

Design Guide for Formed-in-Place Gaskets

1. Scope—This SAE Recommended Practice presents information which is intended as a guide for proper designing, selection, application, and servicing of liquid, formed-in-place gasket (FIPG) materials.

1.1 Definition and Description—Formed-in-place gasket materials are liquids of varying consistencies which can be applied to one of the mating joint surfaces before assembly. When parts are mated, the FIPG material is capable of flowing into voids, gaps, scratch marks, and so forth, and cures to form a durable seal. The concept offers a convenient way of manually or automatically dispensing a seal of varying patterns for assembly. Generally, two types of FIPG materials are used, RTV (Room Temperature Vulcanizing) silicones and anaerobic methacrylate esters. Other types of materials are available but restricted to limited applications and, therefore, are not covered in this manual. The following description and properties for each type of material will help determine the recommended choice of material for a given application. One should thoroughly test any application, and independently conclude satisfactory performance before making final selection.

1.2 Rationale—The Powertrain Systems Group has been unable to convene a group of subject matter experts to perform the 5 year content review of this document. Under these circumstances, it is recommended that this Recommended Practice be cancelled.

2. References

2.1 Applicable Publications—The following publications form a part of this specification to the extent specified herein.

2.1.1 ASTM PUBLICATIONS—Available from ASTM, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959.

ASTM D 1002—Test Method for Strength Properties of Adhesives in Shear by Tension Loading (Metal-to-Metal)

ASTM D 1084—Test Methods for Viscosity of Adhesives

3. Types of Sealants

3.1 One Component RTV Silicone Sealant—The silicone formed-in-place gasket (FIPG) comprises the application of a paste-like silicone sealant bead to the area of a component which is then assembled, usually within 10 min. The silicone compound flows to form a gasket which then cures to a rubbery solid by absorbing the moisture vapor in the environment (see Figure 1). The application can be done by hand from a collapsible tube, caulking cartridge, or on an automated dispensing system.

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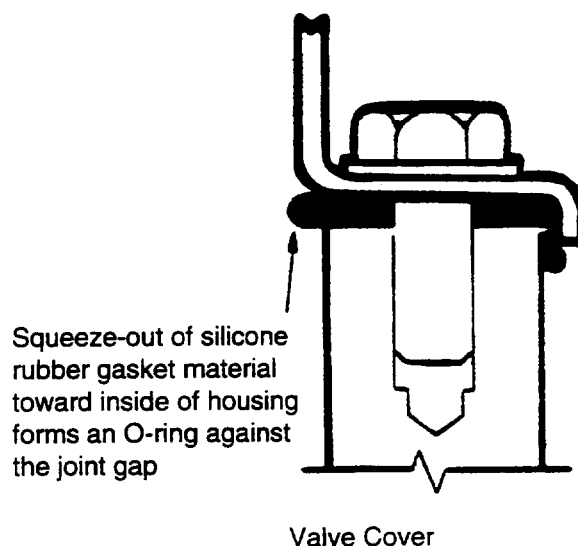


FIGURE 1—JOINT GAP SEAL

3.1.1 THE BASIC CHEMISTRY

3.1.1.1 The FIRST of a three-ingredient silicone sealant is a hydroxy-terminated polysiloxane polymer. See Figure 2.

For most applications, a polydimethyl siloxane polymer is used ($R = \text{CH}_3$). However, for applications where fuel or solvent resistance is necessary, a polymethyl-trifluoropropyl siloxane polymer is used ($R = \text{CH}_2\text{CH}_2\text{CF}_3$). The average molecular weight of the polymers usually ranges from 2.0×10^4 to 1.2×10^5 grams/mole.

The SECOND is the presence of a filler or combination of different fillers like: high surface area silicas, ground quartz, zinc oxide, iron oxide, carbon black, various types of clays and diatomaceous earth.

