

# Sheldahl®

A Flex Company

From the beginning...



Echo II - Manufactured by Sheldahl (1961), Northfield, MN USA

## The Red Book

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## Sheldahl Introduction

### About Sheldahl Flexible Technologies, Inc.

Founded in 1955 G.T. Schjeldahl Company (renamed Sheldahl, Inc. in 1975) initially supplied a variety of laminated products to serve the military, aerospace and defense markets. Over the years the company developed a number of state of the art coating processes for flexible films. We are now a leading producer of flexible substrates and laminates to support the Printed Circuit, Touch Sensor, Aerospace and Defense, Medical, Automotive, Energy, Transportation and Audio industries serving a variety of high tech customer requirements.

We are global specialists in a variety of key technologies, including thin film deposition on flexible materials, adhesives formulation and coatings, laminations and finishing, and patterning and circuitization--all of which use high volume, high quality roll-to-roll equipment and technology.

Our unique combination of products and capabilities plus superior technical and customer support provides a unique "One Source" fully integrated solutions package that provides value to our growing customer base.

### Sheldahl Market Specialization

We service a variety of commercial and industrial markets but specialize in the following four key markets.

- **Aerospace** – We are a world leader in thermal control materials for spacecraft and launch vehicles. We have been involved in every major U.S. space program since the 1950s.
- **Technical Tapes and Adhesives** – We are a world leader in specialty splicing tapes for the abrasives industry and have more than 750 proprietary adhesive formulations.
- **Printed Circuits, Cable Tapes and Bus Bar Materials** – Our Novaclad™ product is an industry leader for ultra-thin build-up copper materials for flexible circuits. Our bus bar materials provide unique performance advantages to the emerging electric powered transportation market.
- **Touch Sensor** – We were one of the first companies to provide volume roll-to-roll patterned ITO films to support the exploding projected capacitive touch sensor market.



## Our Company Heritage

Sheldahl, Inc. was purchased by Multek, Inc. in 2004 and began doing business as Multek Flexible Circuits, Inc. and operated as such until August of 2018 when our parent company, FLEX, returned the Northfield operations back to a form of our heritage by changing our name to Sheldahl Flexible Technologies, Inc.

With over 30 years of flexible printed circuit manufacturing experience Sheldahl Flexible Technologies Inc., offers industry-leading interconnect solutions, Flexible and Rigid-Flex printed circuits for a broad range of applications.

Sheldahl Flexible Technologies, Inc. is a wholly owned subsidiary of Flex, a leading Fortune Global 500 Electronics Manufacturing Services (EMS) provider focused on delivering complete design, engineering and manufacturing services to automotive, computing, consumer, digital, industrial, infrastructure, medical and mobile OEMs. Flex designs, builds, ships, and services electronics products for our customers through a network of facilities in 30 countries on four continents.

## Important Notes:

Sheldahl's Red Book was written to supply detailed product and applications information for thermal control materials used in the aerospace market. In the years since it was first published the Red Book has become recognized as one of the industry's best sources of information on this topic. We hope you enjoy this updated version and we look forward to working with you on your new projects.

The information in this guide and the product bulletins presented are based on data obtained by our research and is considered accurate. However, no warranty is expressed or implied regarding the accuracy of the data and the results obtained from the use thereof. This information is furnished upon the condition that the recipient shall conduct tests to determine the suitability of the product for his or her particular application.

Sheldahl® is a registered trademark of Flex.

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## Thermal Control Overview

One of NASA's many challenges on the Apollo program was insulating moon walking astronauts from lunar daytime temperatures approaching 130°C (265°F) and night time temperatures falling to -110°C (-170°F).

Satellites orbiting the earth are subjected to similar extreme temperature variations. The delicate electronics on man-made satellites would not operate efficiently over this temperature range, so it is necessary to insulate the satellite from the space environment.

