.3%	+/-0.5%

7.0 Contact Resistance

Conductive silicone rubber is achieved by mixing carbon black to silicone rubber.
General hardness of conductive silicone rubber is 65 JIS.

7.1 Conductive Pill Types

Types	Resistance
Carbon Pill	< 50 Ohms
Gold Dust Pill	< 10 Ohms
Metal Pill	< 1 ohms



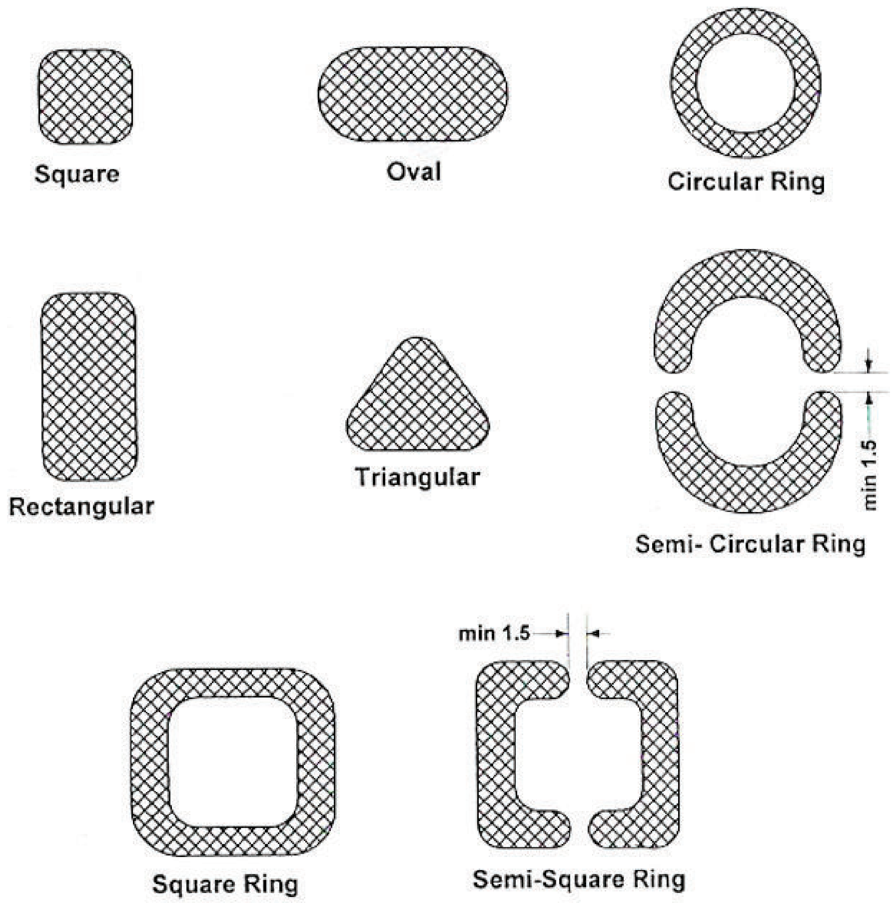
Conductive Pellet Sizes

Diameter (mm)	2.0	2.5	3.0	3.5	4.0	4.5	5.0	6.0	8.0
Thickness (mm)	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7

7.2 Conductive ink can achieved resistivity of 100 ohms and below.
Any shapes can be achieved through conductive in printing.

Conductive Ink coating can be achieved by either Dip/Tempo printing or silk screening.
General ink thickness is between 15-50 microns.

8.0 Conductive Printing Shapes



9.0 Typical Key Structure Design Guide

You may use this guide for key structure design to prevent design change in later stage of design process.

Web Height = **Travel**

Angle = 45 Degree

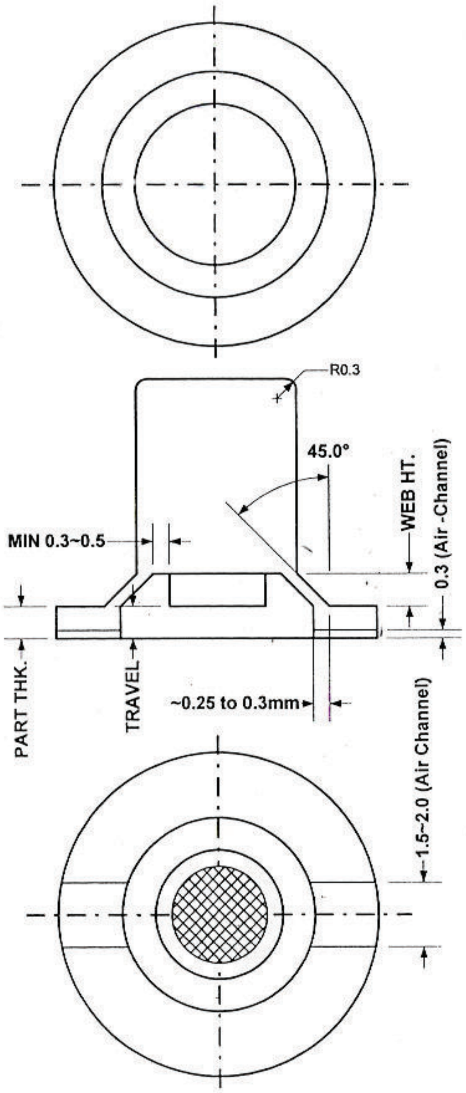
0.3~0.5 shall be minimum distance gap in order to prolong tool life and conductive pill from damage.

Web thickness shall be ~ 0.25 to 0.3 mm

Minimum **Corner Radius** = R0.3 mm

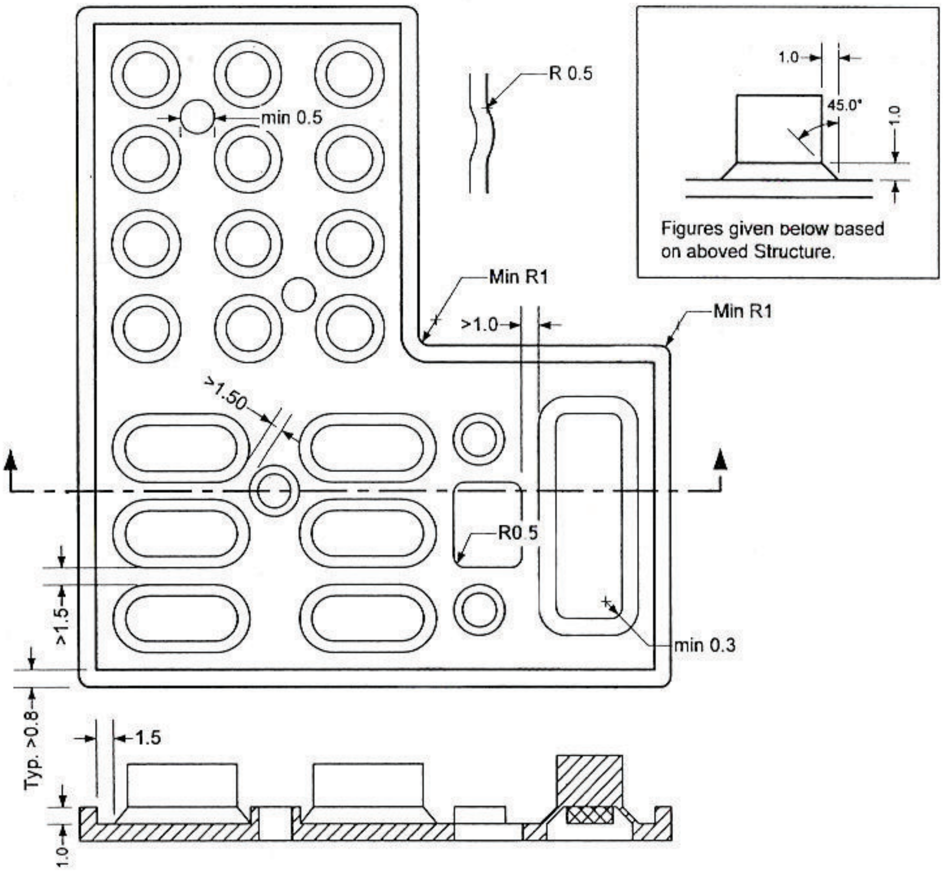
Air Channel = 1.5 X 0.3 Deep

Part Thickness = min 0.8 mm, typical 1.0 mm



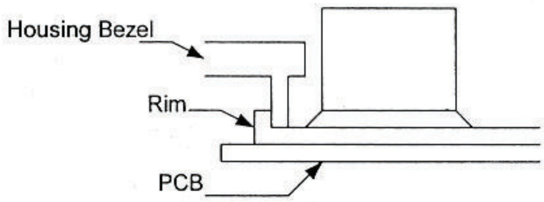
Final web structure shall be at San Teh's supervision in achieving the desire force specification and tactile requirement.

