# Thermal Interface Material Dispensing Guide

## For Thermally Conductive Gels, Cure-in-Place Potting Compounds and Thermal Greases

Parker Chomerics

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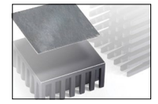
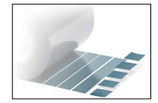
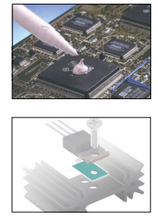
# Thermal Interface Material Dispensing Guide









# Introduction

Parker Chomerics thermal interface material dispensable products are ideal solutions for today's electronic packages. Thermally conductive, dispensable materials have the ability to cover a variety of gaps and form complex geometries.

This ability to conform provides reduced thermal contact resistances and thus reduces the temperature and increases the efficiency of the electronic application, while providing low closure force. When using dispensable products, specifiers should consider factors such as pump equipment, mating surfaces, tolerance stack up, closure force and physical application of the material.

There are many options for dispensing equipment, ranging from manual syringes to high-volume automated dispensing systems. The choice of the proper equipment will depend on several factors, including volume, labor/equipment cost, precision requirements and material type to be dispensed. When choosing the appropriate dispensing equipment, designers should keep in mind how the equipment may interact with the material. The material and the delivery system need to be compatible to optimize equipment life and maintain material properties.

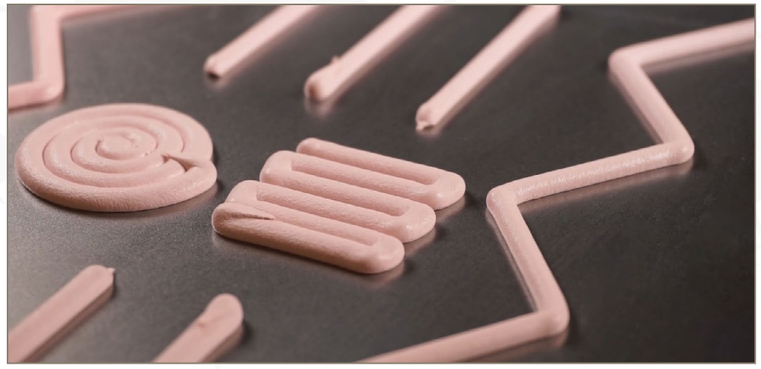
To achieve high thermal conductivity, our thermal materials are filled with ceramic particles. Due to this loading, the thermal compounds are highly viscous and may be abrasive. Therefore, they will dispense differently than common low-viscosity greases or adhesives. Once the proper equipment is chosen, certain factors should be considered to increase the quality and throughput of the material. These factors may include needle/nozzle height, dispensing pattern, dispensing speed, needle diameter, substrate surface finish, etc.

The intent of this guide is to help the user select Parker Chomerics thermally conductive dispensable materials and dispensing equipment and better understand the dispensing process.

RoHS compliant

# THERM-A-GAP™ Gels

## Dispensable, Very Low Compression Force, Thermal Gap Fillers



THERM-A-GAP™ Gels are high-performance, single-component, dispensable thermal materials that are either fully cured or require no curing. These unique gel materials result in much lower mechanical stress on delicate components than even the softest gap-filling pads.

These gels are highly conformable and provide low thermal impedance like greases but are designed to overcome the pump-out and dry-out issues associated with grease. THERM-A-GAP Gels are designed to be dispensed in applications requiring low compression forces and minimal thermal resistance for maximum thermal performance. They are ideal for filling variable thickness gaps in a single application.

### FEATURES / BENEFITS

- Fully cured or require no curing
- Requires no refrigeration, mixing or additional curing
- Proven long-term reliability and superior performance
- No settling occurs in storage

### HIGHLY CONFORMABLE AT LOW PRESSURES

- Ideal for multiple thickness gaps under one common heat sink
- Applies very low stress on components, which makes it ideal for delicate applications
- Allows for design flexibility compared to thermal pads

### ONE-COMPONENT DISPENSABLE

- Eliminates hand assembly
- Decreases installation cost
- Eliminates multiple pad part sizes/numbers

### EXCELLENT SURFACE WETTING

- Excellent for maintaining contact through thermal cycling

### TYPICAL APPLICATIONS

- Automotive electronic control units (ECUs)
- Engine, transmission and braking/ traction controls
- Power conversion equipment
- Power supplies and uninterruptable power supplies
- Power semiconductors
- MOSFET arrays with common heat sinks
- Televisions and consumer electronics

### STORAGE CONDITIONS

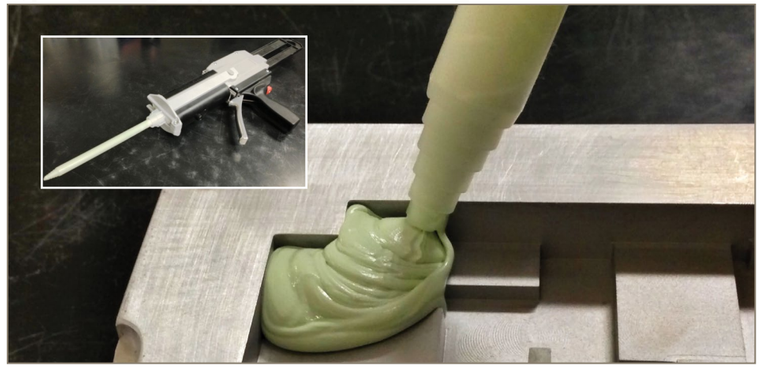
- Materials should be stored at 50 to 90°F (10 to 32°C) at 50% relative humidity.