The THIRD is the moisture vapor affected crosslinking system. It is generally a reactive polyfunctional silane, which is readily hydrolyzable and released during the curing reaction. Examples of the most common crosslinkers and the by-products are shown in Figure 3:

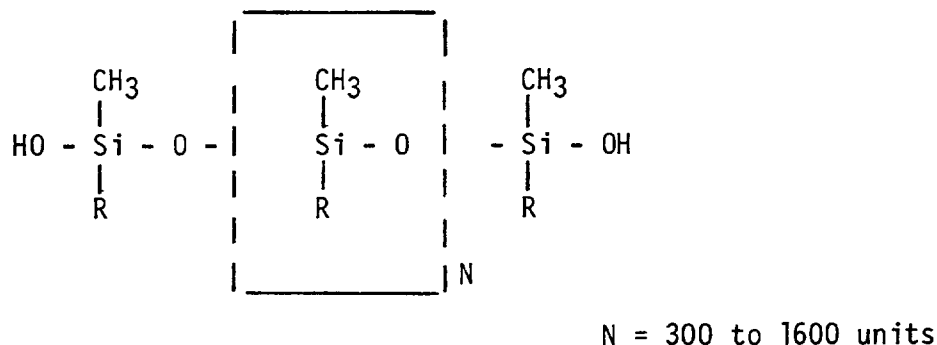
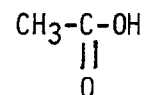
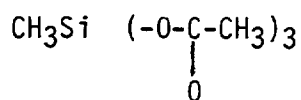


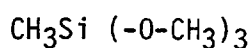
FIGURE 2—HYDROXY-TERMINATED POLYSILOXANE POLYMER

ACETOXY

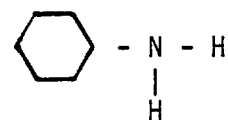
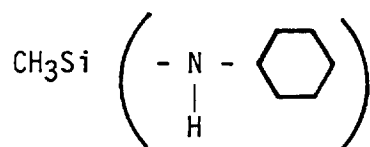
- (1) Methyltriacetoxysilane - Acetic Acid

ALKOXY

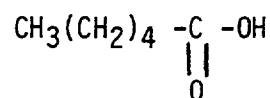
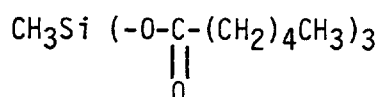
- (2) Methyltrimethoxysilane - Methyl Alcohol

AMINE

- (3) Methyltris (cyclohexylamino) Silane - Cyclohexyl Amine

OCTOATE

- (4) Methyltrihexanoxysilane - Hexanoic Acid

OXIME

- (5) Methyltris (methylethylketoxime) Silane - Methyl-ethylketoxime

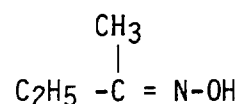
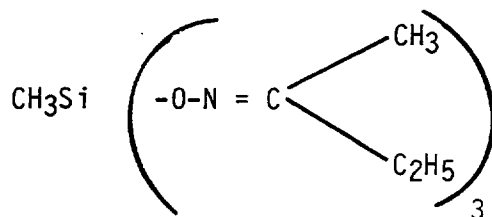


FIGURE 3—EXAMPLES OF THE MOST COMMON CROSSLINKERS AND THE BY-PRODUCTS

3.1.2 SPECIFIC DIFFERENCE IN CURE SYSTEMS—See Table 1:

TABLE 1—CURE SYSTEM 25 °C (77 °F), 50% RH

	(1)	(2)	(3)	(4)	(5)
Tack Free Time (Hours)	0.25–0.5	0.5–4	0.25–0.5	0.25–0.75	0.25–0.5
Cure Time, Hours	12–16	18–24	12–24	16–24	12–24
Adhesion to Iron/Aluminum ⁽¹⁾	Good/Exc.	Good	Fair/Good	Fair/Good	Good/Exc.
Corrosion to Steel ⁽²⁾	Heavy	None	None	Slight	None
Corrosion to Aluminum ⁽²⁾	None	None	Slight	None	None
Exc.—Excellent					

1. Adhesion to plastics is variable and must be individually tested.
2. As tested in a nonvented environment with high humidity per MIL-A-46146A.