10.0 Dimensional Requirements

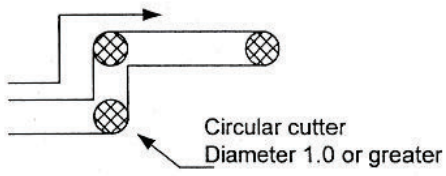


11.0 Rim Design

Rims allow plastic top housing with ribs to rest on the keymat. This serves as a resistance to liquid coming from the top housing.

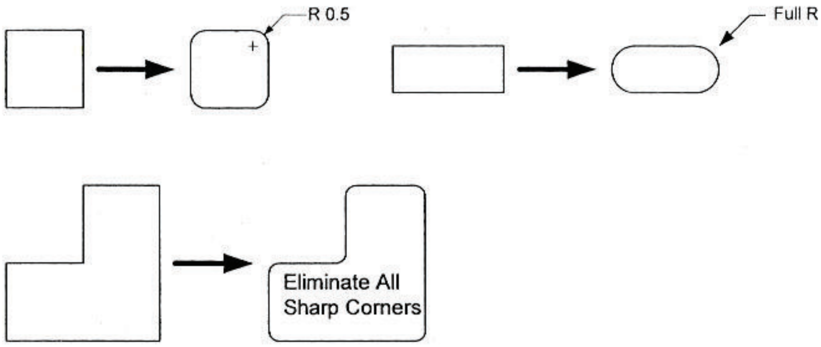


It will be helpful to design rim with a circular cutter in mind as shown in diagram below.
This gives possibility to eliminate EDM (Electric Discharge Machining) process.



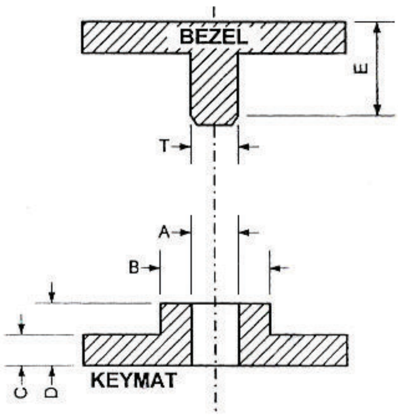
12.0 Holes

If possible use circular shapes for holes instead of rectangular, square or oval shapes. In unavoidable situation, please adhere to the following guides:



13.0 Bosses / Protrusion

These are useful for positioning keymats to plastics housing or vice versa.



T = Diameter of Housing Boss

A = (P+0.1) +/- 0.05

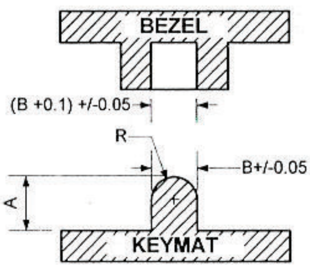
B = 2P or more

C = keymat thickness

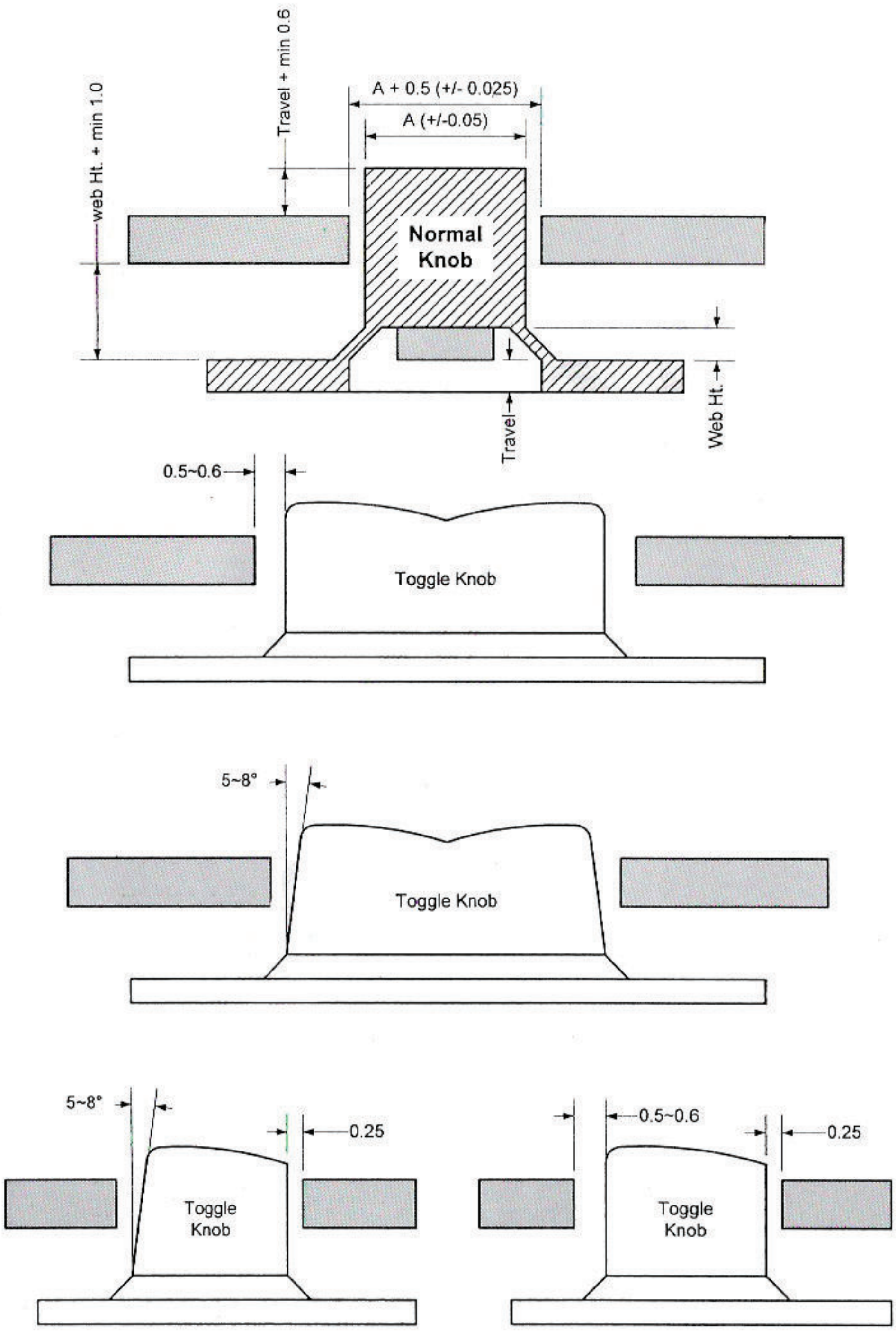
D = 2C

E = D or more

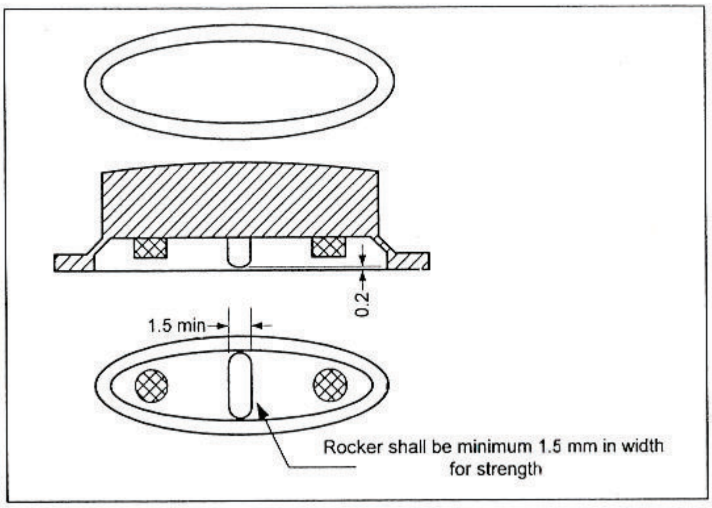
A = min 1.0mm
B = min Dia. 2.5mm
R = Spherical Radius for ease of assembly



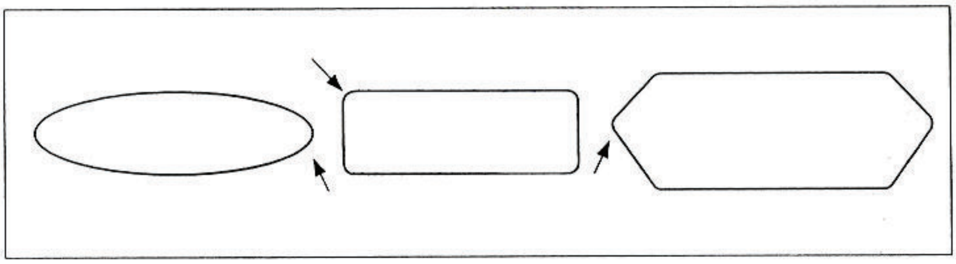
14.0 Keymat and Bezel Clearance Recommendations