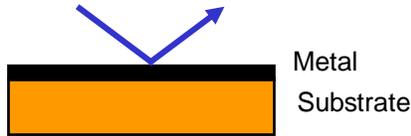
Active thermal control systems such as resistive heaters, thermo-electric coolers, sterling or peltier cycle coolers, and heat pipes are critical tools for managing the temperature in localized areas of the spacecraft. They are of limited value, however, in controlling the mean temperature of a spacecraft. Heating systems consume valuable electrical power. Cooling systems also consume power and actually only concentrate thermal energy in a small volume that must still be passively radiated into space.

In general, there are three modes available for the transfer of thermal energy; conduction, convection, and radiation. Because a satellite is isolated from other objects with mass, the only method available to affect the mean temperature of the satellite is radiation (conduction is important when considering localized temperature within the spacecraft).

All entities radiate thermal energy at a rate depending on their temperature and their efficiency of radiation or emittance. Passive thermal control systems for launch vehicles and spacecraft use engineered materials to control the amounts of energy radiated and absorbed. High emittance materials are used to radiate heat energy into space and cool the spacecraft. These materials may be used to radiate energy that has been concentrated by an active thermal control system. The spacecraft can be isolated from the external environment through the use of multilayer insulation (MLI) blankets consisting of many layers of low emittance materials. The ratio of the solar absorptance to the emittance of the materials illuminated by the sun is chosen to transfer the desired amount of solar energy to the spacecraft.

We manufacture a wide variety of products with engineered absorptance and emittance characteristics for passive thermal control systems. These materials are supplied in large sheets, rolls, and tapes. Our products have been used on nearly every payload and rocket launched since the mid-1960s.

## First Surface Mirrors



A first surface mirror consists of a metallic coating (typically aluminum or gold) on a substrate. For multilayer insulation (MLI) blankets the substrate is usually PET or polyimide film, though FEP is used in some applications. Metallic coatings have very low emittance, so films coated on both sides are typically used for the inner layers of insulation blankets to minimize heat transfer.

Aluminum is the most commonly used coating; it combines low absorptance and emittance with low cost. The surface emittance, and hence energy transfer, can be reduced further through the use of gold coatings. Because gold is nearly inert, it has also been used in applications where the MLI blankets will be subjected to moist (salty) atmosphere for extended periods (e.g. space shuttle). As an alternative in this application, the aluminum can be protected with a corrosion resistant AOC coating.

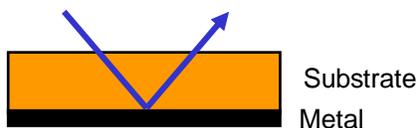
When the internal layers of the blanket will not rise much above room temperature, PET films are used. They form efficient, cost-effective radiative transfer barrier layers. When high temperature operation or burn resistance is required, polyimide is the substrate of choice.

Table 1 gives typical emittance and absorptance values for a variety of metals. The metals in this table are those most commonly used for thermal control. We have the ability to coat films with many other metals including copper, chrome, NiChrome, Inconel™, and Monel™ for other applications.

**Table 1 Absorptance and emittance of metal coatings.**

Metal	Typical Emittance ( $\epsilon$ )	Typical Absorptance ( $\alpha$ )	$\alpha/\epsilon$
Gold	0.02	.28	14
Silver	0.02	.07	3.5
Aluminum	0.03	.12	4

## Second Surface Mirrors



When the sun is shining on a surface, it will be heated and reach an equilibrium temperature based on the amount of sunlight absorbed (solar absorptance,  $\alpha$ ) and the amount of heat energy emitted (emittance,  $\epsilon$ ). The lower the absorptance to emittance ratio, the lower the equilibrium temperature will be. First surface mirrors have an absorptance ratio of between 3 and 15 as seen in Table 1. To reach lower equilibrium temperatures, another device is necessary with a lower absorptance to emittance ratio.

A second surface mirror uses the bulk of the substrate to provide relatively high emittance and a metallic coating to (usually) provide low absorptance. The lowest ratios of absorptance to emittance are obtained by using a clear FEP (Teflon®) film and a highly reflective silver coating. Polyimide films are used when high temperature operation is necessary or when the stretchy FEP film does not supply adequate structural stability.