3.1.3 TYPICAL UNCURED (AS RECEIVED) PHYSICAL PROPERTY RANGES

3.1.3.1 *Viscosity/Application Rate*—The rheological properties of the sealant can be measured in terms of blow-out resistance and extrusion rate as well as a traditional viscosity measurement. The viscosity of the sealing compound can be determined in accordance with ASTM D 1084, Method B. The viscosimeter model, spindle number, and speed shall be reported as part of the viscosity determination.

3.1.3.2 *Application Rate Method (Grams/Minute)*

3.1.3.2.1 Apparatus

- a. ¹Semco model 250-6 sealant gun
- b. ¹Semco plastic nozzle #440 (101.6 mm long × 3.18 mm orifice diameter)
- c. ¹Semco plastic cartridge #250-C6, #250-WP wiper, #250-TS Tri-Seal (standard drum sample)
- d. Stop Watch

3.1.3.2.2 Procedure

- a. Load the cartridge containing the silicone compound into the sealant gun.
- b. Remove the seal and clear out any cured RTV. Attach the nozzle to the cartridge.
- c. Connect the sealant gun to 620.6 kPa ± 13.8 kPa air supply and extrude 5 to 10 g of compound to prep the nozzle.
- d. Extrude the RTV compound in a tared aluminum weighing dish for a period of 10 s, so the test specimen weighs at least 10 g or more.
- e. The number of test specimens depends on the quantity of compound. Recommendation is to use at least three and average.
- f.
$$\text{Grams/minute} = \frac{\text{Weight in Grams}}{10\text{s}} \times \frac{60\text{s}}{\text{Minute}} \quad (\text{Eq. 1})$$
- g. Typical application rates 200 to 450 g/min.

1. Semco, a Division of: Products Research & Chemical Corp.

5454 San Fernando Road
Glendale, CA 91203

Also available from other sources.

3.1.3.3 Application Rate Method (Seconds/50 g)

3.1.3.3.1 Apparatus

- ¹ Semco model 250-6 sealant gun
- Special nozzle (50.8 mm long × 3.18 mm orifice diameter) CR-1010 Steel 1 (**Figure 4)
- ¹ Semco plastic cartridge #250-6, #250-WP wiper, #250-TS Tri-Seal (standard drum sample)
- Stop Watch
- Laboratory balance (0.01 g)
- Weighing Dish
- Pipe Cleaners (for cleaning nozzles)