Overview of Dispensable Materials

RoHS compliant

# THERM-A-FORM™

## Cure-in-Place Potting and Underfill Materials



THERM-A-FORM™ Cure-In-Place (CIP) compounds are thermally conductive dispensed silicone elastomer products designed for heat transfer without excessive compressive force in electronics cooling applications. Unlike THERM-A-GAP Gels, which are either pre-cured or require no curing, THERM-A-FORM materials require curing, hence their name “cure-in-place.”

THERM-A-FORM Cure-In-Place dispensable compounds are RTV (room temperature vulcanizing) liquid materials which can be dispensed and then cured into complex geometries for cooling of multi-height components on a PCB. Each compound is available in ready-to-use cartridge systems, eliminating weighing, mixing and degassing procedures.

### FEATURES / BENEFITS

CURE-IN-PLACE DISPENSABLE COMPOUNDS

- Filling, potting, overfill, under fill, sealing and encapsulating
- Flows around complex parts
- Ideal for multiple thickness gaps under one common heat sink
- Can cure at elevated heat cycle or at room temperature
- Localized encapsulating of components
- Ceramic particles act as natural standoffs for electrical isolation
- Room temperature and elevated cure available

CONFORMABLE (LOW MODULUS)

- Mold to complex irregular shapes without excessive force on components
- Insulates against shock and vibration

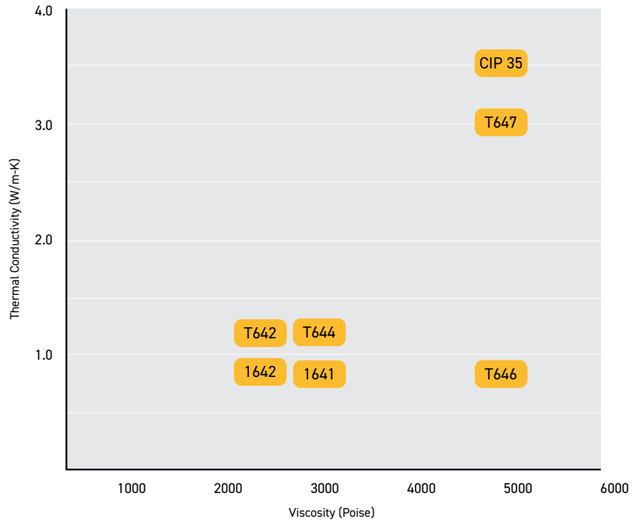
### TYPICAL APPLICATIONS

- Power conversion equipment
- Power supplies and uninterruptable power supplies
- LED modules & power drivers
- Telecom base stations

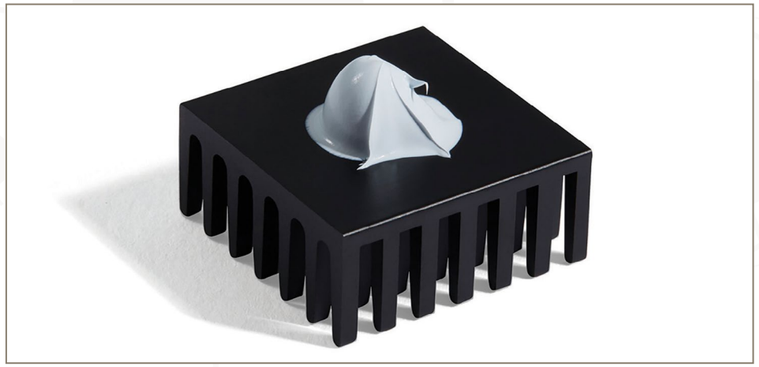
### STORAGE CONDITIONS

- To maintain uniformity, tubes/ cartridges should be stored horizontally. Remixing prior to dispensing is not advised, unless the material can be vacuum degassed, to remove any air bubbles. They should be stored at 50 to 90°F (10 to 32°C) at 50% relative humidity.

### PERFORMANCE GUIDE



# Thermal Greases



Parker Chomerics thermal greases offer a range of performance covering the simplest to the most demanding thermal requirements. These materials are screened, stenciled or dispensed and require virtually no compressive force to conform under typical assembly pressures. They are excellent for conforming to surface micro-voids created by machining/ casting to reduce thermal impedance.

Thermal greases have excellent surface wetting characteristics and flow easily to fill voids at the interfaces resulting in low thermal impedance even at low pressure.

## FEATURES / BENEFITS

HIGHLY CONFORMABLE

- Low thermal impedance
- Deflects under minimal compressive forces
- Great surface wetting
- Excellent ability to fill micro-voids

ONE COMPONENT

- Excellent for screening and stenciling
- Requires no cure cycle

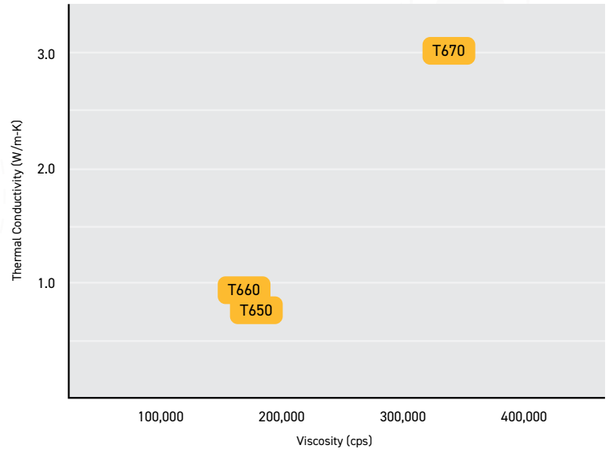
## TYPICAL APPLICATIONS

- LED modules
- Microprocessors (mobile servers & desktops)
- Memory modules
- DC/DC converters
- Power semiconductors
- Telecom base stations

## STORAGE CONDITIONS

- Material may settle overtime in storage. Best practice is to remix the material prior to use. Materials should be stored at 50 to 90°F (10 to 32°C) at 50% relative humidity.

