PACIFIC SILK

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Designing with Silicon Synthetic Rubber

1. Material

Silicone synthetic rubber is one of two materials presently being used for switch contracts (the other is a material called EPDM). ***Silicon offers advantages over natural and most other synthetics as follows:***

- properties unaffected by temperature extremes
- almost no blooming (imperfections caused by liquid catalyst residue)
- non toxic
- carbon impregnated rubber has low resistance
- non carbon rubber has a very high resistance, good insulator

The most popular variety is methyl vinyl silicon. Conductive rubber is made by adding a carbon compound. Pacific Silk conductive rubber has a typical resistance of 2-3 ohm cm. This is measured according JIS C2123.

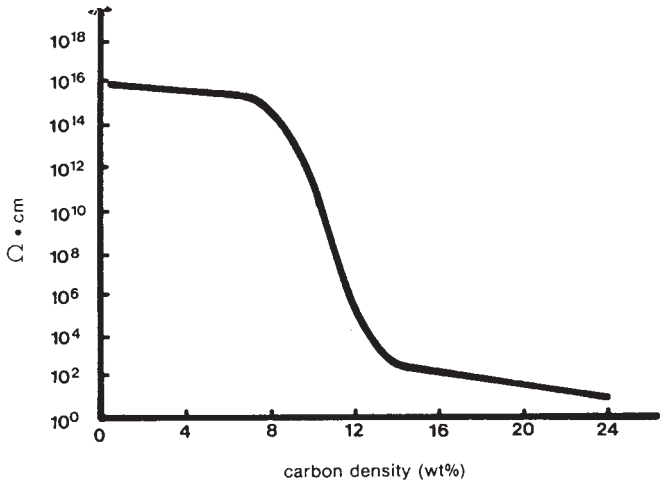

Diagram 1
The Relationship Between the Resistivity of Silicon Rubbers and the Amount of Carbon Black Addition

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2. Curing Process

Pacific Silk uses two stage vulcanization for all its rubber keypad products. The first stage, primary vulcanization, is started by adding oxygen catalyst to a highly polymerized organosiloxane, mixed with colour dye and then compressed in a mold at approximately 170 degrees celcius at a pressure of 200 kg/cm.
The second stage. Or secondary vulcanization., requires oven baking at 200 degrees C for 1.5h.minimum.

This oven process:

- removes residual catalyst
- increases thermal stability
- prevents blooming caused by slow release of oxidant residue left over from the first stage.
- Stabilizes physical properties i.e., hardness, colour, elasticity, shape.

3. Material Characteristics

Table 2
Characteristics of Materials

	Conductive Materials				*Non-conducting or Insulation Material*
	T-2	*SAC-2*	*SAC-3*	*SAC-5*	
Room Temperature Tests:					
Specific Gravity	1.186	1.191	1.223	1.285	1.18
Hardness (JIS-A)	58	60	66	79	50
Tensile Strength (kg/cm^2)	61	64	71	47	72
Elongation (%)	279	288	249	157	320
100% Modulus (kg/cm^4)	24	25	27	34	18
Accelerated Life Test	200° C × 72 hours				
Hardness Change (%)	+2	+5	+3	+3	+2
Tensile Change (%)	± 0	−23	−11.3	−4.3	+9
Elongation Change (%)	−6.8	−28	−16.8	−26.1	−2
100% Modulus Change (%)	± 0	+13.7	+29.6	+20.5	± 0
Permanent Distortion Caused by Compression (percentage of original)	Compress to 75% of original for 22 hours at 150° C				
	11%	15%	10%	12%	1%
Resistivity (Ωcm)	17.4	7.9	3.1	0.28	1×10^{14}

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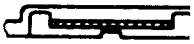
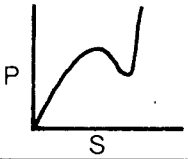
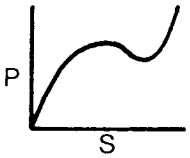
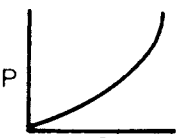
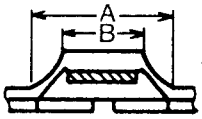
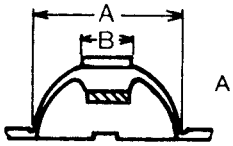
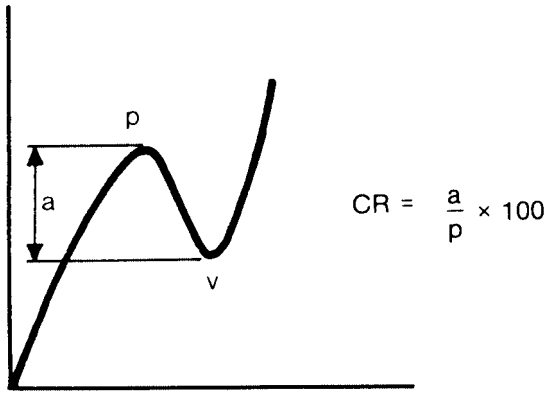
4. General Skirt Shapes and Characteristics

