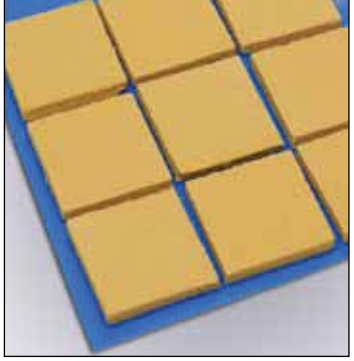
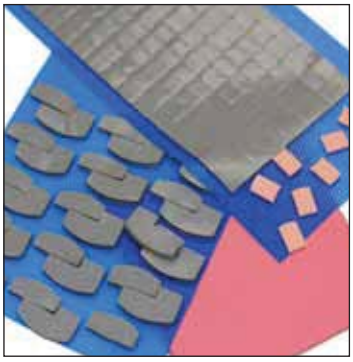
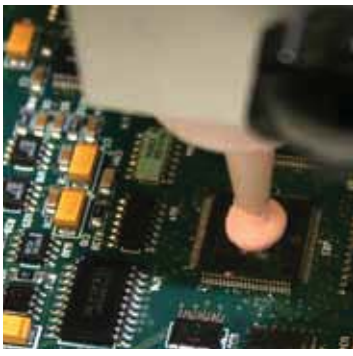




aerospace
climate control
electromechanical
filtration
fluid & gas handling
hydraulics
pneumatics
process control
sealing & shielding

Thermal Interface Materials For Electronics Cooling

Products & Custom Solutions Catalog



Parker | Chomerics

ENGINEERING YOUR SUCCESS.

Customer Responsibility and Offer of Sale Statement

CUSTOMER RESPONSIBILITY

WARNING – USER RESPONSIBILITY

FAILURE OR IMPROPER SELECTION OR IMPROPER USE OF THE PRODUCTS DESCRIBED HEREIN OR RELATED ITEMS CAN CAUSE DEATH, PERSONAL INJURY AND PROPERTY DAMAGE.

This document and other information from Parker-Hannifin Corporation, its subsidiaries and authorized distributors provide product or system options for further investigation by users having technical expertise. The user, through its own analysis and testing, is solely responsible for making the final selection of the system and components and assuring that all performance, endurance, maintenance, safety and warning requirements of the application are met. The user must analyze all aspects of the application, follow applicable industry standards, and follow the information concerning the product in the current product catalog and in any other materials provided from Parker or its subsidiaries or authorized distributors.

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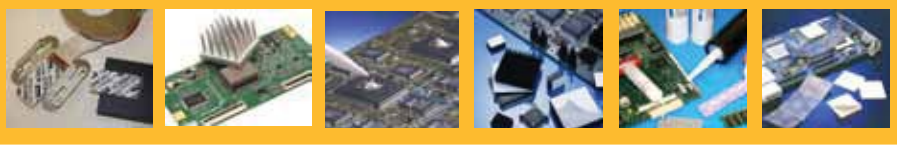
Thermal Management

Products & Custom Solutions Catalog



Introduction

Chomerics, a division of Parker Hannifin Corporation (NYSE:PH), is a global provider of EMI shielding, thermal interface materials, plastics and optical products. Chomerics specializes in providing products and services to OEM and CEM electronics companies in the telecommunications, information technology, consumer, power conversion, medical device, defense, and transportation markets.

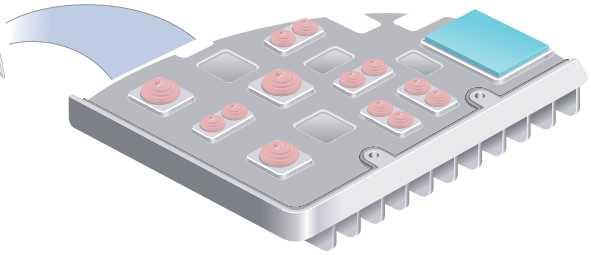
Since 1961, Chomerics has been a leader in the development of electrically conductive elastomers for use as extruded, molded and form-in-place EMI gaskets for telecommunications and electronics applications. Chomerics also offers an extensive family of thermal interface materials, which transfer heat from electronic components to heat sinks. Careful management of thermal interfaces is crucial to maintaining the reliability and extending the life of electronic devices and equipment. As each new electronic product generation requires higher power in smaller packages, the challenges associated with thermal management become more intense. Thermal material drivers include:

- Lower thermal impedance
- Higher thermal conductivity
- Greater compliance and conformability
- High reliability
- Greater adhesion
- Ease of handling, application and use
- Long service life

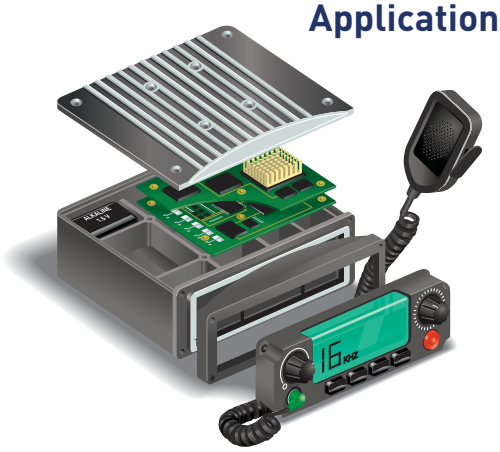
Chomerics has a successful history of providing thermal materials expertise and commitment to developing new, high performance products to meet the thermal challenges of systems designers.
Chomerics products have been designed into thousands of applications and help assure the performance, integrity, survivability and maintainability of communications equipment, radar, aircraft, computers, control systems, telecommunications, consumer devices, automotive and industrial electronics. Our customers are supported with comprehensive applications engineering, supply chain and fabrication services worldwide.

Thermal Interface Materials (TIMs) for Light Emitting Diode (LED) and Industrial Applications

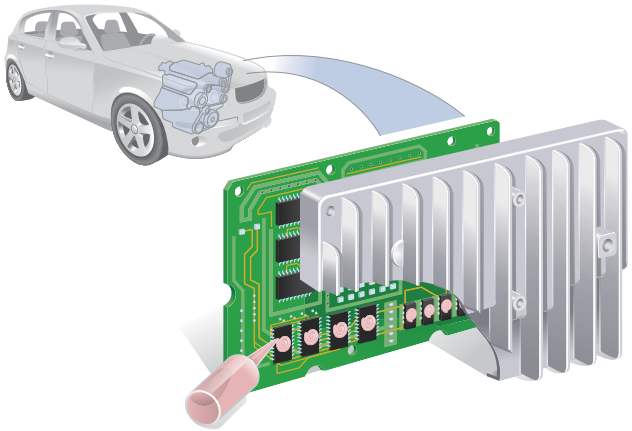
Gap Filler Pad and Dispensed Gels for Telecommunications



TIMs for Military and Aerospace Applications



Dispensed Gels in Automotive Electronic Control Unit (ECU) Application



Parker Chomerics Capabilities include:

THERMAL MANAGEMENT & CONTROL

- Thermally conductive gap filler pads
- Fully cured dispensable thermal gels
- Silicone-free thermal pads
- Phase-change materials (PCM)
- Polymer solder hybrids (PSH)
- Dispensable thermal compounds
- Thermal grease
- Dielectric pads
- Thin flexible heat spreaders
- Custom integrated thermal/EMI assemblies
- RF absorbing gap filler pads

EMI SHIELDING & COMPLIANCE

- Conductive elastomers – molded, extruded, and form-in-place (FIP)
- Conductive foam based gaskets – fabric-over-foam and z-axis foam
- Conductive compounds – adhesives, sealants and caulks
- RF absorbing materials
- EMI shielding plastics and injection molding services
- Coatings – direct metallization and conductive paints
- Metal gaskets – Springfingers, metal mesh and combination gaskets
- Foil laminates and conductive tapes
- EMI shielding vents – commercial and military honeycomb vents
- Shielded optical windows
- Cable shielding – ferrites and heat-shrink tubing/ wire mesh tape/zippered cable shielding
- Compliance and safety test services

OPTICAL DISPLAY PRODUCTS

- EMI shielding filters (conductive coating & wire mesh)
- Ant-reflective/contrast enhancement filters
- Plastic or glass laminations
- Hard coated lens protectors
- Touchscreen lenses

PLASTIC INJECTION MOLDING

- PREMIER® and other filled, electrically-conductive plastics
- Traditional thermoplastics
- EMI and cosmetic coating services
- EMI and environmental gasket integration
- Assembly, pad printing, hot stamping, welding, and heat staking
- Insert molding, two-shot molding, and overmolding capability

About Parker Hannifin Corporation

With annual sales exceeding $10 billion, Parker Hannifin is the world's leading diversified manufacturer of motion and control technologies and systems, providing precision-engineered solutions for a wide variety of mobile, industrial and aerospace markets. The company's products are vital to virtually everything that moves or requires control, including the manufacture and processing of raw materials, durable goods, infrastructure development and all forms of transport. Traded on the New York Stock Exchange under the symbol "PH," Parker is strategically diversified, value-driven and well positioned for global growth as the industry consolidator and supplier of choice.

Introduction

The objective of thermal management programs in electronic packaging is the efficient removal of heat from the semiconductor junction to the ambient environment. This process can be separated into three major phases:

1. heat transfer within the semiconductor component package;
2. heat transfer from the package to a heat dissipater (the initial heat sink);
3. heat transfer from the heat dissipater to the ambient environment (the ultimate heat sink)

The first phase is generally beyond the control of the system level thermal engineer because the package type defines the internal heat transfer processes. In the second and third phases, the packaging engineer's goal is to design an efficient thermal connection from the package surface to the initial heat spreader and on to the ambient environment. Achieving this goal requires a thorough understanding of heat transfer fundamentals as well as knowledge of available interface materials and how their key physical properties affect the heat transfer process.

Basic Theory

The rate at which heat is conducted through a material is proportional to the area normal to the heat flow and to the temperature gradient along the heat flow path. For a one dimensional, steady state heat flow the rate is expressed by Fourier's equation:

$$(1) \quad Q = kA\frac{\Delta T}{d}$$

Where:

k = thermal conductivity, W/m-K
Q = rate of heat flow, W
A = contact area, m^2
d = distance of heat flow, m
T = temperature difference, C

Thermal conductivity, k, is an intrinsic property of a homogeneous material which describes the material's ability to conduct heat. This property is independent of material size, shape or orientation. For non-homogeneous materials, those having glass mesh or polymer film reinforcement, the term "relative thermal conductivity" is appropriate because the thermal conductivity of these materials depends on the relative thickness of the layers and their orientation with respect to heat flow.

Another inherent thermal property of a material is its thermal resistance, **R** , as defined in Equation 2.

$$(2) \quad R = A\frac{\Delta T}{Q}$$

This property is a measure of how a material of a specific thickness resists the flow of heat. The relationship between **k** and **R** is shown by substituting Equation (**2**) into (**1**) and rearranging to form (**3**)

$$(3) \quad k = \frac{d}{R}$$

Equation 3 shows that for homogeneous materials, thermal resistance is directly proportional to thickness. For non-homogeneous materials, the resistance generally increases with thickness but the relationship may not be linear.

Thermal conductivity and thermal resistance describe heat transfer within a material once heat has entered the material. Because real surfaces are never truly flat or smooth, the contact plane between a surface and a material can also

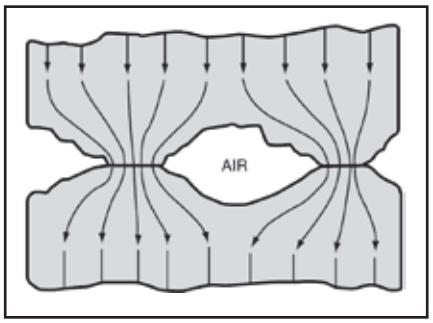


Figure 1a. Schematic representation of two surfaces in contact and heat flow across the interface

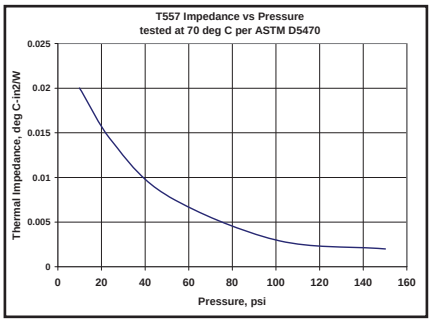


Figure 1b. T557 PCM compressed between two contacting surfaces. As the material softens and deflects, thermal impedence drops.

produce a resistance to the flow of heat. Figure 1a depicts surface irregularities on a micro scale and surface warp on a macro scale. Actual contact occurs at the high points, leaving air-filled voids where the valleys align. Air voids resist the flow of heat and force more of the heat to flow through the contact points. This constriction resistance is referred to as surface contact resistance and can be a factor at all contacting surfaces.

The thermal impedance [□] of a material is defined as the sum of its thermal resistance and any contact resistance between it and the contacting surfaces as defined in Equation 4.

$$(4) \quad \Theta = R_{material} + R_{contact}$$

Surface flatness, surface roughness, clamping pressure, material thickness, the presence of pressure sensitive adhesive (PSA)

and compressive modulus have a major impact on contact resistance. Because these surface conditions can vary from application to application, thermal impedance of a material will also be application dependent.

Thermal Interface Materials (TIMs)

Heat generated by a semiconductor must be removed to the ambient environment to maintain the junction temperature of the component within safe operating limits. Often this heat removal process involves conduction from a package surface to a heat spreader that can more efficiently transfer the heat to the ambient environment. The spreader has to be carefully joined to the package to minimize the thermal resistance of this newly formed thermal joint.

Attaching a heat spreader to a semiconductor package surface requires that two commercial grade surfaces be brought into intimate contact. These surfaces are usually characterized by a microscopic surface roughness superimposed on a macroscopic non-planarity that can give the surfaces a concave, convex or twisted shape. When two such surfaces are joined, contact occurs only at the high points. The low points form air-filled voids. Typical contact area can consist of more than 90 percent air voids, which represents a significant resistance to heat flow.

Thermally conductive materials are used to eliminate these interstitial air gaps from the interface by conforming to the rough and uneven mating surfaces. Because the TIM has a greater thermal conductivity than the air it replaces, the resistance across the joint decreases, and the component junction temperature will be reduced. A variety of material types have been developed in response to the changing needs of the electronic packaging market. These materials can be categorized as follows:

THERMATTACH® Adhesive Tapes

Phase-Change Materials

THERMFLOW® materials are formulated with polymer resins that are loaded with thermally conductive fillers. They combine the high thermal performance of grease with the ease of handling and "peel-and-stick" application of pads. They are used between high performance microprocessors, graphics processors, chipsets and heat sinks.

- Can achieve less than 0.06 °C-in^2/W thermal impedance
- Conform at operating temperature to minimize thermal path thickness
- Excellent surface "wetting" eliminates contact resistance

Phase change materials behave like thermal greases after they reach their melt temperature, typically 45–62°C: their viscosity rapidly diminishes and they flow throughout the thermal joint to fill the gaps that were initially present. This process requires some compressive force, usually a few psi, to bring the two surfaces together and cause the material to flow. This process continues until the two surfaces come into contact at a minimum of three points, or the joint becomes so thin that the viscosity of the material prevents further flow. PCM materials inherently do not provide electrical isolation because they may allow the two surfaces to make contact; however, variations with dielectric films are available. These materials have demonstrated excellent long-term reliability and performance.

THERMFLOW® Phase-Change Materials

Polymer Solder Hybrids

These THERMFLOW® materials incorporate low-melt metal alloy fillers which flow at temperatures around 65°C and provide ultra low thermal impedance, less than 0.1 °C-cm2/W at minimum bond line thickness.

Thermal Tapes

THERMATTACH® tapes are formulated with acrylic or silicone based pressure sensitive adhesive (PSA) loaded with thermally conductive fillers. They are designed to securely bond heat sinks to power dissipating components without an additional clamping mechanism.

- Acrylic based adhesives for metal or ceramic packages
- Silicone based adhesive for bonding plastic packages to heat sinks
- Ionically pure formulations for use inside component packages and on printed circuit boards
- Limited gap filling properties require reasonable surface flatness
- High shear strength at elevated temperatures

Thermal tapes are used primarily for their mechanical adhesive properties, and to a lesser extent for their thermal properties. The thermal conductivity of these tapes is moderate and their thermal performance in an application is dependent on the contact area that can be achieved between the bonding surfaces.

CHO-THERM® Insulator Pads

Gap Fillers

THERM-A-GAP™ gap fillers are a family of low modulus (soft), thermally conductive silicone elastomers for applications where heat must be conducted over a large and variant gap between a semiconductor component and a heat dissipating surface.

- Soft silicone gel binder provides low modulus for conformability at low pressures
- Low modulus allows materials to make up for large tolerance stack ups
- Low pressure applications

Gap fillers are used to bridge large gaps between hot components and a cold surface. The gaps are not only large, but their tolerances can be ±20 % or greater. This means that the gap filler must have sufficient compliance to fill such spaces without stressing components beyond their safe limits. Non-silicone gap fillers are available for silicone sensitive applications.

Gap fillers are supplied in pad-form over a wide range of thickness, 0.5 to 5mm, and can be molded into complex shapes. THERM-A-GAP GELs are also supplied as pre-cured, single component compounds that can be dispensed over the heat generating component.

These unique materials result in much lower mechanical stress on delicate components than even the softest gap-filling sheets. They are ideal for filling variable gaps between multiple components and a common heat sink.

Thermal gels are silicone-based formulations that are loaded with conductive fillers and are cross-linked to form a low-modulus paste. They are highly conformable and provide low thermal impedance like greases but are designed to overcome the pump-out and dry-out issues of grease.

Form-In-Place Compounds

THERM-A-FORM™ compounds are reactive, two-component silicone RTVs (room temperature vulcanizing materials) that can be used to form thermal pathways in applications where the distance between a component and a cold surface is highly variable. They are dispensed onto the component and readily conform over complex geometries and then cured in place.

Form-in-Place Compounds and THERM-A-GAP Gels

- Low-modulus, ceramic filled compounds
- Fill gaps ranging from 0.005 to 0.25 inch without stressing components
- Can cure at room temperature
- Localized encapsulating of components

Insulating Pads

CHO-THERM® insulating pads were developed as a user-friendly alternative to greased mica insulators to be used between discrete power devices and heat sinks.

- Silicone binder provides high temperature stability and good electrical insulation properties
- Glass mesh reinforcement provides cut-through resistance
- High mounting pressure required to minimize contact resistance
- U.L. recognized flammability ratings

This class of product is characterized by high thermal conductivity, very high dielectric strength and volume resistivity. Pads must conduct very large heat loads from discrete power semiconductors to heat sinks, while providing long-term electrical insulation between the live component case and the grounded heat sink.

Thermal Greases

Thermal greases are formulated with silicone or hydrocarbon oils that are loaded with conductive fillers. They are viscous liquids that are typically stenciled or screen printed onto the heat spreader or heat sink. Greases have good surface wetting characteristics and flow easily to fill up voids at the interfaces resulting in low thermal impedance even at low application pressure.

Key Properties of Thermal Interface Materials

Thermal Properties

The key properties of interface materials are thermal impedance and thermal conductivity.

Thermal Impedance

This is the measure of the total resistance to the flow of heat from a hot surface through an interface material into a cold surface. Thermal impedance is measured according to the ASTM D5470 test method. Although the current version of this method is specific to high durometer insulating pad materials tested at high clamping forces, the method has been successfully adapted for use with low durometer materials as well as fluid compounds.

Thermal impedance can be measured using ASTM D5470 at several clamping forces to generate a pressure versus thermal impedance plot as shown in Figure 2. This type of data can be used to generate information about the ability of a material to conform to surfaces to minimize contact resistance. Care must be taken with this type of data because contact resistance is also highly influenced by surface characteristics. To minimize the impact of test equipment variations, this type of work is best performed with the same test surfaces for all materials being tested.

Thermal Conductivity

Thermal impedance data measured according to ASTM D5470 can be used to calculate the thermal conductivity of an interface material. Rearranging Equation (3) to give Equation (5)

$$(5) \quad R_{material} = \frac{d}{k}$$

and substituting into Equation (4) yields Equation (6).

$$(6) \quad \Theta = \frac{d}{k} + R_{contact}$$

Equation (6) shows that for a homogeneous material, a plot of thermal impedance [**Θ**] versus thickness (d) is a straight line whose slope is equal to the inverse of the thermal conductivity and the intercept at zero thickness is the contact resistance shown in Figure 2. Thickness can be varied by either stacking up different layers of the material or by preparing the material at different thicknesses.

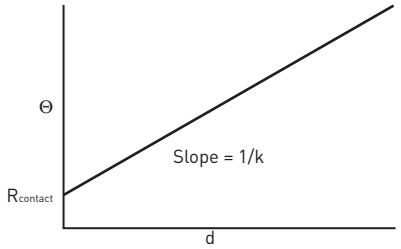


Figure 2. Thermal Impedance vs. Thickness

Coefficient of Thermal Expansion

CTE is the tendency of a material to change in volume in response to changes in temperature.

Heat Capacity

Heat capacity or thermal mass represents the ability of a material to store heat.

Electrical Properties

Voltage Breakdown

This is a measure of how much voltage differential a material can withstand under a specific set of test conditions. This property is usually measured using ASTM D149 where a test specimen is subjected to ramped alternating current voltage such that dielectric failure is reached within twenty seconds after the start of the test. Five specimens are tested and the average voltage breakdown is calculated and reported. The value is an average, not a minimum. Voltage Breakdown can be converted to Dielectric Strength by dividing the voltage breakdown value by the specimen thickness where the dielectric failure occurred. This test is an indication of the ability of a material to withstand high voltages, but does not guarantee how a material will behave over time in a real application. The value is influenced by several factors. Humidity and elevated temperature will reduce the voltage breakdown because absorbed water will degrade the electrical properties of the material.

The size of the test electrode will affect the observed breakdown voltage. A larger test electrode will typically yield a lower breakdown voltage. The presence of partial discharge, as well as mechanical stresses imposed on the interface material, also reduce voltage breakdown.

Volume Resistivity

Volume resistivity is a measure of the bulk electrical resistance of a unit cube of a material. When determined per ASTM D257, volume resistivity can give an indication of how well an interface material can limit leakage current between an active component and its grounded metal heat sink. As with voltage breakdown, volume resistivity can be significantly lowered by humidity and elevated temperature.

Elastomeric Properties

Interface materials exhibit properties typical of highly filled elastomers, namely compression deflection, compression set and stress relaxation.

Compression Deflection

Compression deflection refers to resultant forces a material exerts while being deflected. As a compressive load is applied, the elastomer material is deformed but the volume of the material remains constant. The compression deflection characteristics can vary, depending on part geometry (i.e., thickness and surface area), rate of deflection, size of probe, etc.

Stress Relaxation

When a compressive load is applied to an interface material, there is an initial deflection followed by a slow relaxation process whereby some of the load is relieved. This process continues until the compressive load is balanced by the cohesive strength of the material.

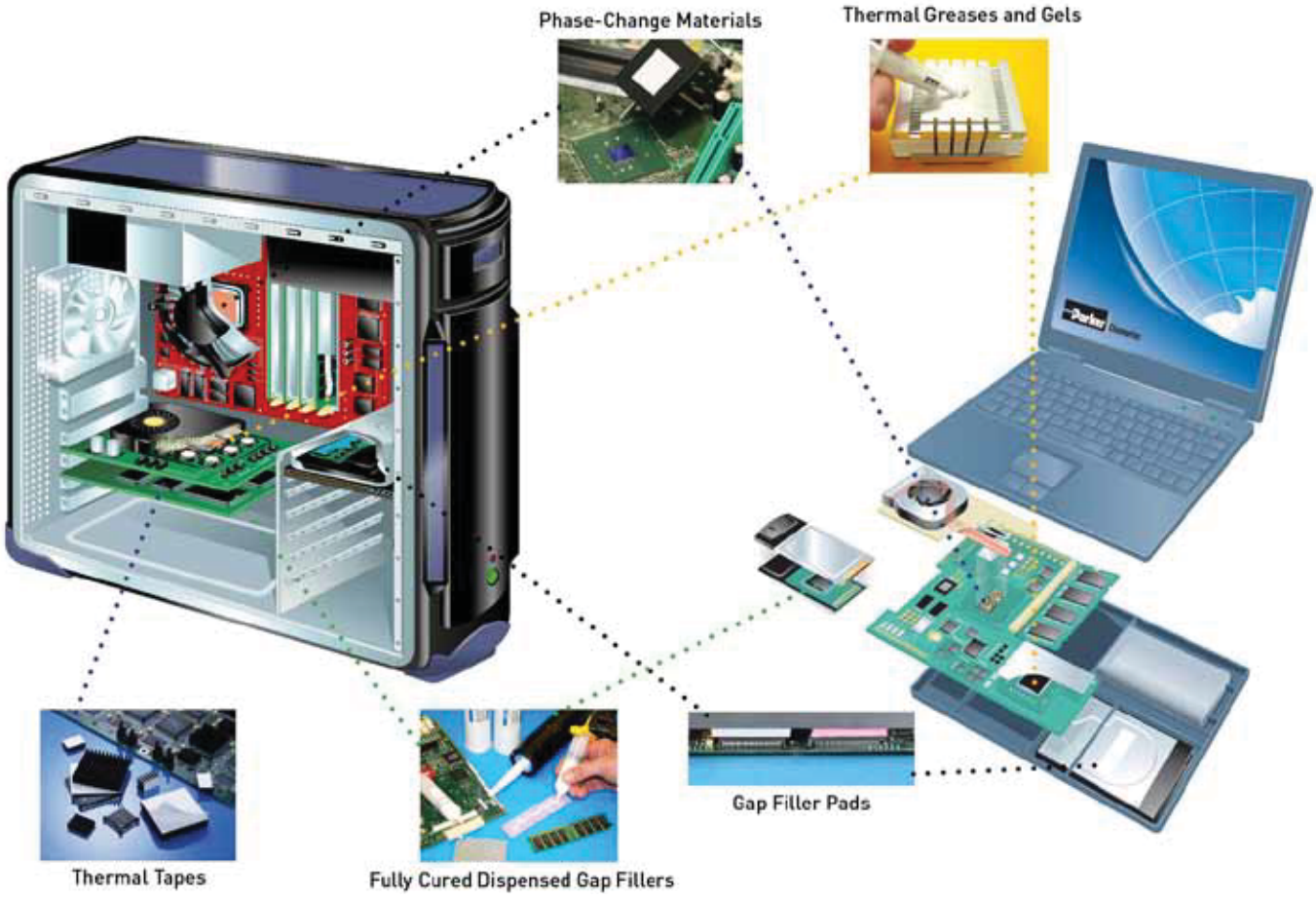
Compression Set

Compression set is the result of stress relaxation. After a material has been subjected to a compressive load for an extended time, part of the deflection becomes permanent and will not be recoverable after the load is reduced.