The absorptance and emittance characteristics of the second surface mirror can be tuned through the choice of substrate material, substrate thickness, and coating. Table 2 shows the typical absorptance of a wide variety of coatings. Table 3 gives the emittance of FEP and polyimide films as a function of the film thickness.

**Table 2 Absorptance of coatings used for FEP second surface mirrors**

Metal	Solar Absorptance
Silver	.06-.09
Aluminum	.10-.14
Copper	.20-.30
Germanium	.50-.70
Inconel™	.60-.70

Inconel is a registered trademark of international Nickel Company

**Table 3 Emittance of polymer films**

Film Thickness		Typical Emittance	
Mils	Microns	FEP	Polyimide
0.5	12.5	0.41	0.52
1	25	0.52	0.64
2	51	0.65	0.76
5	127	0.79	0.85
10	254	0.86	

## Special Purpose Coatings

### Corrosion Resistant Coating — AOC

The Sheldahl® AOC corrosion resistant coating was developed specifically to allow aluminum to replace gold in the Space Shuttle's multi-layer insulation (MLI) blankets.

Gold coatings were chosen in the early 1970's for shuttle blankets and were designed to withstand many launch, mission, re-entry, and mission preparation cycles. When gold reached \$850 per troy ounce, a lower cost approach using aluminum was preferred. Because the MLI blanket fills with air upon reentry, salt vapor and pollutants in the air can corrode aluminum coatings.

Sheldahl<sup>®</sup> AOC “acrylic over coat” was developed to protect the aluminum. The coating is between 2,000 and 4,000 Å thick yet provides environmental protection. Products with AOC protection have passed the following tests:

- 24 hours in 5% salt fog
- 100 thermal cycles between -320° F (-195° C) and +400° F (+205° C)
- 10 humidity cycles
- 25 abrasion cycles per Q000401

## **Black Coating — Thick Film Black (TFB)**

Some thermal control situations require materials with both high emittance and high solar absorptance. In the early days of the space programs there were no commercially available black films that could withstand high temperatures. Sheldahl<sup>®</sup> Thick Black Film coating was developed to address this application.

Thick Film Black is approximately 0.8 mils  $\pm$  0.1 (18 $\mu$ m - 23 $\mu$ m) thick and is composed of a carbon-filled polyester binder. It is typically applied to polyimide substrates to provide both high solar absorptance ( $\geq$  0.85) and high emittance ( $\geq$  0.78). The coating is electrically conductive ( $\leq$ 1,000  $\Omega$ /square) and has a matte finish.

## **Germanium Coating**

Germanium coatings offer several unique features when used in thermal control applications. The germanium provides a surface resistivity on order of  $10^8 \Omega$ /square for static charge dissipation, an absorptance to emittance ratio of about 0.6, and is transparent in the RF spectrum. Germanium coated polyimide is often used on sunshields to protect RF antenna from solar radiation.

Because germanium is a semiconductor, it is an insulator at RF frequencies. In the thermal IR it is largely transparent (though there can be substantial surface reflection due to its high refractive index). Germanium has some absorption bands near the visible that give rise to a high refractive index and reflection of about 40% of the solar energy.

## **SiO<sub>x</sub> Coatings**

SiO<sub>x</sub> coatings form a clear, insulating layer over substrates or other coatings. The coating provides some protection against atomic oxygen and its thickness can be tailored to provide specific emittance levels. Sheldahl's two main product offerings with this coating are polyimide film coated with aluminum and SiO<sub>x</sub> and FEP films and tapes with silver on one side and SiO<sub>x</sub> on the other.

The radiator panels on the International Space Station and the Space Shuttle are covered with silver coated FEP tape. To assure that the tapes would have a long operating lifetime in the presence of atomic oxygen; these tapes were coated with SiO<sub>x</sub>. This clear coating has minimal effect on the optical characteristics of the tape. The SiO<sub>x</sub>, however, acts as an atomic oxygen absorber and extends the life of the tape.