Characteristics \ Skirt Shape	Cone Type	Double Cone Type	Bell Type	Double Bell Type	Flat Type
Profile					
Click Curves P = pressure (g) S = stroke (mm)					
Peak Pressure Range	30–250 (g)	50–250 (g)	80–200 (g) 10–200 (g) (no click)	30–200 (g) 30–200 (g)	–
Relationship Between Peak Pressure and Stroke	*Peak Pressure (g)* 30–50 55–80 85–150 155–200	*Stroke (mm)* 0.5–0.9 0.7–1.4 0.8–1.5 1.2–2.0	Stroke (mm) 1.0–3.5 0.5–3.5 (no click)		Stroke (mm) 0.3–0.7
Relationship Between Keytop Diameter and Skirt Diameter (outside)	 A ≥ B + 2.5mm		 A ≥ B+2.0mm		–
Typical Life Cycle	1×10⁶ cycles		10×10⁶ cycles		50 ×10⁶ cycles
Primary Applications	Portable Calculator Home appliances	Radio Communications	Typewriter	Typewriter Radio Communications	Pocket Calculator Computer



$$CR = \frac{a}{p} \times 100$$

5. Click Ratio

Click ratio is a measurement of tactile feel. It is the ratio of valley force to peak force expressed as a percentage.

$$\text{Click ratio} = \frac{\text{(p) peak force – (v) valley force (gr)}}{\text{(p) peak force (gr)}} \times 100$$

A good tactile feel is achieved with CR of 40% to 60%. Please note in table 3 that the flat type skirt has no CR and no tactile feel. The bell type and cone type have high CR's and would have good tactile feel.

6. Dimensional Tolerance of Rubber

Table 5 shows achievable tolerances when producing rubber components.

The tolerances are affected by:

1. the variances due to shrinkage rates among lot
2. the variances due to molding conditions
3. the dimensional variances of dies.

Dimensions m/m	Tolerances (+) m/m
-10	0.1
10-20	0.15
20-30	0.2
30-40	0.3
40-	0.7%
	(0.5% possible)

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7. Peak Force Tolerance

If peak force is 30 to 50 grams then tolerance is +/- 15gr.

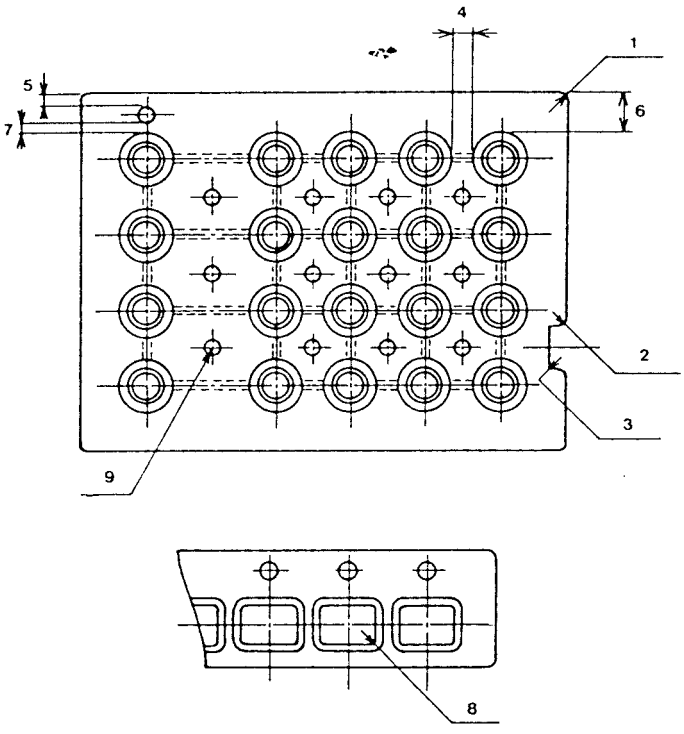
If peak force is 50 to 80 grams then tolerance is +/- 20gr.

If peak force is 80 to 100 grams then tolerance is +/- 30 gr.

If peak force is 100 grams or higher then tolerance is +/- 30%

Tighter tolerances available.