Thermal Conductivity Conversion Guide

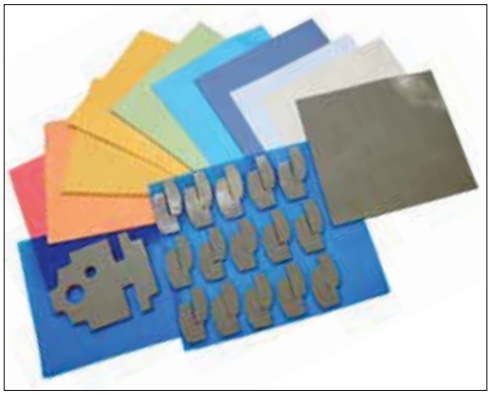
From	$\frac{Cal}{sec\text{-}cm\text{-}^{\circ}C}$		$\frac{BTU\text{-}in}{hr\text{-}ft^2\text{-}^{\circ}F}$		$\frac{W}{m\text{-}K}$	
Multiplier	4.2×10^{2}	2.9×10^{3}	0.14	3.4×10^{-4}	6.94	2.4×10^{-3}
To	$\frac{W}{m\text{-}K}$	$\frac{BTU\text{-}in}{hr\text{-}ft^2\text{-}^{\circ}F}$	$\frac{W}{m\text{-}K}$	$\frac{Cal}{sec\text{-}cm\text{-}^{\circ}C}$	$\frac{BTU\text{-}in}{hr\text{-}ft^2\text{-}^{\circ}F}$	$\frac{Cal}{sec\text{-}cm\text{-}^{\circ}C}$

Thermal Interface Materials (TIMs) for Consumer Electronics and Information Technology



THERM-A-GAP™ HCS10,569,570,579 and 580

Thermally Conductive Gap Filler Pads



Description

THERM-A-GAP™ gap-filler sheets and pads offer excellent thermal properties and highest conformability at low clamping forces.

Features / Benefits

- Ultra low deflection force
- High thermal conductivity
- High tack surface reduces contact resistance
- "A" version offers high strength acrylic PSA for permanent attachment
- UL recognized V-0 flammability
- RoHS compliant

All products are available on aluminum foil "A' or on "clean break" glass "G" fiber carrier. As with all previous Chomerics gap-fillers, the "A" versions have a high strength acrylic pressure sensitive adhesive (PSA) for permanent attachment to the cold surfaces.

THERM-A-GAP™ HCS10, 569, 570, 579 and 580 Thermally Conductive Pads

	Typical Properties	HCS10	569	570	579	580	Test Method
Physical	Color	Orange / Grey Carrier	Grey	Blue	Pink	Yellow	Visual
	Carrier G = Woven glass - no PSA A = Aluminum foil - with PSA PB = PET carrier laminated to glass side*** PT = PET carrier laminated to the unsupported side*** KT = Thermally Enhanced Polyimide Carrier	A or G	A, G, PB, or PT	A or G	A, G, PB, PT or KT	A or G	--
	Standard Thicknesses*, inch (mm)	0.010 - 0.200 (0.25 - 5.0)	0.010 - 0.200 (0.25 - 5.0)	0.020 - 0.200 (0.5 - 5.0)	0.010 - 0.200 (0.25 - 5.0)	0.020 - 0.200 (0.5 - 5.0)	ASTM D374
	Specific Gravity	2.0	2.2	2.2	2.9	2.9	ASTM D792
	Hardness, Shore 00	4	10	25	30	45	ASTM D2240
	Percent Deflection @ Various Pressures** (0.125 in thick sample) @ 5 psi (34 kPa) @ 10 psi (69 kPa) @ 25 psi (172 kPa) @ 50 psi (345 kPa)	% Deflected 26 36 59 73	% Deflected 20 30 50 65	% Deflected 10 15 25 35	% Deflected 22 33 55 68	% Deflected 7 10 20 30	ASTM C165 MOD (0.125 in "G" Type, 0.50 in dia. probe, 0.025 in/min rate)
	Operating Temperature Range, °F (°C)	-67 to 392 (-55 to 200)	-67 to 392 (-55 to 200)	-67 to 392 (-55 to 200)	-67 to 392 (-55 to 200)	-67 to 392 (-55 to 200)	--
Thermal	Thermal Conductivity, W/m-K @ 25 psi	1	1.5	1.5	3	3	ASTM D5470
	Thermal Impedance, °C-in²/W (°C-cm²/W) @ 10 psi, @ 1mm thick, G version	1.5 (9.7)	1.4 (9.1)	1.4 (9.1)	0.7 (4.5)	0.7 (4.5)	ASTM D5470
	Heat Capacity, J/g-K	1	1	1	1	1	ASTM E1269
	Coefficient of Thermal Expansion, ppm/K	N/A	250	250	150	150	ASTM E831
Electrical	Dielectric Strength, V_{AC}/mil (KV_{AC}/mm)	200 (8)	200 (8)	200 (8)	200 (8)	200 (8)	ASTM D149
	Volume Resistivity, ohm-cm	10^{14}	10^{14}	10^{14}	10^{14}	10^{14}	ASTM D257
	Dielectric Constant @1,000 kHz	5.3	6.5	6.5	8.0	8.0	ASTM D150
	Dissipation Factor @ 1,000 kHz	0.013	0.013	0.013	0.010	0.010	Chomerics Test
Regulatory	Flammability Rating (See UL File E140244 for Details)	V-0	V-0	V-0	V-0	V-0	UL 94
	RoHS Compliant	Yes	Yes	Yes	Yes	Yes	Chomerics Certification
	Outgassing, % TML (% CVCM)	0.44 (0.13)	0.42 (0.08)	0.35 (0.09)	0.19 (0.06)	0.18 (0.05)	ASTM E595
	Shelf Life, months from date of shipment G (A)	24 (18)	24 (18)	24 (18)	24 (18)	24 (18)	Chomerics

*Thickness tolerance, in(mm) ±10% nominal thickness @ 0.1in (2.5mm) or less; ± 0.01in (0.25mm) @ nominal thickness greater than 0.1in (2.5mm). Custom thicknesses may be available upon request.
**The typical deflection range is approximately 5-50%
***Laminated polyester film provides low abrasion on one side as well as improved dielectric isolation.

TYPICAL APPLICATIONS

- Telecommunications equipment
- Consumer electronics
- Automotive electronics (ECUs)
- LEDs, lighting
- Power conversion
- Desktop computers, laptops, servers
- Handheld devices
- Memory modules
- Vibration dampening

HANDLING INFORMATION

These products are defined by Chomerics as "articles" according to the following generally recognized regulatory definition for articles:

An article is a manufactured item "formed to a specific shape or design during manufacturing," which has "end use functions" dependent upon its size and shape during end use and which has generally "no change of chemical composition during its end use."

In addition:

- There is no known or anticipated exposure to hazardous materials/ substances during routine and anticipated use of the product.
- The product's shape, surface, and design is more relevant than its chemical composition.

These materials are not deemed by Chomerics to require an MSDS. For further questions, please contact Chomerics at 781-935-4850.

With Glass Carrier

HCS10A
With Aluminium PSA Carrier

PRODUCT ATTRIBUTES

HCS10

- Economical solution
- Highest conformability gap filler sheet

569

- Economical combination of thermal performance and conformability

570

- Best for molding complex parts and vibration dampening

579

- Combination of excellent thermal performance and conformability
- Lowest outgassing

580

- Best for molding complex parts and vibration dampening
- Lowest outgassing

Ordering Information

Part Number:

6W – **XX** – **YYYYY** – **ZZZZ**

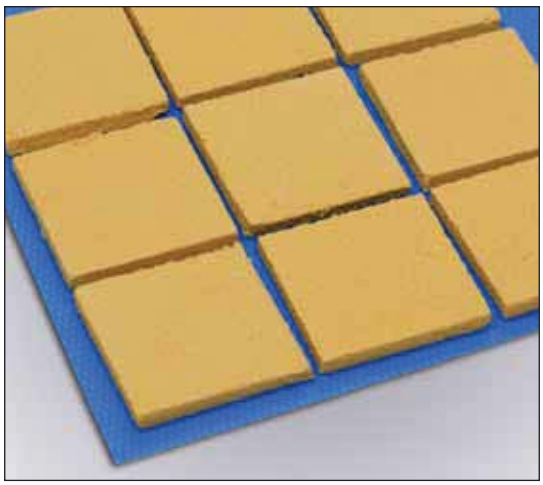
W	XX	YYYYY	ZZZZ
1 = OEM Sheet - No PSA ("G" carrier and HCS40) 2 = OEM Sheet with PSA 1 side ("A" Carrier only)	Material thickness* is in ten mil increments (e.g. 10 = 0.100" or 2.54 mm) (e.g. 02 = 0.020" or 0.50 mm)	**OEM Part Number Examples** 0909 = (9" X 9" Sheet / 22.9 cm X 22.9 cm).	**THERM-A-GAP™ Material Code** **HCS10G & HCS10A** **G569 & A569** **G570 & A570** **G579 & A579** **G580 & A580** (THERM-A-GAP™ 174, 274 and 574 are legacy products and are available upon special request.)
9 = Custom configuration	11 = Custom, no PSA ("G" carrier and HCS40) 12 = Custom, with PSA 1 side ("A" Carrier only)	**Thermally conductive pads are available in the following formats.** **Distributor Part Numbers** - 18" X 18" Sheets 0.010 in = 28539 0.015 in = 28540 0.020 in = 20698 0.030 in = 20913 0.040 in = 20684 0.050 in = 27395 0.060 in = 20991 0.070 in = 20685 0.080 in = 21259 0.100 in = 20672 0.120 in = 27102 0.130 in = 20675 0.140 in = 27100 0.150 in = 27101 0.160 in = 20686 0.180 in = 27103 0.200 in = 20687 **Custom configuration** (Please contact Chomerics for a pre-assigned part number, for custom widths, part sizes, etc.)	

* See typical properties table for thicknesses.

Custom die-cut parts on sheets, or as individual parts
"A" version offered die-cut (up to 40 mil) on continuous rolls (higher volumes)
Custom thicknesses available upon request
(up to 1" thick)
Custom molded designs and ribbed sheets

THERM-A-GAP™ 974, G974 and 976

High Thermal Conductivity Gap Filler Pads



Description

THERM-A-GAP™ 97X gap fillers offer the highest thermal conductivity for low to moderate clamping force applications.

Features/Benefits

- High thermal conductivity
- 974 and G974 supplied with PSA for ease of use
- 976 is softer compared to similar high conductivity materials

Typical Applications

- Telecommunications equipment
- Consumer electronics
- Automotive electronics (ECUs)
- LEDs, lighting
- Power conversion
- Power semiconductors

THERM-A-GAP™ 974, G974 and 976 Thermally Conductive Gap Filler Pads

	Typical Properties	974	G974	976	Test Method
Physical	Color	Blue	Blue	Gold	Visual
	Carrier	PSA	Fiberglass with PSA	None	--
	Standard Thicknesses*, in (mm)	0.020 - 0.080 (0.5 - 1.50)	0.010 - 0.100 (0.25 - 1.50)	0.040 - 0.200 (1.00 - 5.00)	ASTM D374
	Specific Gravity	1.40	1.40	1.30	ASTM D792
	Hardness, Shore A	40	40	10	ASTM D2240
	Penetrometer, mm	25	25	60	Chomerics
	Percent Deflection @ Various Pressures (0.060 in thick sample) @ 5 psi (34 kPa) @ 10 psi (69 kPa) @ 25 psi (172 kPa) @ 50 psi (345 kPa)	% Deflected 7 11 12 13	% Deflected 7 11 12 13	% Deflected 6 10 11 45	ASTM C165 MOD (0.060" thick, 0.50 in diameter, 0.025 in/min rate)
Thermal	Thermal Conductivity, W/m-K	6.0	5.0	6.5	ASTM D5470
	Thermal Impedance, °C-in²/W (°C-cm²/W) 50 psi (@ 345 kPa), 0.040 in (1 mm)	0.45 (2.9)	0.51 (3.3)	0.30 (1.9)	ASTM D5470
	Heat Capacity, J/g-K	0.9	0.9	0.9	ASTM E1269
	Coefficient of Thermal Expansion, ppm/°C	100	100	100	ASTM E831
	Operating Temperature Range, °F (°C)	-67 to 392 (-55 to 200)	-67 to 392 (-55 to 200)	-67 to 392 (-55 to 200)	--
Electrical	Dielectric Strength, Vac/mil (KVac/mm)	200 (5.1)	200 (5.1)	200 (5.1)	ASTM D149
	Volume Resistivity, ohm-cm	10^{14}	10^{14}	10^{14}	ASTM D257
	Dielectric Constant @1,000 kHz	3.2	3.2	3.2	ASTM D150
	Dissipation Factor @ 1,000 kHz	< 0.001	< 0.001	< 0.001	Chomerics Test
Regulatory	Flammability Rating (See UL File E140244 for Details)	Not Tested	V-0	V-0	UL 94
	Outgassing, % TML (% CVCM)	0.59 (0.18)	0.59 (0.18)	0.64 (0.21)	ASTM E595
	RoHS Compliant	Yes	Yes	Yes	Chomerics Certification
	Shelf Life, months from date of shipment	12	12	24	Chomerics

*Thickness tolerance, mm(in.) ±10% nominal thickness @ 2.5mm (100 mil) or less;
± 0.25mm (10mil) @ nominal thickness greater than 2.5mm (100 mil). Custom thicknesses may be available upon request.

Product Attributes

974

- Excellent thermal performance
- Acrylic PSA for improved application

G974

- Excellent thermal performance
- Acrylic PSA for improved application
- Fiberglass reinforced for improved tear strength and improved rework capabilities

976

- Superior thermal performance
- Low compression force under pressure
- Minimal stress on components

Material Handling

These products are defined by Chomerics as "articles" according to the following generally recognized regulatory definition for articles:

An article is a manufactured item "formed to a specific shape or design during manufacturing," which has "end use functions" dependent upon its size and shape during end use and which has generally "no change of chemical composition during its end use."

In addition:

- There is no known or anticipated exposure to hazardous materials/substances during routine and anticipated use of the product.
- The product's shape, surface, and design is more relevant than its chemical composition.

These materials are not deemed by Chomerics to require an MSDS. For further questions, please contact Chomerics at 781-935-4850.

Ordering Information

THERM-A-GAP products are available in the following formats.
Contact Chomerics for custom widths, part sizes, etc.

- Full Sheets, 9"x12" to 20"x25"
- Die-cut parts on sheets
- Custom die-cut parts on sheets, or as individual parts

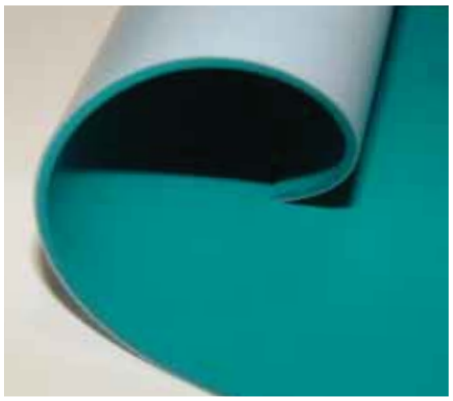
Part Number: 6W — XX — YYYYY — ZZZZ

W	XX	YYYYY	ZZZZ
1 = Sheet - No PSA (976 only) 2 = Sheet with PSA 1 side (974/G974 only)	Material thickness* is in ten mil increments (e.g. 10 = 0.100" or 2.54 mm) (e.g. 02 = 0.020" or 0.50 mm)	0912 = (9" X 12" Sheet / 22.9 cm X 30.5 cm). 2025 = (20" X 25" Sheet / 50.8 cm X 63.5 cm).	ZZZZ = 974, G974, or 976
9 = Custom configuration	11 = Custom, no PSA (976 only) 12 = Custom, with PSA 1 side (974/G974 only)	YYYYY = Custom configuration (Please contact Chomerics for a pre-assigned part number if necessary)	

* See typical properties table for thicknesses.

THERM-A-GAP™ TS15

Thermally Conductive Gap Filler Pads



THERM-A-GAP™ TS15 is designed to provide excellent mechanical integrity in applications where clamping forces exert extreme pressure on parts and where gaps are thicker than what is typical of dielectric pads.

Product Features

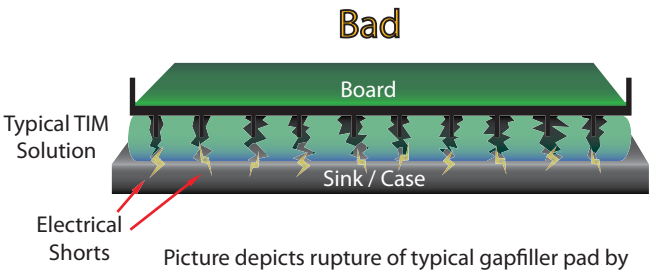
- Increased tear resistance eliminates dielectric failures by preventing puncture from sharp components.
- Thermal performance decreases electronic component temperatures, increasing product lifetimes

Product Attributes

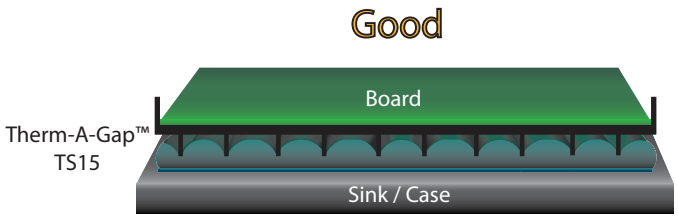
- Good thermal conductivity
- Excellent mechanical strength
- Excellent cut-through resistance

THERM-A-GAP™ TS15 Thermally Conductive Pads			
Typical Properties		**TS15**	**Test Method**
Physical	Color	Teal / Blue	Visual
	Carrier	Fiberglass reinforced dielectric layer with PSA	--
	Standard Thicknesses*, inch (mm)	0.040 - 0.200 (1.0 – 5.0)	ASTM D374
	Specific Gravity	2.2	ASTM D792
	Hardness, Shore A	50	ASTM D2240
	Percent Deflection @ Various Pressures (0.125 in thick sample) @ 5 psi (34 kPa) @ 10 psi (69 kPa) @ 25 psi (172 kPa) @ 50 psi (345 kPa)	% Deflected 3 5 7 9	ASTM C165 MOD (0.125in "G" Type, 0.50 in dia. sample, 0.025 in/min rate)
	Tensile Strength, psi	250	ASTM D412
	Tear Strength, lb/in	40	ASTM D624
Thermal	Elongation, %	20	ASTM D412
	Thermal Impedance, °C-in²/W (°C-cm²/W) @ 10 psi (69 kPa) @ 0.04" (1mm) thickness	1.5 (9.7)	ASTM D5470
	Heat Capacity, J/g-K	1	ASTM E1269
	Coefficient of Thermal Expansion, ppm/K	250	ASTM E831
Electrical	Dielectric Strength, V_{AC}/mil (KV_{AC}/mm)	200 (8)	ASTM D149
	Volume Resistivity, ohm-cm	10^{14}	ASTM D257
	Dielectric Constant @1,000 kHz	6.5	ASTM D150
	Dissipation Factor @ 1,000 kHz	0.013	Chomerics Test
Regulatory	Flammability Rating (See UL File E140244 for Details)	Pending	UL 94
	RoHS Compliant	Yes	Chomerics Certification
	Outgassing, % TML (% CVCM)	Pending	ASTM E595
	Shelf Life, months from date of shipment	18	Chomerics

*Thickness tolerance, inch (mm) ±10% nominal thickness @ 0.100in. (2.5mm) or less;
± 0.010in.(0.25mm) @ nominal thickness greater than 0.100in. (2.5mm). Custom thicknesses may be available upon request.



Picture depicts rupture of typical gapfiller pad by way of unusual high profile / sharp mechanical components



TS15 deflects while resisting rupture to prevent electrical shorts.

Ordering Information

Part Number:

6W – **XX** – **YYYYY** – **ZZZZ**

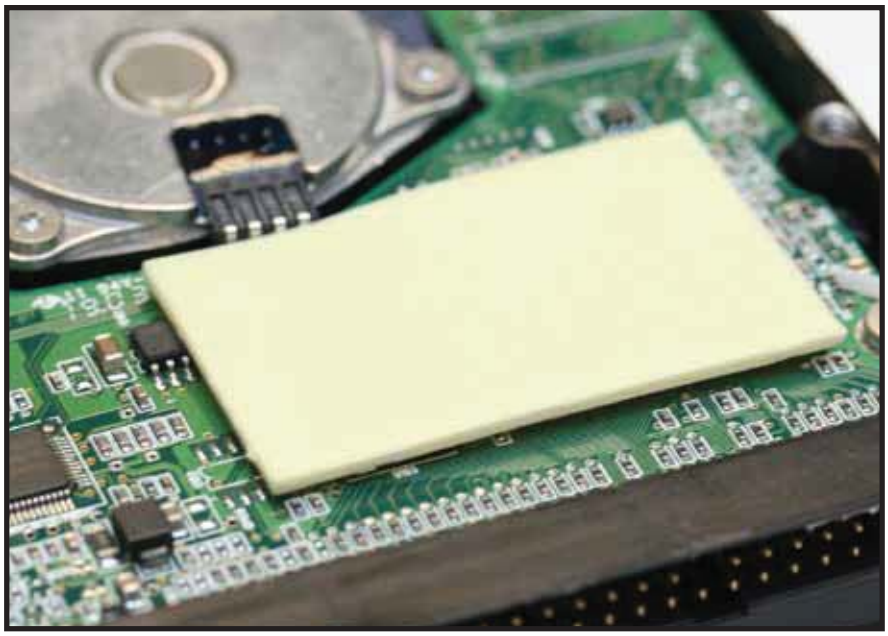
W	XX	YYYYY	ZZZZ
2 = OEM Sheet with PSA 1 side ("T" Carrier only)	Material thickness* is in ten mil increments (e.g. 10 = 0.100" or 2.54 mm) (e.g. 04 = 0.040" or 1.00 mm)	**OEM Part Number Examples** 0909 = (9" X 9" Sheet / 22.9 cm X 22.9 cm).	**THERM-A-GAP™ Material Code** **TS15**
9 = Custom configuration	12 = Custom, with PSA 1 side ("T" Carrier only)	**Thermally conductive pads are available in the following formats.** **Distributor Part Numbers** - 18" X 18" Sheets 0.040 in = 20684 0.050 in = 27395 0.060 in = 20991 0.070 in = 20685 0.080 in = 21259 0.100 in = 20672 0.120 in = 27102 0.130 in = 20675 0.140 in = 27100 0.150 in = 27101 0.160 in = 20686 0.180 in = 27103 0.200 in = 20687 **Custom configuration** (Please contact Chomerics for a pre-assigned part number, for custom widths, part sizes, etc.)	

* See typical properties table for thicknesses.

Custom die-cut parts on sheets
Custom thicknesses available upon request

THERM-A-GAP™ 575-NS

Silicone-Free Soft Acrylic Thermally Conductive Gap Filler Pads



Description

THERM-A-GAP™ acrylic gap filler pads are used in silicone sensitive applications.

Features / Benefits

- Economical with good thermal conductivity
- No silicone outgassing or extractables
- RoHs compliant
- Inherently tacky on both sides for ease of application (No pressure sensitive adhesive option available/necessary)

Typical Applications

- Hard disk drives/storage
- Optical electronics
- Aerospace/Defense
- Desktop computers, laptops, servers
- Telecommunications equipment
- Consumer electronics

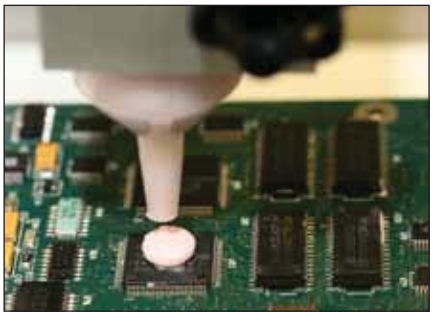
THERM-A-GAP™ Silicone-Free Soft Acrylic Thermally Conductive Pads		
Typical Properties	**575-NS**	**Test Method**
Color	Yellow	Visual
Composition	Ceramic Filled Acrylic	---
Thickness, in (mm)	0.020 -0.100 (0.5 – 2.5)	ASTM D374
Specific Gravity	1.8	ASTM D792
Thermal Conductivity, W/m-K	1.2	ASTM D5470 @ 50 psi
Hardness (Shore 00)	70	ASTM D2240
Operating Temperature Range, °F (°C)	-4 to 212 (-20 to 100)	--
RoHS Compliant	Yes	Chomerics Certification

Ordering Information

Chomerics P/N	Thickness / in. (mm)	Sheet Size
69-11-27154-575NS	0.020 (0.5)	11.8 X 15.7 (300 X 400 mm)
69-11-27155-575NS	0.040 (1.0)	
69-11-27156-575NS	0.047 (1.2)	
69-11-27157-575NS	0.060 (1.5)	
69-11-27158-575NS	0.080 (2.0)	7.9 X 11.8 (200 X 300 mm)
69-11-27159-575NS	0.100 (2.5)	

THERM-A-GAP™ Gels

Dispensable, Very Low Compression Force, Thermal Gap Fillers



Description

THERM-A-GAP™ Gels are highly conformable, pre-cured, single-component compounds. The cross-linked gel structure provides superior long term thermal stability and reliable performance. These unique materials result in much lower mechanical stress on delicate components than even the softest gap-filling sheets. They are ideal for filling variable gaps between multiple components and a common heat sink.

