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About Silicone Foam (Foamed Silicon)

Introduction

Foam urethane has been primarily used as foam material in the past. From the 1950s, polyurethane and polyisocyanates have been developed as heat-insulating material, and the demand for them are increasing year by year. Urethane foam is utilized in the following two fields.
1) for building material with spray working
2) for the molding materials by injection molding in electricity, machinery, and automobile industries.

Besides these usages, various expectations are placed on the foam material and improvement in conventional performance and quality is also expected.

In that circumstances, as the new raw material of formed material, foamed silicone is expected. Silicone has outstanding properties, for example, better heat resistance, weather resistance, ozone-proof and chemical resistance than conventional urethane, and it can be given special functions like excellent electrical isolation and flame resistance.

Various properties of silicone are as follows.

(1) Excellent heat resistance up to 200°C or so.

(2) Excellent cold resistance down to -50°C or so.

(3) Excellent electrical property with stable insulating property in wide range of temperature and frequency.

(4) Excellent weather resistance.

(5) Excellent water resistance.

(6) Excellent safety and health.

(7) Excellent shock absorption and vibration absorption.

(8) Excellent flame resistance up to the level of UL94 V-O is available.

Contents

1. What is foamed silicone ?

There are two kinds of foamed silicone. One is made by adding foaming agent into Millable Silicone Rubber and heat foaming, and another is a self-foaming-reaction type liquid silicone described in this paper. The Millable Silicone Rubber type is widely used as molded rubber products for paper feeding rollers in printers and copy machines and molded sealing packing.

The self-foaming-reaction type is liquid silicone that consists of two components. Mixing and stirring these two parts starts the foaming reaction and result in the foamed material. Since this reaction completes in a short period of time at room temperature, future applications other than the Millable Rubber type are conceivable.

2. Properties of liquid foamed silicone

Properties of liquid foamed silicone are as follows.

(1) With its liquid characteristic, it easily permeates into small details and can be used for potting.

(2) Good operating efficiency because it can cure in 5 to 10 minutes at room temperature.

(3) The ratio of foaming magnification can be set optionally to 2 to 15 times.

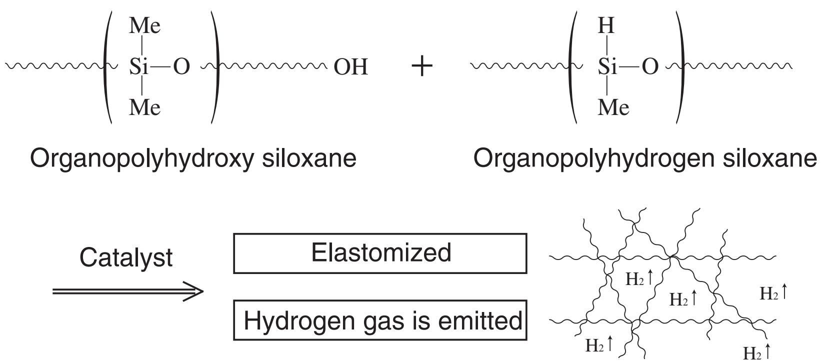
(4) Two options of the form of bubbles, closed type or interconnected type.

(5) Excellent flame resistance up to the level of UL94 V-O is available.

(6) Can be utilized as sound insulation since it cures into elastic body.

3. Curing mechanism of liquid silicone

Liquid silicone cures into elastomer (rubber-like body), emitting hydrogen gas.



Three kinds of catalysts are primarily used in the curing reaction mechanism of liquid foamed silicone: platinum compound, aminoxy compound, and organic tin compound.

Using platinum compounds

Curing mechanism using platinum catalyst is shown below.

$$-\mathrm{Si}-\mathrm{OH} + \mathrm{H}-\mathrm{Si}- \xrightarrow{\text{Cat Pt}} -\mathrm{Si}-\mathrm{O}-\mathrm{Si}- + \mathrm{H_2}\uparrow$$

$$-\mathrm{Si}-\mathrm{CH}=\mathrm{CH_2} + \mathrm{H}-\mathrm{Si}- \xrightarrow{\text{Cat Pt}} -\mathrm{Si}-\mathrm{CH}=\mathrm{CHSi}- + \mathrm{H_2}\uparrow$$

Foamed silicone has the following merits with platinum compound based catalysts.