Some applications require a product with low solar absorptance and an absorptance to emittance ration of less than one. Most metallic coatings are better reflectors in the infrared than in the visible, so metal coatings tend to have an absorptance to emittance ratio of four or more as seen in Table 1. Sheldahl offers products with a SiO<sub>x</sub> coating over aluminum to raise the emittance substantially. We offer two standard products with this construction; one with an emittance of approximately 0.12, the other with an emittance of about 0.25. We can design coatings to provide other emittance levels as required.

## Transparent Conductive Coatings (ITO) For Static Charge Control

Transparent conductive coatings are applied to the front surface of the second surface mirrors to drain static electricity that is typically induced by the van Allen radiation belt. Without the coating, surface charges can build potentials of 20,000 to 30,000 volts.

The most common type of transparent conductive coating is Indium Tin Oxide (ITO). The surface resistance of this coating can be adjusted from as low as 20 Ω/square to as high as about 10,000 Ω/square. As a part of a thermal control system the target surface resistance is a compromise between several competing factors. On the one hand, a thicker, lower surface resistance product is desired to provide a more robust coating. On the other hand, higher surface resistance is desired to reduce surface currents and to maximize the emittance of the product (ITO can be a very good IR reflector).

Our standard product has a target surface resistance of 5,000 Ω/square as a compromise between these competing goals. An ITO coating of this thickness has no measurable impact on emittance and increases the solar absorptance by about 5%. ITO is available in sheets and rolls up to 48 inches wide. We also manufacture tapes with ITO coatings.

**Table 4** below provides the key characteristics of our standard ITO coating.

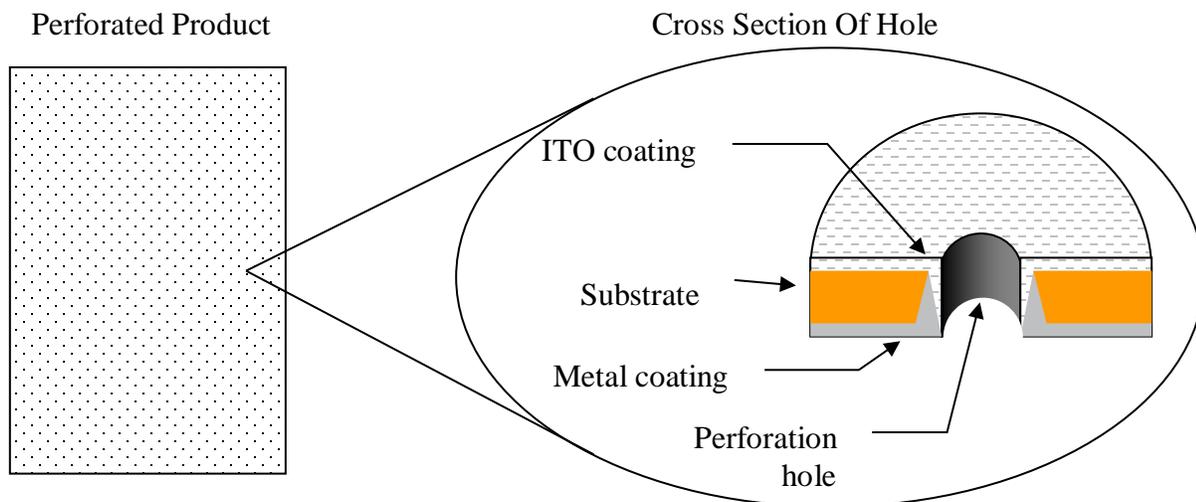
**Table 4 ITO coating key characteristics**

Parameter	Value
Surface Resistance	2,000 to 10,000 Ω/square
Thickness	<100Å
Abrasion On Polyimide	Resistance remains in specification after rubbing 10 cycles with two pound force on cheesecloth (Q000401)
Coating Adhesion	Passes Scotch® Tape Test (Q000084)
Weathering	U.V/Humidity (ASTM 6 53-77) No Change After 144 Hours

## Perforated Interconnects

Connecting ground leads to ITO coated surfaces is difficult. The coating is fragile and many techniques for attaching a ground wire will crack the coating and isolate the ground wire from much of the coating. An alternative is to develop a technique to use the coatings themselves to connect the ITO on one side of the substrate to a highly conductive coating on the other.