Diagram 6



8. Design Notes

a) For plan view drawings (diag. 6)

1,2 Put 1.0mm radius at corners

3. Right angle possible but 1.5mm radius preferred

4. Distance between adjacent skirts must be 1.0mm min.

5,6 The distance between edge of hole and edge of pad must be 1.0mm min. The same distance must be between skirt and edge of sheet

7. The distance between edge of hole and skirt must be 1.0mm min.

8. Radius of corners of rectangular keypads should be 0.2mm min.

9. When pins are placed in mold to make hole, diameter must be 1.0mm min. and distance from hole to anywhere m

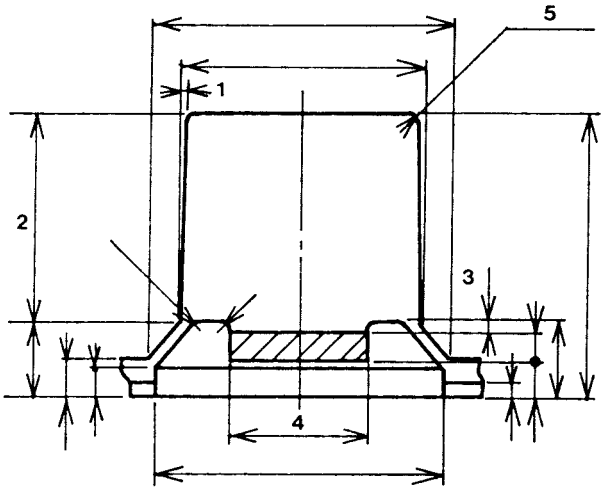


Diagram 7

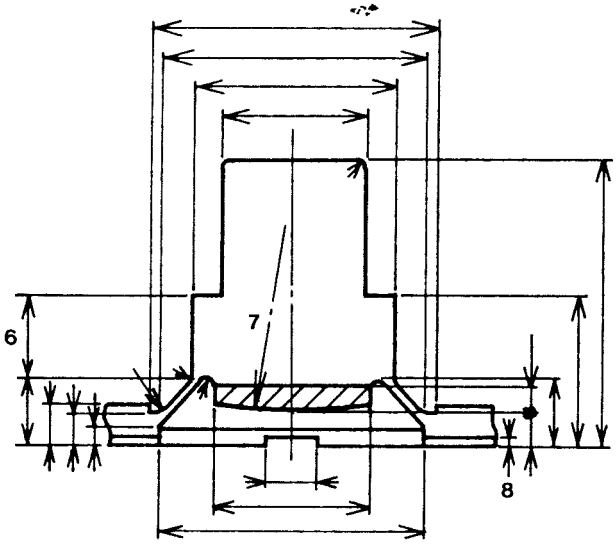


Diagram 8

b) For cross sectional drawings (Diag. 7,8)

1,2 Tapered angles to be 10 00', wherever the dimension of 2 is greater than 5.0mm otherwise taper is not necessary

3. If pill thickness is: 0.8mm : then 0.2mm<3<0.7mm 0.7mm : then 0.2mm<3<0.4mm

4. Pill diameter and thickness must be same for the entire pad regardless of keycap size for min. cost

5. This R should be 0.5mm or depending on the depth of 2 a sharp right angle

6. If a step is made on keytop, 6 should be 1.0mm minimum

7. R for pill depends on the pill diameter as below:

Dia. 2.5mm-R15.0mm

Dia. 3.0mm-R18.0mm

Dia. 3.5mm-R22.0mm

Dia. 4.0mm-R24.0mm

8. An air channel should have a depth of 0.2mm minimum

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c) Misc. notes

1. From cost point of view, the fewer the holes in rubber pad the better (minimize pins in tool)
2. Unless absolutely necessary do not design a hole in the pad. Try for “B”, for mounting holes, or guide locations (Diag.9)
3. Built in gaskets increase price.
4. If gasket is necessary, a 1.0mm min. gasket width is recommended to avoid EDM charges (Diag. 10). (for less than 1.0mm, it must be done by electrical discharge processing.)
5. The following points should be shown on customer drawings (Diag. 11):-
   a. base thickness
   b. skirt height (related to keyboard housing or bezel)
   s. stroke
   h. overall height
   c. keytop outside dimensions
   d. skirt maximum dimensions, as well as the following:
      • peak pressure
      • valley pressure on return curve
      • tactile feel, yes or no

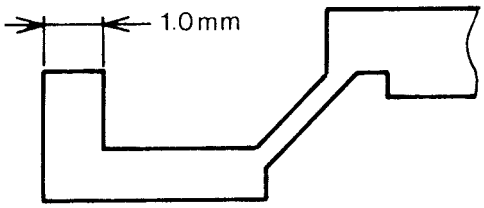


Diagram 10
(see note 4)

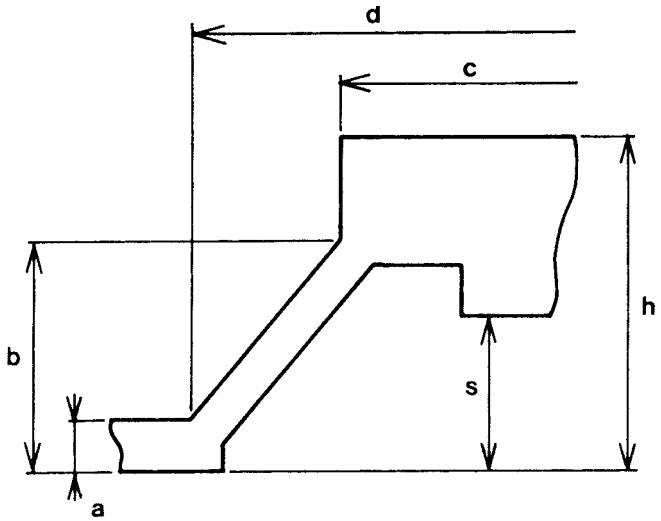


Diagram 11
(see note 5)