## PERFORMANCE GUIDE



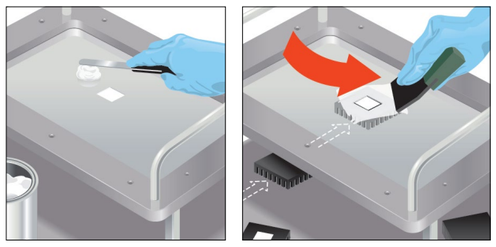
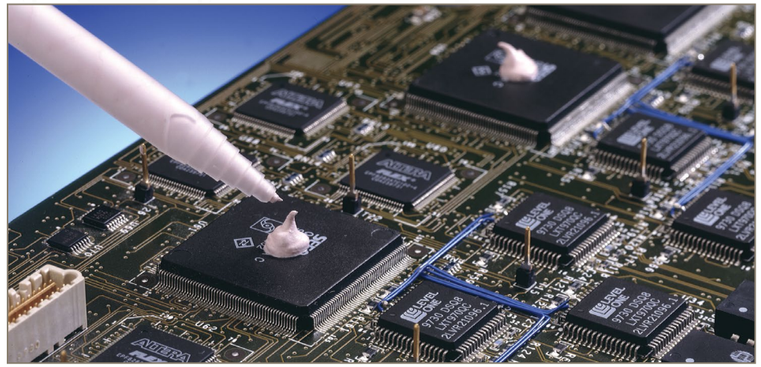



Figure 1: Stenciling Typical application method is to stencil the compound onto the chip or heat-sink. Application patterns can vary depending on the area of coverage. The image above depicts a typical square grease pattern being applied onto a heat-sink with a squeegee or spatula.



# Choosing a Thermal Interface Material (TIM) and Dispensing Method



When designing in a dispensable TIM, there are several considerations to keep in mind when determining the appropriate product. The main purpose of the material is to conduct heat, but with a dispensable TIM, there is more to the selection process than simply evaluating thermal conductivities.

### Temperature and Environment

To choose the appropriate material for the application, there has to be an understanding of the heat generation that must be dissipated, as well as environmental conditions and limits. Occasionally there are substrates that limit the temperatures that be used for curing a THERM-A-FORM cure-in-place material. Other applications (automotive, under-the-hood) may present high vibration exposure or extreme temperature cycling that would restrict the type of material that can be used. For example, a THERM-A-GAP Gel material may be selected over a cure-in-place material in applications with extreme thermal shock and vibration because of its inherent tack and elasticity.

### Mechanical

The nominal gap and expected variation in gap will dictate the amount, or thickness, of TIM required. Forces generated by expansion/contraction or vibration, coupled material hardness, will result in stress on components. Selection of a soft, conformable material with appropriate thickness will minimize potential damage to critical components.

### Dielectric Strength

Parker Chomerics thermal interface materials are comprised of resins and ceramic fillers that are inherently electrically isolating. The largest filler particles will dictate the minimum gap that can be achieved to prevent direct contact of electrical component to heat-spreader.

### Package Size

Parker Chomerics offers various packaging formats and sizes. Selection of the appropriate format will be a function of throughput, shot size and expected change over time, as well as compatibility with dispensing equipment. Custom packaging may be available upon request.

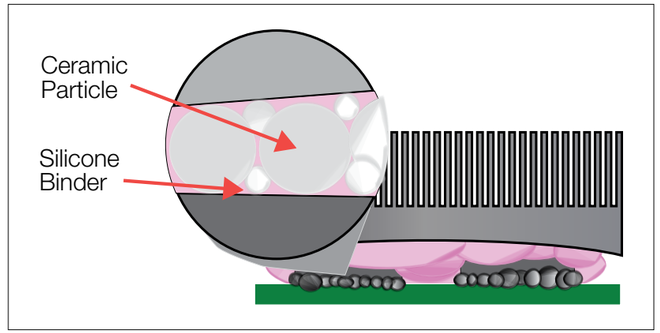



Figure 2: Electrical Isolation
Typical ceramic particles shown as natural mechanical stand-offs for electrical isolation.