Creating an electrical interconnect can be done by perforation a series of holes in the substrate prior to applying the coatings, as seen in Figure 1. When this is done, both the ITO and the metal coatings cover the walls of the perforation hole and form an electrical connection between the top and the bottom of the substrate. This technique provides redundant connections between the two surfaces. Many customers have used this technique successfully with the perforations providing as little as 1% open area.



**Figure 1 Perforated interconnections**

## Adhesives & Laminates

Sheldahl® uses many adhesives in its thermal control products. We manufacture thermal control tapes using commercially available pressure sensitive adhesives (PSAs) such as 3M™966, 3M™9460, 3M™9703, 3M™9713, and Adhesives Research AR®8026. Sheldahl® also offers a wide variety of thermal control laminates. Laminates can be manufactured using a PSA, but better bond strength, lower weight, and lower costs can be achieved through the use of thermosetting adhesives.

We have specifically designed three adhesive systems for our thermal control laminates. All have been flown on missions and are space qualified. For standard temperature applications, our A528 polyester thermosetting adhesive will meet most requirements. When a conductive adhesive is required, our modified Thick Film Black carbon loaded adhesive provides conductivity. For very high temperature or cryogenic applications, our 3P adhesive system is unmatched.

## “3P” Adhesive System

### High Temperature Applications

3P adhesive (polyimide/polyamide/polyester base resin) has been used in applications requiring performance at extreme temperatures. Sheldahl® has provided a variety of film/film, film/fabric, and film/foil laminates primarily to the military and aerospace markets where low outgassing and high temperature resistance is required. Applications include continuous exposure (months) to temperatures in excess of 250° C (450° F), and intermittent exposure (seconds) to temperatures in excess of 535° C (1000° F).

### Low Temperature Applications

3P laminates have also been used successfully at cryogenic temperatures. The SSCL radiation resistance evaluation included mechanical property testing at 4K.

### Radiation Resistance

The mechanical properties of cured, Sheldahl® 3P polyimide film tapes were tested before and after irradiation in the SSCL (Superconducting Super Collider Laboratory) radiation resistance evaluation. Lap shear test specimens coated with 3P adhesive (manufactured and cured by Sheldahl personnel following the recommended cure cycle) have been mechanically tested before and after accelerated irradiation at 4K to simulate the long-term service in cryogenic magnets. No significant changes in ultimate adhesive strength were recorded after exposure dosages in excess of  $4 \times 10^9$  rads. The result of this testing is documented in SSCL Publication Number 635, dated July 1993.

### Outgassing Characteristics

Samples of unsupported 3P (bare adhesive without film) were tested per ASTM E595 (vacuum outgassing). They easily passed the requirements of 1.0% maximum Total Mass Loss (TML) and 0.1% maximum Collected Volatile Condensable Material (CVCM), as shown in Table 5.

**Table 5 Results of ASTM E-595 testing of 3P adhesive**

Agency	Johnson Space Center 313-686-11-04-01	Space Systems Loral July 1993	European Space Agency
Total Mass Loss	0.74%	0.012%	0.94%
Volatile Condensable Material	0.06%	0.002%	0%
Water Vapor Reabsorption	0.36%		0.38%

## Roll-to-Roll Processing - Perforation & Embossing

Our products may be Perforated to facilitate air passage during launch, to provide electrical contact between surfaces, or even Embossed to diffuse optical characteristics or for separation between MLI layers. Sheldahl<sup>®</sup> can run up to 62" wide through state-of-the-art equipment.