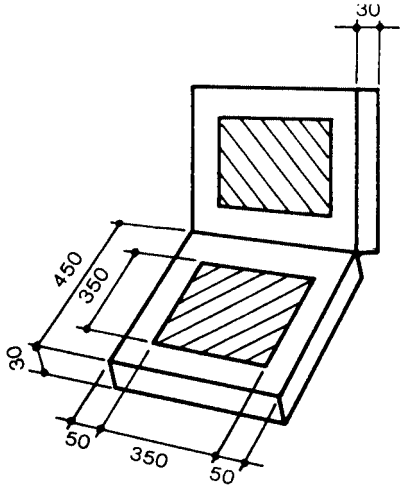
9. Mold Considerations

1. Basic mold dimensions for 150 tonne compression mold (Diag 12). We also have 200 tonne which can handle a 600x600mm mold.
2. Useable mold dimensions and peak pressure (tonnes)

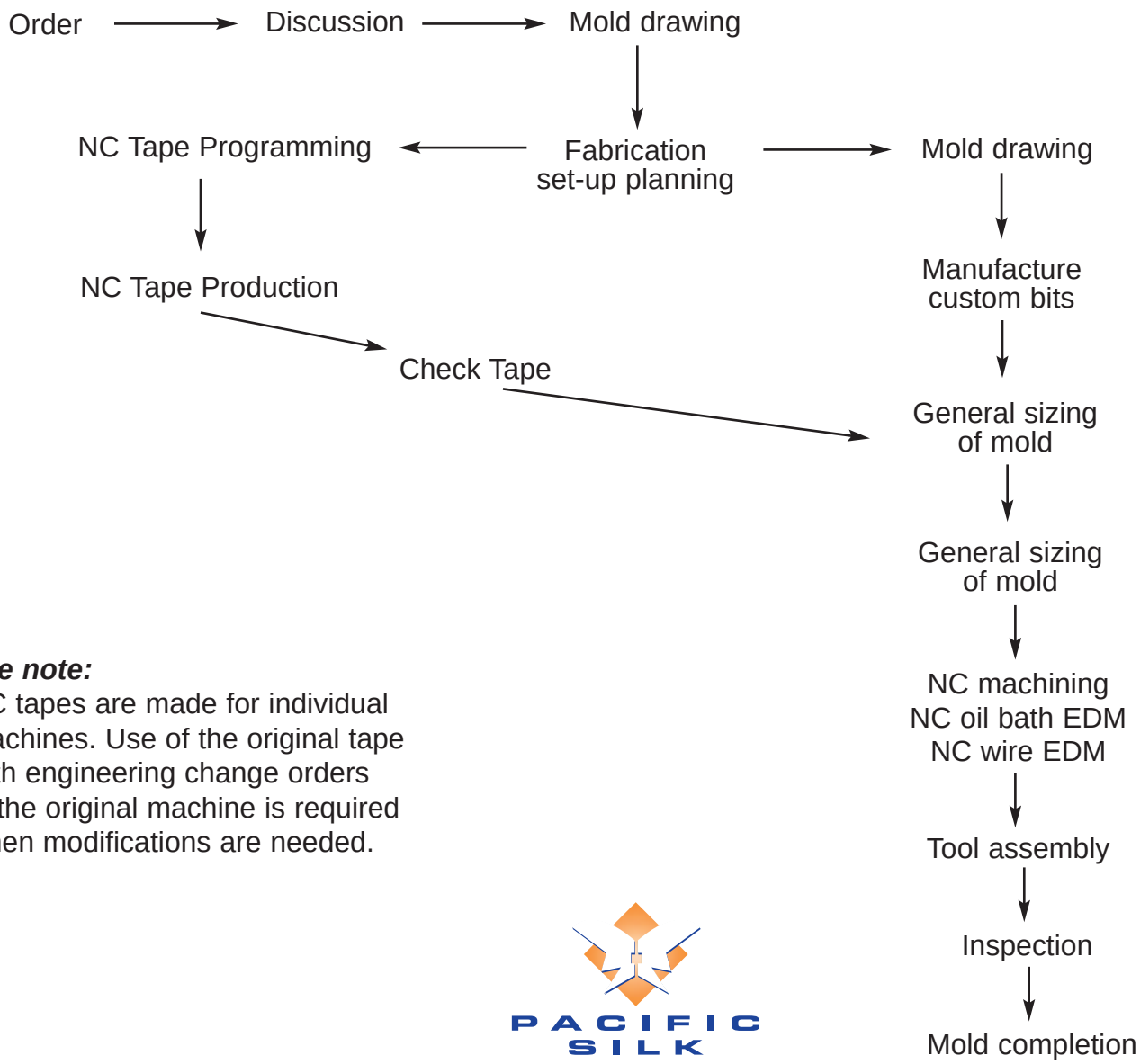
   100 tonnes 300x300

   150 tonnes 350x350

   200 tonnes 500x500



3) Manufacturing Process for Molds



Please note:

NC tapes are made for individual machines. Use of the original tape with engineering change orders in the original machine is required when modifications are needed.