- Easy operation because of 1:1 compounding ratio of foamed silicone and curing agent.
- Easy to be flame resistant
- High magnification of foaming (Up to 15 times)
- Excellent heat resistance
- Short curing completion time

While following are the demerits.

- Catalyst poison. If organic tin compounds, sulfur inclusions, or amine inclusions are mixed or liquid silicone contacts the components containing these compounds during foaming, that might cause a curing failure. To avoid this, careful investigation before use must be conducted.

≪ Materials that cause Curing Failure ≫

Organic rubber (natural rubbers and synthetic rubbers such as chloroprene rubber, nitrile rubber, and EPDM)

Flexible polyvinyl chloride

Amine curing epoxy resin

Polyurethane isocyanates

Condensation-type RTV rubber, except for some alcohols

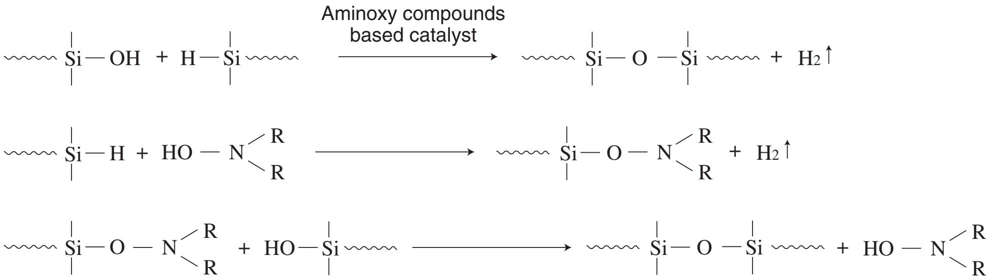
Some adhesives for vinyl tape, adhesive agents, and paints

- Low temperature (10°C or lower) may cause curing failures.

These demerits have to be taken into account before use.

Using aminoxy catalyst

Curing mechanism using aminoxy catalyst is shown below.



Compared with platinum based catalysts, merits using aminoxy catalyst are as follows.

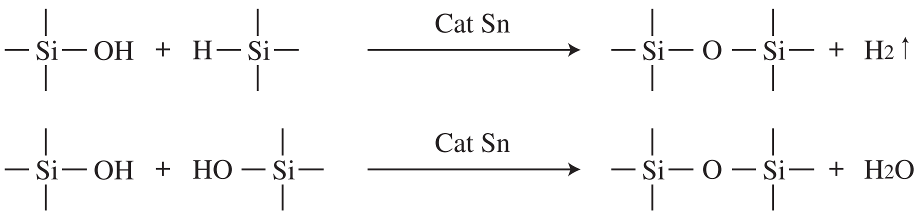
- Relatively high-strength
- Adhesiveness can be given
- Controllable curing time
- Ease of being flame retardant
- No catalyst poison

Demerits are as follows.

- Operational difficulty due to large difference in the compounding ratio of foamed silicone and catalyst
- Long foam completion time
- Corrosiveness to copper
- Odor

Using organic tin based catalyst

Reaction mechanism using organic tin based catalyst is shown below.



Merits using organic tin based catalyst are as follows.

- Can be high-strength
- Adhesive property can be provided
- Controllable curing time
- No catalyst poison

Demerits are as follows.

- Operational difficulty due to large difference in the compounding ratio of foamed silicone and catalyst
- Hard to be flame retardant
- Low heat resistance
- Long foam completion time

Below are shown the usage, characteristics, and application examples of foamed silicone with the curing mechanisms of these three types of catalysts.