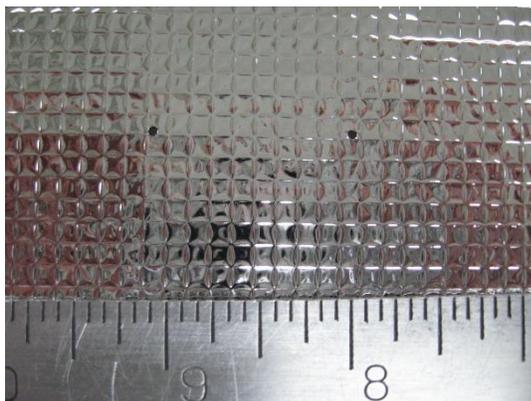
Our process is capable of running very thin gauge films, fabrics, non-wovens, foils and composite laminates either produced here, or supplied by the customer.

Many perforation options exist. Sheldahl<sup>®</sup> materials can be provided with both visible and invisible methods.

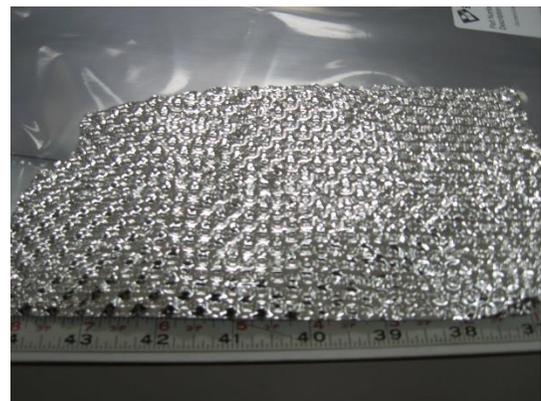
The invisible method is called Porolation or Micro-Venting. This method results in approximately 125 regularly spaced holes per square inch (18,000 holes per Sq. Ft.) that are produced with the end of a needle. No material removal is made with this method, and generally the material must be held up against a back light to see the holes. Porolation is used for air permeability and breathability while preserving the integrity of the material.

With visible perforations, the customer has many more choices to enhance the material's functionality. Sheldahl<sup>®</sup> perforation can be offered with a variety of Pin Densities, % Open Areas, and Hole Patterns. The standards range from hole diameters of 0.045" – 0.187"; hole densities of 0.04 – 10.3 holes per square inch; and % open areas of 0.02 – 2.8%. Many opportunities exist within and outside of these standards for custom applications. Please contact a Sheldahl representative to discuss your project in detail.

Embossing: There are two standard patterns:



Square Tile Pattern consists of 0.125" squares with 64 squares per square inch



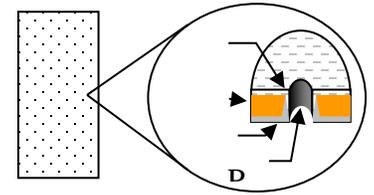
Sheltherm<sup>™</sup> pattern has 3,850 dimples/SQ FT with a profile height of 0.060"

# FILM PERFORATION PATTERNS

S = Square Pattern

D = Diagonal Pattern

No Letter is the Staggered Pattern with holes at 60 degree angles.



Example: 059-0500D

1. Diameter of the perforation holes **.059 inch**
2. The distance between the center of the perforation holes, **.500 inch horizontal and vertical distance between centers.**
3. **D = Diagonal pattern**