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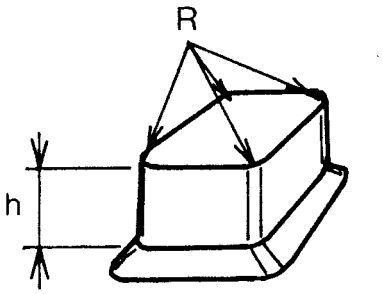

Diagram 13

4) Notes on making mold production easier, quicker and less expensive

a) Minimize different key sizes in same rubber pad

b) Larger radius is better (Diag. 13)
The following can be done by NC machines

H= less than 2mm	R= larger than 0.5
H= less than 4mm	R= larger than 1.0
H= less than 5mm	R= larger than 1.5

Otherwise EDM milling is required.

c) In the case of perimeter gaskets NC machines can be used if width is 1mm maximum, depth is 2mm maximum and radius = * of width. Minimum width is 0.5mm even for EDM (Diag. 14)

d) No revisions of drawings and/or specifications during fabrication of dies should be made. Otherwise changes to NC tape and bits may be required. It is generally best to wait until mold is finished before making any changes. However, any modification after tape generation is expensive.

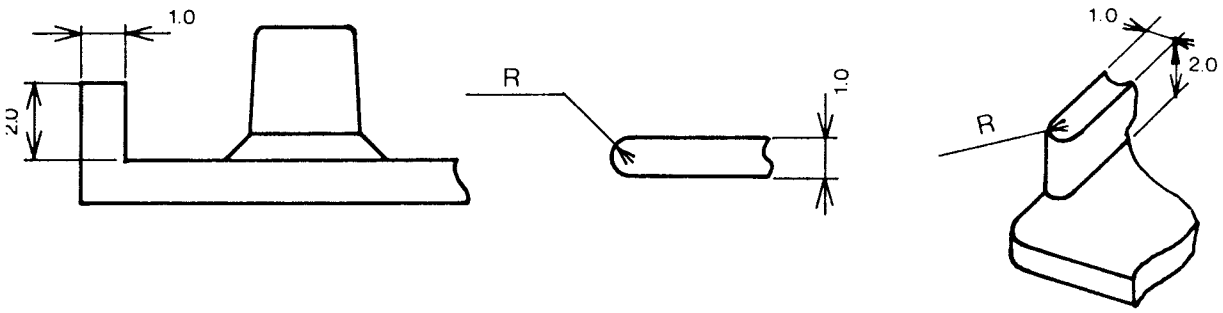

Diagram 14

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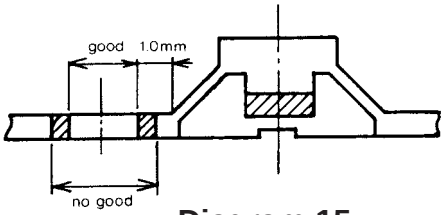


Diagram 15
(see note 3)

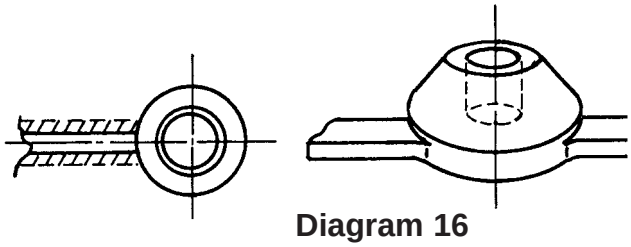


Diagram 16
(see note 4)

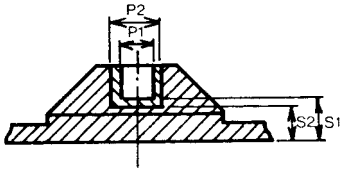


Diagram 17
(see note 5)

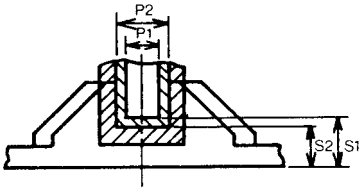


Diagram 18
(see note 6)

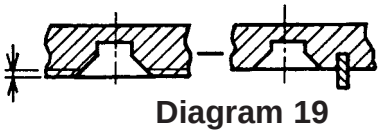


Diagram 19
(see note 7)

Modification notes

1) **Changes to outside dimensions.** This is very difficult because either the upper or the lower mold has to have metal added for any change. If pad is made larger, then material must be added to lower side keycap areas and overflow throughs have to be moved; a new lower mold is cheaper. If pad is de smaller, a new upper mold is generally aper.