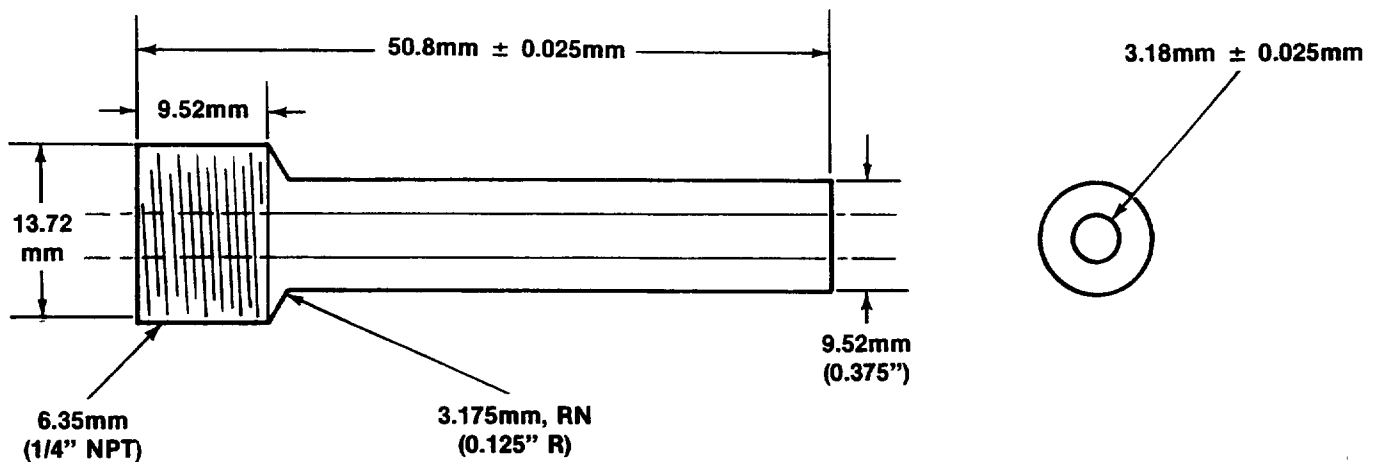


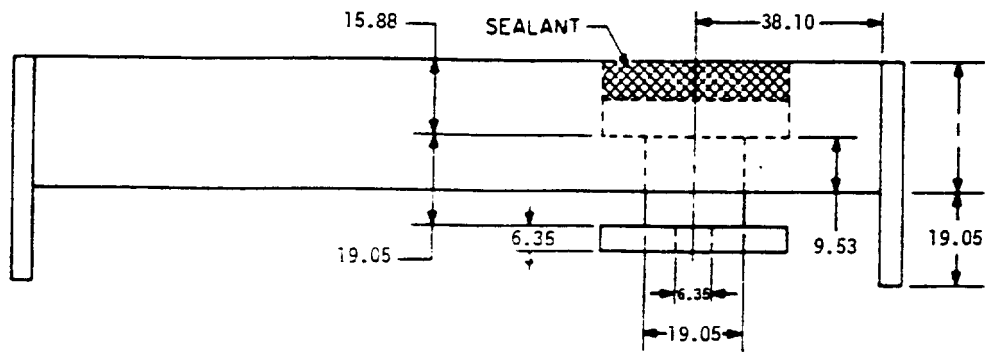
FIGURE 4—SPECIAL NOZZLE

3.1.3.3.2 Procedure

- Load the cartridge containing the silicone compound into the sealant gun.
- Remove the seal cap and clear out any cured RTV. Attach the nozzle to the cartridge.
- Connect the sealant gun to 448.2 kPa ± 13.8 kPa air supply and extrude a few grams of compound to prep the nozzle.
- Extrude the RTV compound in a tared weighing dish for a period of 10 s, so the test specimen weighs at least 10 g or more.
- The number of test specimens depends on the quantity of compound; recommendation is at least three and average.

$$\text{Seconds} = \frac{50\text{g}}{\text{Weight in Grams}} \times \text{Time (Seconds)} \quad (\text{Eq. 2})$$

- Flow Resistance**—The flow test shall be conducted with a flow test jig as shown in Figure 5. Depth of plunger tolerance is critical and shall be controlled within the tolerance during all tests. The flow test jig shall be placed on a table with the front face upward and with the plunger depressed to the limit of its travel. Enough of the silicone compound to fill the recessed cavity of the jig shall be rapidly transferred from a representative sample container. The compound should not be worked with a spatula but shall be leveled off even with the block by scraping with a spatula in two passes, each starting in the center and moving toward the sides of the jig. Within 10 s after the leveling operation, the jig shall be placed on its base and the plunger immediately advanced to the limit of its forward travel. The cylindrical section formed in the flow test jig shall be allowed to flow under its own weight on a vertical surface.