15.0 Toggle Knob's Rocker / Pivot Point

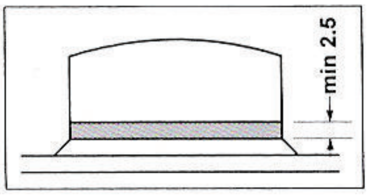


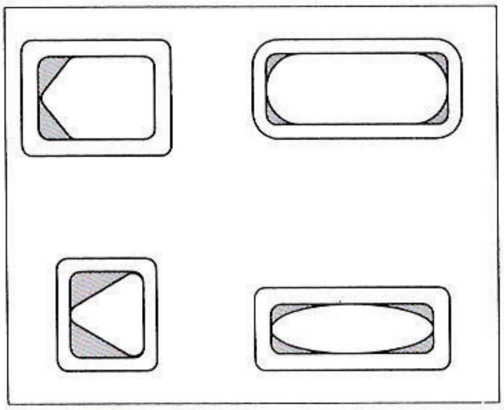
Sharp corners enhance tactile feedback of Toggle knobs



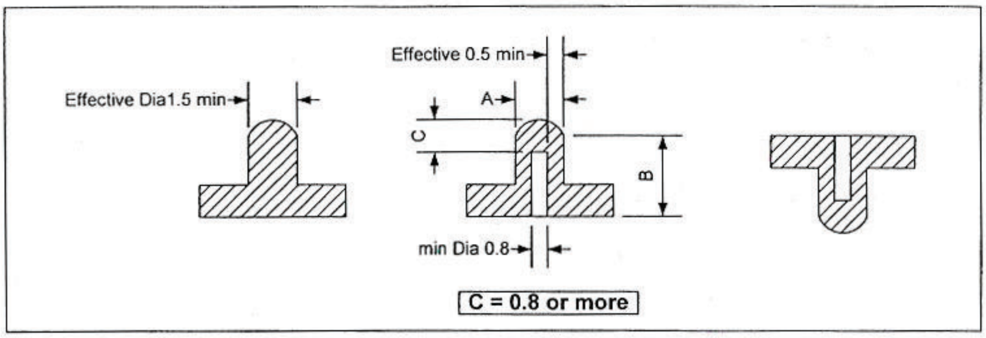
16.0 Shoulder on Knobs

Shoulders are used to enhance the stability of knobs of irregular shapes.

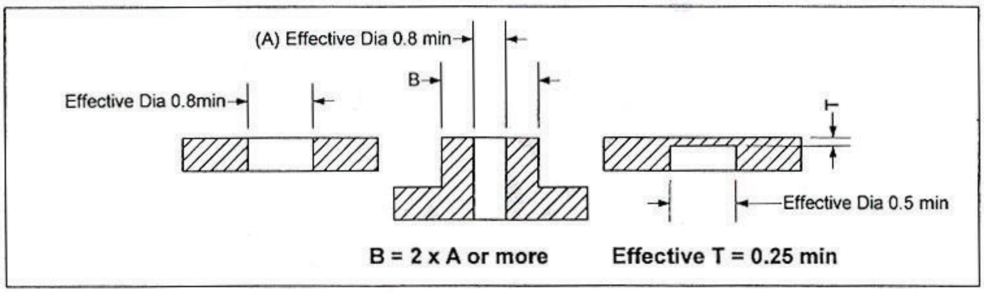




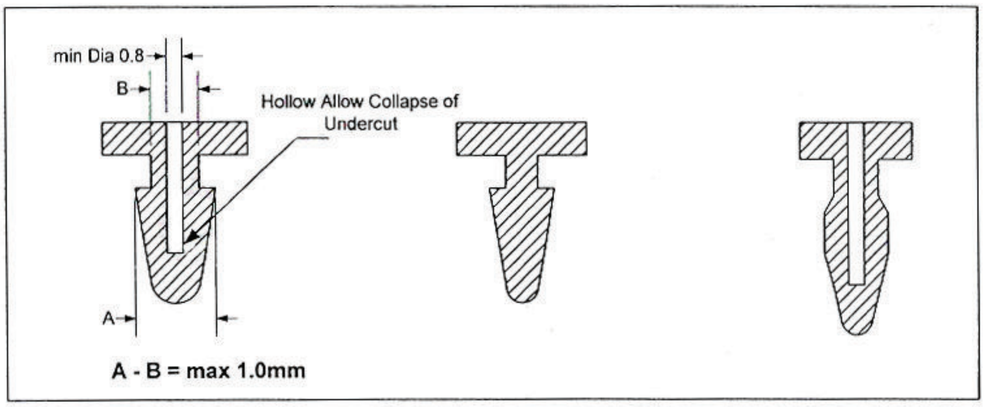
17.0 Guide Post



18.0 Guide Hole



19.0 Undercut Post



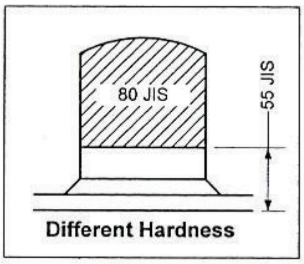
20.0 Keytops and OverFlow

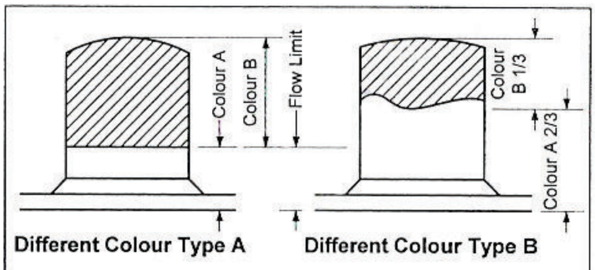
Keytops serve various purposes in silicone keymat moulding,

20.1) different hardness / durometer for a single knob

20.2) different cosmetic colours for different knobs

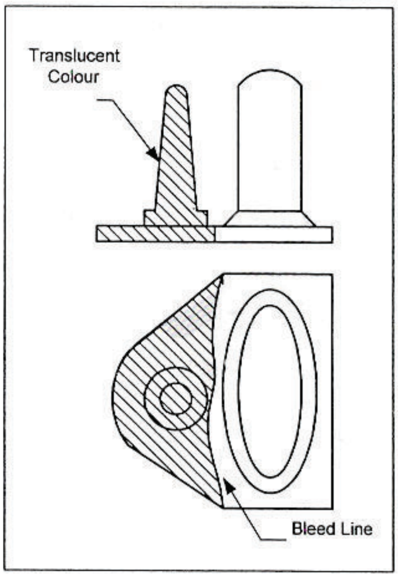
20.3) control over-flow or "bleeding" of colour to neighbouring knobs

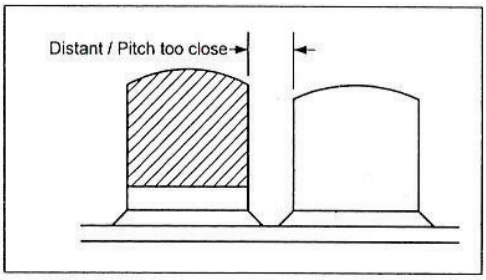




To achieve Type A, a separate Keytop tool needs to be fabricated.

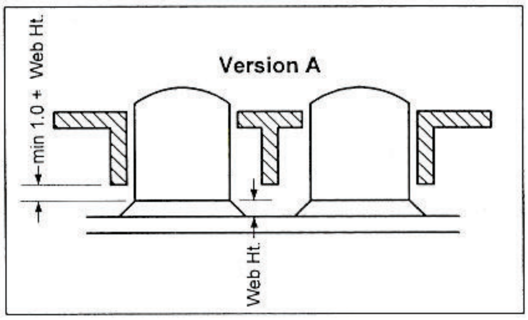
Type B feasibility subject to pitch distant between knobs and other features near by.
Colour flow limit shall be decided by San Teh (see above Type B) unless otherwise stated in drawing.

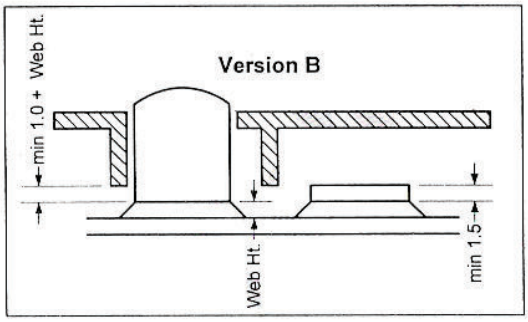




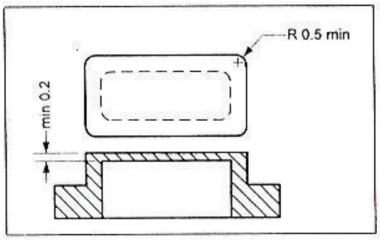
21.0 Cut Key

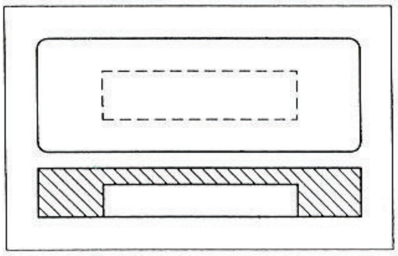
Cut Key has the advantage of allowing various versions of keymats to be moulded out from the same tooling.