2) **Revisions of keytop dimensions.** To make them smaller, the upper dies to be remade (cheaper than modification). To make them higher, minimum of 0.1mm enlargement is required for non round keytops. Keys with round keycaps can be drilled larger no problem.

3) **Addition and removal of pins to make holes. Addition and removal of pins** is usually easy except in the case where pins are located to close to the key skirt. The pins must be separated more than 1.0mm for the bottom of the skirt. *(Diag. 15)*

4) **Addition of air channel.** The addition of steel will be required. This is extremely difficult near the skirt and without damage to the key skirt. The removal of air channels is no problem. *(Diag. 16)*

5) **Change of stroke.** To shortening…easy to cut (S1..S2) To lengthen..difficult add steel; usually er mold has to me remade. *(Diag.17)*

6) **Change to pill diameter** Larger…easy (P1..P2) Smaller….difficult, possibly a new lower mold may be required. *(Diag.18)*

7) **If the core side (the upper base) has to be adjusted** (usually to change key pressure) and it has bosses in it they will be ground off during mod. Process. It will take a long time to reinstall pins to duplicate bosses. *(Diag. 19)*

Blast, Plating…upon inspection of mold, it will be sand blasted and chromium plated. Some pads that have deep square and/or round keys may require plating .

Delivery time for molds. After acceptance of mold drawing by customer.

First offs: 5 weeks
Mass production: 4-6 weeks after first offs

10. Rubber Switch Tests

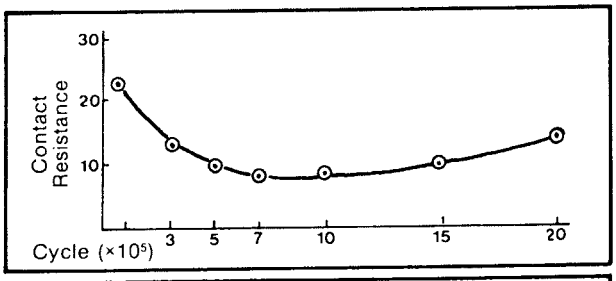


Diagram 20
Contact resistance vs. simulated life (key pressure 200g)

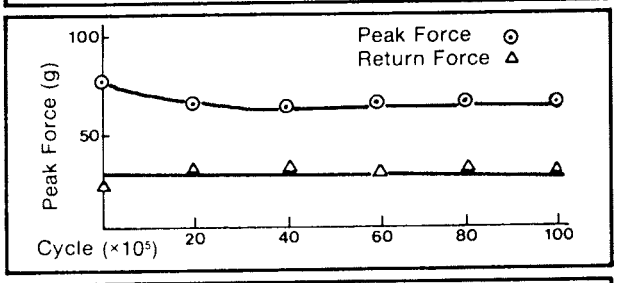
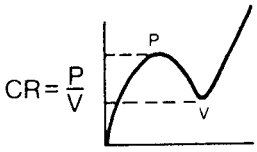


Diagram 21
Peak force and valley force change with cycles (key pressure 200g)



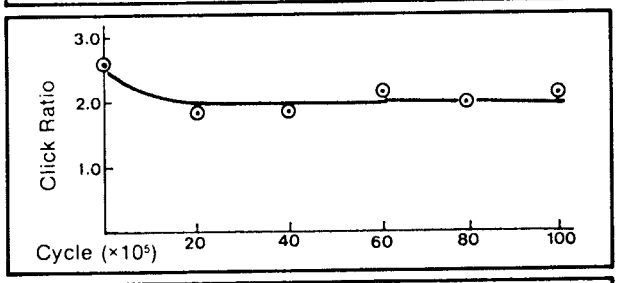


Diagram 22
Click ratio change vs. simulated life (key pressure 200g)

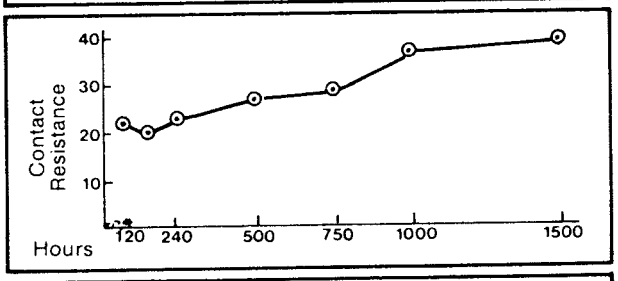
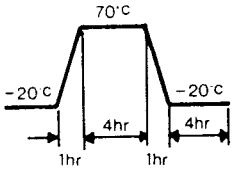


Diagram 23
Humidity test
(60ºC and 90% RH)