- Liquid foamed silicone
  - Platinum catalyst
    - Building use
      - Gap filling and sealing
      - Penetration sealing
      - Potting
    - Industrial use
      - Potting
      - Sheet molding
      - Gap filling and sealing
      - Soundproof materials and vibration-proof materials
      - Coating
  - Aminoxy catalyst
    - Building use
      - Gap filling and sealing
      - Noise-resistant agents
      - Heat insulator
    - Industrial use
      - Adhesive sealants
      - Food samples
  - Organic Tin compounds catalyst
    - Building use
      - Heat insulator
      - Soundproof materials
    - Industrial use
      - Soundproof materials and vibration-proof materials
      - Dust sealant
      - Damper agents
      - Sheet molding

General properties of liquid foamed silicone are shown in the table below.

Table 1. General properties of liquid foamed silicone

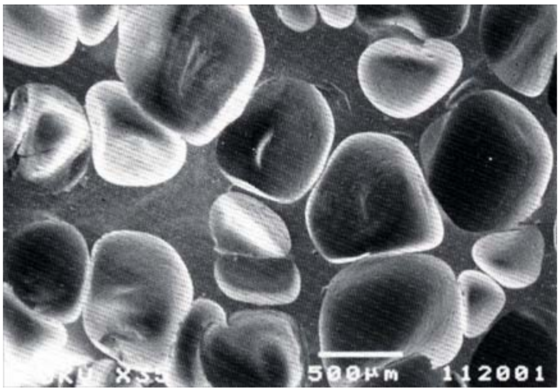
<table>
<tr><td colspan="2"></td><td>Reaction type</td><td colspan="2">Platinum catalyst</td><td colspan="2">Aminoxy catalyst</td><td colspan="2">Organic Tin catalyst</td></tr>
<tr><td colspan="2" rowspan="2">Product name
Item</td><td rowspan="2">Test method</td><td colspan="2">TB5277</td><td colspan="2">12X195</td><td colspan="2">TB5277C</td></tr>
<tr><td>Agent A</td><td>Agent B</td><td>Agent At</td><td>Agent B</td><td>Main agent</td><td>Catalyst</td></tr>
<tr><td rowspan="3">Before curing</td><td>Appearance</td><td>Visual test</td><td>Black</td><td>White</td><td>White</td><td>Black</td><td>Black</td><td>Colorless and transparent</td></tr>
<tr><td>Viscosity</td><td>25°C Pa•S {P}</td><td>7 {70}</td><td>7 {70}</td><td>5 {50}</td><td>3 {30}</td><td>1 {10}</td><td>0.05 {0.05}</td></tr>
<tr><td>Specific gravity</td><td>25°C</td><td>1.10</td><td>1.10</td><td>1.00</td><td>1.00</td><td>1.15</td><td>1.20</td></tr>
<tr><td colspan="2">Compounding ratio</td><td>—</td><td>100</td><td>100</td><td>100</td><td>10</td><td>100</td><td>5</td></tr>
<tr><td colspan="2">Usable life</td><td>25°C min.</td><td colspan="2">2 – 3</td><td colspan="2">5 – 10</td><td colspan="2">5 – 10</td></tr>
<tr><td colspan="2">Foam completion time</td><td>25°C min.</td><td colspan="2">5 – 10</td><td colspan="2">30 – 60</td><td colspan="2">30 – 60</td></tr>
<tr><td rowspan="3">After curing</td><td>Appearance</td><td>Visual observation</td><td colspan="2">Black</td><td colspan="2">Black</td><td colspan="2">Black</td></tr>
<tr><td>Expansion ratio</td><td>(Times)</td><td colspan="2">2 – 3</td><td colspan="2">3 – 4</td><td colspan="2">5 – 7</td></tr>
<tr><td>Hardness</td><td>Asker C</td><td colspan="2">14</td><td colspan="2">13</td><td colspan="2">8</td></tr>
<tr><td colspan="2">Oxygen index</td><td>JIS (Japanese Industrial Standard) K 7201</td><td colspan="2">30</td><td colspan="2">35</td><td colspan="2">—</td></tr>
<tr><td colspan="2">UL94</td><td>3mm</td><td colspan="2">V – O level</td><td colspan="2">—</td><td colspan="2">—</td></tr>
</table>