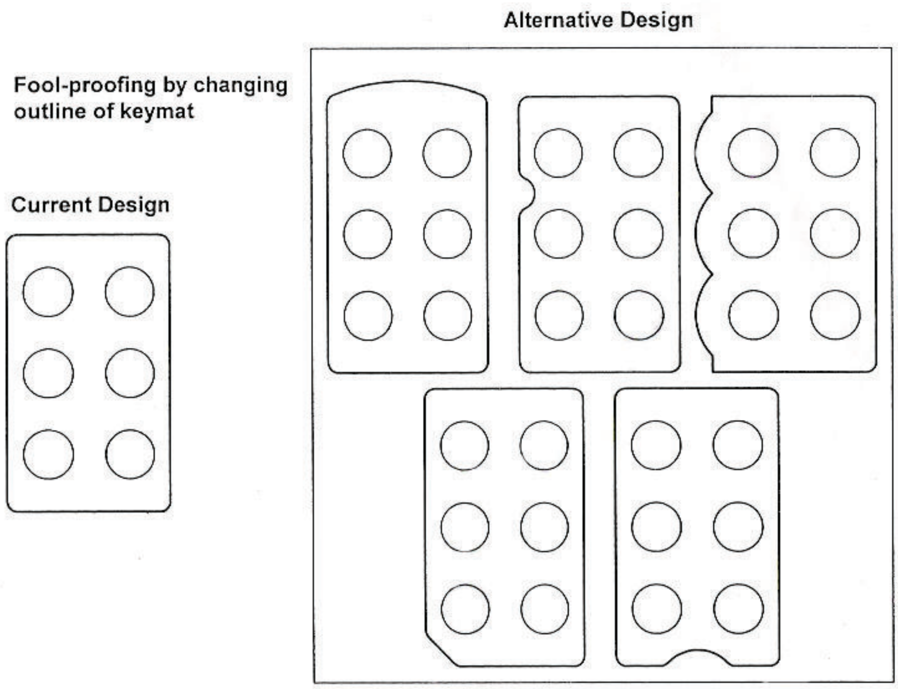
22.0 Pocket

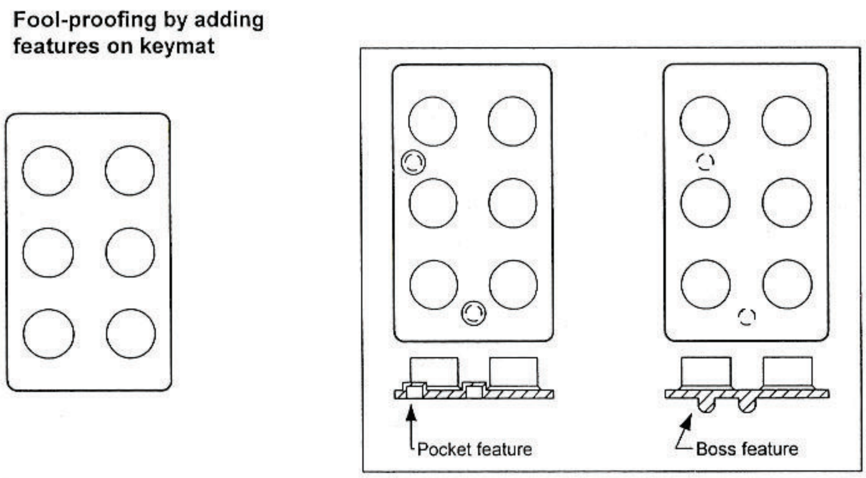




23.0 Printing Requirements

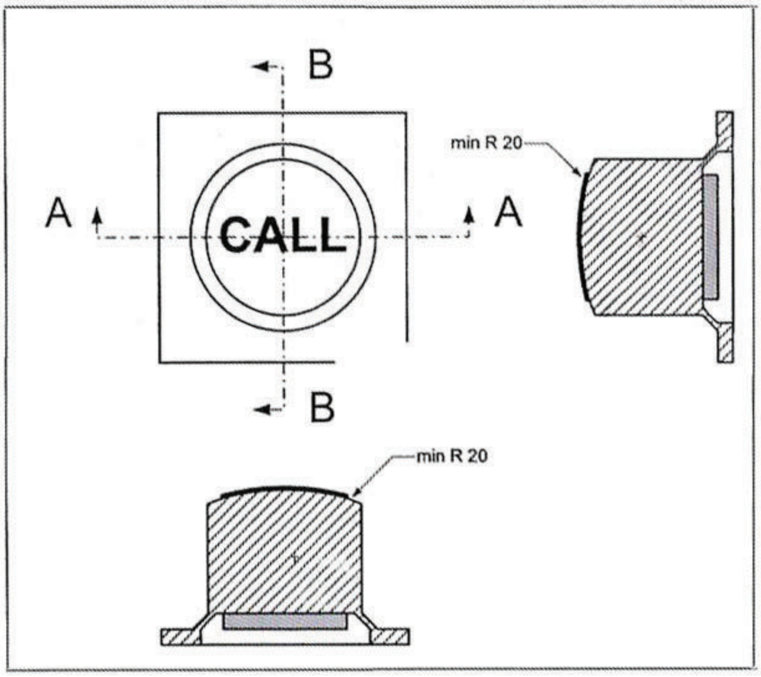
Silicone rubber keymat manufacturing requires several secondary processes to achieve a complete keymat. It is important to consider fool-proofing in product design to help cut down the rejects and increase yield.





24.0 Optimum Print Curvature

To achieve optimum print results and abrasion resistance, minimum radius curvature on top profile of knob shall be as shown:



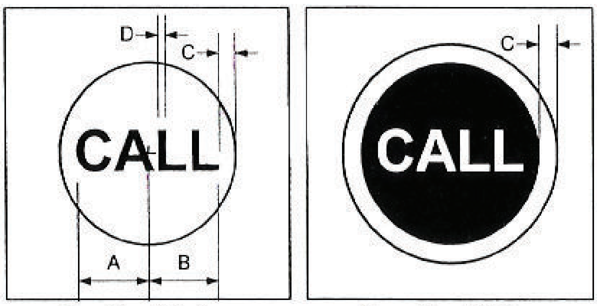
25.0 Graphic Alignment

Centering of text
(A - B) shall be equal or less than 0.3mm

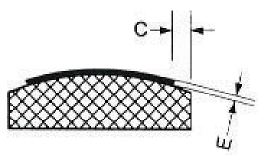
Distance from edge of knob, **C**
min 0.5mm

Minimum printing width, **D**
min 0.35mm

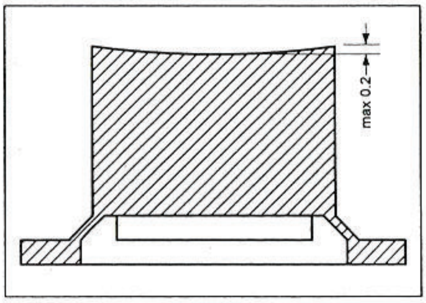
Printed graphic thickness, **E**
20 micron (0.02mm)



Positive Printing | Negative Printing



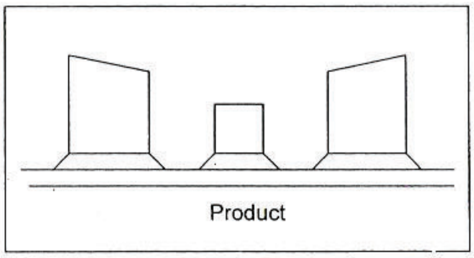
26.0 Printing on Concave surface

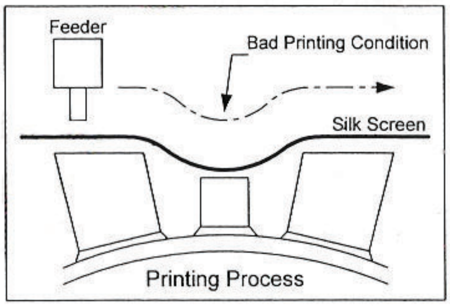


To achieve even coat of ink on a concave profile, 0.2 mm is the maximum depth difference recommended.