JIG PLACED ON TABLE, FRONT FACE UP

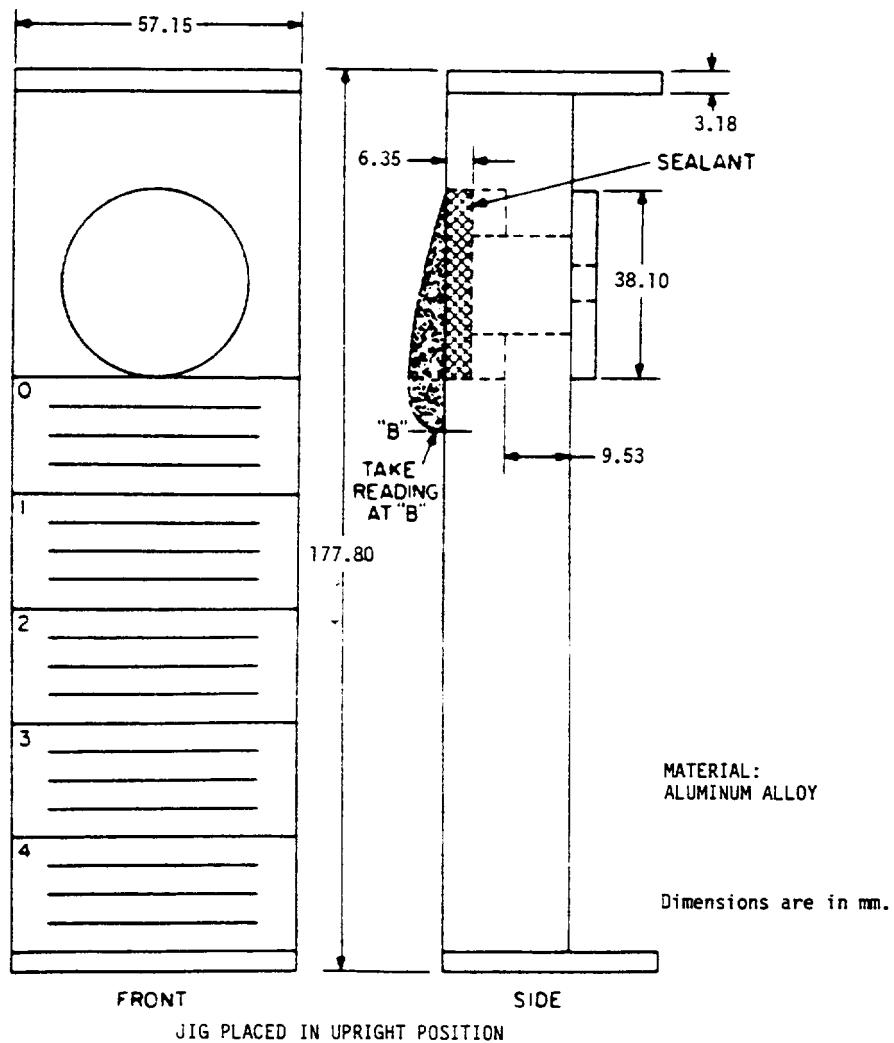


FIGURE 5—FLOW TEST FIXTURE

The flow test shall be when the plunger is advanced to the limit of its forward travel, and the flow measurement shall be taken immediately after the expiration of 3 to 30 min. The flow shall be measured from tangent to the lower edge of the plunger to the farthest point to which flow has occurred. The measurement after the indicated interval shall be considered the initial flow of the silicone compound.

3.1.3.5 Tack Free Time/Cure Rate

3.1.3.5.1 Apparatus

- a. Strip of polyethylene film $50.8 \times 152.4 \times 0.076$ mm
- b. Spatula or doctor blade
- c. Stop Watch

3.1.3.5.2 Procedure

- a. Apply the RTV compound from the container.
- b. The quantity of compound varies. However, a typical 25.4 mm "Hershey Dot" is the recommendation.
- c. With a spatula or doctor blade, spread the compound down the polyethylene film as soon as possible (within 1 min). The shape of an elongated triangle with the initial start area about 3.18 mm thick to a feather ending about 0.127 mm.
- d. Beginning at the time the compound is first applied, determine the tack free time by slightly touching the compound with a fingertip at 5 min intervals.
- e. The test is completed when the surface is dry to the touch and no compound is transferred to the finger.
- f. Typical values are 10 to 30 min at 21.1 °C and 50% RH.