Features / Benefits

- Dispensable
- Fully cured
- Highly conformable at low pressures
- No refrigeration, mixing or filler settling issues in storage
- Single dispensable TIM can eliminate multiple pad part sizes/numbers
- Reworkable

Typical Applications

- Automotive electronic control units (ECUs)
  - Engine control
  - Transmission control
  - Braking/traction control
- Power conversion equipment
- Power supplies and uninterruptible power supplies
- Power semiconductors
- MOSFET arrays with common heat sinks
- Televisions and consumer electronics

THERM-A-GAP™ Dispensed Thermal Gels

	Typical Properties	T630/T630G	T635	T636	Test Method
Physical	Color	White	White	Yellow	Visual
	Flow Rate, cc/min - 30cc taper tip, 0.130" orifice, 90psi (621 kPa)	10	8	8	Chomerics
	Specific Gravity	2.25	1.50	1.20	ASTM D792
	Percent Deflection @ Various Pressures (0.5 psi) (1 psi) (2 psi) (3 psi) (4 psi) (5 psi)	% Deflection -- 36 47 54 59 63	% Deflection -- 13 33 43 50 56	% Deflection -- 6 23 35 43 48	Modified ASTM C165 Dispensed 1.0 cc of material Brought 1" x 1" probe down to 0.100" Test rate 0.025 in/min
	Typical minimum bondline thickness, in (mm)	0.004 (0.10)/ 0.010 (0.25)	0.015 (0.38)	0.015 (0.38)	--
Thermal	Thermal Conductivity, W/m-K	0.7	1.7	2.4	ASTM D5470
	Heat Capacity, J/g-K	1.1	0.9	0.9	ASTM E1269
	Coefficient of Thermal Expansion, ppm/K	350	400	400	ASTM E831
	Operating Temperature Range, °F (°C)	-67 to 392 (-55 to 200)	-67 to 392 (-55 to 200)	-67 to 392 (-55 to 200)	--
Electrical	Dielectric Strength, V_{AC} / mil (KV_{AC}/mm)	200 (5.0)	200 (5.0)	200 (5.0)	ASTM D149
	Volume Resistivity, ohm-cm	10^{14}	10^{14}	10^{14}	ASTM D257
	Dielectric Constant @1,000 kHz	5.5	4.0	4.0	ASTM D150
	Dissipation Factor @ 1,000 kHz	0.010	0.003	0.003	Chomerics
Regulatory	Flammability Rating (See UL File E140244 for Details)	V-0	Not Tested	V-0	UL 94
	RoHS Compliant	Yes	Yes	Yes	Chomerics Certification
	Outgassing, % TML	0.55	0.5	0.4	ASTM E595
	Shelf Life, months from date of manufacture	18	18	18	Chomerics

Product Attributes

T630 / T630G

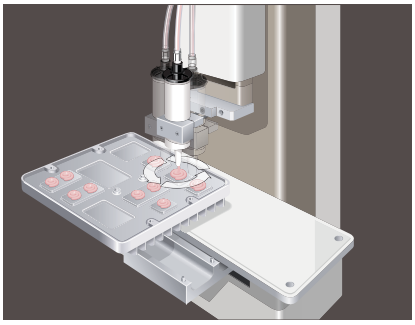
- Years of proven reliability in high-volume automotive applications
- General use material
- Good thermal performance
- Lowest deflection force required
- Minimal stress on components
- "G" version has 0.010" glass beads as compression stops for electrical isolation

T635

- Excellent thermal performance
- Low deflection force required
- Minimal stress on components

T636

- Superior thermal performance
- Solves the toughest heat transfer problems
- Low deflection force required
- Minimal stress on components



Consult Applications Engineering for automated dispensing equipment recommendations

Ordering Information

These materials are available in the following formats.
Contact Chomerics for custom widths, part sizes, etc.

6W – XX – YYYYY – ZZZZ

	W	XX	YYYYY	ZZZZ
GELS	5 = Standard Packaging	00	THERM-A-GAP GEL T630(G), T635 & TT636	0030 = 30cc Taper Tip Tube
				0300 = 300cc Aluminum Cartridge (Caulking Style)
	9 = Custom Configuration	11	25177	T630 (G) = 1 Gallon Pail (1125cc, 5Kg)*
			32768	T635 = 1 Gallon Pail (2800cc, 4.2Kg)*
			32769	T636 = 1 Gallon Pail (2800cc, 3.4Kg)*
			Custom Part Number	THERM-A-GAP Gel Material Code T630(G), T635 & T636

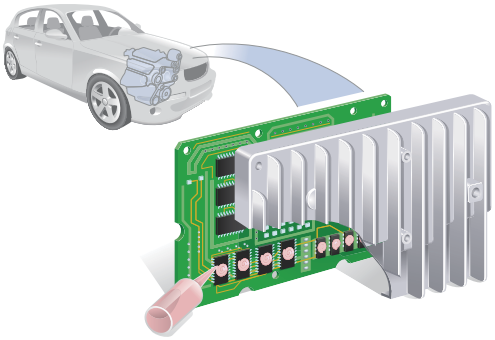
**High volume dispensing equipment required. Please contact Applications Engineering for additional support. Other custom container sizes may be available upon request*

Dispensing Equipment Options	Optional Supplier	Description
Hand-Gun Pneumatic Dispensing 300cc cartridges	Bergdahl Associates	Semco Model 550
Hand-Gun Pneumatic Dispensing 180cc (6oz) cartridges	Bergdahl Associates	Model 250A-6oz Sealant Gun
http://www.bergdahl.com		
Pneumatic Shot Size Controllers 30cc, 180cc and 300cc Shot Size Dispensing Equipment	EFD	Ultra 2400 Series
		Ultra 1400 Series
		Ultra 870 Series
30cc/55cc Adapter Assembly	EFD	10000D5152
Dispensing Sleeve to support 6oz (180cc) Semco Tubes	EFD	5192-6
http://www.efd-inc.com		

SEMCO is a trademark of Bergdahl Associates, Inc

THERM-A-GAP™ GEL 8010 & GEL 30

High Performance Fully Cured Dispensable GELS



Description

Parker Chomerics fully cured dispensable GELs eliminate timeconsuming hand assembly, decreasing installation costs and reducing customer manufacturing and purchasing (logistical) complexity. These products require no mixing or curing, providing superior design flexibility.

- Provides low thermal impedance at thin and thick gaps, allowing use of common heat spreaders
- Proven reliability in extreme temperature cycling and shock & vibration
- Deflects easily under very low compressive forces, decreasing stress on components thus decreasing component failures.

Typical Applications

- Automotive Electronic Control Units (ECU's)
- Power Supplies & Semiconductors
- Memory & Power Modules
- Microprocessors / Graphics Processors
- Flat Panel Displays & Consumer Electronics

Features/Benefits

- Easily dispensable
- Fully-cured / No pump out
- High bulk thermal conductivity
- Low thermal impedance
- Ultra low compression force
- High tack surface & reworkable
- Proven long-term reliability

	Typical Properties	GEL 8010	GEL 30	Test Method
Physical	Color	White	Light Pink	Visual
	Flow Rate, grams/min - 30cc syringe with no tip attachment 0.100" orifice, 90psi (621 kPa)	60	20	Chomerics
	Specific Gravity	2.70	3.20	ASTM D792
	Percent Deflection @ Various Force Levels (See graph on following page)	% Deflection	% Deflection	Modified ASTM C165 Dispensed 1.0 cc of material Brought 1" x 1" probe down to 0.100" Test rate 0.025 in/min
	Typical minimum bondline thickness, in (mm)	0.002 (0.05)	0.004 (0.10)	Chomerics
Thermal	Thermal Conductivity, W/m-K	3.0	3.5	ASTM D5470
	Heat Capacity, J/g-K	1	1	ASTM E1269
	Coefficient of Thermal Expansion, ppm/K	150	150	ASTM E831
	Operating Temperature Range, °F (°C)	-67 to 392 (-55 to 200)	-67 to 392 (-55 to 200)	Chomerics
Electrical	Dielectric Strength, Vac / mil (KVac/mm)	200 (8.0)	200 (8.0)	ASTM D149
	Volume Resistivity, ohm-cm	10^{14}	10^{14}	ASTM D257
	Dielectric Constant @100 kHz	6.3	7.0	ASTM D150
	Dissipation Factor @ 100 kHz	0.002	0.002	Chomerics
Regulatory	Flammability Rating	V-0	V-0	UL 94
	RoHS Compliant	Yes	Yes	Chomerics Certification
	Outgassing, % TML (CVCM)	1.33 (0.34)	0.15 (0.05)	ASTM E595
	Shelf Life, months from date of manufacture	18	18	Chomerics

Product Attributes

GEL 8010

- Thin bondline gel (approximately 2-10 mils)
- Low thermal impedance gel
- Stencil printable with no pump out
- Ideal for high-volume dispensing
- Proven long-term reliability

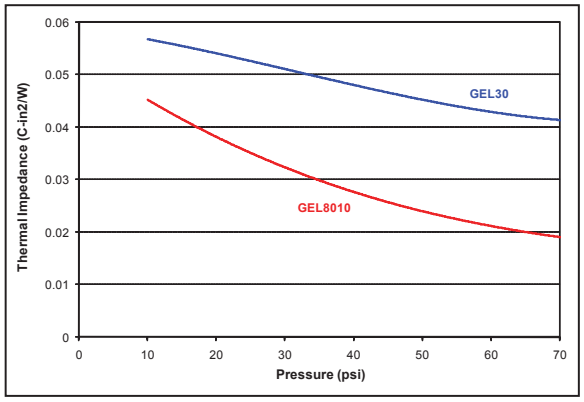
GEL 30

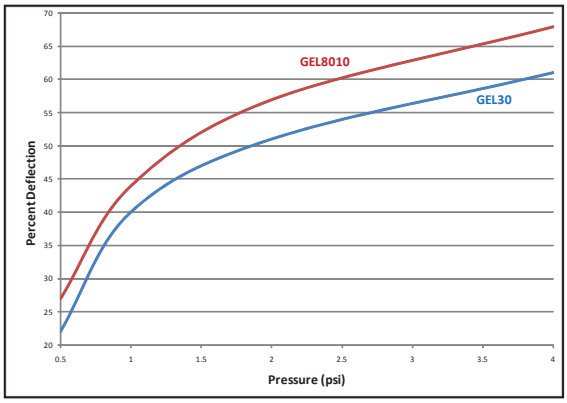
- Accommodates a variety of bond line thicknesses for application to multiple devices
- Moderate bondline gel (approximately 4-40+ mils)
- High Bulk Thermal Conductivity
- Excellent performance-to-price
- Compatible with high volume, automated dispense processes
- Meets Telcordia (Bellcore) silicone specifications

Installation Guidelines

Thermal gels are supplied in plastic syringes and aluminum cartridges. Apply pressure to the rear of the cartridge, simply dispense the desired amount onto components or cooling plates. The gel is reworkable and excess material can be easily wiped off.

Since GEL 8010 gel is conformable, the gel can be stencil printed onto the plates. The thickness of the printed gel can be adjusted depending on the component type and size, but about 6mil thickness is recommended.





Ordering Information

6W – **XX** – **YYYYY** – **ZZZZ**

	W	XX	YYYYY	ZZZZ
GELS	5 = Standard Packaging	00	THERM-A-GAP GEL 8010 & GEL 30	0030 = 30cc Taper Tip Tube
				0300 = 300cc Aluminum Cartridge (Caulking Style)
	9 = Custom Configuration	11	33579	GEL 8010 = 1 Gallon Pail (2800cc, 7.6Kg)*
			28020	GEL 30 = 1 Gallon Pail (2800cc, 9Kg)*
			Custom Part Number	THERM-A-GAP GEL Material Code GEL 8010 & GEL 30

**High volume dispensing equipment required. Please contact Applications Engineering for additional support. Other custom container sizes may be available upon request*

Dispensing Equipment Options	Optional Supplier	Description
Hand-Gun Pneumatic Dispensing 300cc cartridges	Bergdahl Associates	Semco Model 550
http://www.bergdahl.com		
Pneumatic Shot Size Controllers 30cc, 180cc and 300cc Shot Size Dispensing Equipment	EFD	Ultra 2400 Series
		Ultra 1400 Series
		Ultra 870 Series
30cc/55cc Adapter Assembly	EFD	10000D5152
Dispensing Sleeve to support 6oz (180cc) Semco Tubes	EFD	5192-6
http://www.efd-inc.com		

SEMCO is a trademark of Semco, Inc.

THERMFLOW®

Non-Silicone, Phase-Change Thermal Interface Pads

Completely fills interfacial air gaps and voids for best thermal performance

Description

THERMFLOW® phase-change Thermal Interface Materials (TIMs) completely fill interfacial air gaps and voids. They also displace entrapped air between power dissipating electronic components. Phase-change materials are designed to maximize heat sink performance and improve component reliability.

Upon reaching the required melt temperature, the pad will fully change phase and attain minimum bond-line thickness (MBLT) - less than 0.001 inch or 0.0254mm, and maximum surface wetting. This results in a low thermal resistance path.

At room temperature, THERMFLOW materials are solid and easy to handle. This allows them to be consistently and cleanly applied as dry pads to a heat sink or component surface. THERMFLOW material softens as it reaches component operating temperatures. With light clamping pressure it will readily conform to both mating surfaces.

This ability to completely fill air gaps and voids typical of component packages and heat sinks allows THERMFLOW pads to achieve performance superior to any other thermal interface materials.

Standard THERMFLOW products are electrically non-conductive however metal-to-metal contact is possible after the material undergoes phase-change, decreasing their electrical isolation properties. PC07DM-7 is the only phase-change materials recommended for use as a dielectric insulator.

Chomerics offers two types of phase change materials—traditional thermal interface pads and Dual Phase Change Polymer Solder Hybrids.

Dual Phase Change Polymer Solder Hybrid Materials

Dual Phase Change Thermal Interface Materials consist of binder and fillers which both phase-change to exhibit the lowest thermal impedance of the phase-change family.

These Thermal Interface Materials provide superior long term reliability performance.

For optimum performance, the pads must be exposed to temperatures above 64°C during operation or by a burn-in cycle to achieve lowest thermal impedance and highest thermal performance.

Features/Benefits

- Low thermal impedance
- Proven solution – years of production use in personal computer OEM applications
- Demonstrated reliability through thermal cycling and accelerated age testing
- Can be pre-applied to heat sinks
- Protective release liner prevents contamination of material prior to final component assembly
- Tabs available for easy removal of release liner (T710, T725*, T557, T777, PC07DM)
  * T725 is only offered with a tab
- Available in custom die-cut shapes, kiss-cut on rolls
- RoHS Compliant

Typical Applications

- Microprocessors
- Graphics Processors
- Chipsets
- Memory Modules
- Power Modules
- Power Semiconductors

Handling Information

These products are defined by Chomerics as "articles" according to the following generally recognized regulatory definition for articles:

An article is a manufactured item "formed to a specific shape or design during manufacturing," which has "end use functions" dependent upon its size and shape during end use and which has generally "no change of chemical composition during its end use."

In addition:

- There is no known or anticipated exposure to hazardous materials/substances during routine and anticipated use of the product.
- The product's shape, surface, and design is more relevant than its chemical composition.

These materials are not deemed by Chomerics to require an MSDS. For further questions, please contact Chomerics at 781-935-4850.

Application

Material may flow when oriented vertically, especially at higher temperatures. This does not affect thermal performance, but should be considered if appearance is important.

Clean Up

THERMFLOW material can be removed with solvens such a toluene, MEK or isopropyl alcohol.

THERMFLOW® Non-Silicone, Phase-Change Thermal Interface Pads									
	Typical Properties	PC07DM-7	T710 with PSA	T725	T766 / T766-06	T557	T558	T777	Test Method
Physical	Color	Pink	Light gray / off-white	Pink	Purple / Gray foil	Gray	Gray / Gray foil	Gray	Visual
	Carrier	1 mil polyester	2 mil Fiberglass	None - Free Film	1 mil Metal Foil	None - Free film	1 mil Metal Foil	None - Free film	--
	Standard Thicknesses, in (mm)	0.007 (0.178)	0.0055 (0.138)	0.005 (0.125)	0.0035 (0.088) 0.006 (0.152)	0.005 (0.125)	0.0045 (0.115)	0.0045 (0.115)	ASTM D374
	Specific Gravity	1.1	1.15	1.1	2.6	2.4	3.65	1.95	ASTM D792
	Phase Transition Temperature, °C	55	45	55	55	45 / 62***	45 / 62***	45 / 62***	ASTM D3418
	Weight Loss, 125°C for 48 Hours	<0.5%	<0.5%	<0.5%	<0.5%	<0.5%	<0.5%	<0.5%	--
Thermal	Thermal Impedance @ 70°C, °C-in²/W (°C-cm²/W)	Minimum Bond-line Thickness	Minimum Bond-line Thickness @ 50°C	2.9 mil	Minimum Bond-line Thickness	Minimum Bond-line Thickness	Minimum Bond-line Thickness	Minimum Bond-line Thickness	--
	@ 10 psi (69 kPa) @ 25 psi (172 kPa) @ 50 psi (345 kPa)	0.35 (2.2) 0.30 (1.93) 0.28 (1.81)	0.23 (1.48) 0.16 (1.03) 0.12 (0.77)	0.11 (0.71) 0.06 (0.39) 0.04 (0.26)	0.15 (0.97) 0.09 (0.58) 0.06 (0.39)	0.02 (0.13) 0.015 (0.097) 0.008 (0.052)	0.03 (0.19) 0.13 (0.02) 0.097 (0.013)	0.02 (0.13) 0.015 (0.097) 0.0055 (0.035)	ASTM D5470
	Operating Temperature Range, °F (°C)	-67 to 257 (-55 to 125)	-67 to 257 (-55 to 125)	-67 to 257 (-55 to 125)	-67 to 257 (-55 to 125)	-67 to 257 (-55 to 125)	-67 to 257 (-55 to 125)	-67 to 257 (-55 to 125)	--
Electrical	Volume Resistivity, ohm-cm	10^{14}	10^{14}	10^{14}	10^{14} Metal Foil*	Nonconductive **	Nonconductive** / Metal Foil*	Nonconductive**	ASTM D257
	Voltage Breakdown (kVac)	5	N/A	N/A	N/A	N/A	N/A	N/A	ASTM D149
Regulatory	Flammability Rating	Not Tested	Not Tested	V-0	Not Tested	Not Tested	Not Tested	V-0	UL 94
	RoHS Compliant	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Chomerics Certification
	Shelf Life, months from date of shipment	12	12	12	12	12	12	12	Chomerics

*Phase-change material exhibits 10^{14} ohm-cm volume resistivity. Metal foil is electrically conductive.

**The phase-change material is electrically non-conductive. However, as it contains dispersed solder for enhanced thermal properties, it can exhibit through-conductivity at thinner bond line thickness (approximately <2 mils). It should not be used as an electrical insulator.

*** The lower phase-transition temperature is for the polymer. The higher value is for the low melting alloy filler.

TRADITIONAL PHASE CHANGE MATERIALS (PCM)

PC07DM-7

- Utilizes proven T725 phase-change material
- Polyester dielectric layer offers excellent mechanical and electrical insulation properties
- Inherently tacky – no adhesive required
- Good thermal properties
- Tabs available for easy removal

T710

- General use material
- Good thermal performance
- Low deflection force required
- Fiberglass provides dielectric standoff
- Only available with adhesive
- Tabs available for easy removal

T725

- Excellent thermal performance
- Inherently tacky – no adhesive required
- Ideal for vertical applications
- Sticky nature limits flowing in vertical applications
- Tabs available for easy removal

T766

- Excellent thermal performance
- Protective foil eliminates top liner
- Inherently tacky – no adhesive required
- Sticky nature limits flowing in vertical applications
- Also available at 0.006"

POLYMER SOLDER HYBRID MATERIALS (PSH)

T557

- Superior thermal performance
- For attachment remove white release liner first
- Dispersed solder filler offers added thermal performance
- Resin system designed for higher temperature reliability
- Inherently tacky – no adhesive required
- Tabs available for easy removal

T558

- Superior thermal performance
- Conformal foil allows clean break/rework and eliminates top liner
- Dispersed solder filler offers added thermal performance
- Resin system designed for higher temperature reliability
- Inherently tacky – no adhesive required

T777

- Superior thermal performance
- Ideal solution for mobile microprocessors
- Dispersed solder filler offers added thermal performance
- Resin system designed for higher temperature reliability
- Inherently tacky – no adhesive required
- Tabs available for easy removal

Ordering Information

THERMFLOW materials are supplied in several standard formats (see part number guide below).

Custom die-cut shapes can also be provided on kiss-cut rolls by Chomerics' extensive network of distributor/ fabricators. To ease release liner removal, an optional tab can be added.

Standard tolerances for slitting widths and individually cut pieces are ±0.020 inch (±0.51 mm).

Part Number:

6W – XX – YYYY – ZZZZ

6W	XX	YYYY	ZZZZ
4 = Roll stock	10 = 100 ft. 40 = 400 ft. XX = Custom length	YYYY =Roll stock width: Examples 0100 = 1" 0750 = 7.5" 2400 = 24"	ZZZZ = Material class (T710, T725, T766, T557, T558, T777, PC07DM-7)
6 = Roll stock with PSA (T710 only)			
8 = Roll stock with release tabs			
9 = Custom die-cut part	11 = without PSA 12 = with PSA one side (T710 Only)	Custom Part Number. Contact Chomerics	

THERMATTACH® Double-Sided Thermal Tapes
Thermally Conductive Attachment Tapes

Description
THERMATTACH® double-sided thermal interface tapes provide exceptional bonding properties between electronic components and heat sinks, eliminating the need for mechanical fasteners.

THERMATTACH® tapes are proven to offer excellent reliability when exposed to thermal, mechanical, and environmental conditioning. They are offered in a variety of configurations, as detailed in the typical properties table.

Features / Benefits
- Offered in various forms to provide thermal, dielectric, and flame retardant properties
- Offered in custom die-cut configurations to suit a variety of applications
- Eliminates the need for mechanical attachment (i.e. screws, clips, rivets, fasteners)
- Proven reliability under various mechanical, thermal, and environmental stresses
- Embossed version available
- UL recognized V-0 flammability
- Meets RoHS specifications
- No curing required, unlike epoxy or acrylic preforms or liquid systems
- Easily reworkable

Typical Applications
- Mount heat sinks to components dissipating < ~25 W
- Attach heat sinks to PC (esp. graphics) processors
- Heat sink attachment to motor control processors
- Telecommunication infrastructure components

Product Attributes
T418
- Superior adhesive strength
- Best conformability to components
- UL94 V-0 rated
- Good thermal performance

T412
- Good adhesion
- Superior thermal performance
- General use tape with added thermal conductivity of Al foil layer

T411
- Designed for adhesion to plastic packages
- Attaches to low surface energy packages

T404/T414
- Excellent dielectric strength due to polyimide carrier
- Good thermal performance
- UL94 V-0 rated

T405
- General use tape with added thermal conductivity of Al foil layer
- Excellent thermal performance
- UL94 V-0 rated

Thermally Conductive Attachment Tapes							
	Typical Properties	**T418**	**T412**	**T404 / T414**	**T405 / T405-R**	**T411**	**Method**
Physical	Recommended for Plastic Component Attachment	No	No	No	No	Yes	--
	Color	Light Yellow	Gray	Beige	White	Clear / Metallic	--
	Embossed	Optional	Standard	Standard	Standard	No	--
	Reinforcement Carrier	Fiberglass	Aluminum Mesh	Filled Polyimide	Aluminum	Aluminum Mesh	Visual
	Thickness, inch (mm)	0.010 (0.25)	0.009 (0.23)	0.005 (0.127)	0.006 (0.15)	0.010 (0.25)	ASTM D374
	Thickness Tolerance, inch (mm)	± 0.001 (0.025)	± 0.001 (0.025)	± 0.001 (0.025)	± 0.001 (0.025)	± 0.001 (0.025)	--
	Adhesive CTE, ppm/°F	300	300	300	300	400	ASTM D3386
	Glass Transition Temperature Range °F (°C)	-4 (-20)	-22 (-30)	-22 (-30)	-22 (-30)	-58 (-50)	ASTM D1356
	Operating Temperature Range, °F (°C)	-22 to +257 (-30 to + 125)	-22 to +257 (-30 to + 125)	-22 to +257 (-30 to + 125)	-22 to +257 (-30 to + 125)	-58 to +302 (-50 to +150)	--
Thermal	Thermal Impedance °C-in^2 / W (°C-cm^2/W) @ 300psi	1.2 (7.7)	0.30 (2.0)	0.6 (3.7)	0.5 (3.4)	1.0 (6.5)	ASTM D5470
	Thermal Conductivity W/m-K	0.5	1.4	0.4	0.5	0.5	ASTM D5470
Electrical	Voltage Breakdown (kVac)	5	N/A	5	N/A	NA	ASTM D149
	Volume Resistivity, (ohm-cm)	1.0 X 10^{13}	1.0 X 10^{2}	3.0 X 10^{14}	N/A	NA	ASTM D257
Mechanical / Adhesion	Lap Shear Al-Al @25°C, psi (kPa)	150 (1,034)	70 (480)	100 (689)	100 (689)	40 (270)	ASTM D1002
	90° Peel Adhesion to 0.002" aluminum foil, lbf /in (N/cm)	4.0 (6.9)	1.0 (1.76)	1.5 (2.6)	1.5 (2.6)	2.0 (3.5)	ASTM D1000
	Die Shear Adhesion after 400 psi attachment, kPa (psi) – 2 hour sample dwell time 77°F (25°C)	150 (1,034)	135 (931)	130 (897)	125 (862)	110 (759)	Chomerics # 54
	Creep Adhesion, days 77°F (15°C) 302°F (125°C)	>50 >10	>50 >10	>50 >10	>50 >10	>50 >10	PSTC-7
Regulatory	Flammability Rating (See UL File E140244)	V-0	Not Tested	V-0	V-0	Not Tested	UL94
	RoHS Compliant	Yes	Yes	Yes	Yes	Yes	Chomerics Certification
	Shelf-Life, months from shipment	12	12	12	12	12	Chomerics
	Outgassing, % TML (% CVCM)	Not Tested	0.14 (0.00)	0.56 (0.02)	0.25 (0.01)	Not Tested	ASTM E595

Ordering Information

These attachment tapes are available in the following formats.
Contact Chomerics for custom widths, part sizes, etc.

Sheets form, roll form, or die-cut parts. Offered on continuous rolls.
A general ordering information table is included below for reference.

Part Number: 6W – XX – YYYY – ZZZZ

6W	XX	YYYY	ZZZZ
W = 0 (Standard Part)	XX = 13 for PSA two sides	YYYY = 4 digit alpha/numeric part number. Contact Chomerics.	Material Type ZZZZ = T405 T405-R T411 T412 T418
W = 7 (Roll of material)	XX = 10 (100 foot roll) XX = 40 (400 foot roll)	YYYY = 0600 for 6" wide YYYY = 1000 for 10" wide YYYY = 1150 for 11 ½" wide YYYY = 2400 for 24" wide (other sizes available. Contact Chomerics)	
W = 9 (Custom part)	XX = 13 for PSA two sides	YYYYY = Custom Part Number. Contact Chomerics	

Handling Information

These products are defined by Chomerics as "articles" according to the following generally recognized regulatory definition for articles:

An article is a manufactured item "formed to a specific shape or design during manufacturing," which has "end use functions" dependent upon its size and shape during end use and which has generally "no change of chemical composition during its end use."

In addition:

- There is no known or anticipated exposure to hazardous materials/substances during routine and anticipated use of the product.
- The product's shape, surface, and design is more relevant than its chemical composition.

These materials are not deemed by Chomerics to require an MSDS. For further questions, please contact Chomerics at 781-935-4850.