# Equipment Types

## Table 1: Low-Volume Dispensing Methods

| | Jar or Container | Manual Hand Dispensing | | Cartridge Caulking Gun | | | Shot Size Controllers | |
|---|---|---|---|---|---|---|---|---|
| | | Single Component Syringe | Mixpac™ with Static Mixer | Manual | Battery Powered | Air or Pneumatic | Pressure/Time | Positive Displacement |
| **Features & Benefits** | No capital, immediate installations, small & portable, versatile with tip attachment, no purging required | | | | | No capital, small & portable, ergonomically preferred | Repeatable shot size, no purging, versatile tip geometry | Precision shot size control, no purging, versatile tip geometry, improved bead termination |
| **Operator Responsibility** | Dispensed size, cycle-time, location & shape | Dispensed size, cycle-time, pressure, location & shape | | Dispensed size, cycle-time, pressure, location & shape | Dispensed size, cycle-time, location & shape | Dispensed size, location & shape | Location & shape | Location & shape |
| **Variability in Dispensed Part** | Size, shape, rate & location | | | Size, shape, rate & location | Size, shape & location | Size, shape & location | Location & shape | Location & shape |
| **Parker Chomerics Material Package Description** | 1.4 cc & 120 cc (1 pint with vial) | 1-10 cc Syringe | 10:1 35-250 cc 1:1 45-200 cc Cartridge with static mixer | 300 cc Aluminum cartridge | | 30-360 cc Cartridge | 30-360 cc Cartridge | 30-360 cc Cartridge |
| **Material Cost** | Larger bulk containers are the most economical price per cc | | | | | | | |
| **Common Equipment Vendors** | None | None | Sulzer Mixpac™ | Albion, SEMCO® | Albion | Albion & SEMCO® | Nordson EFD, SEMCO® & Fisnar | Fishman, PVA, Nordson EFD |
| **Equipment Description** | None | | B System (35 cc & 45 cc Sulzer) | B26 (Albion) | 846-1E (Albion) | 846-1A (Albion) | Performus I, Performus X100 Dispensers (Nordson EFD) | TBD |
| | | | | | | | DSP501N & JB1113N (Fisnar) | TBD |
| | | | F System (200 cc & 250 cc Sulzer) | 850 (SEMCO®) | TBD | 250-A & 550 (SEMCO®) | 250-B (SEMCO®) | TBD |
| | | | | | | | TBD | TBD |
| **Comments** | For Stenciling use a die-cut mylar that is thicker than the minimum bond-line thickness | Hand-held syringe | Manual dispense system with appropriate mix-ratio (material dependent). | Manual caulking gun may dispense faster depending on the operator. | Battery-powered caulking gun may dispense faster depending on the operator. | Air-powered caulking gun may dispense faster depending on the operator. | Table top unit, that can handle high viscosity compounds and regulates pressure and time. Flow rate is measured at 90 psi directly out of the cartridge. | Table-top unit, that can handle high viscosity compounds and regulates displacement. |

**NOTE:** Parker Chomerics does not officially endorse any of the equipment above or supply it. For equipment technical support please contact the vendors listed.
SEMCO is a registered trademark of PPG Aerospace. Mixpac is a trademark of Sulzer.

# Equipment Types

## Table 2: High-Volume Dispensing Methods

| | Bench-Top Dispensing Systems | High-Volume Dispensing Module | |
|---|---|---|---|
| | | Cartridge Pumping and Robotic Dispense System | Pail Pump and Transport System |
| **Features & Benefits** | Repeatable shot size and shape, programmable XYZ direction and speed, continuous dispensing, low capital investments | Fastest cycle type, lowest material cost, visual inspection systems, fully automated system, best control and yield, continuous dispensing, repeatability in shot size & shape | Fastest cycle type, lowest material cost, visual inspection systems, fully automated system, best control and yield, continuous dispensing, repeatability in shot size & shape, multi-process step |
| **Operator Responsibility (Post Programing & General System)** | Seating application under dispensing head | Purging dispense system between materials | Purging dispense system between materials |
| **Variability in Dispensed Part** | None | | |
| **Parker Chomerics Material Package Description** | 30-360 cc Cartridge | 6 oz (180 cc), 8 oz (240 cc), 12 oz (360 cc), 20 oz (610 cc), & 32 oz (953 cc) Cartridge | 1-5 Gallon pail |
| **Material Cost** | Larger bulk containers are the most economical price per cc | | |
| **Common Equipment Vendors** | Camelot, Fisnar and Nordson EFD | Please contact local territory sales manager or applications engineering for high-volume equipment recommendations | |
| **Equipment Description** | F4200N (Fisnar) | | |
| | I+J4100LF & DSP501A-LF (Fisnar) | | |
| **Comments** | Programmable table top unit that is compatible with available packaging. | Pump dispenses directly out of the cartridge to dispensing value. Gear pumps and soft metal component pumps are not recommended. Short hoses with minimum ID, and limited bends and elbows are ideal to minimize shear. | Pump dispenses directly out of the pail to dispensing value. Conductive filler is abrasive. Gear pumps and soft metal component pumps are not recommended. Short hoses with minimum ID, and limited bends and elbows are ideal to minimize shear. |

**NOTE:** Parker Chomerics does not officially endorse any of the equipment above or supply it. For equipment technical support please contact the vendors listed.

# High Volume Equipment Considerations

High volume applications will require an appropriate dispensing system designed for larger package formats (i.e.. SEMCO cartridges and pails).

- The proper equipment choice will be a function of geometry, throughput requirements, material type and package.
- Material selection should be defined *prior* to selecting equipment to optimize material performance and long-term equipment maintenance.

Most thermal interface materials contain high concentrations of ceramic filler to maximize their thermal performance, so they dispense differently than unfilled polymers or greases. THERM-A-GAP Gels are unique materials, in that they are thermally conductive polymers that are either fully cured or require no post cure and can be extruded.

The advantage in using THERM-A-GAP Gels is that they do not require any mixing or curing once they are dispensed.