Closed cell and interconnected cell

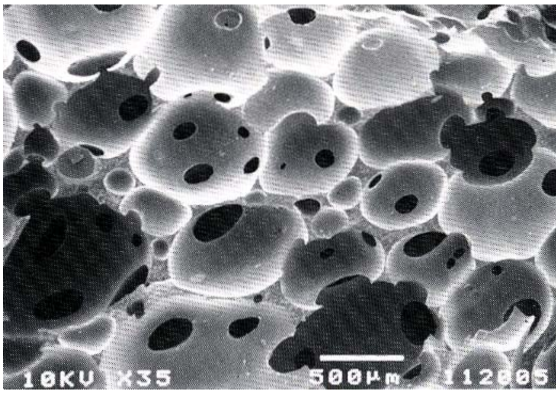
There are two kinds of bubble growth of foamed silicone, closed cell and interconnected cell.

Film forming reaction during foam curing and emitted hydrogen gas determines the type of foam growing. If emission of hydrogen gas is faster than the rate of film forming reaction, growing foam will be interconnected cell type. Conversely, if the rate of film forming reaction is faster than the emission of hydrogen gas, it will be closed cell type.

The electron microscopic pictures of both types are shown below.



Closed cells



Interconnected cells

Basically, the closed cell type is used in the environment where airtight and watertightness are required. The interconnected cell type is applied to the environment where elasticity, low stress, and low repulsion properties are required.

*TB is the abbreviation of ThreeBond.

4. Practical application samples using foamed silicone

Liquid foamed silicone has various properties and has various applications described above.

Following illustrate the practical examples of primary uses.

I. Application examples in construction field

1-1. Foamed silicone for fire resistant air tight method

In atomic power plants and other ordinary buildings, fire and smoke prevention measures of the places of walls and floors, through which electric cables and various plumbing run, are becoming major issues. Particularly, if cables penetrate through fire compartments of buildings, the penetrated portions are required by statutes to provide fire preventive measures. (Article 112, Paragraph 15 and Article 129-2, Paragraph 1, Item 7 of Enforcement Ordinance of Construction Standard Law of Japan)

Article.112 (The regulation prescribing the case that pipes penetrate through fire compartments)

Paragraph 15

If feed water pipes, power distribution pipes or other pipes penetrate the fire resistant structure or fire protected floor and wall prescribed in Paragraph 1 to 5, Paragraph 8, the purview of Paragraph 9, the purview of Paragraph 10, Paragraph 12 and Paragraph 13, or the marquee, floor, wing wall, and other similar structures in the case mentioned in Paragraph 10 (hereafter in this Paragraph and the next Paragraph, referred to as "fire compartments such as fire resistant structures"), the gaps between the said pipes and fire compartments such as fire resistant structures shall be filled with cement mortar or other non-combustible materials.

Article.129-2 (Installation and configuration of plumbing for emergency lighting equipment)

Paragraph 1, Item 7

If feed water pipes, power distribution pipes, or other pipes penetrate the fire compartments such as fire resistant structures prescribed in Article 112, Paragraph 15, fire walls prescribed in Article 113, Paragraph 1, the party wall prescribed in Article 114, Paragraph 1, the partitioning wall prescribed in Article 114, Paragraph 2, or the partition wall prescribed in Article 114, Paragraph 3 and Paragraph 4, the said portion where the pipes penetrate and the portion within 1 meter distance of both sides from the said penetrated portion shall be built of fire resistant materials. However, the same shall not apply for such the portion inside the floor and wall of fire resistant structure or inside the pipe shaft and pipe duct and other similar things separated from other parts of the building by A class fire door or the portion which complies with the standard provided by the Construction Minister after approval that there is no problem from fire prevention control point of view.

The purpose of these regulations is preventing the portions of walls and floors of buildings where cables penetrate from functioning as flow paths of fire, smoke and toxic gas.