Materials Needed

- Clean lint-free cloth rag
- Industrial solvent
- Rubber gloves

For optimal performance, Chomerics recommends interface flatness of 0.001 in/in (0.025 mm/25 mm) to 0.002 in/in (0.050 mm/25 mm) maximum.

Step 1: Ensure that bonding surfaces are free from oil, dust, or any contamination that may affect bonding. Using rubber gloves, wipe surfaces with a cloth dampened with industrial solvents such as MEK, toluene, acetone or isopropyl alcohol.

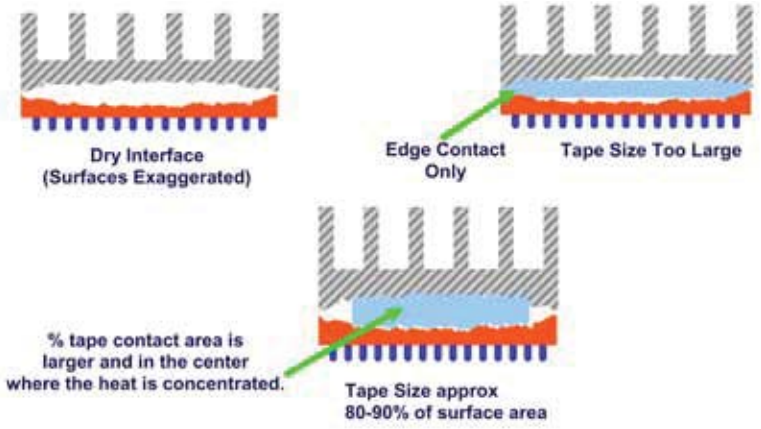
Step 2: Cut tape to size* and remove a liner or remove pre-cut tape from roll.

*Note: Due to variations in heat sink surfaces, Chomerics' data indicates that it sometimes is beneficial to be cut slightly smaller than the area of the heat sink. See illustration.

Step 3: Apply to center of heat sink bonding area and smooth over entire surface using moderate hand pressure / rubbing motion. A roller may be useful to help smooth the part to the surface by rolling from the center out to beyond the edges of the part. This ensures optimal contact between tape and heat sink.

Step 4: Center heat sink onto component and apply using any one of the recommended temperature/ pressure options:

More pressure equals better wetting out of the adhesive to the contact surfaces. A twisting motion during assembly of the substrates will typically improve wetting.



Minimum: 10 psi at room temperature for 15 seconds

PREFERRED: 30 psi at room temperature for 5 seconds

Note that typically 70% of the ultimate adhesive bond strength is achieved with initial application, and 80-90% is reached within 15 minutes. Ultimate adhesive strength is achieved within 36 hours; however the next manufacturing step can typically occur immediately following the initial application.

Removal Instructions

Materials needed: Single-edged razor blade or a small, thin-bladed pocketknife; soft, thin metal spatula. Use safety precautions when handling sharp instruments and organic solvents.

Step 1: Carefully insert the blade edge into the bond line at a corner between the heat sink and the component. The penetration need not be very deep.

Step 2: Remove the blade and insert the spatula into the wedge. Slowly twist the spatula blade so that it exerts a slight upward pressure.

Step 3: As the two surfaces start to separate, move the spatula blade deeper into the bond line and continue the twisting motion and upward force.

Step 4: After the two components are separated, the tape can be removed and discarded. If adhesive remains on the component surfaces, it must be removed. Wipe with a clean rag (lint-free) dabbed with MEK, toluene, or isopropyl alcohol. Use sufficient solvent to remove all adhesive.

Step 5: Solvent cleaned components must be verified 100% free of cleaning solvent prior to reattachment of adhesive.

Relative Thermal Performance

Thermally Conductive Attachment Tapes

	Typical Properties	T418	T412	T404 / T414	T405 / T405-R	T411
Performance*	Ceramic Attachment	5	3	4	4	4
	Metal Attachment	5	3	4	4	4
	Plastic Attachment	N/R	N/R	N/R	N/R	5
	Dielectric Performance	3	N/R	5	N/R	N/R
	Thermal Performance	2	5	3	4	2

* Performance rated on a scale of 1-5, 5 being the best. N/R = Not Recommended.

THERM-A-FORM™ T64x and 164x Series

Cure-in-Place Potting and Underfill Materials

Description

THERM-A-FORM™ thermally conductive silicone elastomer products are dispensable form-in-place compounds designed for heat transfer without excessive compressive force in electronics cooling applications. These versatile liquid reactive materials can be dispensed and then cured into complex geometries for cooling of multi-height components on a PCB without the expense of a molded sheet. Each compound is available in ready-to-use cartridge systems, eliminating weighing, mixing, and degassing procedures.

THERM-A-FORM™ Cure-in-Place Potting and Underfill Materials

	Typical Properties	T647	T646	T644	T642	1642	1641	Test Method
Physical	Color	Gray	Yellow	Pink	Blue	Purple	White	Visual
	Binder	Silicone	Silicone	Silicone	Silicone	Silicone	Silicone	--
	Filler	Aluminum Oxide	Aluminum Oxide	Boron Nitride	Boron Nitride	Aluminum Oxide	Aluminum Oxide	--
	Number of Components	2-part	2-part	2-part	2-part	2-part	1-part	--
	Mix Ratio	1 : 1	1 : 1	1 : 1	10 : 1	100 : 3	N/A	--
	Specific Gravity	2.80	2.45	1.45	1.50	2.30	2.10	ASTM D792
	Hardness, Shore A	25	50	15	70	76	56	ASTM D2240
	Viscosity, poise	> 5000	> 5000	3000	2500	2500	3000	ASTM D2196
	Pot Life, minutes	300	300	360	60	60	30	Time to 2X Starting Viscosity at 23 °C
	Cure Cycles	3 min. @ 150 °C 60 min. @ 60 °C 48 hrs. @ 23 °C	3 min. @ 150 °C 60 min. @ 60 °C 48 hrs. @ 23 °C	3 min. @ 150 °C 60 min. @ 60 °C 72 hrs. @ 23 °C	3 min. @ 150 °C 30 min. @ 70 °C 48 hrs. @ 23 °C	60 min. @ 100 °C 4 hrs. @ 65 °C 1 week @ 23 °C	48 hrs. @ 23 °C @ 50% RH	Chomerics
	Brittle Point, °F (°C)	-67 (-55)	-67 (-55)	-67 (-55)	-67 (-55)	-103 (-75)	-103 (-75)	ASTM D2137
	Extractable Silicone, %	4	8.5	15	1 - 2	Not Tested	Not Tested	Chomerics
Thermal	Thermal Conductivity, W/m-K	3.00	0.90	1.20	1.20	0.95	0.90	ASTM D5470
	Heat Capacity, J/g-K	0.9	1.0	1.0	1.0	1.0	1.0	ASTM E1269
	Coefficient of Thermal Expansion, ppm/K	150	250	300	300	200	150	ASTM E831
	Operating Temperature Range, °F (°C)	-58 to 302 (-50 to 150)	-58 to 302 (-50 to 150)	-58 to 302 (-50 to 150)	-58 to 302 (-50 to 150)	-94 to 392 (-70 to 200)	-94 to 392 (-70 to 200)	--
Electrical	Dielectric Strength, KVac/mm (Vac / mil)	10 (250)	10 (250)	20 (500)	20 (500)	20 (500)	20 (500)	ASTM D149
	Volume Resistivity, ohm-cm	1.0×10^{14}	1.0×10^{14}	1.0×10^{13}	1.0×10^{13}	1.0×10^{13}	1.0×10^{13}	ASTM D257
	Dielectric Constant @1,000 kHz	8	6.5	4.0	4.0	3.9	3.9	ASTM D150
	Dissipation Factor @ 1,000 kHz	0.010	0.013	0.001	0.001	0.010	0.010	Chomerics
Regulatory	Flammability Rating (See UL File E140244)	VO Not Tested	HB	Not Tested	Not Tested	Not Tested	Not Tested	UL 94
	RoHS Compliant	Yes	Yes	Yes	Yes	Yes	Yes	Chomerics Certification
	Outgassing, % TML (%CVCM)	Not Tested	0.17 (0.10)	0.39 (0.29)	0.32 (0.21)	0.40 (0.18)	Not Tested	ASTM E595
	Shelf Life, months from date of manufacture	3	3	3	3	12	6	Chomerics

Features / Benefits

- Dispensable form-in-place gap filling, potting, sealing, and encapsulating
- Excellent blend of high thermal conductivity, flexibility, and ease of use
- Conformable to irregular shapes without excessive force on components
- Ready-to-use cartridge system eliminates weighing, mixing, and de-gassing steps
- Variety of kit sizes and configurations available to suit any application (handheld twin-barrel cartridges, Semco® tubes, and pneumatic applicators)
- Vibration damping

Product Attributes

1641

- One-component moisture-cure RTV, supplied with primer 1086 (primer is not required for cure but promotes adhesion)
- Non-acetic acid generating

1642

- General duty, economical thermal solution
- Two-component thermally conductive encapsulant/sealant/caulk/potting compound, supplied with primer 1087. (primer is not required for cure but promotes adhesion)

T642

- High thermal performance with flexibility
- Ideal for underfilling
- Low outgassing

T644

- Very low modulus material for transferring heat from fragile electronic components

T646

- Provides combination of high thermal performance and low cost

T647

- Superior thermal performance while maintaining low modulus
- Flows into complex geometries to maintain intimate contact with components

Application Instructions

35cc and 45cc Kits (See Figure 1)

Push safety latch (A) upward. Insert the pushrod (B) into the applicator with the pushrod gear teeth facing downward. Insert the cartridge (C) into the slots on top of the applicator. Push the retainer clamp (D) down firmly to lock the cartridge in place. Remove the cartridge cap (E) with a 1/4 turn counter-clockwise. Attach the static mixer (F) to the cartridge. (For the 10:1 cartridge, make certain that the small notch on the mixer tube face is toward the large barrel containing Part A.) Turn the mixer tube 1/4 turn clockwise to lock it in place. Cut the tip of the mixing nozzle to obtain the desired bead size, or attach a needle with the Luer adapter. After use, discard the static mixer and replace the cap on any remaining material.

Ordering Information

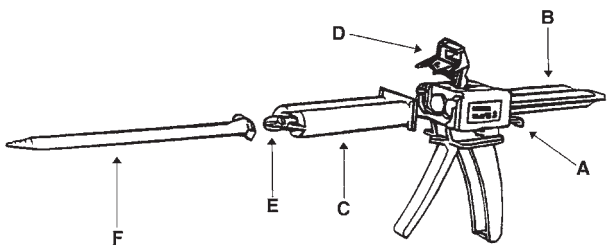


Figure 1: Typical Applicator

Mixpac® Dispensing Systems are available from multiple sources. When contacting Mixpac® equipment suppliers, reference cartridge volume (cc) and dual element cartridge A:B mix ratio. Refer to table for volume and mix ratio information.

Product	Part Number	Volume (mass)	Description
1641	65-00-1641-0000	2.5 fluid ounces (70 grams)	1-Component squeeze tube
	65-01-1641-0000	12 fluid ounces (340 grams)	1-Component SEMCO® cartridge
1642	65-00-1642-0000	277 grams (approx 120 cc)	1-Pint Plastic jar A / vial of B
T642	65-00-T642-0035	35 cc (53 grams)	10:1 Dual element Cartridge
	65-00-T642-0250	250 cc (372 grams)	
T644	65-00-T644-0045	45 cc (68 grams)	1:1 Dual element Cartridge
	65-00-T644-0200	200 cc (300 grams)	
T646	65-00-T646-0045	45 cc (115 grams)	
	65-00-T646-0200	200 cc (507 grams)	
T647	65-00-T647-0045	45 cc (125 grams)	
	65-00-T647-0200	200 cc (560 grams)	

THERMAL GREASES

High-Performance and General Duty Thermal Greases

Description

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.

The excellent surface wetting results in low interfacial resistance.

- **T670** is offered with a very high bulk thermal conductivity of 3 W/m-K. Product offers low impedance as it will achieve a thin bondline of about 0.001 in.
- **T660** contains solder fillers for extremely low thermal impedance at thinner bondline thicknesses (down to about 0.001in.).
- **T650** is a general duty grease for typical applications.

Features/Benefits

- Silicone based materials conduct heat between a hot component and a heat sink or enclosure
- Fills interface variable tolerances in electronics assemblies and heat sink applications
- Dispensable, highly conformable materials require no cure cycle, mixing or refrigeration
- Thermally stable and require virtually no compressive force to deform under typical assembly pressures
- Supports high power applications requiring material with minimum bond line thickness and high conductivity
- Ideal for rework and field repair situations

Thermal Greases					
Typical Properties		**T650**	**T660**	**T670**	**Test Method**
Physical	Color	Pale Blue	Light Gray	White	Visual
	Specific Gravity	2.3	2.4	2.6	ASTM D792
	Viscosity, cps	190,000	170,000	350,000	NA
	Operating Temperature Range, ºF (ºC)	-58 to 392 (-50 to +200)	-58 to 392 (-50 to +200)	-58 to 392 (-50 to +200)	NA
	Phase Transition Temperature, °F (°C)	N/A	144 (62)	N/A	ASTM D3418
	Weight Loss % @150°C, 48 Hours	0.21	0.17	< 0.2	TGA
Thermal	Thermal Conductivity, W/m-K	0.8	0.9	3.0	ASTM D5470
	Thermal Impedance,°C-in²/W (°C-cm²/W) @ 100 psi	0.02 (0.13) @ 50°C 0.02 (0.13) @ 65°C	0.02 (0.13) @ 50°C 0.009 (0.06) @ 65°C	0.01 (0.07) @ 50°C 0.01 (0.07) @ 65°C	ASTM D5470
	Heat Capacity, J/g-K	1	1	1	ASTM E1269
	Coefficient of Thermal Expansion, ppm/K	300	300	150	ASTM E831
Electrical	Volume Resistivity, ohm-cm	10^{14}	N/A	10^{14}	ASTM D257
	Voltage Breakdown Vac/mil	150*	N/A*	150*	ASTM D149
Regulatory	Flammability Rating	Not Tested	Not Tested	Not Tested	UL 94
	RoHS Compliant	Yes	Yes	Yes	Chomerics Certification
	Outgassing, % TML	0.21	0.17	<0.2	ASTM E595
	Shelf Life, months from date of manufacture	24	24	24	Chomerics

*Not recommended for dielectric applications.

Thermal Greases

Typical Applications

- Mobile, desktop, server CPUs
- Engine and transmission control modules
- Memory modules
- Power conversion equipment
- Power supplies and UPS
- Power semiconductors

Product Attributes

T670 Highest Thermal Performance

- High bulk thermal conductivity
- Extremely low thermal impedance at thin and thick bondline thicknesses
- Stencil screen printed part application

T660 High Performance

- Dispersed solder spheres for high performance applications above 62°C
- Excellent thin bondline performance (less than 0.002 - 0.003 in)

T650 General Duty

- Used on general purpose applications

Material Application

T650

Material is supplied in 3, 15 or 30cc syringes for easy dispensing onto components or heat sinks. Bulk packaging is also available. Excess material can be wiped with a clean cloth and suitable solvent.

T660

Packaging the same as T650. For optimum performance, the processor should be allowed to reach temperatures greater than 65°C (149°F). This causes the solder fillers to melt and conform to the mating surfaces, obtaining a minimum bondline thickness at the interface. This process only needs to occur one time to achieve optimum thermal performance of the grease.

T670

T670 high performance thermal grease is supplied in easy access metal cans or pails. Mix with a spatula and remove the desired amount onto the component or stencil screen. Stencil desired pad part size onto heat sink for immediate assembly or shipping.

Ordering Information

Part Number Examples
65-00-T650-0003 = T650 Material in a 3 cc Syringe
65-00-T670-3790 = T670 Material in a 3790 cc (Gallon Pail)

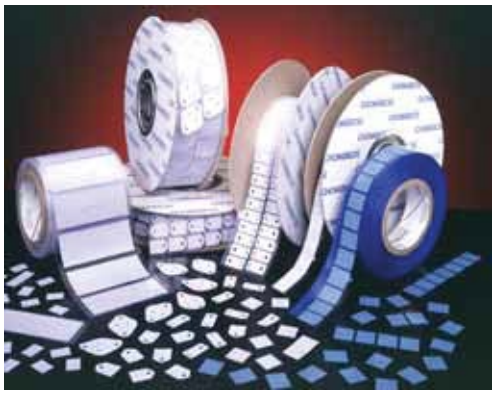
Part Number:

65 – 00 – YYYY – ZZZZ

YYYY	ZZZZ
YYYY = Material (T670, T660 , or T650)	ZZZZ = Volume in cc 0003 = 3 cc syringe 0015 = 15 cc syringe 0030 = 30 cc syringe 0300 = 300 cc cartridge 3790 = 1 gallon pail

CHO-THERM®

Commercial Grade Thermally Conductive Electrical Insulator Pads



Description

CHO-THERM®Commercial Grade Thermal Insulator Pads are designed for use where solid thermal and electrical properties are required at an economical price. These products are offered as dry pads, or with an optional adhesive (PSA) layer for attachment. Materials with PSA are available die-cut on continuous rolls. Versions are offered with either polyimide or fiberglass reinforcement to protect pads against tear, cut-through and punctures.

Features / Benefits

- Good thermal properties
- Good to excellent dielectric strength
- Excellent mechanical strength and puncture resistance
- Available with and without acrylic PSA
- UL recognized V-0 flammability rating
- Meet RoHS specifications
- Available on continuous rolls for easy peel and stick application

CHO-THERM® Commercial Grade Thermal Insulator Pads								
Properties		**T609**	**T444**	**1674**	**T441**			**Method**
Physical	Color	Lt. Green	Beige	Blue	Pink			Visual
	Reinforcement Carrier	Fiberglass	Kapton® MT	Fiberglass	Fiberglass			Visual
	Thickness, inch (mm)	0.010 (0.25)	0.003 (0.08)	0.010 (0.25)	0.008 (0.20)	0.013 (0.33)	0.018 (0.46)	ASTM D374
	Thickness Tolerance, inch (mm)	0.001 (± 0.025)	0.0005 (± 0.013)	0.001 (± 0.025)	0.001 (± 0.025)	0.001 (± 0.025)	0.001 (± 0.025)	--
	Operating Temperature Range, °F (°C)	-40 to +392 (-40 to +200)	-40 to +392 (-40 to +200)	-40 to +392 (-40 to +200)	-40 to +392 (-40 to +200)	-40 to +392 (-40 to +200)	-40 to +392 (-40 to +200)	--
Thermal	Thermal Impedance, °C-in²/W (°C-cm² / W) @ 300 psi*	0.33 (2.1)	0.37 (2.4)	0.41 (2.6)	0.41 (2.6)	0.56 (3.6)	0.64 (4.1)	ASTM D5470
	Thermal Conductivity, W/m-K	1.5	0.4	1.0	1.1	1.1	1.1	ASTM D5470
	Heat Capacity, J/g-°C	1.0	1.0	1.0	1.0	1.0	1.0	ASTM E1296
	Coefficient of Thermal Expansion, ppm/°C	150	400	300	300	300	300	ASTM E831
Electrical	Voltage Breakdown Dry, Vac	4,000	5,000	2,500	8,700	11,400	13,800	ASTM D149
	Voltage Breakdown Wet, Vac	Not Tested	Not Tested	Not Tested	8,100	10,500	12,900	ASTM D149
	Volume Resistivity Dry, ohm-cm	10^{14}	10^{14}	10^{14}	10^{14}	10^{14}	10^{14}	ASTM D257
	Volume Resistivity Wet, ohm-cm	Not Tested	Not Tested	Not Tested	10^{14}	10^{14}	10^{14}	ASTM D257
Mechanical	Tensile Strength, psi (Mpa)	3,900 (26.9)	3,000 (20.7)	1,500 (10.3)	2,800 (19.3)	2,500 (17.3)	2,000 (13.8)	ASTM D412
	Tear Strength, lb/in (kN/m)	300 (52.5)	150 (26.3)	100 (17.5)	135 (23.6)	110 (19.3)	70 (12.25)	ASTM D642
	Elongation, %	30	NA	2	40	40	40	ASTM D412
	Hardness, Shore A	70	90	85	80	80	80	ASTM D2240
	Specific Gravity	2.10	1.70	2.45	2.45	2.45	2.45	ASTM D792
Regulatory	Flammability Rating (See UL File E140244)	V-0	V-0	V-0	V-0	V-0	V-0	UL94
	RoHS Compliant	Yes	Yes	Yes	Yes	Yes	Yes	Chomerics Certification
	Outgassing, % TML (%CVCM)	Not Tested	Not Tested	0.45 (0.20)	Not Tested	Not Tested	Not Tested	ASTM E595
	Shelf-Life, months from shipment, Dry Pad (with PSA)	24 (6)	12 (12)	24 (12)	24 (12)	24 (12)	24 (12)	Chomerics

KAPTON is a trademark of E.I. DuPont de Nemours and Company.
*Tested without PSA. PSA typically adds 0.05 °C-in²/W (0.30 °C-cm²/W)

Typical Applications

- Power conversion equipment
- Power supplies and UPS
- Power semiconductors
- Automotive electronics
- Motor and engine controllers
- Televisions and consumer electronics

Product Attributes

T609

- Good thermal and dielectric properties
- Economically priced
- Best value for moderate to high performance pad
- PSA version available in economical kiss-cut format on continuous rolls

T441

- Superior dielectric strength (wet and dry)
- Economically priced
- Excellent for outdoor, high-humidity power supplies
- PSA version available in economical kiss-cut format on continuous rolls

1674

- Original commercial grade pad with good thermal and electrical performance
- Available in economical kiss-cut format on continuous rolls (with and without PSA)
- Passes NASA outgassing

T444

- Non-silicone with excellent dielectric and mechanical strength (polyimide interlayer)
- Strong acrylic adhesive (one side)
- Available in economical kiss-cut format on continuous rolls

Handling Information

These products are defined by Chomerics as "articles" according to the following generally recognized regulatory definition for articles:

An article is a manufactured item "formed to a specific shape or design during manufacturing," which has "end use functions" dependent upon its size and shape during end use and which has generally "no change of chemical composition during its end use."

In addition:

- There is no known or anticipated exposure to hazardous materials/substances during routine and anticipated use of the product.
- The product's shape, surface, and design is more relevant than its chemical composition.

These materials are not deemed by Chomerics to require an MSDS. For further questions, please contact Chomerics at 781-935-4850.

Ordering Information

Thermal insulator pads are available in the following formats.
Contact Chomerics for custom widths, part sizes, etc.

Die-cut parts on continuous rolls
Slit rolls from ½" wide to 24" wide
Custom die-cut parts on sheets, or as individual parts

Part Number: 6W — XX — YYYY — ZZZZ

6W	XX	YYYY	ZZZZ
W = 0 Standard die-cut Part	11 = without PSA 12 = with PSA one side	YYYY = For standard die-cut parts, please see tables on pages 37 to 39	ZZZZ = Material class (1674, T441, T444, T609)
W = 4 Roll Stock W = 6 Roll Stock with PSA	10= 100 ft Roll Stock 40 = 400 ft Roll Stock	0075= 0.75 in 0100= 1.00 in 0150= 1.50 in 0200= 2.00 in 1150 = 11.5 in. 2400 = 24 in. (T444*) 0800 = 8 in. 1600 = 16 in. (1674*) 1100 = 11 in. 2200 = 22 in. (7441*)	
W = 9 Custom die-cut part	11 = without PSA 12 = with PSA one side	YYYY = Custom Part Number. Contact Chomerics	

* Standard bulk roll width

CHO-THERM®

High Power Thermally Conductive Electrical Insulator Pads

Description

CHO-THERM® HIGH-POWER THERMAL INSULATOR PADS are thermally conductive materials designed for use where the highest possible thermal, dielectric, and mechanical properties are required.

Fiberglass cloth reinforcement strengthens CHO-THERM® pads against tear, cut-through and punctures.

These materials are available in sheet form and die-cut configurations. An optional acrylic adhesive layer (with PSA) is available on one or two sides. With a proven track record spanning several decades in multiple applications, these products are the first choice for high-end power supplies, industrial, aerospace, and military/avionics applications.

Available in several different forms to suit various applications.

Features / Benefits

- Excellent thermal properties
- High dielectric strength
- Excellent mechanical strength and puncture resistance

CHO-THERM® High Power Insulator Pads					
	Typical Properties	**T500**	**1678**	**1671**	**Method**
Physical	Color	Green	Pink	White	Visual
	Reinforcement Carrier	Fiberglass	Fiberglass	Fiberglass	--
	Thickness, inch (mm)	0.010 (0.25)	0.010 (0.25)	0.015 (0.38)*	ASTM D374
	Thickness Tolerance, inch (mm)	± 0.002 (0.050)	± 0.002 (0.050)	± 0.002 (0.050)	--
	Operating Temperature Range, °F (°C)	-40 to +392 (-40 to +200)	-40 to +392 (-40 to +200)	-40 to +392 (-40 to +200)	--
Thermal	Thermal Impedance, °C-in²/W (°C-cm² / W) @ 300 psi**	0.19 (1.2)	0.20 (1.26)	0.23 (1.48)	ASTM D5470
	Thermal Conductivity, W/m-K	2.1	2.0	2.6	ASTM D5470
	Heat Capacity (J/g-°C)	1.0	1.0	1.0	ASTM E1269
	Coefficient of Thermal Expansion (ppm/K)	250	250	250	ASTM E831
Electrical	Voltage Breakdown Dry, (Vac)	4,000	2,500	4,000	ASTM D149
	Volume Resistivity Dry, (ohm-cm)	10^{16}	10^{16}	10^{16}	ASTM D149
	Dielectric Constant at 1,000 kHz	3.5	3.6	3.6	ASTM D150
	Dissipation Factor at 1,000 kHz	0.003	0.007	0.007	Chomerics Test
Mechanical	Tensile Strength, psi (Mpa)	3,000 (20.7)	3,000 (20.7)	3,000 (20.7)	Chomerics
	Tear Strength, lb/in (kN/m)	400 (70)	200 (35)	400 (70)	Chomerics
	Elongation, %	20	20	15	Chomerics
	Hardness, Shore A	80	80	80	ASTM D2240
	Specific Gravity	1.60	1.55	1.55	ASTM D792
Regulatory	Flammability Rating (See UL File E140244)	V-0	V-0	HB	UL 94
	RoHS Compliant	Yes	Yes	Yes	Chomerics Certification
	Outgassing, % TML (%CVCM)	0.40 (0.10)	0.55 (0.12)	0.76 (0.07)	ASTM E595
	Shelf-Life, months from shipment, Dry Pad (with PSA)	24 (18)	24 (18)	24 (18)	Chomerics

* 1671 material is available in custom thicknesses.
** Tested without PSA. PSA typically adds 0.05 °C-in²/W (0.30 °C-cm²/W)

Features/Benefits...cont.