27.0 Drastic Key height Difference

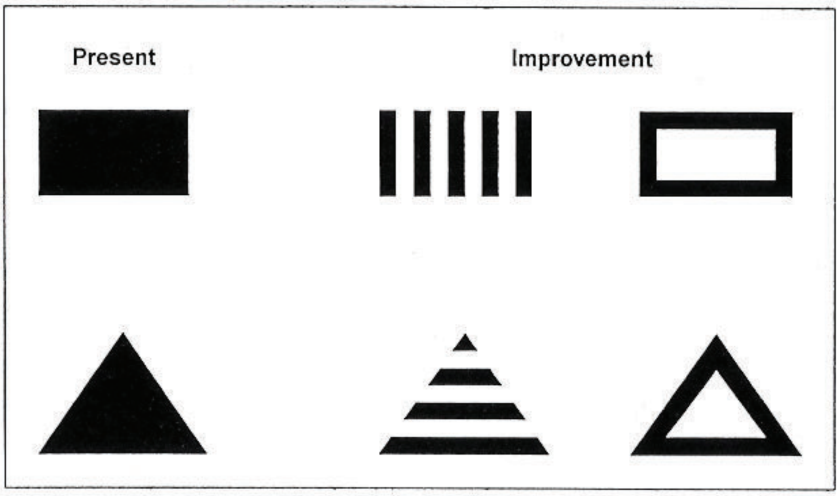
Avoid drastic difference in key heights as this will cause difficulties in printing :



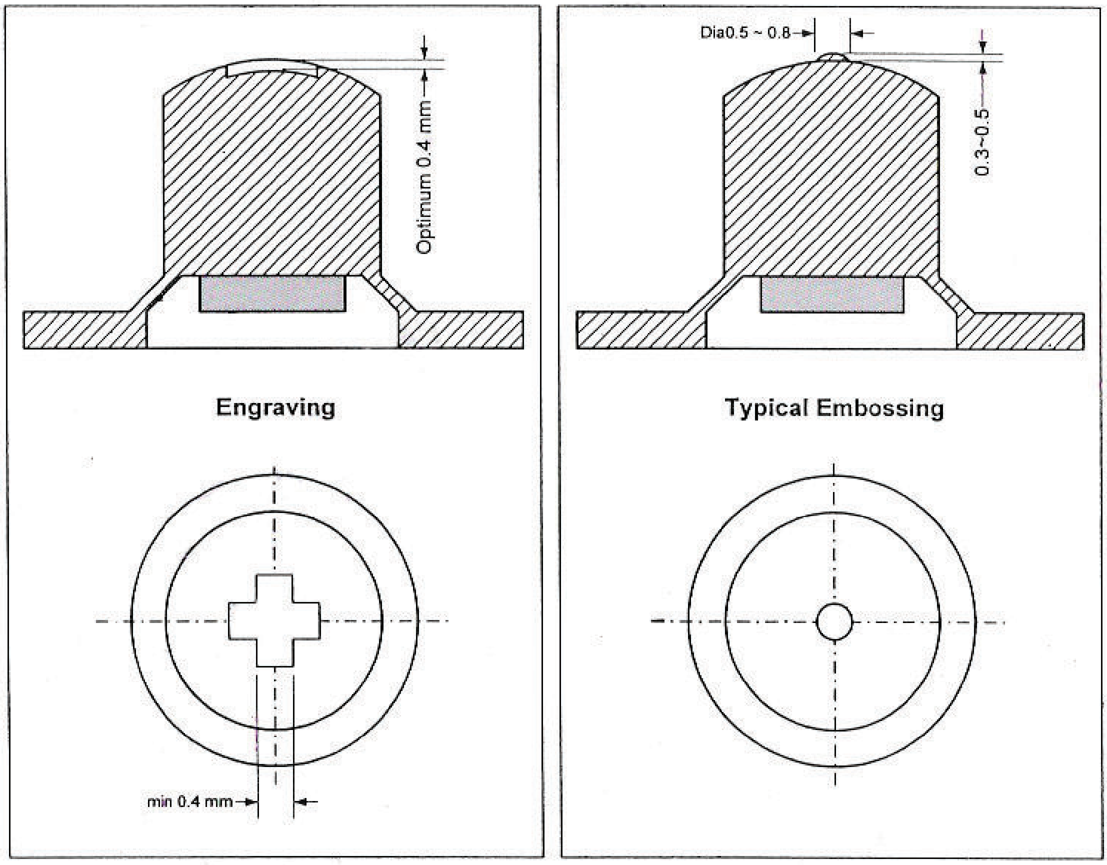


28.0 Printing on Large surface area

To enhance the abrasion resistance of large print area, you may consider the following:



29.0 Engrave and Emboss on Knob



30.0 HardTop

There are various ways of achieving a hard top button.

30.1) Co-mould (direct bonding)

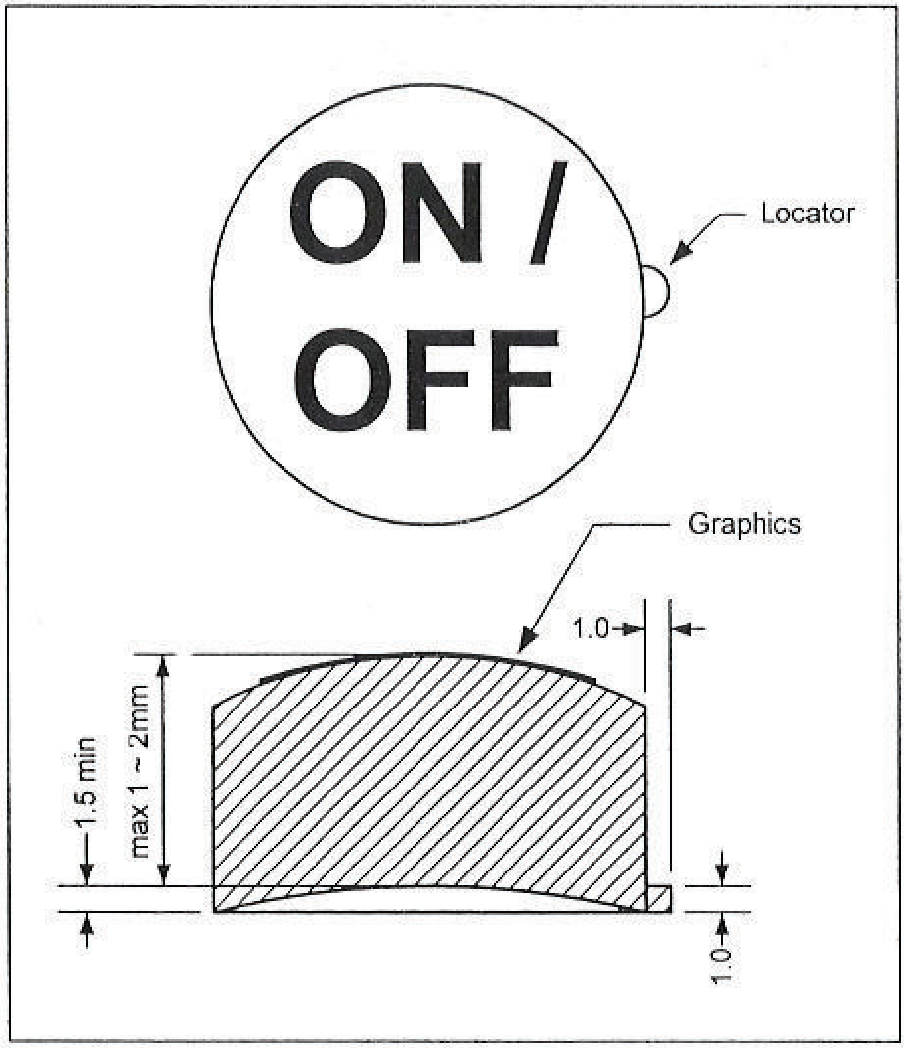
30.2) Adhesive bonding

30.3) Plastic keycap insert

30.4) Hard encapsulation

30.1 Co-mould (direct moulding)

The plastic is bonded unto the rubber with the help of primer applied on the plastic's bottom surface.
The plastic bottom surface must be made to a convex surface.
If button is circular in shaped and top profile is not symmetrical, a locator is needed to prevent the plastic from rotating during moulding process.
Printing can only be on top of plastic surface.
Feasibility of this pro~ss is determined by the height of the button.