In the past, for this purpose, inorganic fibrous filler materials like rock wool, asbestos, ceramics, and glass wool, or urethane foam which is given fire-resistant characteristic have been used as packing materials. However, their performance is not so good neither as fire-resistant structures nor from the aspect of airtightness, installability, and safety to human body. Moreover, low flame resistance of urethane foam leads to toxic gas emission when burning.

In order to solve these problems, foamed silicone has been developed. Following are the features of foamed silicone TB5277 for fire-resistant and airtight construction methods.

(1) Performance

- Excellent heat resistance and flame retardance of cured foam (Figure 1)
- Excellent airtightness and water-tightness of closed cell foamed material
- No toxic gas emitted when burning
- Good radiation resistance
- Closest packing due to liquid state
- Excellent weather resistance (Table 2)

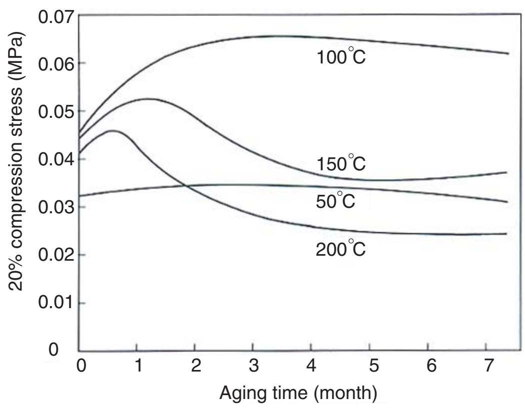


Figure 1. Compression stress and heat aging characteristic of TB5277 foam

The above figure shows that TB5277 foam can withstand thermal aging at 200°C.

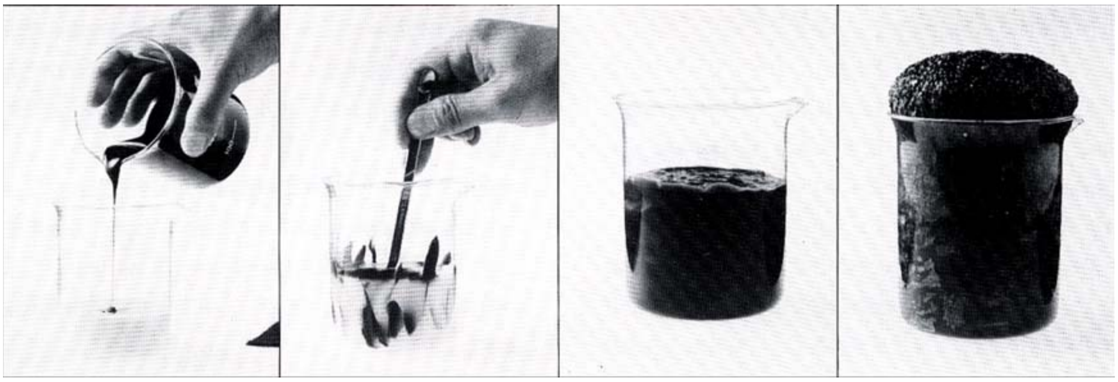
Table 2. Weather resistance of TB5277 foam

	TB5277 foam	Urethane foam
Form after 1600 hours (equivalent to 5 years) by weather meter	No discoloring and elasticity kept.	Turned yellow and constricted significantly.

Weather meter conditions: ASTM0822-E (consistent UV, water spraying for 18 minutes every 2 hours)

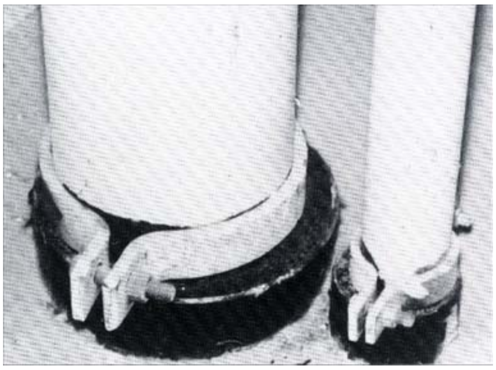
(2) Operability

- Good operability with 1:1 compounding ratio
- Fast curing (completion in 5 to 10 minutes)
- Controllable reaction rate with retarders
- Little or no toxicity