- 100% inspected for dielectric properties on every sheet
- Acrylic PSA attachment option available
- UL recognized flammability ratings
- Meets RoHS specifications
- Extremely low NASA outgassing
- Proven through decades of use in demanding military and aerospace applications

Typical Applications

- Power conversion equipment
- Power supplies and UPS
- Power semiconductors
- Automotive electronics
- Motor and engine controllers
- Televisions and consumer electronics

Product Attributes

T500

- Best thermal performance
- Excellent dielectric properties

1671

- Highest reliability in rigorous applications
- Proven in aerospace/defense applications

1678

- Economically-priced
- Low thermal impedance

Handling Information

These products are defined by Chomerics as "articles" according to the following generally recognized regulatory definition for articles:

An article is a manufactured item "formed to a specific shape or design during manufacturing," which has "end use functions" dependent upon its size and shape during end use and which has generally "no change of chemical composition during its end use."

In addition:

- There is no known or anticipated exposure to hazardous materials/substances during routine and anticipated use of the product.
- The product's shape, surface, and design is more relevant than its chemical composition.

These materials are not deemed by Chomerics to require an MSDS. For further questions, please contact Chomerics at 781-935-4850..

Ordering Information

Thermal insulator pads are available in the following formats.
Contact Chomerics for custom widths, part sizes, etc.

Sheets 8" X 10" or 17" X 21"
Custom die-cut parts on sheets, or as individual parts

Part Number: 6W — XX — YYYY — ZZZZ

W	XX	YYYY	ZZZZ
W = 0 Standard die-cut part	11 = without PSA 12 = with PSA one side 13 = PSA 2 Sides	YYYY = Custom 4- part alpha/numeric part number. See pages 37 to 39 or contact Chomerics.	ZZZZ = Material class (T500, 1671, or 1678)
W = 1 Sheet stock W = 2 Sheet stock with PSA 1 Side W = 3 Sheet stock with PSA 2 Sides	XX = material thickness in mils (1671 material available up to 60 mils)	0808 = 8" X 8" Sheet 0810 = 8" X 10" Sheet	
W = 9 Custom die-cut part	11 = without PSA 12 = with PSA one side 13 = with PSA both sides	YYYY = Custom Part Number. Contact Chomerics	

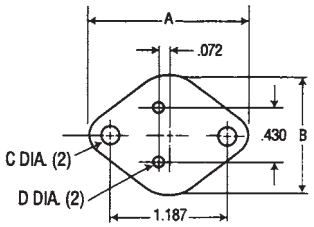
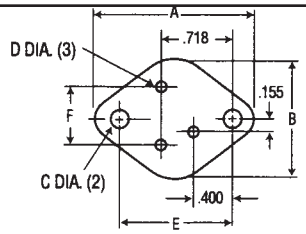
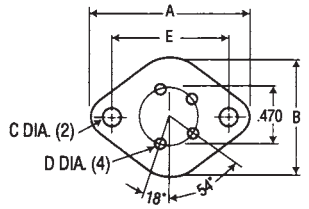
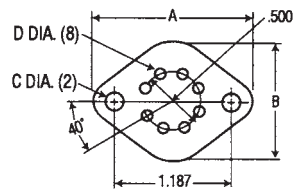
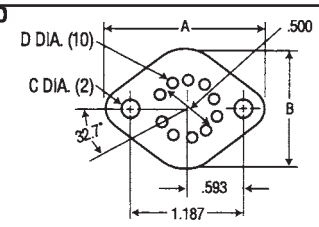
How to Order Die-Cut CHO-THERM® Insulators

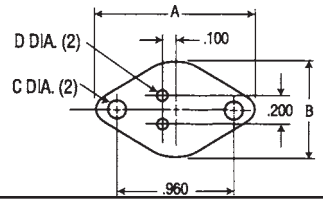
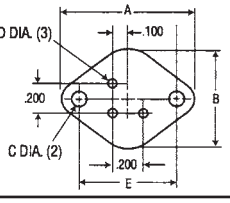
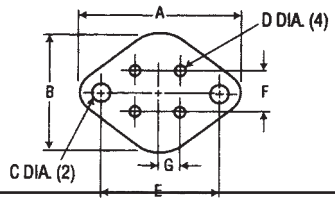
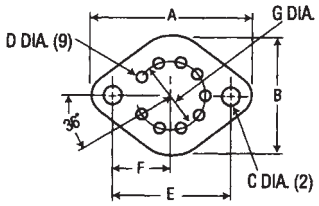
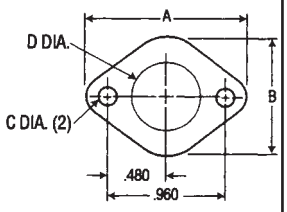
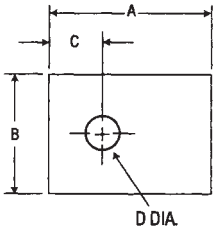
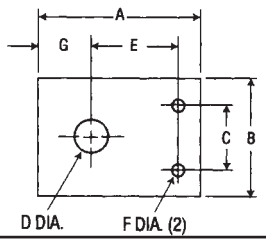
Thermattach Tapes & Reinforced Therm-A-Flow Products

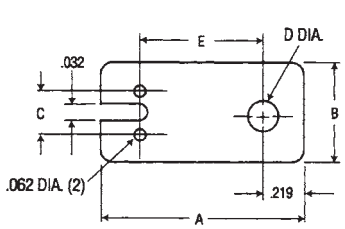
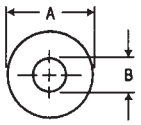
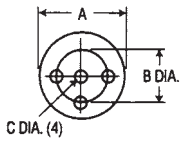
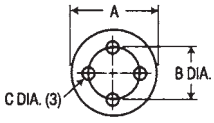
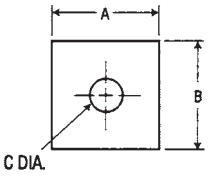
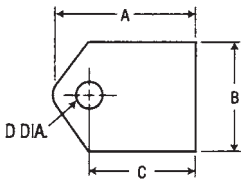
Standard die-cut parts are ordered using the following part number system. For custom parts, contact Chomerics.

Part Number: 60 – XX – YYYY – ZZZZ

- 60 = standard die cut part
- XX: 11 = No PSA; 12 = PSA one side; 13 = PSA both sides
- YYYY: Standard Configuration Drawing Number
- ZZZZ: CHO-THERM® Material Example: 1671, T500, etc.

Recommended Screw Torque	Configuration	Dimensions (inches)							Ordering Number
		A	B	C	D	E	F	G	
#4-40 5 in-lb #6-32 6 in-lb	**TO-3** 	1.563 1.563 1.593 1.650 1.650 1.650 1.650 1.650 1.650 1.700 1.730 1.780 1.780 1.780 2.07	1.050 1.050 1.100 1.065 1.140 1.140 1.140 1.140 1.140 1.187 1.250 1.250 1.250 1.250 1.56	0.140 0.140 0.156 0.140 0.122 0.140 0.165 0.140 0.165 0.156 0.156 0.140 0.165 0.140 0.122	0.080 0.140 0.070 0.046 0.062 0.093 0.062 0.046 - 0.062 0.062 0.093 0.094 0.046 0.062				WW-XX-D065-ZZZZ WW-XX-4305-ZZZZ WW-XX-4511-ZZZZ WW-XX-D370-ZZZZ WW-XX-D371-ZZZZ WW-XX-6875-ZZZZ WW-XX-D372-ZZZZ WW-XX-D373-ZZZZ WW-XX-D374-ZZZZ WW-XX-4996-ZZZZ WW-XX-5442-ZZZZ WW-XX-D375-ZZZZ WW-XX-D376-ZZZZ WW-XX-D377-ZZZZ WW-XX-D378-ZZZZ
#4-40 5 in-lb #6-32 6 in-lb	**3 LEAD TO-3** 	1.65	1.140	0.140	0.093	1.187	0.430		WW-XX-D379-ZZZZ
#4-40 5 in-lb #6-32 6 in-lb	**4 LEAD TO-3** 	1.560 1.563	1.050 1.050	0.158 0.156	0.080 0.063	1.170 1.187			WW-XX-D380-ZZZZ WW-XX-D381-ZZZZ
#4-40 5 in-lb #6-32 6 in-lb	**8 LEAD TO-3** 	1.650	1.187	0.156	0.60				WW-XX-D382-ZZZZ
#4-40 5 in-lb #6-32 6 in-lb	**10 LEAD TO-3** 	1.650	1.140	0.165	0.040				WW-XX-D383-ZZZZ

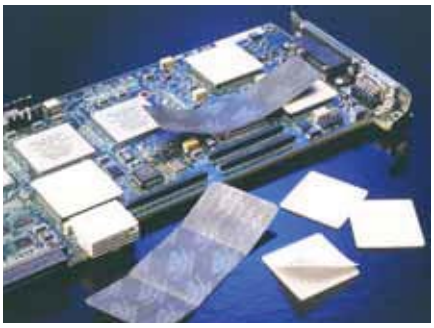
Recommended Screw Torque	Configuration	Dimensions (inches)							Ordering Number
		A	B	C	D	E	F	G	
#4-40 3 in-lb #6-32 4 in-lb	**TO-66** 	1.250 1.312 1.375 1.440	0.700 0.762 0.825 1.000	0.140 0.140 0.140 0.140	0.062 0.062 0.062 0.075				WW-XX-4353-ZZZZ WW-XX-5527-ZZZZ WW-XX-4997-ZZZZ WW-XX-D384-ZZZZ
#4-40 3 in-lb #6-32 4 in-lb	**3 LEAD TO-66** 	1.275	0.750	0.156	0.100	0.960			WW-XX-D385-ZZZZ
#4-40 3 in-lb #6-32 4 in-lb	**4 LEAD TO-66** 	1.312	0.762	0.140	0.062	0.960	0.200	0.100	WW-XX-D386-ZZZZ
#4-40 3 in-lb #6-32 4 in-lb	**9 LEAD TO-66** 	1.440	1.000	0.140	0.055	0.960	0.480	0.325	WW-XX-D387-ZZZZ
#4-40 3 in-lb #6-32 4 in-lb	**MULTI LEAD TO-66** 	1.35	0.800	0.140	0.400				WW-XX-D388-ZZZZ
#4-40 2 in-lb	**TO-220** 	0.437 0.437 0.500 0.610 0.687 0.710 0.750 0.750 0.750 0.750 0.750 0.750 0.855 0.855 0.860 1.125 1.410	0.312 0.312 0.385 0.560 0.562 0.500 0.410 0.500 0.500 0.500 0.600 0.600 0.562 0.630 0.740 0.625 0.810	0.140 0.140 0.170 0.245 0.218 0.160 0.225 --- 0.187 0.187 0.240 0.240 0.218 0.230 0.200 0.200 0.355	0.093 0.122 0.120 0.125 0.125 0.141 0.156 --- 0.147 0.125 0.150 0.115 0.125 0.093 0.160 0.145 0.147				WW-XX-D389-ZZZZ WW-XX-D390-ZZZZ WW-XX-D391-ZZZZ WW-XX-D392-ZZZZ WW-XX-5791-ZZZZ WW-XX-8302-ZZZZ WW-XX-D393-ZZZZ WW-XX-8531-ZZZZ WW-XX-6956-ZZZZ WW-XX-D394-ZZZZ WW-XX-D395-ZZZZ WW-XX-D396-ZZZZ WW-XX-D397-ZZZZ WW-XX-D398-ZZZZ WW-XX-D399-ZZZZ WW-XX-D400-ZZZZ WW-XX-D401-ZZZZ
#4-40 2 in-lb		0.910 0.983	0.500 0.750	0.200 0.432	0.125 0.156	0.580 0.665	0.046 0.101	0.265 0.217	WW-XX-402-ZZZZ WW-XX-D403-ZZZZ

Recommended Screw Torque	Configuration	Dimensions (inches)							Ordering Number
		A	B	C	D	E	F	G	
#4-40 2 in-lb	**TYPE II TO-220** 	1.00	0.500	0.200	0.141	0.626			WW-XX-4969-ZZZZ
#10-32 2 in-lb #25-28 7 in-lb	DIODE WASHERS DO-4  DO-5	0.360 0.510 0.510 0.512 0.625 0.750 0.800 0.800 0.812 0.812 0.875 1.000 1.000 1.180 1.250 1.500 1.500	0.260 0.140 0.200 0.161 0.195 0.125 0.190 0.260 0.115 0.145 0.313 0.140 0.255 0.515 0.380 0.200 0.500						WW-XX-D404-ZZZZ WW-XX-D405-ZZZZ WW-XX-D406-ZZZZ WW-XX-D407-ZZZZ WW-XX-4659-ZZZZ WW-XX-D408-ZZZZ WW-XX-D409-ZZZZ WW-XX-D410-ZZZZ WW-XX-D411-ZZZZ WW-XX-D412-ZZZZ WW-XX-D413-ZZZZ WW-XX-D414-ZZZZ WW-XX-4661-ZZZZ WW-XX-D415-ZZZZ WW-XX-D416-ZZZZ WW-XX-D417-ZZZZ WW-XX-D418-ZZZZ
	TO-36 	1.063	0.690	0.200					WW-XX-4306-ZZZZ
	TO-5 and TO-18 3 holes 4 holes 	0.250 0360 0.390 0.250 0.360 0.390	0.100 0.200 0.200 0.100 0.200 0.200	0.036 0.040 0.040 0.036 0.040 0.040					WW-XX-D419-ZZZZ WW-XX-4374-ZZZZ WW-XX-D420-ZZZZ WW-XX-D421-ZZZZ WW-XX-D422-ZZZZ WW-XX-D423-ZZZZ
#4-40 2 in-lb	RECTIFIER 	1.000 1.125 1.250	1.000 1.125 1.250	0.187 0.140 0.200					WW-XX-D424-ZZZZ WW-XX-D425-ZZZZ WW-XX-D426-ZZZZ
#4-40 2 in-lb	TIP PACKAGE 	0.865 0.865 0.984 0.984 1.260	0.650 0.650 0.787 0.787 0.787	0.650 0.650 --- 0.780 0.984	0.140 0.140 --- 0.142 0.142				WW-XX-5792-ZZZZ WW-XX-D427-ZZZZ WW-XX-D428-ZZZZ WW-XX-D429-ZZZZ WW-XX-D430-ZZZZ

(1 in-lb = 1.152 kg-cm)

T-WING® and C-WING™ Heat Spreaders

Thin Heat Spreaders



Description

Chomerics' family of thin heat spreaders provides a low-cost, effective means of cooling IC devices in restricted spaces where conventional heat sinks are inappropriate.

T-Wing spreaders consist of 5oz. (0.007inch/0.18mm thick) flexible copper foil between electrically insulating films. High strength silicone PSA (pressure-sensitive adhesive) provides a strong bond to the component. The compliant nature of these "thermal wing" heat spreaders permits nearly 100% adhesive contact with non-flat package surfaces, optimizing thermal and mechanical performance.

C-Wing spreaders are a ceramic version available for EMI-sensitive applications. They consist of aluminum oxide substrates with the same silicone PSA used on T-Wing heat spreaders.

Features/Benefits

- Component junction temperature reduction of 10-20°C is common
- Easily added to existing designs to lower component temperatures and improve reliability
- Custom shapes available for complex designs

Typical Applications

- Microprocessors
- Memory modules
- Laptop PCs and other high density, handheld portable electronics
- High speed disk drives

C-Wing

- Used where localized sensitivity to EMI (electromagnetic interference) exists
- Low profile
- Peel and stick application

T- Wings

- Low profile (0.33mm/0.013in) allows use in limited space environments
- Easy peel and stick adhesion to all surfaces, including packages with residual silicone mold release
- Offers low cost cooling for many package types

T-WING® and C-WING™ Heat Spreaders				
	Typical Properties	T-Wings	C-Wings	Test Method
Physical	Color	Black	Tan	Visual
	Total Thicknesses, inches (mm)	0.013 (0.33)	0.060 (1.53)	ASTM D374
	PSA Type	Silicone based	Silicone based	--
	PSA thickness, inches (mm)	0.002 (0.05)	0.003 (0.076)	Visual
	Insulator Type	Black polyester	N/A	--
	Insulator Layer Thickness, inches (mm)	0.001 (0.025)	N/A	--
	Weight, oz/inch^2	0.039	0.076	--
	Themal Conductor	Copper	Aluminum Oxide	--
	Maximum Operating Temperature °F (°C)	257 (125)	257 (125)	--
	Thermal Conductor Thickness, inches (mm)	0.007 (0.178)	0.063 (1.6)	--
Electrical	Dielectric Strength, Vac/mil (KVac/mm)	5,000 (200) for each dielectric layer	300 (12)	ASTM D149
	Volume Resistivity, (ohm-cm)	N/A	>10^{14}	ASTM D149
	Dielectric Constant @1,000 MHz	N/A	9.1	ASTM D150
	Dissipation Factor @ 1,000 kHz	N/A	0.001	Chomerics Test
Regulatory	Flammability Rating (See UL File E140244)	V-0	Not Tested	UL 94
	RoHS Compliant	Yes	Yes	Chomerics Certification
	Shelf Life, months from date of manufacture	12	12	Chomerics

T-Wings Continued...

- Low application force (<5psi/ 0.03MPa) minimizes risk of damage to component
- Available in a range of standard sizes
- Pliable nature allows conformance to concave or otherwise non-flat surfaces for optimal thermal and mechanical performance
- Light weight (0.039 oz/inch2)
- Standard parts are scored for easy forming and alignment
- Easy removal for device replacement
- Available die-cut on continuous rolls

Typical Thermal Properties (Performed on surface of 196 lead 3 Watt PQFP package)				Standard Part Size inches(mm)					
T-Wing	Environment*	Sizes (inches)	Without T-Wing	0.5x2 (12.7x50.8)	0.5x3 (12.7x76.2)	0.75x3 (19.1x76.2)	1x3 (25.4x76.2)	1x4 (25.4x101.6)	1.5x4 (38.1x101.6)
	Restricted Convection**	Thermal Resistance Rj-a (°C/W)	26	25	23	23	22	20	19
		Case Temperature (°C)	92	82	78	76	72	70	68
	100 LFM***	Thermal Resistance Rj-a (°C/W)	18	16	14	14	14	13	12
		Case Temperature (°C)	68	57	52	49	46	44	44
C-Wing	Environment*	Sizes (inches)	Without C-Wing	0.5x2 (12.7x50.8)	0.5x3 (12.7x76.2)	0.75x2 (19.1x76.2)	0.75x3 (19.1x76.2)	1.5x1.5 (38.1x38.1)	N/A
	Restricted Convection**	Case Temperature (°C)	102	96	90	90	87	87	N/A
	100 LFM		85	80	75	76	73	74	N/A

* Measured values do not account for heat losses through bottom of case and leads. Ambient temperature range from 21°C to 24°C
** Restricted convection in a simulated notebook computer environment-a 1x5x6inch (2.54x12.7x15.2cm) plexiglass box
*** T-Wing long axis perpendicular to air flow direction in wind tunnel

Notes
Rj-a = thermal resistance from junction to ambient
LFM = airflow rate (linear feet per minute)

Typical Adhesion Performance

Test	Procedure	Result	Test Method
Lap Shear - Room Temperature	apply/60 min. R.T. dwell/R.T. pull	960 oz/in^2 (414 kPa)	ASTM D1000
Lap Shear - Elevated Temperature	apply/60 min. R.T. dwell/100°C pull	53 oz/in^2 (23 kPa)	ASTM D1000
90° Peel - Room Temperature	apply/1 min. R.T. dwell/R.T. pull	40 oz/in (441 g/cm)	ASTM B571/D2861
90° Peel - Elevated Temperature	apply/60 min. R.T. dwell/100°C pull	20 oz/in (220g/cm)	ASTM B571/D2861
Creep Adhesion, days	275°F (135°C), 7 oz/in^2 (3 kPa), on aluminum	>80 days, no failure	P.S.T.C. No. 7

Environmental Stress Thermal Performance

Environment	Before	After
Heat Aging		
Rj-a (°C/W) Restricted Convection	20.3	20.6
Rj-a (°C/W) 100 LFM	12.7	13.1
High Temperature/Humidity		
Rj-a (°C/W) Restricted Convection	21.4	21.4
Rj-a (°C/W) 100 LFM	14.1	14
Temperature Cycling		
Rj-a (°C/W) Restricted Convection	21.4	21.7
Rj-a (°C/W) 100 LFM	14.1	13.9

Note: Tested with a 1" x 4" (25.4 x 101.6 mm) T-WING

Environmental Stress Adhesive Performance

Environment	90° Peel Strength	
	oz/in	(gm/cm)
Control	36	393
Heat Aging	36	393
High Temperature/Humidity	46	514
Temperature Shock	38	424
Temperature Cycling	30	335

Note: Average of three samples tested per ASTM B571/D2861.

Testing Summary

Summaries of test procedures used for T-Wing heat spreaders are described below. Thermal performance, adhesion strength and visual inspection were used as pass/fail criteria.

Apparatus

Anatek® Thermal Analyzer: The ATA was used to measure Rj-a before and after environmental stressing. **PQFP:** 196 lead, plastic PQFPs known to contain silicone mold release were evaluated. **T-Wing Heat Spreader:** 1 inch x 4 inch TWing parts were applied to the PQFP packages with a 5 psi (0.03 MPa) mounting pressure.

Thermal Performance

Various sizes of T-Wing heat spreaders were applied to a 196 lead PQFP using less than 5 psi (0.03 MPa) bonding pressure. Within 30 minutes of application, the test boards were mounted in an Analysis Tech® thermal analyzer. The devices were heated to equilibrium (45 to 60 minutes) with approximately 3 watt load on 3 x 3 inch (7.6 x 7.6 cm) test boards. Two test environments were used: restricted convention, achieved with a 1 x 5 x 6 inch (2.5 x 12.7 x 15.2 cm) plexiglass box; and 100 LFM (30m/min) air flow. Results were obtained using thermocouples for Tc (centered on case) and Rj-a.

Environmental Stressing

Control: Specimens were maintained for 1000 hours at standard laboratory conditions, 23°C, 35-60% RH.

Heat Aging: Test specimens were placed in a forced convection hot air oven maintained at 150°C ±5°C for 1000 hours. Test specimens were then removed and tested.

Elevated Temperature/High Humidity: Specimens were placed in a humidity chamber maintained at 85°C ±2°C and 90%-0 +10% RH for 1000 hours.

Temperature Cycling: Specimens were subjected to 500 cycles from -50°C to +150°C in a Tenney Temperature Cycling Oven.

Temperature Shock: Specimens were subjected to 100 temperature shocks by immersion into -50° and +150°C liquids. Temperatures were monitored with thermocouples.

Evaluation Procedure

Visual: All test specimens were examined for de-bonding, delamination or other signs that the tape was failing after environmental stress.

Thermal Performance: T-Wing was applied to the PQFP with 5 psi mounting pressure. After a one hour dwell, the Rj-a of each specimen was measured at 100 LFM and under restricted convection conditions. The Rj-a was again measured after environmental stressing.

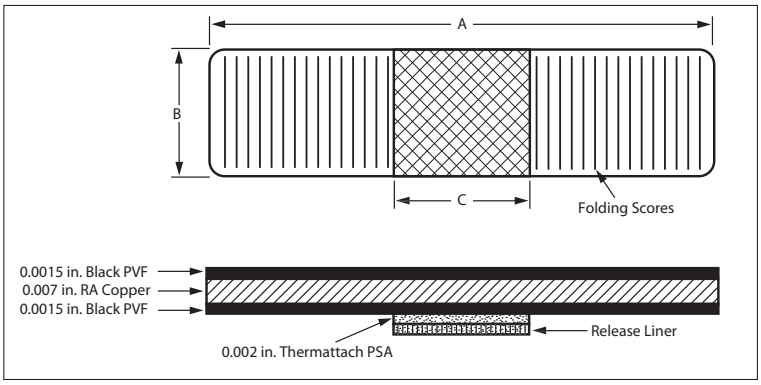
90° Peel Strength: A T-Wing heat spreader was applied to each PQFP with 5 psi mounting pressure. The specimens were subjected to environmental stress and then tested for 90° peel strength at room temperature.

Ordering Information

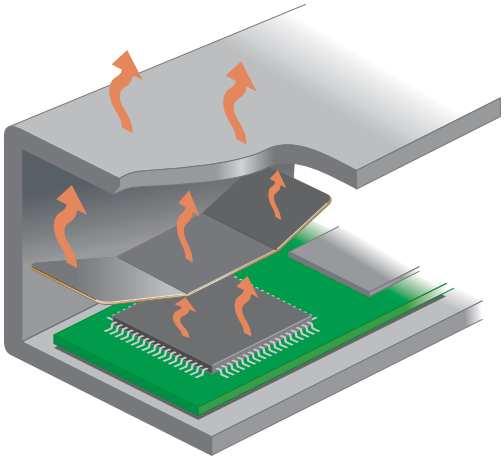
Available in standard sizes 1,000 parts per plastic tray. Also available die-cut on continuous rolls.

Material	Part Numbers	Size (inches/mm)		
		A: Length mm (inches)	**B:** Width mm (inches)	**C:** Adhesive Width mm (inches)
T-Wing	60-12-20264-TW10	50.8 (2.0)	12.7 (0.50)	12.7 (0.50)
	60-12-20265-TW10	76.2 (3.0)	12.7 (0.50)	12.7 (0.50)
	60-12-20266-TW10	76.2 (3.0)	19.1 (0.75)	19.1 (0.75)
	60-12-20267-TW10	76.2 (3.0)	25.4 (1.00)	25.4 (1.00)
	60-12-20268-TW10	101.6 (4.0)	25.4 (1.00)	25.4 (1.00)
	60-12-20269-TW10	101.6 (4.0)	38.1 (1.50)	38.1 (1.50)
C-Wing	69-12-22745-CW10	14.0 (0.55)	20.0 (0.79)	N/A
	69-12-23802-CW10	19.1 (0.75)	19.1 (0.75)	N/A
	69-12-22849-CW10	31.8 (1.25)	31.8 (1.25)	N/A

Figure 1.



Dimensions are typical



Ordering Information

Standard Parts: Refer to table below for Part Numbers and sizes. T-Wing heat spreaders are available in standard packages of 100 parts/pkg.

Custom Parts: Custom configured T-Wing parts are also available. Contact Chomerics' Applications Engineering Department for details.

Results

Visual: There was no visual evidence of T-Wing adhesion failure to the PQFP after the environmental stresses.