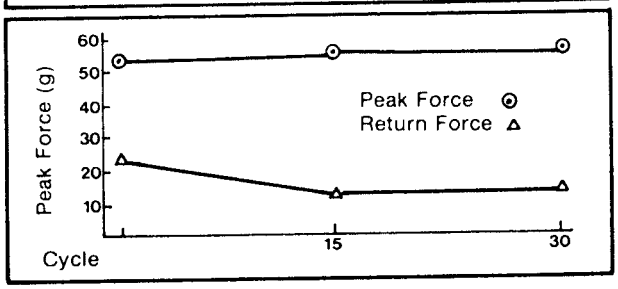


Diagram 24
Thermal gradient test

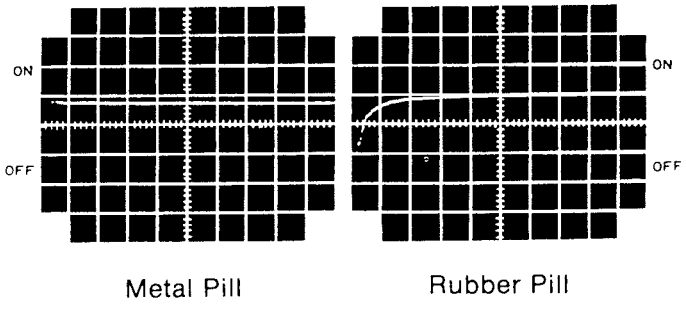


Diagram 25
Contact bounce
(vertical direction 0.5v/Div.)
(horizontal direction 1msec/Div.)

11. Keytop printing

1. Ink (colour) We can mix ink to match any colour you specify.

2. **Printing methods *(Diagram 26)***

Standard ***Inlay***
Proprietary process
Expensive to tool/unit price high
Long life

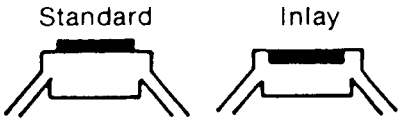


Diagram 26

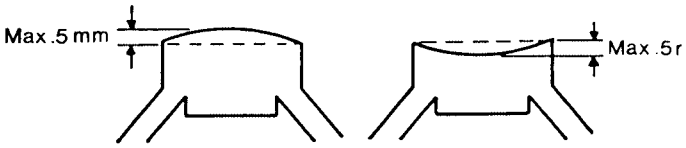


Diagram 27

3. Suitable shapes for printing by silkscreen ***(Diagram 27)***

4. Minimum printing sizes (*Diagram 28)*
Legend size: minimum 1mm square with 0.2mm line widths Legend line spacing minimum 0.5mm

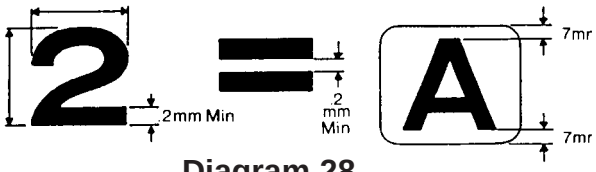
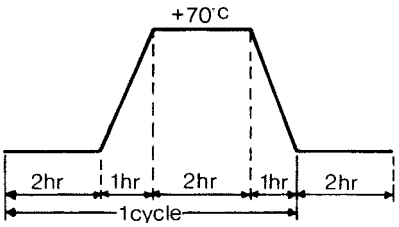


Diagram 28

Sulfuric acid test	Soak in acid solution 5% by weight at 40º for 72 hrs	Pass No failures or rejects
Acetic acid test	" "	"
Caustic soda test	" "	"
ph7 detergent test	Soak in 20% by weight detergent solution at 40ºC for 72 hrs	"
Alcohol test	Soak in 95% (vol.) ethanol at room temp for 72 hrs	"
Hand cream test	Spread hand cream (Serishasu Kanebo) over the keytop surface for 72 hrs	" "
Paint thinner test	Soak in commercially available paint thinner for 72 hrs	"
Simulated human perspiration	Soak in simulated human perspiration at 20ºC + 20ºC for 24 hrs	"
Ultraviolet rays test	Irradiate ultraviolet rays by carbon fed meter at 65ºC + 20ºC for 600 hrs	"
Wear resistance	Apply a 200 cyclic load of 500g	"
Abrasion test	through Lion PL-500 rubber eraser	
Contact key wear test	Apply 1X10 contacts 200g each	"
High temperature test	Remain in a constant temp chamber of 70ºC for 60 hrs	"
Low Temperature test	Remain in a constant temp chamber of -40ºC for 60 hrs	"
High temperature/ humidity test	Remain in an environmental chamber of 65ºC / 95% RH for 60 hrs	"
Thermal gradient test	8 cycles	"
		
Thermal shock test	Apply a total of 5 cycles each consisting of -40ºC for 30 min, +20ºC for 5 min, 70ºC for 30 min and 20ºC for 5 min	"

12. Conductive Ink Pill

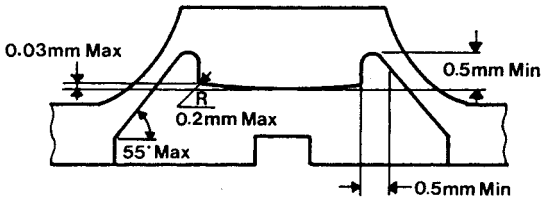
Most of the present switches utilize conductive silicon rubber pills. A recent trend is to utilize conductive ink for computers and remote control switches. It makes the selection of contract shapes virtually unlimited (pills are round) and offer a slight cost reduction.