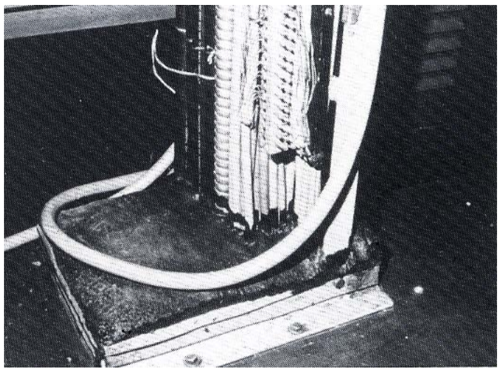


Mix main agent with curing agent | Agitate the mixture | Foaming | Foaming complete

Foaming procedure and foamed state of TB5277



Air ducts



Cables

Construction example of TB5277

In these days, foamed silicone for fire proof and air proof is applied to atomic power plants, high-rise buildings, intelligent buildings, and petrochemical complex, and it is becoming widely used in various places.

II. Application examples to industrial fields

As application examples of foamed silicone in industrial fields, following applications are conceivable: potting of electric/electronic materials; sound proof and vibration-proof materials for housing; applications for interior equipment of automobiles, wheeled vehicles, and aircrafts in transportation fields; and sound proof for the panels in automobile engine compartments.

Moreover, the replacement of vibration-proof rubber formed products commonly used in internal-combustion engines or sound proof glass wool formed products with foamed silicone products are also conceivable.

In this section, newly developed twin cartridge type foamed silicone product, TB5277B, and foam OLGS (Foam On Line Gaskets System), which has been developed aiming for on site forming, are introduced.

(1) Foamed silicone twin-cartridge gun system

In the conventional working procedures using foamed silicone, two liquid agents are mixed with 1:1 compounding ratio and stirred on site just before infusion. Since the work is conducted in almost manual fashion, following problems have been occurred, which made the work extremely difficult: insufficient stirring due to manual operations, dirty working environment, and curing failures caused by rough estimation of mixing agents even with 1:1 compounding ratio. Moreover, inexperienced stirring work has caused unexpected foaming during stirring and addition of too much material for mixing has caused waste of resins. Thus, in fact the work is regarded as very difficult.

In case of using large amount of material, the automated two-part mixing dispenser with 20 liter pail cans has been often used, however, in most sites, it is not practical because the machine often needs a large space and a source of power that most sites can not afford. Then, foamed silicone TB5277B and twin-cartridge gun system, which constitute the on-site foamed silicone installation system that is portable and need no power and no large on site working space, have been developed.

With foamed silicone TB5277B the extent of precipitation and separation during storage, which has been a critical issue of conventional flame resistant foamed silicone, has been reduced. This anti-settling method enables us to create the cartridges of foamed silicone. In (Table 3) is shown the properties of TB5277B.

Table 3. Properties of TB5277B

Property: before curing

	Main agent	Curing agent
Appearance	Black liquid	Black liquid
Viscosity 25°C, Pa•s {P}	6 {60}	8 {80}
Specific gravity (25°C)	1.06	1.06
Compounding ratio (weight)	Main agent/curing agent=100/100	

Property: foaming body

Appearance	Black foam
Specific gravity (25°C)	0.3
Expansion ratio	2-3 times
Closed cell content	90% or more
Tensile strength	0.2MPa {2.0kgf/cm^2}
Rebound resilience	60%
Hardness (Asker C)	20

Both agent A and agent B of TB5277B are filled in the cartridges, they are mounted on the twin-cartridge gun as shown in Figure 2, and the agents are dispensed from the static mixer on the tip of the gun.