Thermal Performance: The before and after thermal resistances are given in Table 4. The data shows that the thermal resistances were essentially unchanged by the exposures.

90° Peel Strength: The results of the peel strength tests are given above. The data shows that the average peel strength actually increases with high temperature/humidity and temperature shock, while remaining unchanged with heat aging and decreasing slightly with temperature cycling.

Application Instructions

Materials needed: Clean cotton cloth or rag, industrial solvent, rubber gloves.

Step 1: For best results, clean the top surface of the component using a lint-free cotton cloth.

Step 2: Wipe the bonding surface of the component with an industrial solvent, such as MEK, acetone or isopropyl alcohol. In the case of a plastic package, select a cleaner that will not chemically attack the plastic substrate. Do not touch the cleaned surface during any part of the assembly process. If the surface has been contaminated, repeat Steps 1 and 2.

Step 3: Remove the clear release liner from the T-Wing part, exposing the pressure-sensitive adhesive (PSA). Avoid touching exposed adhesive with fingers.

Step 4: For best bond strength and contact area, center the exposed PSA onto the component. Press and smooth the entire T-Wing bonding area with firm finger pressure of about 5 psi, for 5 seconds.

Note: Bond strength will increase as a function of time as the adhesive continues to wet out the bonding surface. Increasing any of the application variables (pressure, temperature and time) can improve bonding results.

Thermal Management Glossary

Alumina (Al_2O_3): A relatively inexpensive ceramic in powder or sintered sheet form. Its thermal conductivity of 30 W/m-K and excellent dielectric properties make it useful in low to moderate power commercial applications.

Ambient Temperature: The temperature of the air surrounding a heat source.

Apparent Thermal Conductivity: This value differs from bulk thermal conductivity as apparent thermal conductivity also includes contact resistance when measured, as described in the *Heat Transfer Fundamentals* section of this guide. Also see Thermal Conductivity.

Arcing: An electrical discharge between the edges of metal semiconductor package and the metal heat sink on which it is mounted.

Binder: A polymer (i.e. silicone, urethanes, acrylic, epoxy etc.) used in thermal interface materials to provide desired mechanical, thermal and electrical properties and hold in a stable form the fillers whose primary purpose is the transfer of heat. Binders are also good electrical insulators.

Bondline Thickness: Average thickness between heat spreading device and components.

Boron Nitride (BN): A non-abrasive ceramic material that has higher thermal conductivity than alumina. Because it is an expensive raw material, it is usually used in high performance interface materials.

Breakdown Voltage: The amount of voltage required to cause a dielectric failure through an insulator when tested under a set of specific conditions. This value does not imply that the insulator can be operated at those voltages.

Burr: A thin ragged fin left on the edge of a piece of metal (semiconductor package or heat sink) by a cutting or punching tool.

Calorie: A unit of energy equal to the quantity of heat required to raise the temperature of 1 gram of water by one degree Celcius.

Ceramic: A name given to oxides of metals. Ceramics are usually hard, heat and corrosion resistant and high dielectric strength powders that can be formed into shapes by fusion or sintering.

Chamfer: A bevel cut into the edge of heat sink mounting holes.

Coefficient of Thermal Expansion (CTE) : A measure of a material's change in volume in response to a change in temperature.

Compression Set: The permanent deformation of an elastomeric material caused by a compressive force.

Conduction: The transfer of heat energy through matter.

Convection: The transfer of heat that results from motion of a fluid (gas or liquid).

Corona: An electrical discharge within or on an insulator accompanied by ionization of the air within or contacting the surface of the insulator. Also called partial discharge. It is the main mode of insulation failure exposed to long term AC voltages.

Creep Distance: The distance that an insulator has to extend beyond the edge of a semiconductor package to prevent arcing.

Cure-In-Place: Any material that is dispensed as a liquid and cures in the application.

Cut-Through: A phenomenon that occurs when sharp edges or burrs on the metal semiconductor package or heat sink cut through the thermal pads and reduce or eliminate their insulating strength.

Compression / Deflection: The change in thickness of an elastomeric interface material in response to a compressive load. Because these materials are incompressible, deflection is accompanied by a proportional increase in area.

Degreaser or Degreasing Solvent: The solvent used to clean flux and other organic residues off printed circuit boards after they are manufactured. Interface materials must be able to tolerate exposure to degreasing solvents without degrading performance.

Dielectric: A material that acts as an insulator.

Dielectric Constant: See Permittivity.

Dielectric Strength: The voltage gradient, expressed as kV/mm, that will cause a dielectric failure in an insulating material under very specific test conditions. Dielectric strength does not imply that the insulator can withstand those potential gradients for an extended period of time.

Durometer: An instrument for measuring the hardness of rubber. Measures the resistance to the penetration of an indentor point into the surface of the rubber.

Electronic Control Unit or Electronic Control module (ECU/ECM): Various electronic coltrollers, typically used in automotive applications. (i.e. steering anf braking)

Electrical Insulator: A material having high electrical resistivity and high dielectric strength and therefore suitable for separating components at different potentials to prevent electrical contact between them.

Filler: A fine, dispersible ceramic or metallic powder (i.e. boron nitride, alumina, graphite, silver flake, etc.) whose thermal conductivity is at least twenty times greater than that

of the binder.

Flow Rate: The volume, mass, or weight of a fluid passing through a device of any type, per unit of time, expressed in gallons -or liters-per-hour.

Flux: An organic compound used to enhance the wetting and adhesion of metal solder to the copper surfaces on printed circuit boards.

Footprint: The area of the base of an electronic device which comes in contact with a thermal interface material.

Hard Tooling: A die cutting tool manufactured from a machined metal block. The cost is high, therefore it is normally used when long runs are anticipated.

Hardness: A measure of the ability of a material to withstand penetration by a hard pointed object. Regarding thermal interface materials, this property is usually inversely proportional to the ability of a material to conform to uneven surfaces.

Hardness Shore A (Shore D, Shore 00): An instrument reading on a scale of 0 to 100 measuring the hardness of a material. There are three scales: Shore 00, A and D. Shore 00 is used for soft rubbers like gels, Shore A is used for hard rubbers and Shore D for inelastic plastics.

Heat (Q): A form of energy generated by the motion of atoms or molecules. Heat energy is expressed in units of joules.

Heat Capacity: The measure of a materials ability to store heat.

Heat Flow: The rate at which heat is flowing per unit time expressed as Watts.

Heat Flux (Q/A): The rate of heat flow per unit surface area expressed as Watts / cm^2.

Heat Transfer: The movement of heat from one body to another (solid, liquid, gas, or a combination) by means of conduction, convection, or radiation.

Interface: A boundary that exists between any two contacting surfaces. There are five types of interfaces that can exist between the different forms of matter: gas-liquid, liquid-liquid, gas-solid, liquid-solid, and solid-solid.

Junction: The junction is the active part of a semiconductor, usually silicon, where the current flow causes heat to be generated.

MBLT: Minimum bond line thickness. When two opposing substrates obtain closest possible distance under pressure.

Micro-inch: This unit of measure, a millionth of an inch, is used to describe the roughness of a surface and is the average distance between the peaks and valleys on the surface.

Mil: A unit of length equal to one-thousandth of an inch.

PCM: Abbreviation of phase change material.

Permeability: A measure of a material's ability to align its magnetic domains in response to an applied magnetic field.

Permittivity: A measure of a dielectric material's ability to polarize in response to an applied electric field, and transmit the electric field through the material.

Polyimide: An organic polymer with exceptional electrical insulation and high temperature capabilities. In film form, it is used on everything from printed circuit boards to space suits.

Power Supply: A self contained unit which converts AC current to DC for use in electronic devices.

Pressure Sensitive Adhesive (PSA): An adhesive that is tacky at normal temperatures and requires only slight pressure to form a permanent bond. A PSA requires no further cure to maintain the bond.

PSH: Class of polymer solder hybrid. A synergistic blend of eutectic solder and specialty polymers. They provide a highly reliable thermal interface material with a resin carrier and filler content that both melt to obtain minimum bond line thickness.

Radiation: A heat transfer process whereby heat is given off through electromagnetic radiation, usually infrared rays.

Reinforcement: A woven glass mesh or polymer film that is used as a support in thermal interface materials.

Permanent Set: Permanent Set is defined as the amount of residual displacement in a rubber part after the distorting load has been removed.

Relaxation: Stress Relaxation is a gradual increase in deformation of an elastomer under constant load over time, accompanied by a corresponding reduction in stress level.

Rheology: The science of the deformation and flow of materials.

Semiconductor: An electronic material that can be an insulator under one condition and switch to a conductor under a different condition

Shear-Thinning: A characteristic of a fluid whereby the fluid's viscosity decreases with increased shear stress. Materials the exhibit shear-thinning are also described as pseudoplastic. Filled polymer resins commonly exhibit this behavior. (Example: toothpaste is shear-thinning. It does not flow when left alone, but when squeezed with increased force, it flows more readily)

Silicon: A non-metallic element occurring extensively in the earth's crust in silica and silicates. Silicon is the basis for the junction found in most semiconductor devices.

Solder: A mixture of metals that is used to connect electronic devices to the copper patterns on a printed circuit board.

Solvent Resistance: The ability of thermal management products to resist swelling when exposed to organic solvents such as degreasing solvents, hydraulic fluids, coolants and jet fuel.

Specific Gravity: The ratio of the density of a substance to the density of water. The specific gravity of water is 1 at standard condition temperature and pressure.

Specific Heat: The amount of heat per unit mass required to raise the temperature by one degree Celsius. (See Heat Capacity.)

Steel Mill Die: A die cutting tool of moderate cost, cast from steel. It is used for high speed cutting.

Steel Rule Die: A low cost die cutting tool manufactured by shaping sharpened steel foil to the desired shape and fixing in a plywood and steel rule metal. It is used for short runs.

Surface Finish: A measure of the roughness of a surfaces, usually expressed in units of micro-inches.

Swelling: A phenomenon that results when an elastomer is exposed to a degreasing solvent and the elastomer absorbs the solvent. The volume of the elastomer increases and its physical strength is greatly reduced. In this swollen state, the elastomer can be easily damaged and should not be subjected to any mechanical stress until the elastomer has been dried.

Tear Strength: A measure of the ability of a material to withstand tearing/ ripping stresses. It is usually measured in pounds force per inch of thickness.

Temperature: A measure of the average kinetic energy of a material. The standard unit of temperature is a Kelvin, (K). Temperature determines the direction of heat flow between any two systems in thermal contact. Heat will always flow from the area of higher temperature (T source) to one of lower temperature (T sink).

Temperature Gradient (ΔT): The difference in temperatures in the direction of the heat flow between two points in a system.

Tensile Strength: A measure of the ability of a material to withstand a tension (pulling apart) force. It is usually measured in MPa or psi of material cross section.

Thermal Conductivity (K): A quantitative measure of the ability of a material to conduct heat expressed in units of W/m-K.

Thermal Contact Resistance (R_i): The resistance to the flow of heat caused by interstitial air trapped in the irregularities of between contacting solid surfaces. Units are K-cm^2/W.

Thermogravimetric Analysis: Chemical analysis by the measurement of weight changes of a system or compound as a function of increasing temperature.

Thermal Impedance (θ): Thermal impedance is the sum of the thermal resistance of an interface material and the thermal resistances at the interfaces in contact with the material. K-in^2 / Watt.

Thermal Interface Materials (TIMs): Materials that are inserted between two contacting solid surfaces and aid heat flow by eliminating gaps between the irregular surfaces. Interstitial air is replaced by material that is significantly more conductive than air.

Thermal Resistivity: The quantitative measure of a material's resistance to the conduction of heat. (It is the inverse of thermal conductivity.)

Thermocouple: A thermoelectric device consisting of two dissimilar metallic wires fused into a bead which generates a voltage proportional to the temperature of the bead.

Thixotropy: a characteristic of a fluid whereby the fluid's viscosity decreases as a function of time at a fixed shear rate. Viscosity tends to re-build with time as the shear stress is reduced. (Example: gels and colloids are often thixotropic. The longer they are shaken in a can, the more readily they flow)

Tolerance: The permissible variations in the dimensions or other characteristic of a part or substance.

Torque: A turning or twisting that is equal to the value of the force (f) multiplied by the rotational distance over which it is applied (usually measured in ft-lbs.).

Viscoelastic material: A material whose response to a deforming load combines both viscous (does not recover its original shape/ size when load removed) and elastic (will recover size/shape when load removed) qualities. The common name for such a material is "plastic."

Volume Resistivity: A measure of a material's inherent electrical resistance expressed as ohm-cm.

Watt: An SI unit of power equal to one joule per second.

Parker Safety Guide

Parker Safety Guide for Selecting and Using Parker Seals, Isolation Devices, EMI Shielding Materials, Thermal Management Materials and Related Accessories

WARNING – USER RESPONSIBILITY

Failure or improper selection or improper use of Parker seals, isolation devices, EMI shielding, thermal management materials, or related accessories can cause equipment failure or damage, personal injury or death. Possible consequences of such failure, improper selection or improper use include, but are not limited to:

- **Contamination of systems and environments from leaking fluids or gases.**
- **Ingress of dust, fluids or other substances.**
- **High velocity fluid discharge.**
- **Physical contact with released fluids or gases that may be hot, cold, toxic or otherwise injurious.**
- **Contact with suddenly moving, falling or suddenly halted objects that are to be held in position or moved in part or fully by the function of the product.**
- **Improper function or failure of host devices or equipment, or connected devices or equipment.**
- **Burn-inducing temperatures, smoke or flame from overheated devices or equipment.**
- **Injuries resulting from inhalation, ingestion or physical exposure to solvent-based systems.**

Before selecting or using any Parker seals, isolation devices, EMI shielding, thermal management materials, or related accessories, it is important that you read and follow the following instructions:

1.0 General Instructions

1.0.1 Scope

This safety guide provides instructions for selecting and using (including designing, assembling, installing and maintaining) seals (including all elastomeric, polymeric, thermoplastic, metallic and/or plastic products commonly called 'seals'); isolation devices (including elastomeric, polymeric, thermoplastic and/or thermoplastic in the form of boots, bearings, bellows, bushings, grommets, and/or vibration isolation mounts); EMI (electromagnetic interference) shielding (including all conductive elastomers, metal-based materials, conductive fabrics and conductive fabric-based materials, conductive paints, conductive adhesives and caulks, metal/plastic laminates, and/or conductively coated or plated substrates commonly referred to as 'EMI shielding '); and thermal management materials (including thermally conductive elastomer or acrylic-based interface materials, thermally conductive adhesive tapes, metal or ceramic-based heat spreaders, thermally conductive adhesives and caulks, and/or solder/film-based thermally conductive assemblies) manufactured or sold by the world wide Parker Hannifin organization (including its Chomerics operations) . It also includes related accessories (including mounting hardware, surface preparation solvents, protective liners, application systems, containers and packaging materials). All such devices are collectively referred to as "Products" in this safety guide. This safety guide is a supplement to and is to be used with the specific Parker publications for the specific seals, isolation devices, EMI shielding, thermal management materials, and related accessories that are being considered for use.

1.0.2 Fail-Safe

Products can and do fail without warning for many reasons. Design all systems and equipment in a fail-safe mode, so that failure of the Products will not endanger persons or property.

1.0.3 Distribution

Provide a copy of this safety guide to each person who is responsible for designing, specifying, selecting, purchasing of these Products. Do not select these Products without thoroughly reading and understanding this safety guide as well as the specific Parker publications for the products considered or selected.

1.0.4 User Responsibility

Due to the wide variety of operating conditions and uses for these Products, Parker and its distributors do not represent or warrant that any particular Product is suitable for any specific end use system. This safety guide does not analyze all technical parameters that must be considered in selecting a product. The users, through their own analyses and testing, are solely responsible for:

- **Making the final selection of the seal, isolation device, EMI shielding product or thermal management material.**
- **Assuring that the users' requirements are understood and met and that the use presents no health or safety hazards.**
- **Providing all appropriate health and safety warnings on and with the equipment on which the seals, isolation devices, EMI shielding or thermal management materials are used.**

1.0.5 Additional Questions

Contact the appropriate Parker applications engineering department or your Parker representative if you have any questions or require any additional information. See the Parker publication or web pages for the product being considered or used, for telephone numbers and/or e-mail addresses of the appropriate applications engineering department.

2.0 Sealing Performance

2.0.1 Sealing Performance: Seals

In general, seals are used to maintain an unbroken sealing line separating adjoining volumes of media or fluid, under all normal operating conditions. Some seals may be designed to provide other functions (e.g., mechanical check valves). Maintaining the sealing line may be necessary when that line is formed on a surface that remains stationary relative to the seal (i.e., static sealing). Or, the sealing line may be formed against a surface that moves (i.e., dynamic sealing). Numerous criteria are involved in typical sealing designs, including choice of sealing material, gland design, and/or other seal retention and mating features, etc. Specific sealing requirements and the performance of any related sealing system must be clearly defined for every given application in order to select the best sealing solution. The user should provide these definitions, ideally in partnership with applications support from Parker at the earliest possible stages of the design process.

2.0.2 Sealing Performance: Isolation Devices

Many isolation devices are used to prevent ingress of environmental contaminants, including moisture, grease and dirt under normal operating conditions, while isolating noise, vibration and harshness. Other isolation products are used for absorbing shock, reducing equipment noise and insulating against vibration. Performance safety concerns should include the ability of the Parker isolation device to prevent contaminant ingress, and/or isolate noise, vibration, and shock depending on the application requirements. The user should provide Parker application engineers with the isolation performance criteria early in the design stages to optimize material choices and overall design/use of the isolation device. Certain isolation device solutions may be designed to incorporate separate and distinct sealing systems. For these applications, the specific sealing performance should also adhere to the goals described in Section 2.0.1.

2.0.3 Sealing Performance: EMI Shielding

EMI shielding materials are used to reduce the transmission of electromagnetic energy. While many EMI shielding materials may also provide some level of sealing, any specific sealing performance requirements should adhere to the goals described in Section 2.0.1 above. Certain EMI shielding solutions may be designed to incorporate separate and distinct sealing systems. For these applications, the specific sealing performance should also adhere to the goals described in Section 2.0.1. Other types of EMI shielding materials provide no sealing performance, inconsequential sealing performance, or widely varied sealing properties. Finally, EMI shielding materials, like other materials used in a given design, may affect the performance of proximate sealing systems. The above factors should be considered in the design stages and specification of EMI shielding (and seals), ideally in partnership with applications support from Parker at the earliest possible stages of the design process.

2.0.4 Sealing Performance: Thermal Management Materials

Thermal management materials are used to assist in the transmission of heat energy. Some thermal management products may also provide some level of sealing, but any specific sealing performance should adhere to the goals described in Section 2.0.1 above. Certain thermal management solutions may be designed to incorporate separate and distinct sealing systems. For these applications, specific sealing performance should also adhere to the goals described in Section 2.0.1. Other types of thermal management materials provide no sealing performance, inconsequential sealing performance, or widely varied sealing properties. Finally, thermal management materials, like other materials used in a given design, may affect the performance of proximate sealing systems. The above factors should be considered in the design stages and specification of thermal management materials (and seals), ideally in partnership with applications support from Parker at the earliest possible stages of the design process.

2.1 Electrical Conductivity

2.1.1: Electrical Conductivity: Seals

Extreme care must be exercised when selecting seals for

applications in which electrical conductivity or non-conductivity is a factor. Parker seals designed for sealing against liquids and gases may be developed with electrically conductive properties to meet specific application requirements. Conversely, non-conductive seals can be provided for applications prohibiting electrical conductivity.

The electrical conductivity or non-conductivity of Parker seals is dependent upon many factors and may be susceptible to change. These factors include, but are not limited to, the materials used to make the seal and/or related parts (including seal-bearing assemblies provided by Parker), how and where the seals and/or related parts are installed, moisture content of the seal at any particular time, and other factors. Users should be aware of any safety-related issues with using electrically conductive, or insulating, seals in a given application. These concerns should be documented and discussed with Parker before or during the seal selection process.

2.1.2: Electrical Conductivity: Isolation Devices

Most isolation device materials are made from elastomeric, polymeric, thermoplastic or plastic materials that are typically non-conductive. However, some isolation devices are fabricated with conductive features, e.g., metal frames, threaded fasteners, metallic sealing materials, etc. Users should be aware of any safety-related issues with using electrically conductive, or insulating, isolation devices in a given application. These concerns should be documented and discussed with Parker before or during the isolation device selection process.

2.1.3: Electrical Conductivity: EMI Shielding

Parker EMI shielding materials are inherently electrically conductive, which is essential to providing shielding performance. Levels of conductivity vary by product type and factors of application. Thus, care should be used when selecting these materials. EMI shielding products can be designed with non-conductive elements, (e.g., mounting features) depending on the application requirements.

The electrical performance of Parker EMI shielding is dependent upon many factors and may be susceptible to change. These factors include but are not limited to the various materials used to make the EMI shielding and/or related parts (including shielding assemblies provided by Parker), how and where the EMI shielding and/or related parts are installed, moisture content of the shielding at any particular time, corrosion over time, and gap mechanics (stiffness, fastener spacing, etc.).

2.1.4: Electrical Conductivity: Thermal Management Materials

Extreme care must be used when selecting thermal management products in which electrical conductivity or non-conductivity is a factor. Certain Parker thermal management materials are designed to be electrically non-conductive, i.e., electrical insulators, while others are specifically designed to be electrically conductive. And other thermal management materials are inherently electrically non-conductive only below certain current levels.

The electrical conductivity of Parker thermal management products is dependent upon many factors and may be susceptible to change. These factors include the various materials used to make the thermal management materials and/or related parts (including thermal management assemblies provided by Parker), how and where the thermal management parts and/or related parts are installed, moisture content of the thermal products at any particular time, and other factors.

2.2 Temperature Range And Flammability

2.2.1 Temperature Range and Flammability: Seals

Temperatures can affect seal performance, including occurrences such as heat hardening and oxidation. The temperature range of a given seal application, and the expected performance of any sealing system within this range, must be clearly defined in order to select the best sealing solution. Temperature at the seal itself may vary widely from the ambient condition, sometimes by hundreds of degrees. The user should provide the temperature range, ideally in partnership with applications support from Parker at the earliest possible stages of the design process. Temperature range is generally defined as the maximum and minimum temperature limits within which a seal compound is expected to function properly in a given application.

Virtually all Parker sealing materials feature a recommended use temperature range, which should be regarded in the seal selection process. This information can normally be found on related Parker web pages, product literature or from Parker Seal Group applications engineering. In addition, temperature range should be considered for all integral seal elements (e.g., fasteners, adhesives, plastics, metals, etc.) and for application features such as gland dimensions, fluid temperatures, dynamic or static operation, etc. For example, temperature, or the range of temperature, for a given operation may require some modification of the gland dimensions.

Changing the fluids a seal is exposed to will change the

temperature limits of the seal. This is because some chemical reactions take place at elevated temperatures, but not necessarily at lower temperatures. Seals can fail at low temperatures as well. These failures are typically caused by some mechanical instability in the system, which would cause the seal to loose its seal interface. The temperature limit in a particular sealing application cannot be properly determined without knowing what specific fluids or other media the seal will be exposed to. Flammability information is available for most Parker seal materials. Certain materials are available with various UL (Underwriters Laboratories) ratings for flammability/flame resistance. When Parker seal materials are integrated with other materials (e.g., plastic frames), the user, or Parker, may need to determine the flammability data for these other materials.

For more safety information on temperature and flammability, consult with Parker Seal Group applications engineering.

2.2.2 Temperature Range and Flammability: Isolation Devices

Most Parker isolation devices are produced from materials that perform over a broad temperature range, e.g., -65 to +600 degrees F. Some materials are better suited for wider temperature ranges, or for higher or lower temperature extremes. Temperature range data is available for most of these materials and should be considered in the overall selection process. Users should also determine whether flammability issues are of concern to their application. When Parker isolation devices are integrated with other materials (e.g., plastic frames), the user, or Parker, may also need to determine the flammability data for these other materials. Consult with Parker engineers on available flammability data, e.g., UL ratings, required for a choice of an isolation device.

2.2.3 Temperature Range and Flammability: EMI Shielding

Temperatures can affect EMI shielding performance to the extent they may affect electrical continuity within a shielding design. This could result from physical changes to electrically conductive shielding components (conductive panels, coatings, platings, flanges, compounds, gaskets, fasteners, adhesives, etc.) due to temperature extremes, changes, etc. In addition, while some shielding materials such as conductive compounds (paints, adhesives, caulks, inks) should be applied at specific temperature ranges (e.g., ambient), they will provide shielding performance over a broader temperature range. Other shielding materials such as compounds may require curing at elevated temperatures, which may in turn affect substrates or other exposed components. Temperature ranges for effective shielding performance are available for most Parker EMI shielding materials, including integral attachment systems (e.g., pressure sensitive adhesives). Consult Parker's literature or web pages, and consult with Parker applications engineers to review shielding material selection relevant to temperature range.

Flammability information is available for many Parker shielding materials. Certain materials are available with various UL (Underwriters Laboratories) ratings for flammability/flame resistance. When Parker shielding products are integrated with other materials (e.g., plastic frames), the user, or Parker, may need to determine the flammability data for these other materials.

For more safety information on temperature and flammability, consult with Parker technical service department. Curing of products at elevated temperatures may generate off gas components. Any need to use local exhaust ventilation should be based off customer assessment.

2.2.4 Temperature Range and Flammability: Thermal Management Materials

Temperature range is defined as the maximum and minimum temperature limits within which a thermal management material or product will function properly in a given application. Normally, the key feature of these products is their ability to conduct thermal energy (heat), particularly within a target temperature range and in specific design configurations. However, temperature extremes can affect the performance of these thermal management materials or systems.

Many Parker thermal management materials feature a recommended application temperature range, which should be regarded in the seal selection process. This information can normally be found on related Parker web pages, product literature or from Parker technical services departments.

In addition, temperature range should be considered for all integral elements of a thermal management system (e.g., fasteners, adhesives, plastics, metals, etc.) and for various other application features, such as mounting surfaces, etc. The temperature range of a given thermal management system, and the expected performance of any thermal management system within this range, must be clearly defined in order to select the best solution. The user should provide the temperature range, ideally in partnership with applications support from Parker at the earliest possible stages of the design process.

Flammability information is available for most Parker thermal management materials. Certain materials are available with various UL (Underwriters Laboratories)

ratings for flammability/flame resistance. When Parker thermal management materials are integrated with other materials (e.g., plastic frames), the user, or Parker, may need to determine the flammability data for these other materials. For more information, consult with Parker technical service department.