- To maintain the material's integrity as it is dispensed in high volume, the user should minimize tubing lengths, maximize tubing inside diameters and reduce the number of elbows (i.e., bends or angular connections).
- Using a larger-orifice needle tip reduces the amount of shear on the material (please refer to "Technical Parameters: Dispense Patterns & Process Considerations").

To successfully dispense THERM-A-GAP Gels with minimal impact to their physical properties, simple ram/piston pump systems with adequate force capability have proven most reliable.

- It is not recommended to use reciprocating pumps, gear pumps or other complex pumping designs as they can impart excessive stress on the material.
- Pump systems that have high a degree of mechanical interaction with the material may increase maintenance needs due to the high concentrations of thermally conductive and sometimes abrasive fillers. The valve that dispenses, or controls, the amount of material dispensed needs to be constructed of wear-resistant components to endure a maximum number of cycles.

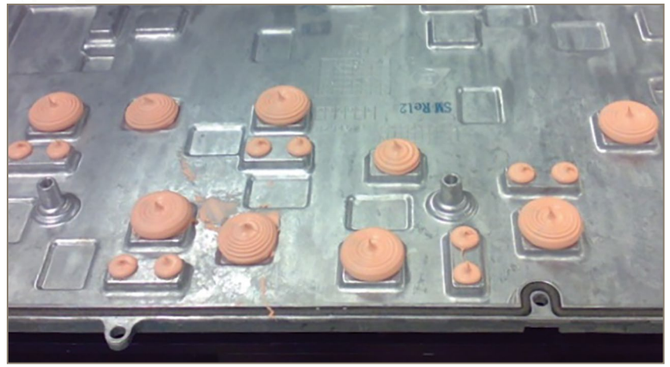
The most successful valves use a progressive cavity (i.e., displacement type option) and are geometrically simple. Other features that are available in valves, including a "snuff-back design" as well as built-in shot-size calibration/control, can aid in the termination of the dispensed bead.

THERM-A-FORM CIP materials are two-component materials and require similar equipment design as THERM-A-GAP Gels, but must also take into consideration mixing, metering and curing.

- THERM-A-FORM materials require maximizing the tubing's inside diameter while minimizing tube lengths and number of elbows used (i.e., bends or angular connections).
- Mix carefully so as not to introduce any air voids – can also be done under vacuum.
- Use a static mixer to blend both components of the material.
- Metering, ensuring the proper amount of each side is blended, must be accurate to maintain the material's end properties.



# Part Considerations



Once a thermal interface material (TIM) has been selected and the dispensing system has been defined, the next step is to analyze the part(s) to ensure that the correct volume of TIM is delivered to the required location in the correct shape.

As a starting point, use the following tasks to guide part analysis:

- Define number of target locations.
- Determine whether the TIM will be dispensed on the component side or heat sink side.
- Consider all operations that occur post-dispense and prior to final assembly that may affect form, placement, cleanliness, position, etc.
- Define dispense technique (this is a function of TIM type, geometry, etc.) Examples include screening, potting, injection and direct dispense to target.
- Consider any physical obstructions that the dispense head will have to navigate around.
- Calculate shot size per dispense location (function of the area of coverage, gap(s) and shape.
- Assess the surfaces that will be in contact with the TIM: composition, roughness and geometric features.
- Address cleanliness for proper wetting and thermal performance.

Assess the special conditions that the TIM will be subject to (please refer to "Technical Parameters: Special Material Considerations").

- Orientation, vibration, mechanical stresses and temperature extremes
- Cure conditions when high temperature cure is required for a THERM-A-FORM CIP, with low melt materials in proximity
- Transporting of part to multiple locations, i.e., packaging, climate, protection, etc.

| Surface Roughness Values | | |
|---|---|---|
| **Grade number** | **Micro-meter** | **Micro inches** |
| **N8** | 3.2 | 125 |
| **N9** | 6.3 | 250 |

Table 3: A surface roughness of N8 or rougher is recommended

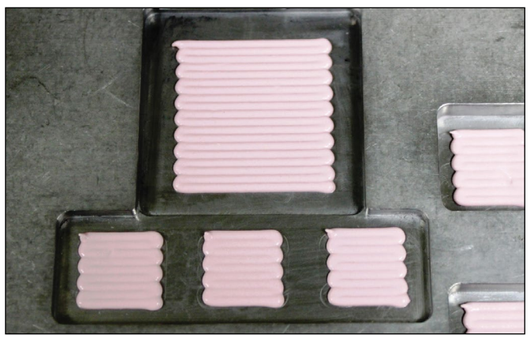


Figure 4: Multiple location casting

# Dispense Patterns & Process Considerations

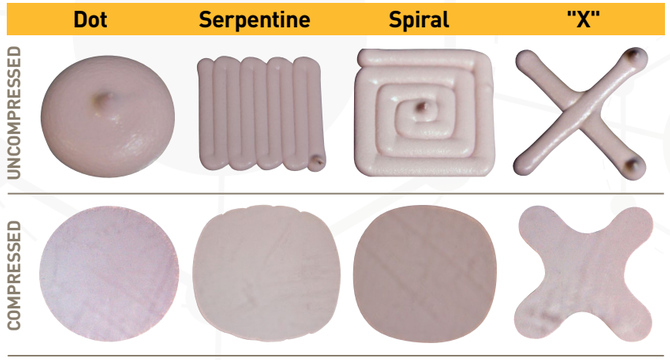



Figure 5: Dispensing Patterns  A simple dot like the first pattern provides adequate coverage, shortest cycle time and least chance of introducing air into the TIM. The more complex the profile, the greater the probability for introducing air (e.g., serpentine and spiral).