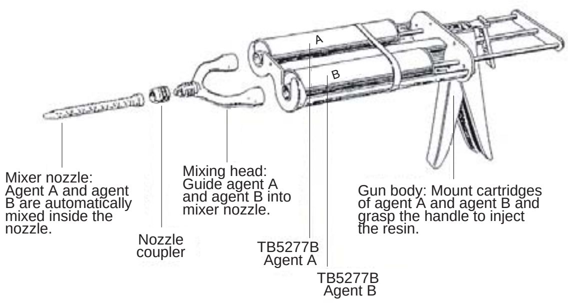
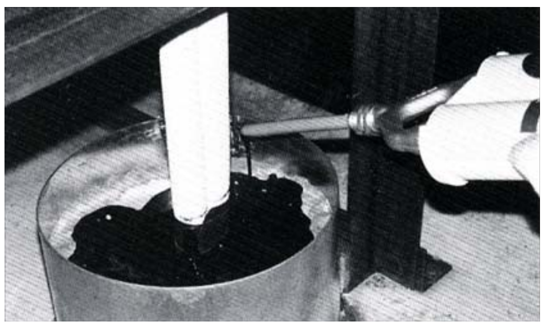


Figure 2. Operation image of twin-cartridge gun TB5277B



Operation image of TB5277B

(2) Foam OLGS

In the past, many foamed sponge gaskets have been used in transportation industry to electric/electronics fields primarily for water resistance and dust sealing purposes. Following are some examples: timing belt covers and head covers for automobiles, switch boxes and junction blocks for electric equipment, and body panels for computers and word processors. These sponge formed products requires manpower for their installation work and so the work using these products has been regarded as far behind in automation.

For example, assembling the sponge to timing belt covers in automobile engine assembly lines always needs assembly specialists, and thus the line is far behind in automation, while other lines are automated. In other industries as well, the assembling work of foamed packing is left untouched as an obstacle to automation.

It is the foam OLGS (Foamed On Line Gaskets System), which has been developed as a method for solving these problems.

2-1. Introduction to foam OLGS

Some parts have used foamed sponge for the purposes of water resistance and dust sealing in the past. But in this new system, by deploying two-part mixing and coating robots that apply the room temperature fast-curing type liquid foam silicone, spongy foamed silicone gasket can be formed in a short period of time on any parts with much complex shape.

This innovative rationalization system eliminates the manual work of mounting the sponge for automation.

2-2. Silicone resin for foam OLGS

Silicone resin of foam OLGS cures in a short period of time at room temperature only by mixing with 1:1 compounding ratio, and grows into high-strength silicone foam with good foaming performance

The cured object shows not only excellent heat resistance, cold resistance, weather resistance, and endurance similar to the other types of silicon foam but also excellent sealing property because of the high closed cell ratio of foamed cells.

And thanks to the heat insulating and cushioning properties that silicone foam originally has, it can be widely used not only for sealing material but also for other applications.

Table 4 shows general properties of silicone resin for foam OLGS.

Table 4. General properties of silicone resin for foam OLGS (12X-105)

Item	Unit	12X-105		Remarks
		A	B	
Before curing				
Appearance		Paste form	Paste form	
Viscosity	Pa•s {P}	16 {160}	14 {140}	
Specific gravity		1.1	1.1	
Curing characteristics				
Rise time	min.	2-3		at room temperature
Gel time	min.	4-6		at room temperature
Characteristics after curing				
Hardness	Asker C	25		Dumbbell No.2
Elongation	%	110		Dumbbell No.2
Tensile strength	MPa	0.34		Dumbbell No.2
	(kgf/cm^2)	3.5		
Bulk density	g/cc	0.44		
Expansion ratio	times	2.5		
Air permeability	cc/10 sec	0		*1
Number of Cells	Number/25mm	140		*2
Residual compressive strain	%	10		*3
Thermal conductivity	kJ/m•h•°C	0.21		

Test method

*1 Measuring the amount of leakage per 10 seconds by applying the air pressure of 0.1MPa{1kgf/cm^2} on the foam with 40mm in diameter and 10mm in thickness.