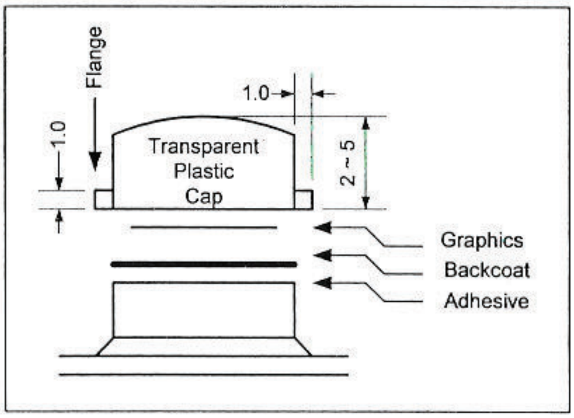
30.2 Adhesive Bonding

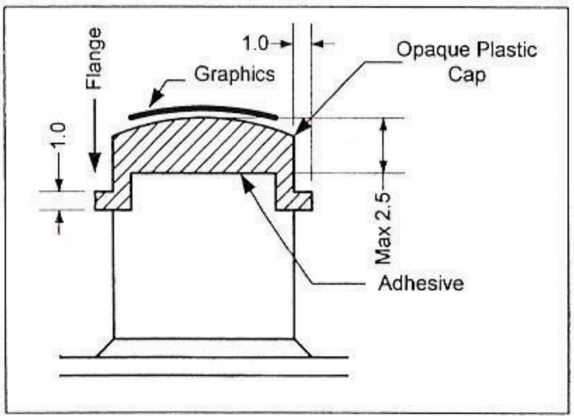
Adhesive is applied in between the plastic and rubber surface.
Graphics can be printed on the plastic's base surface if it is transparent.
A "opaque coat" is needed to prevent the visibility of the adhesive.

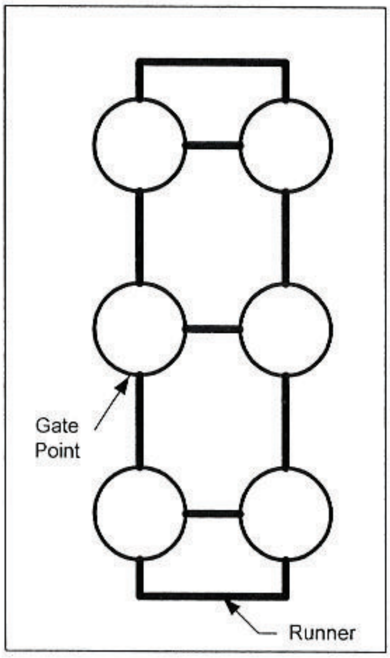
Maximum thickness for plastic shall be 2.0mm to 5.0mm in-order to prevent sink mark on the surface.

If thickness exceed 5.0mm, a flange may be added to assist the plastic in ejection from the mould.

Depending on the pitching and size of the plastic caps, all caps may be moulded out within the same mould by adjoining runners and gates.

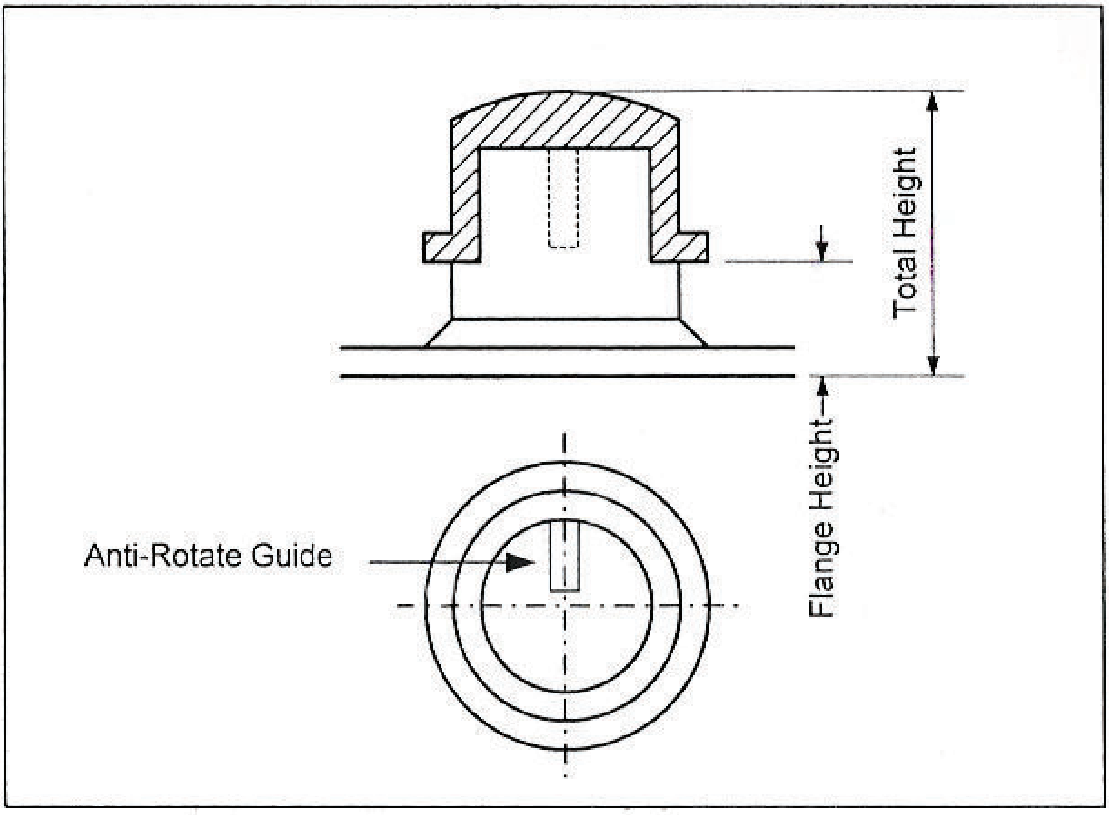

Flange
1.0
1.0
Transparent
Plastic
Cap
2 ~ 5
Graphics
Backcoat
Adhesive


Flange
1.0
1.0
Graphics
Opaque Plastic
Cap
Max 2.5
Adhesive


Gate
Point
Runner

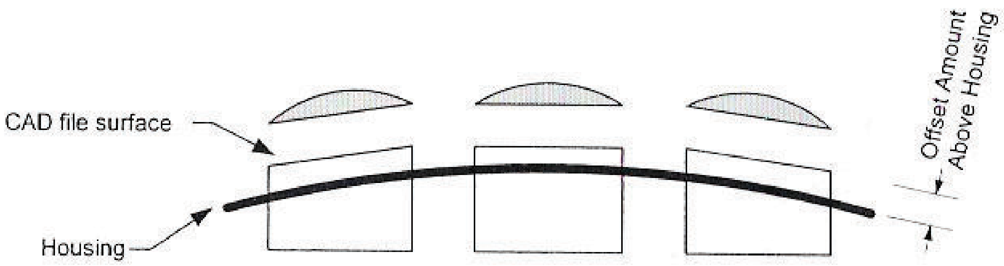
30.3 Plastic Key Cap

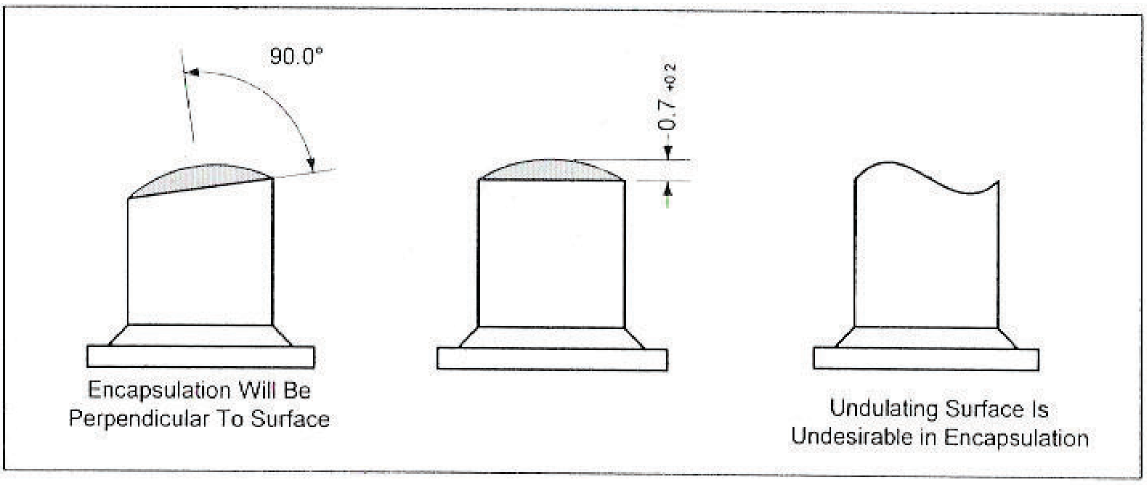
This method is direct insertion of plastic key cap to rubber keymat.
San Teh Manufacturing is able to design the internal details between the plastic and rubber fitting on your behalf.
All you need is to indicate the total height and flange height (if any). San Teh Manufacturing will design the fit and forward for your approval if required by you.