To maximize thermal performance, the thermal material must contact the entire target area on both the component and heat sink surfaces without air entrapment. In order to achieve this, a proper dispense pattern is critical.

Taking part considerations into account (as discussed on the previous page), the next process design task is to specify the dispensed material pattern.

Consider the following parameters:

- Volume required – a function of the nominal gap, tolerances and geometries
- Shape of bead required to "wet out" the entire targeted area
- Shot location and registration
- Elimination of potential trapped air

Process verification:

- Visual inspection (if possible)
- Automatic/integrated optical verification
- Functional tests (measurement of critical junction temperatures as a function of power)

Achieve repeatable shot volume:

- If repeatability is inadequate, consider the effect of the dispense tip, the effect of shear and time, the effect of cure (if it is a CIP material) and the effect of adding a precision valve (if necessary).
- Always establish a minimum volume that is required to cover the entire range of gap volumes.
- Build in a shot-size calibration process to verify that dispense rates are not variable. Adjust dispense pressure or shot times as a function of shot-size measurements.

Optimize the shape of the dispensed material:

- Determine a dispense pattern (dot, line or serpentine) that will "wet" the entire target, and that offers a bead height enough to fully contact the opposing target surface without air voids
- Consider the path of egress to minimize any possible air entrapment.
- Optimization of pattern can reduce material consumption while ensuring the functional gap is filled.

To properly locate (or register) the dispensed material to the part:

- Start with a proper fixturing and adjustment scheme to ensure registration between dispense head and part.
- Build appropriate verification checks into the process.

To optimize cycle time:

- Adjust dispense pressure (increase), needle orifice diameter (increase) and hose lengths/angles/flow obstructions of the delivery system (decrease).
- Beware of trade-offs associated with improvement of flow and cycle time, such as effects of shear on the material, sag/slump behavior, effects on shape of pattern and filler separation in delivery system (damming).



# Surface Wetting

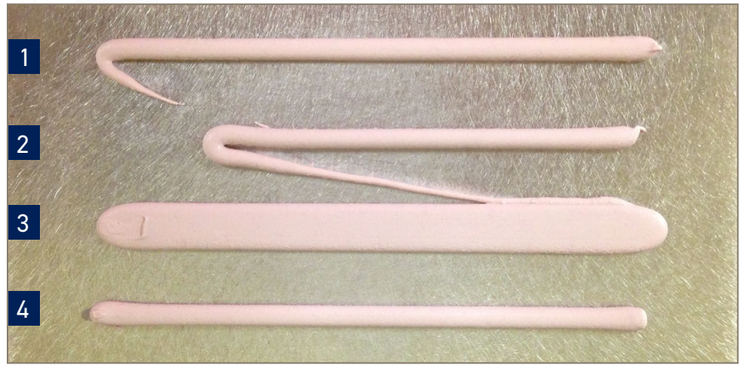



Figure 6: Common Line Dispensing Concerns  Common dispensing issues: (1, top) system did not have a program for bead termination; (2, middle top) needle was too high and there was no bead termination programed; (3, middle bottom) needle too low; (4, bottom) correct height with bead termination.

Proper adherence starts with a clean surface. Confirm that your part's surface is free of lint, processing oils and FOD (foreign object debris). If there is a concern with cleanliness, the surface can cleaned with a mild solvent, such as isopropyl alcohol (IPA), or any suitable surface cleaner.

The objective is to have the dispense tip as low as possible to achieve sufficient wetting and bead initiation/termination (see figure 6). This may require some dispensing trials to determine the appropriate combination of dispense tip diameter, height
and corresponding speed and service pressure.

- Be sure to target each bead shape and volume to properly wet and fill the gap between the two surfaces.
- Consider a bead height of 2X to 3X the nominal gap to promote wetting.

As a general rule, increased surface roughness will increase the surface area available for wetting. In vertical applications, the increased surface roughness will provide an increased resistance to slide. For additional technical support regarding vertical gap dispensing, please contact Parker Chomerics Applications Engineering.

- Increasing the shot size, contact area and surface roughness will aid in slide resistance of the material.

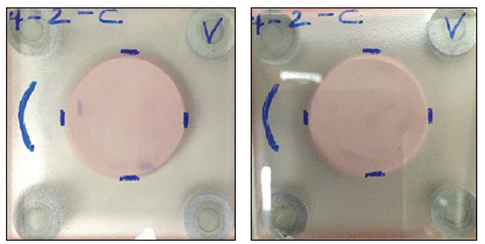


Figure 7: Reliability Reports  The images above show one of the 18 trials that were performed on THERM-A-GAP Gel 30 in a vertical orientation tested under several different surface roughnesses, gaps and surface areas. The test fixtures were subject to temperature shock and random vibration. Contact Parker Chomerics Applications for report. (Image to the left is before and Image to the right is after the treatment.)

- Staging time (prior to further processing) will enhance wetting of the material to the target surfaces (i.e., component, heat spreader).

For re-work:

- First remove the bulk of the material using a soft tool that will not damage the substrate (i.e., a rubber spatula, tongue depressor).
- Apply a mild surface cleaner such as IPA to remove remaining residue and clean the surface, then reapply the TIM.