*2 Measuring the number of cells per 25mm using magnifying glass

*3 Measuring the decreasing rate. At first, put the cylindrical test piece with 48mm in diameter and 20mm in thickness that is compressed into 50% of its original size in the drying furnace for 24 hours at 150°C. Next, take it out from the dryer, and leave it to stand for 30 minutes at room temperature. Then measure the thickness to calculate the decreasing rate.

2-3. Advantages and manufacturing processes of foam OLGS

Manufacturing processes and advantages of Foam OLGS are shown below.

Advantages

(1) Formable with about 10 to 50 seconds of forming cycle.

(2) Almost no heat exchange during curing because the foam OLGS system is the highly energy conservative forming system.

(3) Small curing line space due to short curing completion time like about 10 minutes.

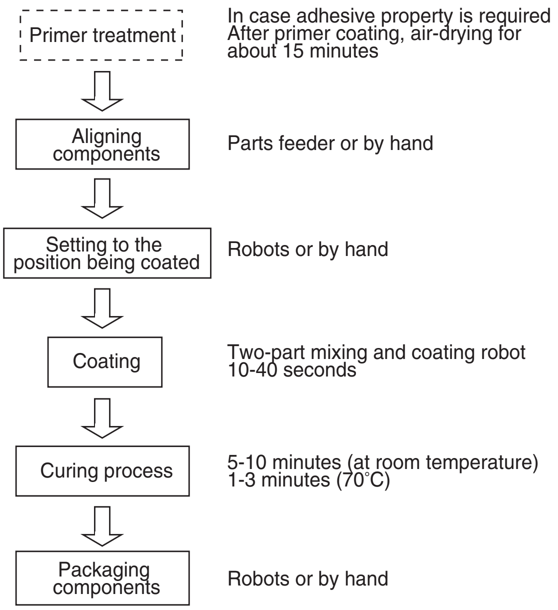


Figure 3. Production process of foam OLGS

2-4. Primary applications of foam OLGS

Silicone resin for foam OLGS is cured and foamed in a short period of time at room temperature (expansion ratio is 2.5 to 3.0 times), and it grows into silicone sponge with excellent heat resistance, weather resistance, endurance, and heat insulation.

With taking advantage of these characteristics, it is used primarily as waterproof sealing and dust sealing. Besides them, it can possibly be applied to various applications such as for sound proof, vibration resistance, and heat insulation.

These primary applications are shown in Figure 4.

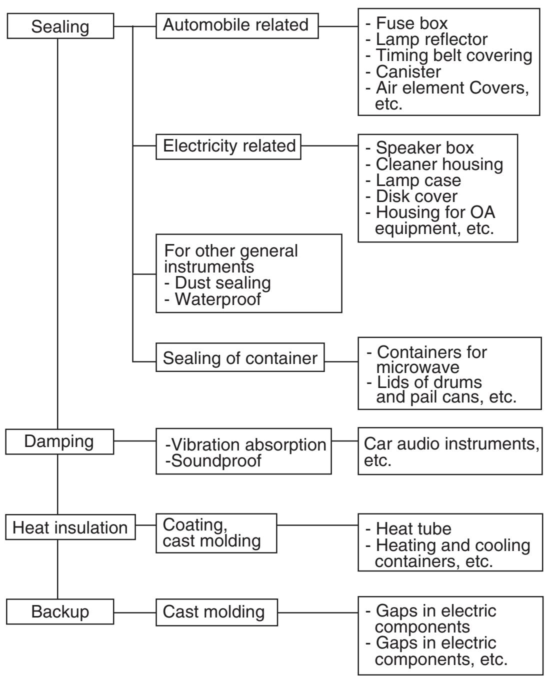


Figure 4. Primary applications of foam OLGS

Conclusion

So far the outline of the foamed silicone is discussed. Practically, the application of foamed silicone to industry has only begun now, and we are sure that there is much room for research and development for the usage in which we can take advantage of the potential of silicone and properties as foam.

We will continue to pursue potentiality of foamed silicone, and we are very happy if you read this report for reference and become interested in this resin.

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