2.3 Compression And Pressure

Most Products require some level of compression to function properly. Different materials and configurations will have varying compression characteristics, including resilience, and diverse compressive force requirements. Product materials may undergo compression set or other compression-related changes depending on the specific application. Fluids and other media may physically affect a Product and cause changes to the Product's compression characteristics in an application. Compression (and decompression) qualities of materials, compression force requirements, and related compression requirements should be considered for a given application in order to select the best Product solution. This also includes the number of pressure cycles to which the Product will be exposed, and the number of times a Product will be disassembled. Compression data is available on most Parker Product materials, and users should consult with Parker applications engineering early in their design and Product selection processes.

Pressure has a bearing on Product design and selection, as it may affect the choice of compound composition, geometry, hardness and other properties. Proper selection may require the choice of higher or lower durometer materials to accommodate more severe pressure situations. Compatibility with the medium should be of concern e.g., excessive swell in an application can generate extremely high pressures. If not considered in the design and selection stages, high pressures in an application can affect mating assemblies and lead to Product failure, e.g., by extrusion of the Product material. Pressure data should be provided as part of the selection process, as well as the choice of interface design and materials. This includes maximum and minimum pressures and cycling conditions.

2.4 Fluid And Other Media Compatibility

2.4.1 Compatibility: Seals

This is a critical aspect of proper seal selection, based on the number of fluids or other media with which seals are expected to interact. All media that may come in contact with the seal and retainer should be considered. For example, if the system is to be cleaned or purged periodically, be sure to anticipate what cleaning fluids will be used. Also, consider any lubricants, e.g., friction reducers, which may be affected by the sealed media. These secondary fluids are as important to selecting the most compatible seal material as the principal operating media selects.

Any increase in seal mass (volume) due to exposure to the sealed fluid, must be a design consideration. Excessive swell in an application can generate extremely high pressures and affect the seal function. Conversely, any decrease in seal volume, caused by a reaction to the sealed fluid can also degrade performance by reducing compression force or causing other severe dimensional changes resulting in possible loss of the sealing interface.

Seals exposed to atmosphere, including ozone and air pollutants, or to vacuum may experience some types of degradation. Corrosion issues should also be considered, particularly of metallic mating or seal mounting hardware (see 2.6.1). In all cases, fluid and gas compatibility should be a major consideration for every sealing application, and fully discussed with Parker Seal Group applications engineering.

2.4.2 Compatibility: Isolation Devices

Many isolation devices are designed to retain or seal a number of fluids across a variety of applications, while also protecting against contaminants (see 2.6.2). Others are designed exclusively to control noise, vibration, shock or motion. Users should assess the nature, volume, etc., of all fluids and gases that will be contact with the isolation devices in their applications. These assessments should be discussed with Parker applications engineers in selecting and designing the appropriate isolation device solution.

2.4.3 Compatibility: EMI Shielding

Fluid and gas compatibility concerns in EMI shielding applications include the potential effects on electrical conductivity, corrosion, and issues related to shielding materials that also provide environmental sealing. Consider ALL media that may come in contact with the shielding components. For example, if the system is to be cleaned or purged periodically, be sure to anticipate what cleaning fluids will be used. Exposure to fluids and gases may effect shielding performance (immediately and long term) and the application conditions should be discussed with Parker engineers. Occurrence of galvanic corrosion should be a major concern where metal or metal-filled shielding materials are used in the presence of fluids or humidity. This includes metallic parts used for attaching shielding gaskets or other shielding components. Consult with Parker applications engineers to optimize the shielding design and/or choice of shielding materials to address

corrosion issues. Many EMI gasket forms will provide little or no barrier to fluids or gases, unless they include an integrated sealing system. The environmental seal, such as a non-conductive rubber, will feature its own fluid and gas compatibility issues. (Refer to 2.4.1 when considering non-conductive and/or conductive elastomers for use in an EMI shielding system.) In all cases, fluid and gas compatibility should be addressed in each EMI shielding application, and fully discussed with Parker technical service department.

2.4.4 Compatibility: Thermal Management Materials

Fluid and gas concerns in thermal management applications include the potential effects on thermal performance, and safety-related effects such as corrosion occurring to the Parker thermal product or associated hardware. Consider ALL media that may come in contact with the thermal components. For example, if the system is to be cleaned or purged periodically, be sure to anticipate what cleaning fluids will be used. Exposure to fluids and gases may effect thermal performance (immediately and long term) and the application conditions should be discussed with Parker engineers. Fluid or gas exposure may also affect integral portions of the supplied thermal management product, such as pressure sensitive adhesives. Occurrence of corrosion should be a concern where metal or metal-filled thermal materials are used in the presence of fluids or humidity. This also includes metallic parts used for attaching thermal management components. Consult with Parker applications engineers to optimize the thermal design and/or choice of materials to address corrosion issues. In all cases, fluid and gas compatibility should be addressed in each application, and fully discussed with Parker technical service department.

2.5 Corrosion And Environment

2.5.1 Corrosion and Environment: Seals

Seal corrosion is not typically seen with elastomer-based sealing materials, but corrosion of integrated metal seal components, mounting devices and mating hardware can be a safety-related factor when choosing sealing solutions. Corrosion of these materials can compromise the integrity, proper function and normal results of the seal design. As such, potential corrosion opportunities should be determined and accounted for in the seal design process (e.g., using coated or plated metals). Similarly, environmental issues should be considered when developing sealing designs and specifying seal materials. Environmental conditions, e.g., weather, temperature, salt spray, dust, etc. can affect the sealing material, sealing hardware and/or the media being sealed, which in turn can affect the sealing properties. Consult with Parker Seal specialists on seal design in respect to corrosion and environmental issues.

2.5.2 Corrosion and Environment: Isolation Devices

Corrosion issues should factor into selecting elastomeric and thermoplastic-based isolation devices. Isolation devices with integral metal plates, flanges, screws, fasteners and other metallic features may experience corrosion under certain conditions. Further, corrosion can affect the integrity of other component parts in an isolation system. Corrosion control should be part of the design and selection process when choosing isolation devices.

Some types of isolation devices, such as boots and bellows, are typically designed for preventing ingress of environmental dust and dirt, water, fuel and other fluids, grease and other potential contaminants. Users should carefully review potential environmental conditions and contaminants to which an isolation device or system may be exposed. Some isolation materials may also be affected by exposure to ultraviolet (UV) light, e.g. reflected solar energy. Selection of the materials, attachment systems and overall design should have the primary goal of keeping out contamination from the environment. Review corrosion and environmental issues with Parker applications engineers as part of the selection process.

2.5.3 Corrosion and Environment: EMI Shielding

Corrosion issues must be considered in the design and selection of EMI shielding. The metals used in providing a conductive pathway, enclosure, etc. and ultimately an effective EMI shield can be subject to corrosion that can affect shielding performance. The level of this corrosion is determined by the metals used and by their exposure to corrosion-supporting environments. For example, galvanic corrosion can occur when conductive shielding materials experience battery-like physical conditions. As such, potential corrosion opportunities should be determined and accounted for in the EMI shielding design process (e.g., choice of EMI gasket type, use of corrosion inhibiting coatings, weather seals, etc.). Similarly, environmental factors should be considered when developing EMI shielding designs and selecting shielding materials. Environmental situations, e.g., weather, temperature, radiation, salt spray, dust, etc. can affect the shielding material, integrated hardware and other components of a system's overall shielding design. Consult with Parker technical service department on shielding design in respect to corrosion and environmental issues.

2.5.4 Corrosion and Environment: Thermal Management Materials

Corrosion should be addressed when designing and choosing thermal management products. Those products containing metals as thermal conductors or as part of an integral thermal management assembly can be subject to corrosion that may affect thermal performance. The level of this corrosion is determined by the metals used and by their exposure to corrosion-supporting environments. Potential corrosion opportunities should be determined and accounted for in the thermal management design process (e.g., choice of thermally conductive materials, integrated fasteners or other components, use of corrosion inhibiting coatings, weather seals, etc.). Similarly, environmental issues should be considered when designing and selecting thermal management systems. Environmental situations, e.g., weather, temperature, radiation, salt spray, dust, etc. can affect the thermal transfer material, integrated hardware (fasteners, clips, heat sinks, etc.), and other components of a system's overall thermal management design. Consult with Parker specialists on thermal management design in respect to corrosion and environmental issues.

2.6 Leakage

2.6.1 Leakage: Seals

Leakage control and acceptable leakage rates are fundamental to the design of any efficient sealing system. When properly used in sealing liquids there should be no detectable leakage of a liquid over a given period of time in the case of static sealing. Dynamic sealing provides of a controlled leakage that is typically very low concentrations over extended periods of time.

Gases, on the other hand, will typically diffuse through the rubber at some very low rate that can be detected by a leak detector, a mass spectrometer or other very sensitive measuring device. The leakage rate depends primarily on the temperature, the pressure differential, the type of gas and the type of elastomer used. Out-gassing is a vacuum phenomenon wherein a substance spontaneously releases volatile constituents in the form of vapors or gases. In rubber compounds, these constituents may include water vapor, plasticizers, air, inhibitors, etc. To identify and address safety concerns, consult with Parker Seal applications engineers on leakage issues relevant to all seal designs and selections.

2.6.2 Leakage: Isolation Devices

When properly designed and installed, isolation devices for preventing ingress of contaminants should demonstrate either no leakage or an ingress level well within the user-provided specifications. This need for properly selecting isolation devices may also pertain to preventing or minimizing 'leakage', or egress, of noise, vibration, shock or other phenomena. Leakage problems can lead to system malfunctions, breakdowns, and safety hazards to equipment, operators and other personnel. User-specifications must address any and all safety concerns over leakage. These should be reviewed with Parker applications engineers early in the selection process.

2.6.3 Leakage (Including Electro-magnetic Energy Leakage): EMI Shielding

Leakage in an EMI shielding design can refer to the flow of fluids and gases, as well as the passage of electromagnetic energy through the shield.

With respect to the flow of fluids and gases, some Parker EMI shielding products will provide a certain barrier level to fluid and gas leakage, e.g., shielded windows, conductive elastomer gaskets. However, only a limited number of these products are specifically designed for this feature, e.g., conductive sealants. Other Parker shielding products e.g., shielded vents, are actually designed to facilitate airflow. Conductive elastomers and other kinds of conductive shielding materials may also experience out-gassing. This is a vacuum phenomenon wherein a substance spontaneously releases volatile constituents in the form of vapors or gases. In rubber compounds, these constituents may include water vapor, plasticizers, air, inhibitors, etc. In addition, improperly installed shielding products, as well as gaps throughout a device's shielding system, may lead to leakage. This includes any leakage of improperly cured shielding compounds, e.g., coatings, inks, epoxies, etc. To help you identify and address fluid and gas leakage concerns, consult with Parker Seal applications specialists on leakage issues relevant to all EMI shielding designs and selections.

With respect to the passage of electromagnetic energy through the EMI shielding material, EMI shielding materials reduce but do not eliminate this passage. Specifications and testing of EMI shielding materials are directed toward the amount of the reduction. The electromagnetic energy that is emitted from any electronic device is dependent upon many factors including the source of the electromagnetic energy, the amount of electromagnetic energy developed or transmitted by the source, the distance from the source, and any desired transmission of signals from the device such as through an antennae. The EMI shielding material is just one component of the entire device, and the designers of the device are solely responsible to determine

the amount of electromagnetic energy transmitted by the device under all conditions and to assure that all performance, endurance, maintenance, safety and warning requirements for the device are met.

2.6.4 Leakage: Thermal Management Materials

Leakage potential of fluids or gases through thermal management materials should be addressed by consulting with Parker Seal design engineers before or during the material selection process. Some Parker thermal management products will provide a certain barrier level to fluid and gas leakage, but only a limited number of these products are specifically designed for this feature, e.g., thermal potting compounds. Elastomers and other types of thermally conductive materials may also experience out-gassing. This is a vacuum phenomenon wherein a substance spontaneously releases volatile constituents in the form of vapors or gases. In rubber compounds, these constituents may include water vapor, plasticizers, air, inhibitors, etc. In addition, improperly installed thermal management products, as well as gaps throughout a thermal management system, may lead to leakage and resulting safety problems. This includes any leakage of improperly cured thermally compounds, e.g., adhesives, caulks, etc. To identify and address safety concerns, consult with Parker Seal applications specialists on leakage issues relevant to all thermal management designs and selections.

2.7 Aging

Product selection should consider both the shelf life and the installed life. Parker maintains cure date records for many Products. For some Products, Parker also follows established industrial, customer, United States or other global age control standards. Certain materials, e.g. conductive coatings, inks, adhesives, etc. have a relatively limited shelf life and use life. Integral materials, e.g., pressure sensitive adhesives; on Products may have aging properties different from the main Product material. Users should consult available Parker data, and consult with Parker applications engineers to determine shelf life standards and installed seal life guidelines, and relevant procedures, when selecting seals for their applications.

2.8 System Weight

Product selection should include considerations related to Product weight, hardware/peripherals weight, and total system weight. Material weights are available from Parker web sites, literature, or from Parker applications engineers. When weight is critical to achieving a proper application, this should be addressed as early as possible with Parker applications engineers.

Parker can often provide technical prediction of Product performance via finite element analysis and other analytical tools. Successful results are best accomplished by working closely with Parker applications engineers beginning early in the design stages.

3.0 Handling

Safe handling of Products refers to the safety of the handlers and to the security of the seal parts. Any safety concerns relative to the safety of Product assemblers; inspectors, maintenance personnel, etc. should be addressed with Parker before the Products enter the handling stages. Though not usually required, Parker can provide available Material Safety Data Sheets and other safe handling and storage documents for certain Products. Consult with Parker applications engineers on the need and availability of this form of documentation. The Products should always be handled in ways that will not cause physical (visible or not) changes to the materials that could affect performance in their intended application. It is recommended that Parker applications engineers be consulted on best practices for safe storage and handling of these Products

Safe operation of automated handling, assembly, insertion, storage, etc. equipment used with the Products, should be optimized for safe use by operators, maintenance personnel, etc. Automated or manual equipment, used for handling seal products, should not affect the Products in any way that can alter their attributes and result in unsafe conditions. It is recommended that Parker applications engineers be consulted on best practices for safe handling of the Products.

3.1 Pre-Installation Inspection

Prior to installation, a careful examination of the Product must be performed. This includes checking for correct size, style, quantity, and part number. The Product should be examined for cleanliness, abrasion and any other visible defects. Faulty Products should be properly discarded or carefully stored away from other inventories. Quality assurance testing programs for the Products should be established in consultation with Parker quality engineers or other authorized personnel.

3.2 Preparing The Installation Area

Cleanliness of the Product and its installation area are key to successful installation and performance. Every precaution must be taken to insure that all parts are clean at assembly. Cleanliness is important for proper Product functions. Foreign particles in the installation area, including dirt, metal debris etc. can damage the Product or impede function. Remove all sharp edges near mounting surfaces. When required, use lubricants on the isolation

parts and/or contacting surfaces only after discussion with Parker applications engineers. Cleaning solvents can cause swelling or other damage of some Products. Thus, cleaning solvents should be cleaned off thoroughly. Some Products may require priming of installation surfaces. These processes should be done according to instructions from Parker. EMI gaskets may have specific installation requirements depending on their construction and composition. Consult with Parker applications engineers for specific gasket application needs and to review installation requirements for all Parker EMI shielding. Customer assumes responsibility/risk assessment when handling hazardous substances for cleaning or surface preparation.

3.3 Assembly

3.3.1 Assembly: Seals And Isolation Devices

Seal and isolation devices typically do not have assembly requirements beyond normal installation into a system or a system sub-assembly.

3.3.2 Assembly: EMI Shielding and Thermal Management Materials

While most Parker EMI shielding and thermal management materials are provided ready to install, some types require minor assembly, sizing, mixing or other preparatory operations prior to installation. Assembly may include customer-performed integration of attachment systems, i.e. adding hardware or adhesive. Sizing operations include customer-performed trimming or other fabrication. Mixing operations are often required of customers using Parker conductive coatings and adhesive products. In all cases, customers should use good safety procedures and equipment used in performing these functions. Consult with Parker Seals applications engineers with any questions or concerns regarding the safe assembly, sizing or mixing of EMI shielding and thermal management materials.

3.4 Installation

The Products have various installation methods, including manual insertion,, use of hand tools and automated systems. Sharp-edged installation tools should be used with care, or avoided, to prevent Product damage. If clamping or crimping is used, avoid over clamping or over crimping. Consult with Parker applications engineers to determine the issues to be addressed using whatever installation method is selected.

3.5 Cure/Set Time

3.5.1 Cure/Set Time: Seals and Isolation Devices

Parker seals and isolation devices are typically supplied in cured form. When using uncured seal material (or other curable products) follow the cure time instructions provided by Parker.

3.5.2 Cure/Set Time: EMI Shielding and Thermal Management Materials

Some Parker EMI shielding and thermal management materials require customer-managed cure periods. These include conductive coatings, inks, adhesives, and form-in-place gasket compounds, caulks and primers. Some adhesives (conductive or non-conductive) used for bonding may have a recommended set time. Temperature, humidity and other conditions can affect curing. Improperly cured materials may provide abnormal performance, working life, abrasion resistance, attachment, and other properties. Some curable materials are volatile and/or pose health issues in uncured form. Refer to all relevant Material Safety Data Sheets (MSDS) and consult with Parker applications engineers on the appropriate curing methods, timing and evaluation for Products requiring curing or setting periods.

3.6 Post Installation Inspection And Testing

Installed Products should be inspected for proper fit and any damage incurred during installation. In some cases, pressure, conductivity (electrical or thermal), or impedance testing, or other procedures can help identify any performance problems. Identified problems should be documented and brought to the attention of all associates involved. Consult with Parker applications engineers in developing appropriate inspection and test standards and procedures.

3.7 Removal

3.7.1 Removal: Seals

Seal removal may require use of manual or automated tools. Safety procedures and training may also be necessary to ensure the safe use of removal tools, compounds, etc. Care must be taken to preserve surface finishes and other application part features. Inspect and clean/repair application parts as needed prior to installing new seals. Inspect removed seals for wear, damage and other features that may indicate conditions requiring attention. Consult with Parker regarding appropriate removal tools and procedures.

3.7.2 Removal: Isolation Devices

Many isolation devices are intended to remain in place for the life of the system, e.g. vehicle. When necessary, these parts must be carefully removed to avoid damaging material or attachment hardware; changing the part dimensions, or contaminating

protected areas. Inspect removed devices for wear, damage and other features that may indicate conditions requiring attention. Consult with Parker regarding appropriate tools and procedures.

3.7.3 Removal: EMI Shielding and Thermal Management Materials

Removing EMI shielding or thermal management materials may require use of manual or automated tools, as well as the use of solvents, abrasives or other compounds. Safety procedures and training may also be necessary to ensure the safe use of removal tools, compounds, etc. Care must be taken to preserve surface finishes and other part features, particularly those comprising the shielding or thermal management system. Inspect and clean/repair application parts as needed prior to installing new Products. If possible, inspect removed materials for wear, damage, performance and other features that may indicate conditions requiring attention. Consult with Parker regarding appropriate removal tools and procedures.

4.0 Storage

Storage conditions can affect Product integrity and performance, and pose safety issues. These include temperature extremes, contamination and time. Storage procedures should address these issues. Typically, the Products should be kept at room temperature, and away from temperature extremes or high humidity. Product lots and part numbers should be identified and tracked to ensure attention to shelf life and that the correct Products are always installed. Products installed on stored equipment should also be protected from potential temperature and environmental effects. Avoid sulfur containing packaging materials when storing conductive elastomers as it will promote corrosion. Their working life must also be tracked and distinguished from typical bulk/bag storage life. Discuss proper storage procedures with Parker engineers. Follow guidelines in Parker literature for special handling and storage instructions.

4.1 Maintenance

Users of these Products should establish maintenance procedures, and these are typically determined through customer component testing. Maintenance should normally include Product inspection, correct part replacement, and for those specific Products approved by Parker, conditioning of the Product for reuse. Parker applications engineers can be consulted when creating maintenance procedures.

5.0 User Responsibility

This document and other information from the world wide Parker-Hannifin organization (including Chomerics) and its subsidiaries and authorized distributors provide product or system options for further investigation by users having technical expertise. To the extent that Parker or its subsidiaries or authorized distributors provide component or system options based upon data or specifications provided by the user, the user is responsible for determining that such data and specifications are suitable and sufficient for all applications and reasonably foreseeable uses of the components or systems. The user, through its own analysis and testing, is solely responsible for making the final selection of the system and components and assuring that all performance, endurance, maintenance, safety and warning requirements of the application are met. The user must analyze all aspects of the application, follow applicable industry standards, and follow the information concerning the product in the current product catalog and in any other materials provided from Parker or its subsidiaries or authorized distributors.

Chomerics Division Of Parker Hannifin Corporation Terms And Conditions Of Sale (7/21/04)

1. Terms and Conditions of Sale: All descriptions, quotations, proposals, offers, acknowledgments, acceptances and sales of Seller's products are subject to and shall be governed exclusively by the terms and conditions stated herein. Seller's prices for the products have been established on the understanding and condition that the terms set forth herein shall apply to this sale to the exclusion of any other terms. Seller expressly reserves the right to an equitable adjustment to the price in the event that any material provision hereof is deemed not to govern the rights and obligations of the parties hereto. Buyer's acceptance of any offer to sell is limited to these terms and conditions. Any terms or conditions in addition to, or inconsistent with those stated herein, proposed by Buyer in any acceptance of an offer by Seller, are hereby objected to. No such additional, different or inconsistent terms and conditions shall become part of the contract between Buyer and Seller unless expressly accepted in writing by Seller. Seller's acceptance of any offer to purchase by Buyer is expressly conditional upon Buyer's assent to all the terms and conditions stated herein, including any terms in addition to, or inconsistent with those contained in Buyer's offer. Acceptance of Seller's products shall in all events constitute such assent.

2. Product Selection. If Seller has provided Buyer with any component and/or system recommendations, such recommendations are based on data and specifications supplied to Seller by Buyer. Final acceptance and approval of the individual components as well as the system must be made by the Buyer after testing their performance and endurance in the entire application under all conditions which might be encountered.

3. Payment: Payment shall be made by Buyer net 30 days from the date of delivery of the items purchased hereunder. Any claims by Buyer for omissions or shortages in a shipment shall be waived unless Seller receives notice thereof within 30 days after Buyer's receipt of the shipment.

4. Delivery: Unless otherwise provided on the face hereof, delivery shall be made F.O.B. Seller's plant. Regardless of the method of delivery, however, risk of loss shall pass to Buyer upon Seller's delivery to a carrier. Any delivery dates shown are approximate only and Seller shall have no liability for any delays in delivery.

5. Warranty: Seller warrants that the items sold hereunder shall be free from defects in material or workmanship for a period of 365 days from the date of shipment to Buyer. THIS WARRANTY COMPRISES THE SOLE AND ENTIRE WARRANTY PERTAINING TO ITEMS PROVIDED HEREUNDER. SELLER MAKES NO OTHER WARRANTY, GUARANTEE, OR REPRESENTATION OF ANY KIND WHATSOEVER. ALL OTHER WARRANTIES, INCLUDING BUT NOT LIMITED TO, MERCHANTABILITY AND FITNESS FOR PURPOSE, WHETHER EXPRESS, IMPLIED, OR ARISING BY OPERATION OF LAW, TRADE USAGE, OR COURSE OF DEALING ARE HEREBY DISCLAIMED.

NOTWITHSTANDING THE FOREGOING, THERE ARE NO WARRANTIES WHATSOEVER ON ITEMS BUILT OR ACQUIRED, WHOLLY OR PARTIALLY, TO BUYER'S DESIGNS OR SPECIFICATIONS.

6. Limitation of Remedy: SELLER'S LIABILITY ARISING FROM OR IN ANY WAY CONNECTED WITH THE ITEMS SOLD OR THIS CONTRACT SHALL BE LIMITED EXCLUSIVELY TO REPAIR OR REPLACEMENT OF THE ITEMS SOLD OR REFUND OF THE PURCHASE PRICE PAID BY BUYER, AT SELLER'S SOLE OPTION. IN NO EVENT SHALL SELLER BE LIABLE FOR ANY INCIDENTAL, CONSEQUENTIAL OR SPECIAL DAMAGES OF ANY KIND OR NATURE WHATSOEVER, INCLUDING BUT NOT LIMITED TO LOST PROFITS ARISING FROM OR IN ANY WAY CONNECTED WITH THIS AGREEMENT OR ITEMS SOLD HEREUNDER, WHETHER ALLEGED TO ARISE FROM BREACH OF CONTRACT, EXPRESS OR IMPLIED WARRANTY, OR IN TORT, INCLUDING WITHOUT LIMITATION, NEGLIGENCE, FAILURE TO WARN OR STRICT LIABILITY.

7. Inspection: Seller shall be given the opportunity to correct or replace defective products prior to cancellation. Final acceptance by Buyer shall take place not later than 90 days after shipment.

8. Changes, Reschedules and Cancellations: Buyer may request to modify the designs or specifications for the items sold hereunder as well as the quantities and delivery dates thereof, or may request to cancel all or part of this order; however, no such requested modification or cancellation shall become part of the contract between Buyer and Seller unless accepted by Seller in a written amendment to this Agreement. Acceptance of any such requested modification or cancellation shall be at Seller's discretion, and shall be upon such terms and conditions as Seller may require.

9. Special Tooling: A tooling charge may be imposed for any special tooling, including without limitation,

dies, fixtures, molds and patterns, acquired to manufacture items sold pursuant to this contract. 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 apparatus belonging to Seller that is utilized in the manufacture of the items sold hereunder, even if such apparatus has been specially converted or adapted for such manufacture and notwithstanding any charges paid by Buyer. Unless otherwise agreed, Seller shall have the right to alter, discard or otherwise dispose of any special tooling or other property in its sole discretion at any time.

10. Buyer's Property: Any designs, tools, patterns, materials, drawings, confidential information or equipment furnished by Buyer or any other items which become Buyer's property, may be considered obsolete and may be destroyed by Seller after two (2) consecutive years have elapsed without Buyer placing an order for the items which are 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.

11. Taxes: Unless otherwise indicated on the face hereof, all prices and charges are exclusive of excise, sales, use, property, occupational or like taxes which may be imposed by any taxing authority upon the manufacture, sale or delivery of the items sold hereunder. If any such taxes must be paid by Seller or if Seller is liable for the collection of such tax, the amount thereof shall be in addition to the amounts for the items sold. Buyer agrees to pay all such taxes or to reimburse Seller therefor upon receipt of its invoice. If Buyer claims exemption from any sales, use or other tax imposed by any taxing authority, Buyer shall save Seller harmless from and against any such tax, together with any interest or penalties thereon which may be assessed if the items are held to be taxable.