As THERM-A-GAP Gel materials are either pre-cured or do not require a cure, THERM-A-FORM cure-in-place materials may be more difficult to peel once they cure.

The best way to remove the THERM-A-FORM material is to abrade the surface with a soft tool (wooden stick or cotton swab) and then clean the surface with IPA (toluene may work better).

# Special Material Considerations

THERM-A-GAP GELs are filled elastomers that are either fully cured or do not require post cure and are loosely cross-linked and can easily be extruded. Excessive shear force from complex dispense geometries and high pressure can affect the material structure and affect the rheology of the material.

- It is important to minimize the degree of shear imparted on THERM-A-GAP Gels during application by using a needle with a larger orifice, larger inner diameter tubing, fewer elbows and lower pressure.

Due to this sensitivity to shear, THERM-A-GAP Gels are designed to be dispensed out of the packaging *only once*. Repackaging would change the mechanical properties of the material.

For THERM-A-GAP Gel rework:

- Use a cloth, lint-free towel or spatula to remove the THERM-A-GAP Gels from the substrate.
- After the material is removed, fresh material should be reapplied.

THERM-A-FORM CIP (Cure-In-Place) compounds are designed to be dispensed and cured directly into the application.

- Surfaces should be free from any cure-inhibiting contaminants, especially those containing:
  - Nitrogen
  - Sulfur
  - Tin
  - Phosphorus
  - Latex

It is important to consider cure times and temperatures required to fully cure the material, and their effect on processing, cycle times and substrates.

- Every 10°C (50°F) increase in cure temperature will reduce the cycle to half of the original time (keeping in mind the exposure limits of other components).

THERM-A-FORM pot life considerations:

- Once catalyzed, there is a finite amount of time that the material will flow adequately.
- Proper measures must be addressed to ensure shot size control.
- Static mixing nozzles are provided with all standard two-component THERM-A-FORM products.
- Use the appropriate static mixing nozzle as they differ with mix ratio (i.e., 1:1 and 10:1).

For THERM-A-FORM compound rework:

Components encapsulated by a THERM-A-FORM compound can be removed by notching and peeling away the cured compound from the components.

Thermal Greases were designed to achieve minimum bond-line.

- Typical application is through stenciling or screen printing.
- Be sure that the screen or stencil is a minimum of 3X thicker than the maximum particle size in the compound.

If the holes of the screen are too small or the stencil is too thin, it may filter out some of the thermally conductive particles in the grease. Due to the non-crosslinked nature of thermal greases, they may tend to separate in the package. It is best practice to always mix the material prior to use.

For Thermal Grease rework:

- Thermal greases can be removed with a simple cleaning solvent prior to reapplying.

## Packaging Options

**Table 4 - Packaging Options**

| Code | Packaging Options Pictured Below | Standard Fill Level (cc) |
|---|---|---|
| A | 30 cc Taper Tip Cartridge | 27 |
| B | 30 cc Optimum Cartridge/Tip | 27 |
| C | 35 cc Cartridge Kit (10:1) w/ Static Mixer | 34/3.4 |
| D | 45 cc Cartridge Kit (1:1) w/ Static Mixer | 22/22 |
| E | 200 cc Cartridge Kit (1:1) | 95/95 |
| F | 250 cc Cartridge Kit (10:1) w/ Static Mixer | 244/2.4 |
| G | 300 cc Aluminum Caulking Tube (13 oz) | 300 |
| H | 6 oz SEMCO | 150 |
| I | 6 oz EFD | 150 |
| J | 20 EFD | 320 |
| K | 20 oz SEMCO | 570 |
| L | 1 Gallon Pail | 3250 |
| **Code** | **Packaging Options Not Pictured** | **Standard Fill Level (cc)** |
| M | 10 cc Syringe w/ Cap | 10 |
| N | 4 oz Primer Vial | 118 |
| O | 1.4 cc Jar | 1.4 |
| P | 2.5 cc Tube | 2.5 |
| Q | 55 cc Optimum® Cartridge | 52 |
| R | 8 oz SEMCO | 225 |
| S | 8 oz Plastic Jar | 80/160 for greases |
| T | 12 oz SEMCO | 320 |
| U | 20 oz SEMCO | 570 |
| V | 32 oz SEMCO | 900 |
| W | 32 oz EFD | 900 |
| X | 5 Gallon Pail | 7800 |