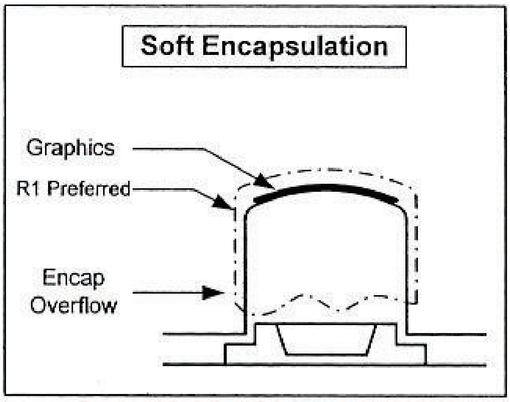
30.4 Hard Encapsulation

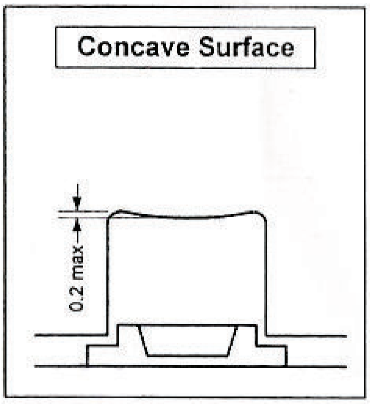
This method offers hard top feel as well as good cosmetic appearance.
All printed graphics are well protected by the hard epoxy coat giving good abrasion resistance.
Only constraint is unable to achieve complex top profile of knob.
There is no need to provide encapsulation top surface on CAD file.





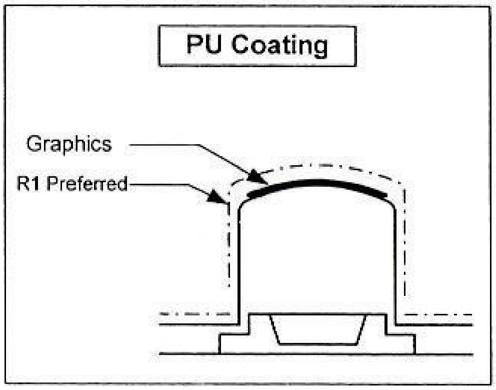
31.0 Soft / Spray Encapsu1ation
A layer of soft coat is sprayed onto the surface of the button (inclusive of the side, above the web)
Cosmetic appearance is gloss in appearance and printed graphics well protected.
Able to achieve complex profile of button if not constraint by the distant between buttons.

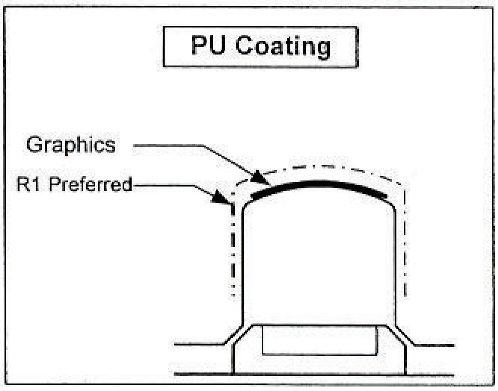




Preferably used in the Polydome Type Key structure

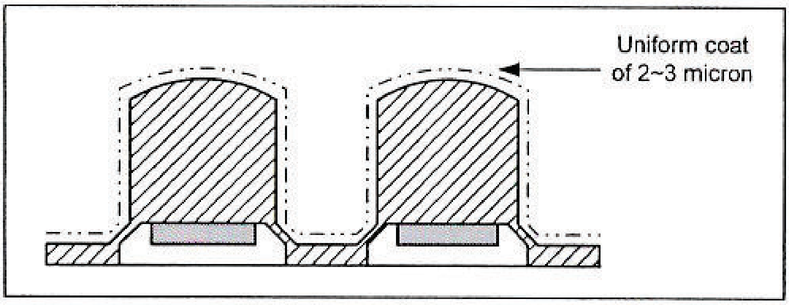
32.0 PU (Polyurethane) coating
A layer of soft coat is sprayed onto the surface of the button (inclusive of the side, above the web)
Cosmetic appearance is matt in appearance and printed graphics well protected.
Able to achieve complex profile of button if not constraint by the distant between buttons.





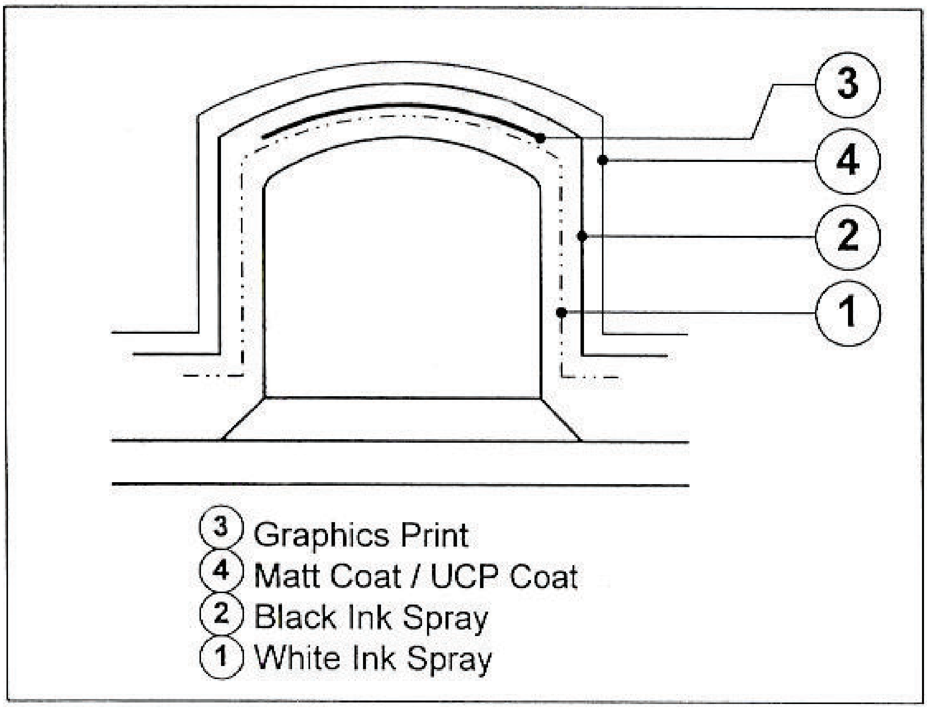
33.0 UCP - Ultima Coating Process

UCP - a vacuum deposition coating process for silicone rubber. It is capable of coating keymats with complex profile with a uniform thickness film for protection.
Material used in UCP is a transformation from parylene family offering unmatched coating protection.