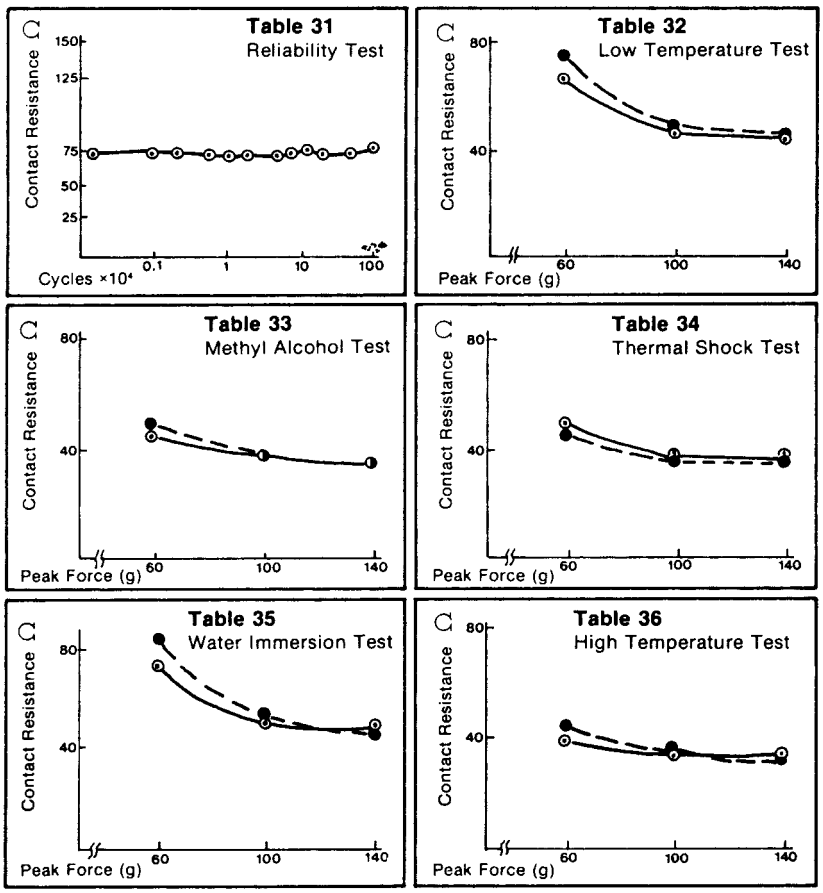
Thickness of conductive ink: approx 15-20 microns.
Contact resistance: less than 100 OHMS
Using 4mm pill diameter 200 gr Keycap pressure, interlaced finger pattern gold plated.
Life expectancy: more than 1x10 power 6 cycles
Required shape for printing conductive ink: cross sectional diagram.

No projections allowed on bottom of rubber pad (that would obstruct silkscreen)

PACIFIC SILK

Diagram 30:
Guidelines for Designing with Conductive Ink





12. Conductive Ink test data

Table 31
Reliability test for conductive ink contact
200g peak force
Ink used: SPC-07
Pill diameter: 3.5mm
PCB with gold plated pattern with 3mm gap interlaced finger pattern

Table 32
Low temperature test for conductive ink contact
Ink used: SPC-07 / Pill diameter: 3.5mm
PCB with gold plated pattern with 3mm gap interlaced finger pattern
Test conditions:
Cold soak -20ºC for 240 hrs then raised to +21C for 24 hrs.
◉ = Before cold soak cycle ● = After cold soak cycle

Table 33
Methyl alcohol test
(Same as Table 32)
Test conditions:
Soak in methyl alcohol for 24 hrs at 22ºC then remove; leave for 24 hrs at 22ºC.
◉ = Before immersion ● = After immersion

Table 34
Thermal shock test
(Same as Table 32)
Test conditions:
Cycle 2 hrs at -20ºC, 2 hrs 60ºC for 5 cycles
After 5 cycles leave 24 hrs at 22ºC then test.
◉ = Before test ● = After test

Table 35
Water immersion test
(Same as Table 32)
Test conditions:
Soak in distilled water at 22ºC for 240 hrs; remove then leave for 24 hrs at 22ºC. Then test.
◉ = Before test ● = After test

Table 36
High Temperature test
(Same as Table 32)
Test conditions:
Soak at +60C for 240 hours; remove to 22ºC for 24 hours, then test.
◉ = Before test ● = After test