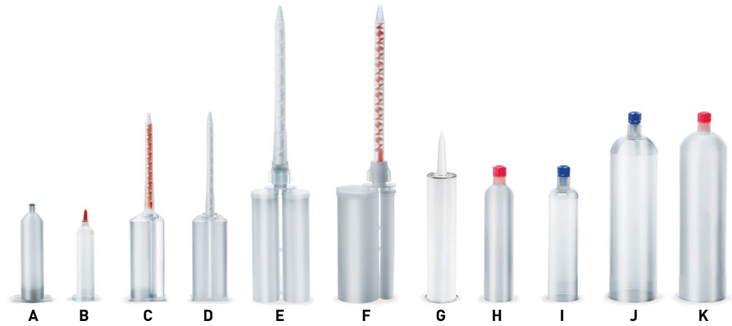



Figure 8: Typical packaging options


Figure 9: Typical high-volume packaging options

## *Offer of Sale*

**PARKER-HANNIFIN CORPORATION**
**OFFER OF SALE**

**1. Definitions**. As used herein, the following terms have the meanings indicated.
**Buyer:** means any customer receiving a Quote for Products from Seller.
**Goods:** means any tangible part, system or component to be supplied by the Seller.
**Products:** means the Goods, Services and/or Software as described in a Quote provided by the Seller.
**Quote:** means the offer or proposal made by Seller to Buyer for the supply of Products.
**Seller:** means Parker-Hannifin Corporation, including all divisions and businesses thereof.
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**6. Claims; Commencement of Actions**. Buyer shall promptly inspect all Products upon receipt. No claims for shortages will be allowed unless reported to the Seller within ten (10) days of delivery. Buyer shall notify Seller of any alleged breach of warranty within thirty (30) days after the date the non-conformance is or should have been discovered by Buyer. Any claim or action against Seller based upon breach of contract or any other theory, including tort, negligence, or otherwise must be commenced within twelve (12) months from the date of the alleged breach or other alleged event, without regard to the date of discovery.

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**8. Loss to Buyer's Property**. Any designs, tools, patterns, materials, drawings, confidential information or equipment furnished by Buyer or any other items which are or become Buyer's property, will be considered obsolete and may be destroyed by Seller after two (2) consecutive years have elapsed without Buyer ordering the Products manufactured using such property. Seller shall not be responsible for any loss or damage to such property while it is in Seller's possession or control.

**9. Special Tooling**. Special Tooling includes but is not limited to tooling, jigs, fixtures and associated manufacturing equipment acquired or necessary to manufacture Products. A tooling charge may be imposed for any Special Tooling. Such Special Tooling shall be and remain Seller's property notwithstanding payment of any charges by Buyer. In no event will Buyer acquire any interest in Special Tooling belonging to Seller that is utilized in the manufacture of the Products, even if such Special Tooling has been specially converted or adapted for such manufacture and notwithstanding any charges paid by Buyer. Unless otherwise agreed, Seller has the right to alter, discard or otherwise dispose of any Special Tooling or other property in its sole discretion at any time.

**10. Security Interest**. To secure payment of all sums due, Seller retains a security interest in all Products delivered to Buyer and, Buyer's acceptance of these Terms is deemed to be a Security Agreement under the Uniform Commercial Code. Buyer authorizes Seller as its attorney to execute and file on Buyer's behalf all documents Seller deems necessary to perfect its security interest.

**11. User Responsibility**. The Buyer through its own analysis and testing, is solely responsible for making the final selection of the Products and assuring that all performance, endurance, maintenance, safety and warning requirements of the application of the Products are met. The Buyer must analyze all aspects of the application and follow applicable industry standards, specifications, and other technical information provided with the Product. If Seller provides Product options based upon data or specifications provided by the Buyer, the Buyer is responsible for determining that such data and specifications are suitable and sufficient for all applications and reasonably foreseeable uses of the Products. In the event the Buyer is not the end-user, Buyer will ensure such end-user complies with this paragraph.

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**13. Cancellations and Changes**. Buyer may not cancel or modify any order for any reason, except with Seller's written consent and upon terms that will indemnify, defend and hold Seller harmless against all direct, incidental and consequential loss or damage. Seller, at any time, may change Product features, specifications, designs and availability.

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**15. Force Majeure**. Seller does not assume the risk and is not liable for delay or failure to perform any of Seller's obligations by reason of events or circumstances beyond its reasonable control ("Events of Force Majeure"). Events of Force Majeure shall include without limitation: accidents, strikes or labor disputes, acts of any government or government agency, acts of nature, delays or failures in delivery from carriers or suppliers, shortages of materials, or any other cause beyond Seller's reasonable control.

**16. Waiver and Severability**. Failure to enforce any provision of these Terms will not invalidate that provision; nor will any such failure prejudice Seller's right to enforce that provision in the future. Invalidation of any provision of these Terms by legislation or other rule of law shall not invalidate any other provision herein and, the remaining provisions will remain in full force and effect.

**17. Termination**. Seller may terminate any agreement governed by or arising from these Terms for any reason and at any time by giving Buyer thirty (30) days prior written notice. Seller may immediately terminate, in writing, if Buyer: (a) breaches any provision of these Terms (b) appoints a trustee, receiver or custodian for all or any part of Buyer's property (c) files a petition for relief in bankruptcy on its own behalf, or one if filed by a third party (d) makes an assignment for the benefit of creditors; or (e) dissolves its business or liquidates all or a majority of its assets.

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**20. Governing Law**. These Terms and the sale and delivery of all Products are deemed to have taken place in, and shall be governed and construed in accordance with, the laws of the State of Ohio, as applicable to contracts executed and wholly performed therein and without regard to conflicts of laws principles. Buyer irrevocably agrees and consents to the exclusive jurisdiction and venue of the courts of Cuyahoga County, Ohio with respect to any dispute, controversy or claim arising out of or relating to the sale and delivery of the Products.

**21. Entire Agreement**. These Terms, along with the terms set forth in the main body of any Quote, forms the entire agreement between the Buyer and Seller and constitutes the final, complete and exclusive expression of the terms of sale. In the event of a conflict between any term set forth in the main body of a Quote and these Terms, the terms set forth in the main body of the Quote shall prevail. All prior or contemporaneous written or oral agreements or negotiations with respect to the subject matter shall have no effect. These Terms may not be modified unless in writing and signed by an authorized representative of Seller.

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**5/2017**

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