12. Indemnity For Infringement of Intellectual Property Rights: Seller shall have no liability for infringement of any patents, trademarks, copyrights, trade secrets or similar rights except as provided in this Part 12. Seller will defend and indemnify Buyer against allegations of infringement of U.S. patents, U.S. trademarks, copyrights, and trade secrets (hereinafter 'Intellectual Property Rights'). Seller will defend at its expense and will pay the cost of any settlement or damages awarded in an action brought against Buyer based on an allegation that an item sold pursuant to this contract infringes the Intellectual Property Rights of a third party. Seller's obligation to defend and indemnify Buyer is contingent on Buyer notifying Seller within ten (10) days after Buyer becomes aware of such allegations of infringement, and Seller having sole control over the defense of any allegations or actions including all negotiations for settlement or compromise. If an item sold hereunder is subject to a claim that it infringes the Intellectual Property Rights of a third party, Seller may, at its sole expense and option, procure for Buyer the right to continue using said item, replace or modify said item so as to make it non infringing, or offer to accept return of said item and return the purchase price less a reasonable allowance for depreciation. Notwithstanding the foregoing, Seller shall have no liability for claims of infringement based on information provided by Buyer, or directed to items delivered hereunder for which the designs are specified in whole or part by Buyer, or infringements resulting from the modification, combination or use in a system of any item sold hereunder. The foregoing provisions of this Part 12 shall constitute Seller's sole and exclusive liability and Buyer's sole and exclusive remedy for infringement of Intellectual Property Rights. If a claim is based on information provided by Buyer or if the design for an item delivered hereunder is specified in whole or in part by Buyer, Buyer shall defend and indemnify Seller for all costs, expenses or judgments resulting from any claim that such item infringes any patent, trademark, copyright, trade secret or any similar right.

13. Export Limitations. The items sold hereunder are authorized by the U.S. government for export only to the country of ultimate destination indicated on the face hereof for use by the end-user. The items may not be transferred, transshipped on a non-continuous voyage, or otherwise be disposed of in any other country, either in their original form or after being incorporated into other end-items, without the prior written approval of the U.S. government.

14. Commercial Items. Unless otherwise indicated on the face hereof, the items being sold hereunder if sold for military or government purposes constitute Commercial Items in accordance with FAR 2.101, and as such the assertions delineated in the DFAR's 252.227-7013, 252.227-7014, 252.227-7017 and FAR 52.227-15 (c) shall not apply to this contract. Additionally, in view of the Commercial Item status, any deliverable technical data and/or computer software to be provided will contain Seller's normal commercial legend subject to the restrictions contained therein.

15. Force Majeure: Seller does not assume the risk of and shall not be liable for delay or failure to perform any of Seller's obligations by reason of circumstances beyond the reasonable control of Seller (hereinafter 'Events of Force Majeure'). Events of Force Majeure shall include without limitation, accidents, acts of God, strikes or labor disputes, acts, laws, rules or regulations of any government or government agency, fires, floods,

delays or failures in delivery of carriers or suppliers, shortages of materials and any other cause beyond Seller's control.

16. Premier™ Conductive Plastics: Parker Chomerics™ Premier™ conductive plastics are sold under license solely for use in the following applications: (i) EMI/RFI shielding, i.e., electromagnetic and/or radio frequency interference shielding or compatibility and surface grounding therefore; (ii) earth grounding, corona shielding, and anti-static and/or electrostatic discharge protection shielding; and (iii) as thermally conductive members to dissipate heat generated by electronic devices.

The resale of Premier™ conductive plastics in pellet or any other raw material form is expressly prohibited, as is their use in any application other than as stated above, and any such resale or use by you or your customers shall render any and all warranties null and void ab initio.

You shall defend, indemnify, and hold Parker Hannifin Corporation and its subsidiaries (Parker) harmless from and against any and all costs and expenses, including attorney's fees, settlements, and any awards, damages, including attorney's fees, and costs, resulting from any claim, allegation, suit or proceeding made or brought against Parker arising from any prohibited use of Premier™ conductive plastics by you or your customers.

17. Entire Agreement/Governing Law: The terms and conditions set forth herein, together with any amendments, modifications and any different terms or conditions expressly accepted by Seller in writing, shall constitute the entire Agreement concerning the items sold, and there are no oral or other representations or agreements which pertain thereto. This Agreement shall be governed in all respects by the law of the State of Ohio. No actions arising out of the sale of the items sold hereunder or this Agreement may be brought by either party more than two (2) years after the cause of action accrues.

Parker Hannifin plc

Conditions of Sale

(Practice Note: These terms are not suitable for use in other countries unless Parker Hannifin Plc is the Seller) (as of March, 08 2005)

Goods sold under these conditions are subject to retention of title - Condition 10

1. Definitions

In these Conditions:

"the Company" means Parker Hannifin plc including all divisions and businesses thereof and any subsidiary undertaking thereof (as defined in Sections 258 and 259 Companies Act 1985 as amended);

"Conditions" means the Standard Conditions of Sale set out in this document together with any special terms agreed in writing between the Company and the Buyer;

"Contract" means any contract between the Company and the Buyer for the sale and purchase of the Goods formed in accordance with Condition 2;

"the Buyer" means any company, firm or individual or agent thereof to whom the Company's quotation or acknowledgement of order is addressed;

"the Goods" means the products (including any parts or accessories), materials and/or services to be supplied by the Company.

2. Applicability Of Conditions

The Company concludes Contracts for the supply of Goods subject only to these Conditions. The Buyer accepts that these Conditions shall govern relations between himself and the Company to the exclusion of any other terms and conditions including, without limitation, conditions and warranties written or oral express or implied even if contained in any of the Buyer's documents which purport to provide that the Buyer's own terms and conditions shall prevail. No variation or qualification of these Conditions or of any quotation or Contract arising herefrom shall be valid unless agreed in writing by the Secretary or a Director of the Company or other person duly authorised by the Board of Directors of the Company.

3. Quotations

The Company's quotations are given without commitment and no Contract between the Company and the Buyer shall arise unless and until the Company has accepted in writing the Buyer's order placed on the Company's quotation. Quotations shall be valid for a period of 30 days from the date of issue, or (if different) the period specified with the quotation itself.

4. Representations

No employee of the Company other than the Secretary or a Director of the Company is authorised to make any statement or representations as to the Goods, save that this restriction shall not apply to any notice or statement

containing a warning or restriction of use ("Warnings") which may be provided in connection with the Goods. Subject to such Warnings, the Buyer, therefore, shall not be entitled to rely or to seek to rely upon any statement or representation made by an employee or agent of the Company other than the Secretary or a Director.

5. Prices

(i). Subject to Condition 3, prices contained in a quotation price list catalogue and similar matter shall be based upon current costs ruling at the date thereof and are for guidance only. Subject to the later provisions of this Condition 5 the contract price shall be the price current at the date of delivery of the goods and/or when services are performed as the case may be.

(ii). Where firm prices are agreed (including without limitation any quotation where the price is fixed pursuant to Condition 3) the prices will remain firm provided that full information permitting manufacture to proceed is received by the Company promptly after acknowledgement of the order by the Company, and further provided the Buyer takes delivery of the order when ready. If delivery of the order or any part thereof is delayed at the 'Buyer's request or through the Buyer's failure to provide the full information mentioned above, the Company reserves the right to amend the price of the undelivered portion to the Company's price list prevailing at the date when delivery is made.

(iii). Where a quotation is given dependent on information supplied by the Buyer, the Buyer will be responsible for the accuracy of the information given, and for the supply of all relevant particulars. Any increased cost incurred either during or after manufacture resulting from any inaccuracy or omission shall be borne by the Buyer alone and shall be paid promptly, and independently of the main contract price.

(iv). Unless otherwise stated prices do not include VAT which will be chargeable at the date of despatch and/or performance of services as the case may be.

6. Despatch And Delivery

(i). Delivery shall be deemed to occur and the risk of loss or damage of any kind in the Goods shall pass to the Buyer on whichever of the following events occur earlier.

(a) collection by or on behalf of the Buyer or by a carrier for despatch to the Buyer (whether or not such carrier be the Company's agent or servant)

(b) 14 days from the date of notice given by the Company that the Goods are ready for collection or despatch.

(ii). In the event that the Company shall at the specific request of the Buyer store the Goods or arrange for the Goods to be despatched or dealt with otherwise than by collection by the Buyer then the Buyer shall pay to the Company any reasonable charges made in the Company's absolute discretion for the provision or procurement of such services. Any such services provided by the Company shall be performed subject to these Conditions. In the event that such services are to be provided by a carrier or other third party then the Company shall in arranging for the provision of the same act only as the agent of the Buyer and the Buyer shall indemnify the Company against any cost, charge liability or expense (including demurrage) thereby incurred by the Company.

(iii). The Buyer shall carefully examine the Goods on receipt of the same and shall by written notice to be received by the Company within 21 days of receipt of the Goods notify the Company of any short delivery, over delivery or any defects reasonably discoverable on careful examination. In the absence of receipt of such notice, then subject only to Condition 11, the Company shall be discharged from all liability in respect of such defects or short or over delivery.

(iv). If the Buyer neglects to serve notice under sub Condition (iii) above of any over delivery then the Company may at its option either repossess the excess Goods or invoice them and be paid forthwith by the Buyer for the excess Goods at the price ruling at the date of delivery.

7. Time For And Form Of Delivery

(i). The Company will use reasonable commercial endeavours to deliver the Goods and to perform services in accordance with any time stated in the contract but time of delivery or performance shall not be of the essence to the contract. Any such times are stated by way of general information only and in the event of failure to despatch or deliver or perform within such times for any cause (whether within or) outside the Company's reasonable control, the same shall not be a breach or repudiation of the contract nor shall the Company have any liability to the Buyer for any direct, indirect or consequential loss (all three of which terms include without limitation pure economic loss, loss of profits, loss of business, depletion of goodwill and like loss) however caused (including as a result of negligence) by delay or failure in delivery except as set out in this Condition 7(i). Any delay or failure in delivery will not entitle the Buyer to cancel the order unless and until the Buyer has given 60 days' written notice to the Company requiring delivery to be made and the Company has not fulfilled delivery within that time. If the Buyer then cancels the order:

(a) the Company will refund the Buyer any sums the Buyer has paid to the Company in respect of that cancelled order; and

(b) the Buyer will be under no liability to make any payments in respect of that cancelled order.

(ii). (a) If the Contract does not otherwise provide the Company shall be entitled to deliver Goods by

single delivery or by instalments at its option.

(b) If the Contract provides for delivery by instalments or the Company so elects each instalment shall be deemed to be the subject of a separate contract on these conditions and without prejudice to sub-paragraph (i) hereof non-delivery or delay in delivery shall not affect the balance of the contract nor entitle the Buyer to terminate the same.

(iii). In the event that the Goods shall not have been collected by or on behalf of the Buyer or by a carrier for despatch to the Buyer within 14 days of the Company's written notice pursuant to Condition 6 (i) (b) hereof then the Company may at any time thereafter send to the Buyer a further notice notifying the Buyer of the Company's intention to sell the same after the expiration of a period of not less than 7 days from the date of the notice and any such sale by the Company may be on a forced sale basis. The Buyer shall be liable for the Company's charges and expenses for the sale and for the storage of the Goods (which shall be at the risk of the Buyer) pending their sale hereunder or delivery to the Buyer. The Company shall charge all costs incurred on a weekly basis for storage.

8. Performance Prevented Or Hindered

The Company shall not be liable for any delay of failure in carrying out its obligations which is caused wholly or partly by reason of act of God, delay in transportation, labour disputes, fire, flood, war, accident, Government action, inability to obtain adequate labour, materials, manufacturing facilities or energy, or any other cause beyond the Company's control or that of its servants or agents, and if the delay or failure has continued for a period of 3 months then either party may give notice in writing to the other determining the contract and on such termination the Company shall refund to the Buyer the price of the Goods or any part thereof already paid to the Company after deduction of any amount due to the Company including any amount under Condition 17 hereof.

9. Payment

(i). Unless expressly agreed in writing payment shall be made in sterling in cleared funds without any deduction set-off, restriction condition or deferment on account of any disputes or cross claims or present or future taxes, levies, duties or charges whatsoever (unless and to the extent the Buyer is required by law to make such deduction) on or before the last day of the month following the month of the invoice for the Goods. Where full payment is not received by the due date interest shall accrue on the sum outstanding at the rate of 3% per annum above the base rate of Lloyds Bank plc (as varied from time to time) calculated on a daily basis but without prejudice to the Company's rights to receive payments on the due dates.

(ii). Time for payment shall be of the essence and in the event of delay or default in any payment for more than 7 days, the Company shall be entitled to suspend deliveries of Goods (being those Goods the subject of the default and any other Goods the subject of any agreed order) and/or treat the Contract (and any other Contract between the Company and the Buyer) as repudiated and/or re sell any of the Goods in its possession and be indemnified by the Buyer for any loss thereby incurred.

(iii). All sums payable to the Company under the Contract will become due immediately on termination of the Contract.

(iv). The Buyer shall pay for any samples, sale or return, loan or demonstration goods and/or materials, including drawings, plans, specifications etc. not returned within one month from the date of receipt by the Buyer unless a different period for the return of such goods and/or materials is agreed between the Company and the Buyer.

10. Property In Goods

(i) The Company shall retain absolute ownership of the property in the Goods which shall not pass to the Buyer and the Buyer shall keep and retain the Goods as bailee for and on behalf of the Company and shall deliver up the Goods to the Company at the Company's request until the Company has received full payment of the price of the Goods and full payment of any other sums whatsoever which are outstanding from the Buyer to the Company whether or not due and owing, and until such time the Buyer:

(a) shall insure the Goods against the usual risks with an insurance office of repute;

(b) shall store separately the Goods or in some other way ensure that the Goods are readily identifiable as the property of the Company;

(c) irrevocably authorises the representatives of the Company at any time in circumstances where the provisions of Condition 19 may apply to enter the Buyer's premises where the Goods are or are thought by the Company to be stored for the purpose of repossessing the Goods;

(d) shall keep and retain the Goods free from any charge lien or other encumbrance thereon.

(ii). Provided always that no circumstances have arisen where the provisions of Condition 17 may apply the Buyer shall be entitled to offer for sale and sell the Goods in the ordinary course of business as principal and not as agent at the best obtainable price, and shall be a sale of the Company's property on the Buyer's own behalf and the Buyer will deal as principal in respect of such sale. Notwithstanding the other provisions of the Contract, payment shall become due (unless payment

has already become due or been paid) when the Buyer receives payment upon its own sale of the Goods (or other items incorporating the Goods).

(iii). If the Buyer incorporates any Goods within other equipment or products provided that the Goods remain readily identifiable and a removable part of such other equipment or products the provisions of Condition 10(i) shall apply.

(iv). If the provisions of Condition 10(iii) apply the Buyer shall store separately the other equipment or products incorporating the Goods and shall notify the Company of the precise location and position thereof. The provisions of Condition 10(ii) hereof shall apply mutatis mutandis in respect of the Goods contained within such other equipment or products owned by the Company.

(v). The Company shall be entitled to exercise a general lien or right of retention on all goods or any parts thereof in the Company's possession which are the Buyer's property for any sums whatsoever due to the Company and pursuant to such lien or right the Company shall be entitled without notice to the Buyer to sell all or any part of such Goods or part thereof privately or by auction or otherwise and to keep the proceeds of sale in diminution of such sums and of all costs and expenses incurred by the Company in effecting the said sales.

11. Warranty And Limitation Of Liability

(i). The Company warrants that products, parts or materials manufactured by it will be of good materials and workmanship and that reasonable care will be employed in assembling or incorporating items not manufactured by it and in performing services so that upon the Buyer giving written notice to the Company that Goods have not been supplied or services performed as aforesaid if the same be established the Company will at its own expense at its option replace or repair such defective goods or remedy such defaults in service. The warranty obligation shall not apply where the Goods have been tampered with, improperly altered, repaired or maintained, installed or connected or subject to misuse (in each case other than as a result of the Company's own acts or omissions). The Buyer shall at its own cost return the Goods to the Company for inspection.

(ii). The same term shall apply mutatis mutandis in respect of such replacement, repair or remedial services.

(iii). The above warranty shall apply in respect of matters whereof the Buyer gives written notice within 12 months of delivery or 6 months from installation (whichever is the shorter period) or within 12 months of performance or of replacement repair or remedial services respectively after which any claim in respect thereof shall be absolutely barred (subject to the other provisions of this Condition 11).

(iv) . The Company does not exclude its liability (if any) to the Buyer:

(a) for breach of the Company's obligations arising under Section 12 Sale of Goods Act 1979 or Section 2 Supply of Goods and Services Act 1982;

(b) for personal injury or death resulting from the Company's negligence;

(c) under section 2(3) Consumer Protection Act 1987;

(d) for any matter which it would be illegal for the Company to exclude or to attempt to exclude its liability; or

(e) for fraud.

(v). Except as provided in Conditions 7(i) and 11(i) to (iv), the Company will be under no liability to the Buyer whatsoever (whether in contract, tort (including negligence), breach of statutory duty, restitution or otherwise) for any injury, death, damage or direct, indirect or consequential loss (all three of which terms include, without limitation, pure economic loss, loss of profits, loss of business, depletion of goodwill and like loss) howsoever caused arising out of or in connection with:

(a) any of the Goods, or the manufacture or sale or supply, or failure or delay in supply, of the Goods or performance or failure or delay in performance of services by the Company or on the part of the Company's employees, agents or sub-contractors;

(b) any breach by the Company of any of the express or implied terms of the Contract;

(c) any use made or resale by the Buyer of any of the Goods, or of any product incorporating any of the Goods;

(d) any statement made or not made, or advice given or not given, by or on behalf of the Company.

(vi). Except as set out in Conditions 7(i) and 11(i) to (iv), the Company excludes to the fullest extent permissible by law all conditions, warranties and stipulations, express (other than those set out in the Contract) or implied, statutory, customary or otherwise which, but for such exclusion, would or might subsist in favour of the Buyer.

(vii) Each of the Company's employees, agents and subcontractors may rely upon and enforce the exclusions and restrictions of liability in Conditions 7(i) and 11(iv) to (vi) in that person's own name and for that person's own benefit as if the words "its employees, agents and subcontractors" followed "Company" where it appears in those Conditions (save for Condition 11(v)(a)).

(viii). Without prejudice to the foregoing if called upon so to do by the Buyer in writing the Company shall use its best endeavours to assign to the Buyer the benefits of any warranty, guarantee, indemnity, claim, privilege or other rights which the Company may

have in regard to manufacturers or suppliers of any goods not manufactured by the Company in relation to the quality, condition or description of such goods.

12. Operating Instructions

(i) The Company supplies with the Goods adequate information as to their design and conditions of the instructions for operation for compliance with its obligations under Section 6 (1) (c) of the Health and Safety at Work Act 1974.

(ii) The Buyer undertakes that all necessary steps will be taken to ensure that the Goods will be safe and without risk to health when properly used in accordance with Section 6 (8) of the Health and Safety at Work etc. Act 1974.

13. Drawings, Specifications Etc.

(i) All descriptions, drawings, illustrations, particulars of weights and measures rating standard statements or details or specifications or other descriptive matter, whether or not contained in the contract document, are approximate only. The Goods will be in accordance with the Company's specifications at the time of manufacture and any earlier specifications drawings, descriptions, illustrations, particulars as to weights and measures rating standard statements or details shall not form part of the description of the parts or services supplied or to be supplied so that the Company shall not be under any liability in respect thereof.

(ii) Where Goods are supplied by the Company to the Buyer in accordance with the Buyer's design or specification or where the Company shall design items not within the standard range of products at the Buyer's request no warranty is given or implied as to the suitability of such goods or items unless the Buyer has made the Company aware of the particular purpose for which the Buyer is proposing to use the goods or items in which case Condition 11 shall apply. The Company shall be entitled to charge a fee for any research or design undertaken in connection with the supply of Goods not within their standard range of products.

14. Inspection And Testing

The Company undertakes inspection of all Goods prior to delivery and where practicable submits to standard tests at the Company's premises Special tests or standard tests in the presence of the Buyer or his representative may be undertaken by the Company at the request and expense of the Buyer but unless otherwise agreed such tests shall be conducted at the Company's premises.

15. Industrial Property Rights

(i) All intellectual property rights subsisting in or relating to any calculations, data, specifications, designs, drawings, papers, documents, procedures, techniques, acceptance, maintenance and other tests special and recommended parts and other equipment and any other material and information whatsoever given to the Buyer by the Company in connection with the supply of the Goods by the Company to the Buyer or otherwise are vested in the Company. The Buyer will not whether by itself its officers servants agents or any of them or otherwise howsoever copy or reproduce any such items or material in whole or in part nor will it disclose any such information in whole or in part to any third party. Further the Company shall be entitled to the ownership of all intellectual property rights subsisting in or relating to any calculations, data, specifications, designs, drawings, papers, documents or other items material or information conceived originated developed or produced by the Company for the Buyer pursuant to the contract for the supply of Goods.

(ii) The Buyer shall not at any time for any reason whatsoever disclose or permit to be disclosed to any person or persons whatsoever or otherwise make use of or permit to be made use of any trade secrets or other confidential information relating to the equipment technology business affairs or finances of the Company or any associated Company or organisation of the Company or relating to the Company's agents distributors licensees or other customers or in respect of any of their dealings or transactions.

(iii) The Buyer shall not seek to apply or apply to register in its own name any of the Company's intellectual property rights and in particular those subsisting in or relating to the Goods or a part thereof nor shall it represent in any way that it has any right or title to the ownership of any such intellectual property rights nor shall it do any act or thing which might be contrary to the interest or rights of the Company in such rights and in particular challenge the ownership or validity of such rights.

(iv) The Buyer at its own expense shall do all such acts and things and shall sign and execute all such deeds and documents as the Company in its sole discretion may require in connection with any steps or proceedings taken by the Company to restrain the infringement of it intellectual property rights.

(v) The Buyer undertakes and agrees that the use of any of its calculations, data, specifications, designs, drawings, papers, documents, procedures, techniques, acceptance, maintenance and other tests special and recommended parts and other equipment and other material and information by the company when manufacturing and supplying the Goods will not infringe any intellectual property

rights of a third party and shall indemnify the Company in respect of any such infringement.

(vi) The Buyer shall not alter or remove any trade mark of the Company which has been applied to the Goods nor apply any other trade mark to the Goods nor make any alteration to their packaging and get up.

(vii) The provisions of this Condition 15 shall survive the expiry or termination of any Contract for whatever reason.

16. Sub Contracting
The Company shall be entitled to sub contract all or any of its obligations hereunder.

17. Determination
If the Buyer shall make default in or commit a breach of the contract or of any of his obligations to the Company or if any distress or execution shall be levied upon the Buyer's property or assets, or if the Buyer shall make or offer to make any arrangement or composition with creditors or commit any act of bankruptcy, or if any petition or receiving order in bankruptcy shall be presented or made against him, or if the Buyer is a limited company and any resolution or petition to wind up such company's business (other than for the purpose of a solvent amalgamation or reconstruction) shall be passed or presented, or if a receiver of such company's undertaking property or assets or any part thereof shall be appointed the Company shall have the right forthwith to determine any Contract then subsisting and upon written notice of such determination being given to the Buyer any subsisting Contracts shall be deemed to have been determined and the Company shall be entitled to recover from the Buyer all losses thereby arising including but not limited to those under Condition 18 of these Conditions or otherwise.

18. Partial Completion
In the case of partial completion of an order by reason of any of the events referred to in Conditions 8 or 17 the Company shall be entitled to a quantum meruit in respect of all work done by it including labour costs and materials and any charges or expenses which the Company is committed to pay sub contractors or third parties without prejudice to its rights should non completion be occasioned by the Buyer.

19. Notices
Unless otherwise provided in writing any written communication or notice under the Contract shall be made or given by sending the same by ordinary prepaid first class letter post in the case of the Company to its current address and in the case of the Buyer to its last known address and if so sent shall be deemed to be made or given two days after the date when posted.

20. Waiver
Any failure by the Company to enforce any or all these Conditions shall not be construed as a waiver of any of the Company's rights.

21. Contracts (Rights Of Third Parties) Act
The parties to the Contract do not intend that any of its terms will be enforceable by virtue of the Contracts (Rights of Third Parties) Act 1999 by any person not a party to it.

22. Law And Interpretation
The Contract shall be governed by English law and the Buyer shall submit to the non exclusive jurisdiction of the English Courts. If any of these Conditions or any part thereof is rendered void or unenforceable by any legislation to which it is subject or by any rule of law it shall be void or unenforceable to that extent and no further.

Notes:

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Parker Chomerics Capabilities include:

THERMAL MANAGEMENT & CONTROL

- Thermally conductive gap filler pads
- Fully cured dispensable thermal gels
- Silicone-free thermal pads
- Phase-change materials (PCM)
- Polymer solder hybrids (PSH)
- Dispensable thermal compounds
- Thermal grease
- Dielectric pads
- Thin flexible heat spreaders
- Custom integrated thermal/EMI assemblies
- RF absorbing gap filler pads

EMI SHIELDING & COMPLIANCE

- Conductive elastomers – molded, extruded, and form-in-place (FIP)
- Conductive foam based gaskets – fabric-over-foam and z-axis foam
- Conductive compounds – adhesives, sealants and caulks
- RF absorbing materials
- EMI shielding plastics and injection molding services
- Coatings – direct metallization and conductive paints
- Metal gaskets – Springfingers, metal mesh and combination gaskets
- Foil laminates and conductive tapes
- EMI shielding vents – commercial and military honeycomb vents
- Shielded optical windows
- Cable shielding – ferrites and heat-shrink tubing/wire mesh tape/zippered cable shielding
- Compliance and safety test services

OPTICAL DISPLAY PRODUCTS

- EMI shielding filters (conductive coating & wire mesh)
- Ant-reflective/contrast enhancement filters
- Plastic or glass laminations
- Hard coated lens protectors
- Touchscreen lenses

PLASTIC INJECTION MOLDING

- PREMIER® and other filled, electrically-conductive plastics
- Traditional thermoplastics
- EMI and cosmetic coating services
- EMI and environmental gasket integration
- Assembly, pad printing, hot stamping, welding, and heat staking
- Insert molding, two-shot molding, and overmolding capability

About Parker Hannifin Corporation

With annual sales exceeding $10 billion, Parker Hannifin is the world's leading diversified manufacturer of motion and control technologies and systems, providing precision-engineered solutions for a wide variety of mobile, industrial and aerospace markets. The company's products are vital to virtually everything that moves or requires control, including the manufacture and processing of raw materials, durable goods, infrastructure development and all forms of transport. Traded on the New York Stock Exchange under the symbol "PH," Parker is strategically diversified, value-driven and well positioned for global growth as the industry consolidator and supplier of choice.