3.1.4 TYPICAL CURED ² PHYSICAL PROPERTY RANGES

- a. Specific Gravity—1.03 ----- 1.60
- b. Hardness, Shore "A"—15 ----- 60
- c. Tensile Strength—1035 ----- 5520 kPa
- d. Elongation, %—100 ----- 600
- e. Low Temp. Flexibility— -45.5 °C
- f. Thermal Stability—260°C, Special products—343 °C
- g. Fluids and Oil Sealability—(Usage Applications)

Engine Lube Oil
 Engine Coolant
 Automatic Transmission Fluid
 Rear Axle Lubricant

3.1.5 BOND STRENGTH DEVELOPMENT—Most silicone sealants bond to clean surfaces without the aid of primers. A preliminary evaluation should be made to determine acceptable adhesive properties on the substrate used in the specific application. The adhesive bond strength will depend on the joint configuration, material thickness, and surface area. Normally, sufficient strength will develop in one day, with maximum strength after seven days.

3.1.6 PACKAGING AND STORAGE—Most sealants are supplied in ready-to-use collapsible aluminum squeeze tubes, caulking cartridges, and in bulk containers 18.9 to 208.2 L.

When stored in the original unopened containers at temperatures less than 27 °C, most sealants offer a shelf life of one year. To prevent curing of the unused portion of an opened container, reseal air tight.

2. Cured 7 days at 25 °C and 50% RH.

Proper rotation of inventory is a recommended practice.

3.1.7 ADVANTAGES AND DISADVANTAGES

3.1.7.1 *Advantages*

- a. Lower cost than preformed gaskets
- b. Eliminates need for large and costly gasket inventory
- c. One component, therefore, no mixing required
- d. Easily pumped on automatic or semi-automatic equipment
- e. Ideally suited for robots and automated assembly lines
- f. Has capability to fill large gaps
- g. Does not flow under its own weight; can be applied to parts in horizontal, vertical, and overhead positions
- h. Good adhesion (unprimed) to many metal surfaces
- i. Temperature range— -46 to 260 °C
- j. Good resistance to outdoor weathering, vibration, moisture, and ozone
- k. Good fluid resistance to most oils, lubricants, and coolants.

3.1.7.2 *Disadvantages*

- a. Some RTV silicones generate by-products while curing which can cause corrosion if not properly vented
- b. Prolonged contact with uncured sealant can cause irritation to skin and eyes
- c. Working time is dependent on temperature and humidity
- d. Requires clean mating surfaces
- e. Slower cure in low humidity environment
- f. Removal of cured sealant difficult when applied to clean surfaces
- g. Most sealants cannot be painted
- h. Due to the low thickness as clamped, limited ability to follow movement between flanges

3.2 **Anaerobic Methacrylate Ester Sealant**—The word "anaerobic" is derived from the Greek, meaning life in the absence of air. Hence, anaerobic compounds cure in the absence of air and in the presence of metal or other active surfaces.

Cure rates at room temperatures range anywhere from a few minutes to several hours. Since there are no solvents, the conversion from liquid to solid is virtually 100%, completely filling the voids, surface imperfections, tool marks, and so forth, eliminating all potential leak paths.

There are a variety of sealant types, selection of which depends on the following:

- a. Fluid/gas to be sealed
- b. System pressure/temperature
- c. Surface configuration and finish
- d. Flange makeup (rigid/flexible)
- e. Number, grade, and size of bolts
- f. Disassembly requirements

3.2.1 THE BASIC CHEMISTRY—Anaerobic formed-in-place gaskets cure through a process called "polymerization." These long cross-linked polymer chains are typical of the cured anaerobic products and are indicated chemically in Figure 6.