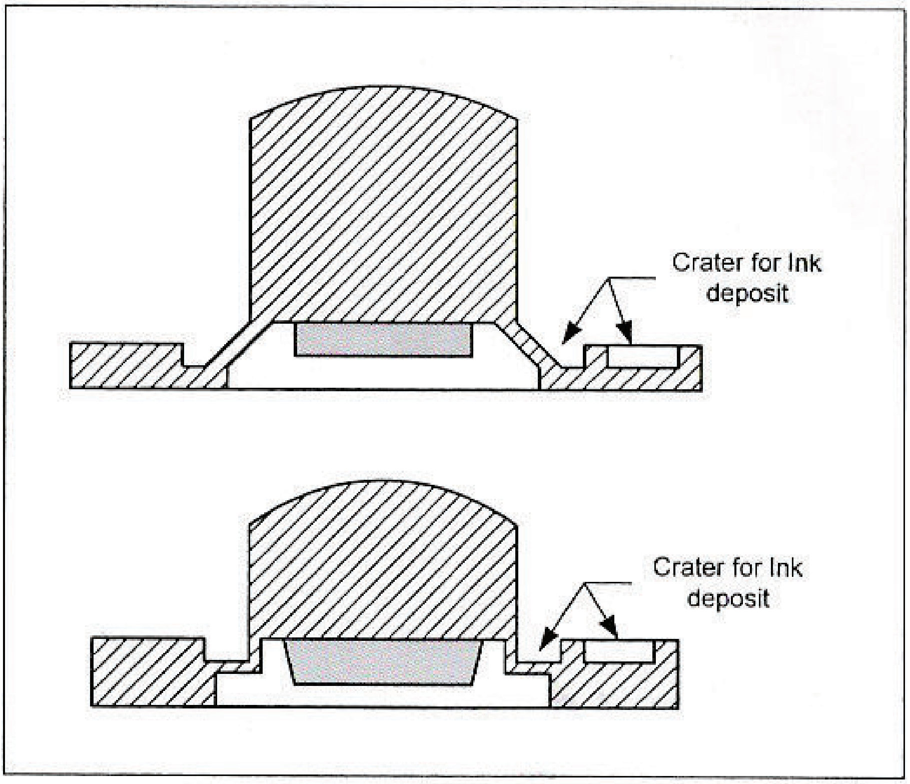


34.0 Laser Etched Keymat

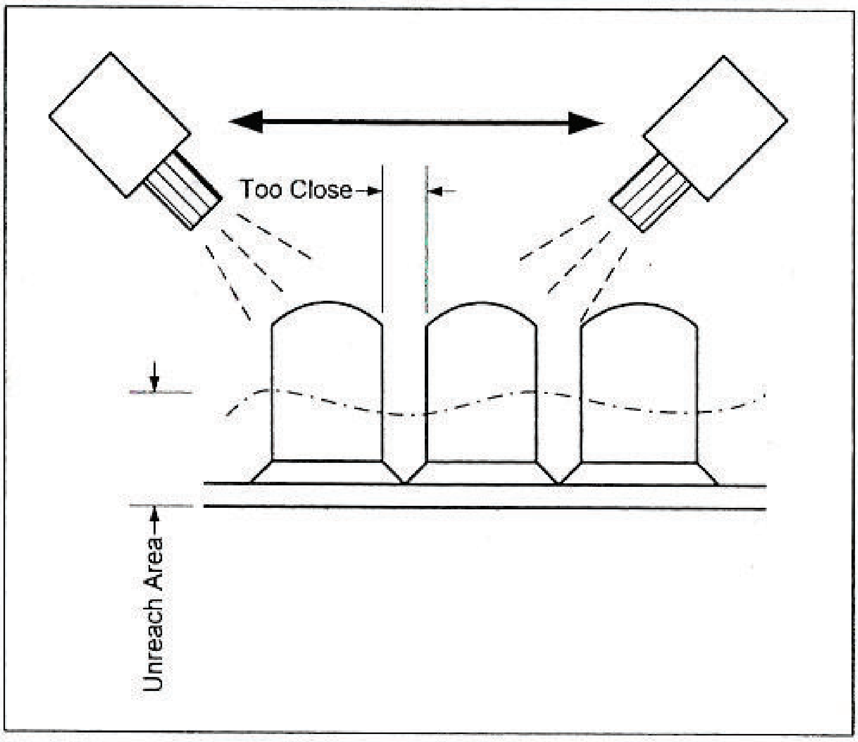
Diagram shows the the number of ink layers involved in a Laser Etched Keymat.



34.1 Knob Structure to avoid for Ink Spray keymat

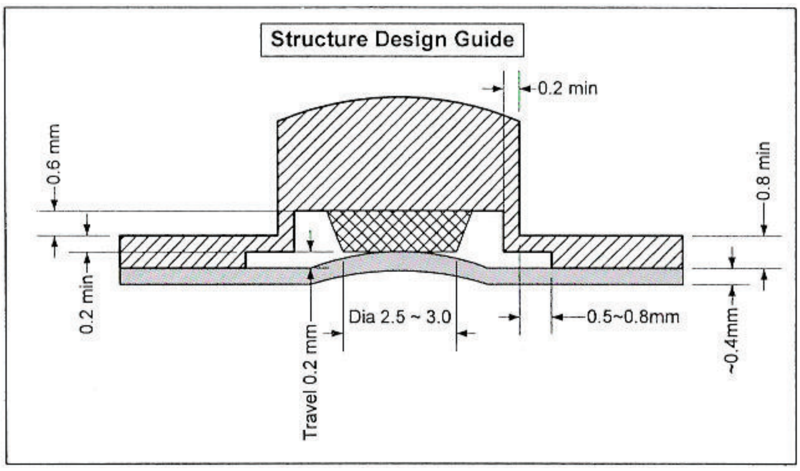


34.2 Tight Pitch Between Knobs

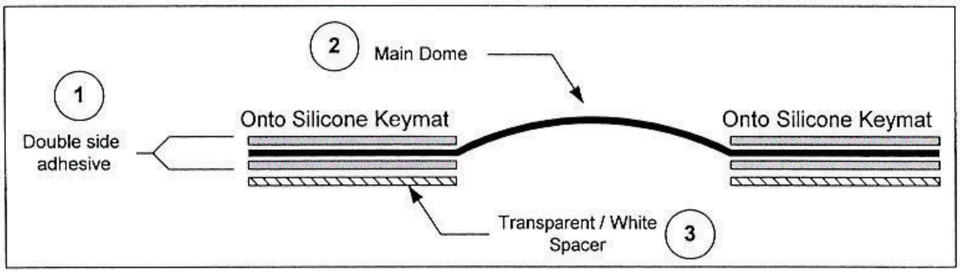


35.0 PolyDome Keymat

San The Manufacturing is able to provide complete assembly of Keymat with Polydome.



35.1 Polydome



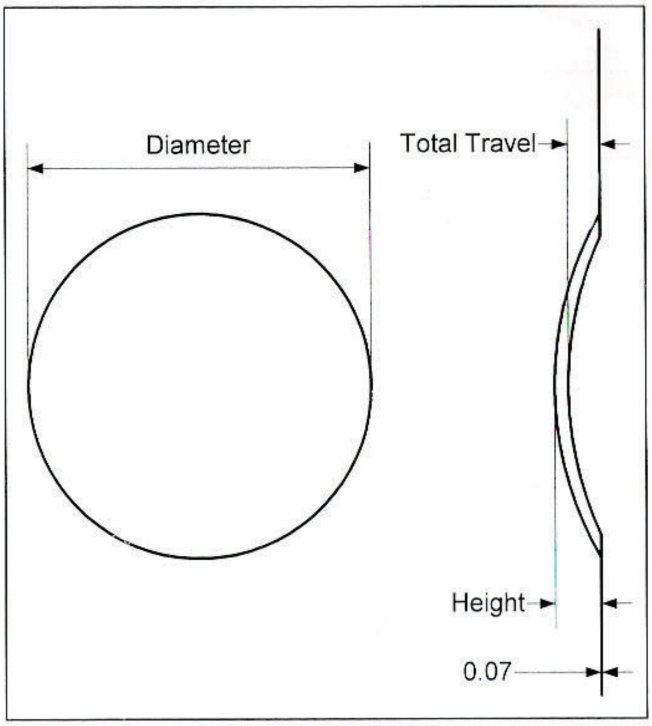
1 ~ 0.05 mm

2 ~ 0.1 - 0.125 mm PET (Polyethylene terephthalate)

3 ~ 0.1 - 0.125 mm PET (Polyethylene terephthalate)
White Colour helps to enhance light emitting of LED

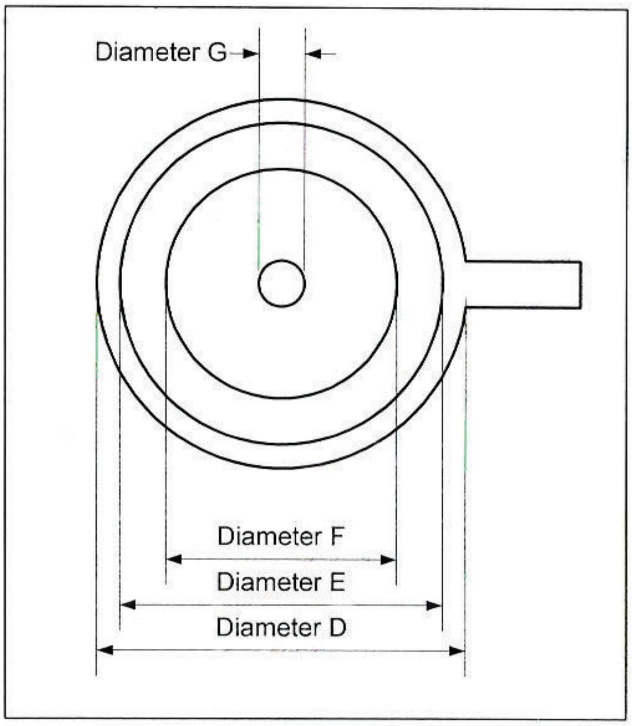
Material	PET
Storage Temp	-30C ~ +70C
Operating Temp	-10C ~ +55C
Actuation Force	As required
Rebound Force	As required
Total Travel	0.3 +/- 0.1
Click Ratio	70 +/- 20 %
Contact life	Min 500,000 cycles
Contact Resistance	Below 100 Ohms

36.0 Metal Dome



Material	Stainless Steel
Storage Temperature	-40C ~ +90C
Operating Temperature	-30C ~ +80C
Actuation Force	170 +/- 20 g
Rebound Force	65 +/- 15 g
Height (mm)	0.27 +/-0.05
Total Travel (mm)	0.2 +/- 0.05
Diameter (mm)	6.0/5.0 +0/-0.2
Click Ratio	60 +/-15 %
Contact life @ < 400g Load	Min 500K cycles
Contact Resistance	below 50 Ohms

36.1 PCB Circuit for Metal Dome



Diameter	D	E	F	G
6.0 mm	6.76	5.24	2.50	0.41
5.0 mm	5.76	4.24	2.00	0.41

37.0 IMD – In Mould Decoration