PATTERN NUMBER	PATTERN	HOLES/ SQ. IN	% OPEN	Page
045-0270	60° STAGGERED	15.583	2.48%	16
045-0405	60° STAGGERED	7.132	1.13%	17
045-0405S	SQUARE	6.045	0.96%	17
045-0810	60° STAGGERED	1.743	0.28%	18
051-1156S	SQUARE	0.760	0.16%	18
051-3000S	SQUARE	0.110	0.02%	19
059-0312S	SQUARE	10.295	2.81%	19
059-0500D	DIAGONAL	8.000	2.19%	20
059-0750D	DIAGONAL	3.550	0.97%	20
059-0843D	DIAGONAL	2.823	0.77%	20
059-1000D	DIAGONAL	2.000	0.55%	22
059-1000S	SQUARE	1.000	0.27%	22
125-4000S	SQUARE	0.073	0.09%	23
187-5500S	SQUARE	0.044	0.12%	23

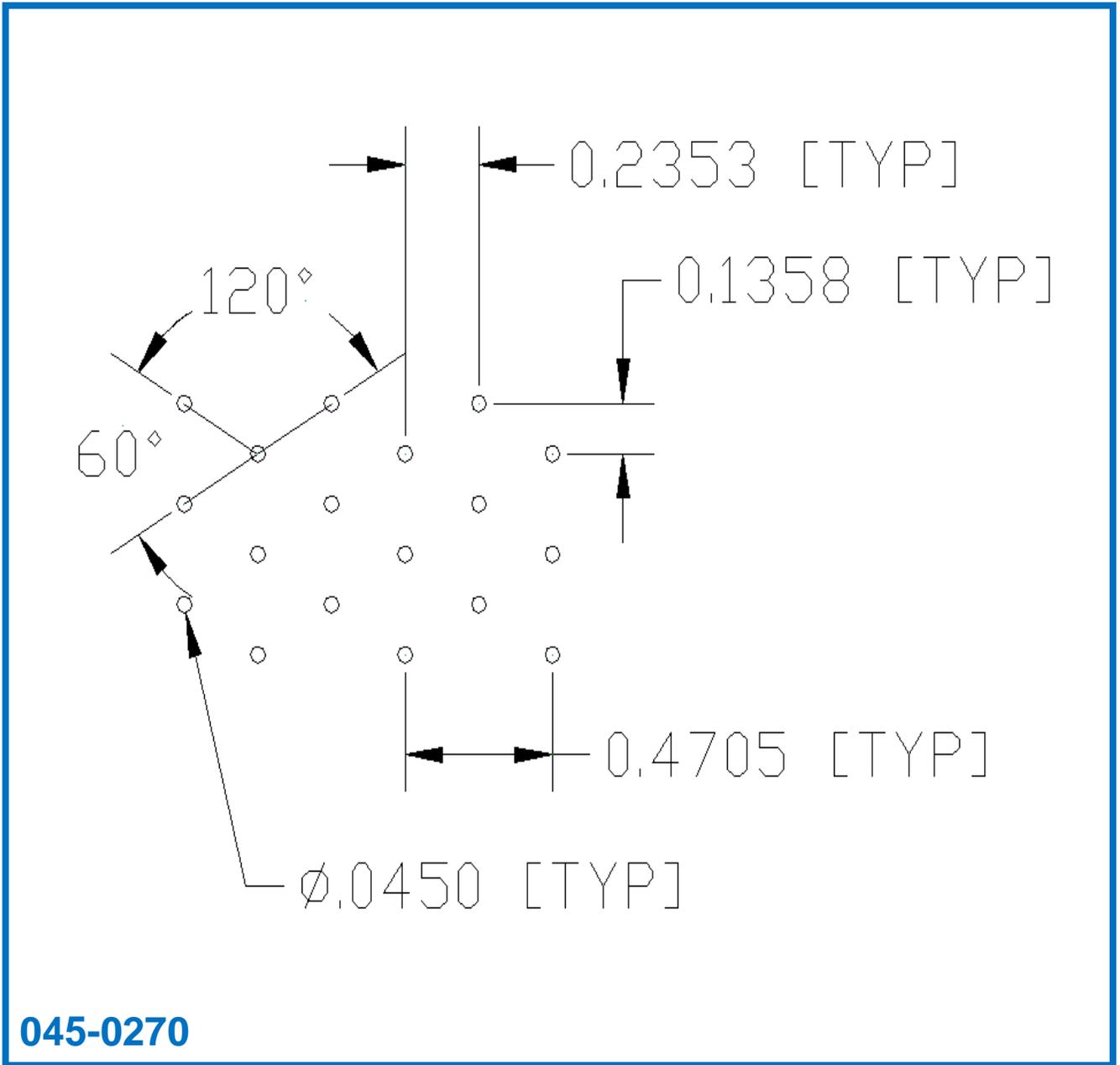
## POROLATION PATTERN

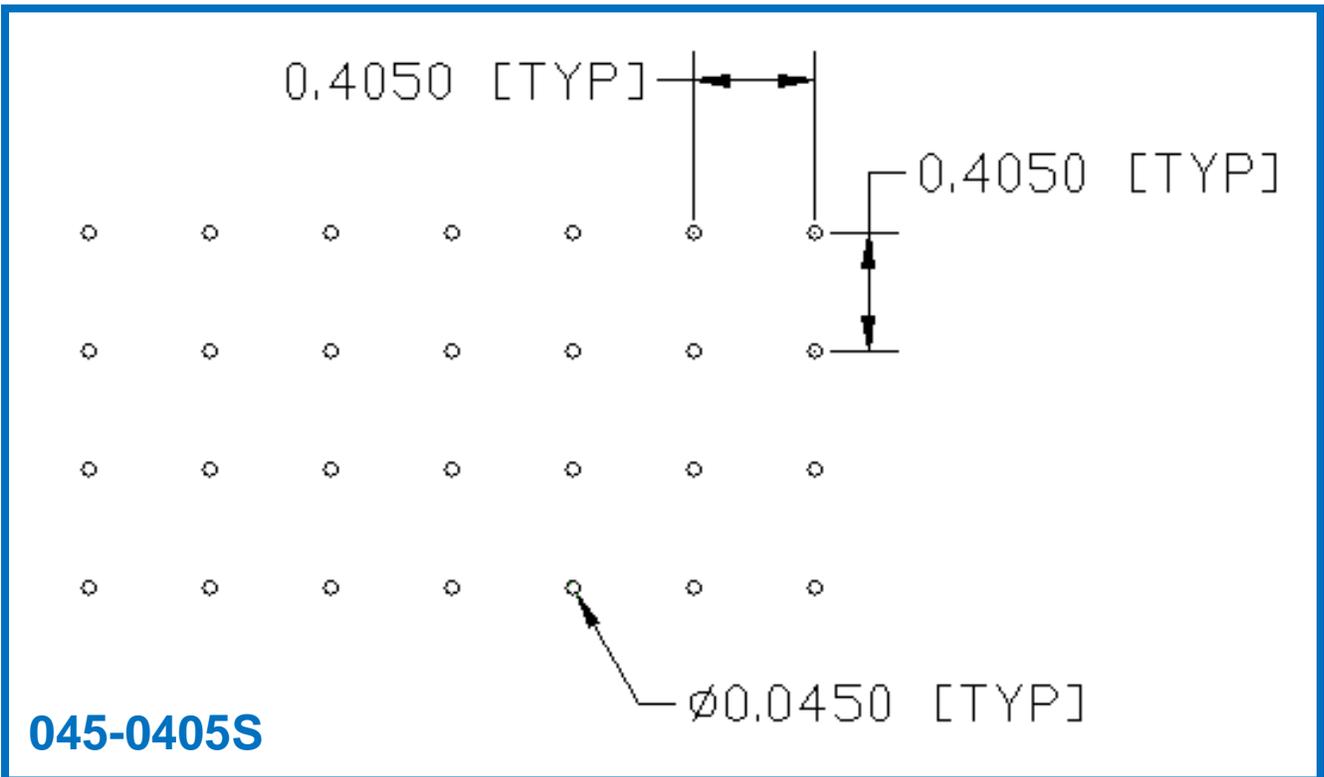
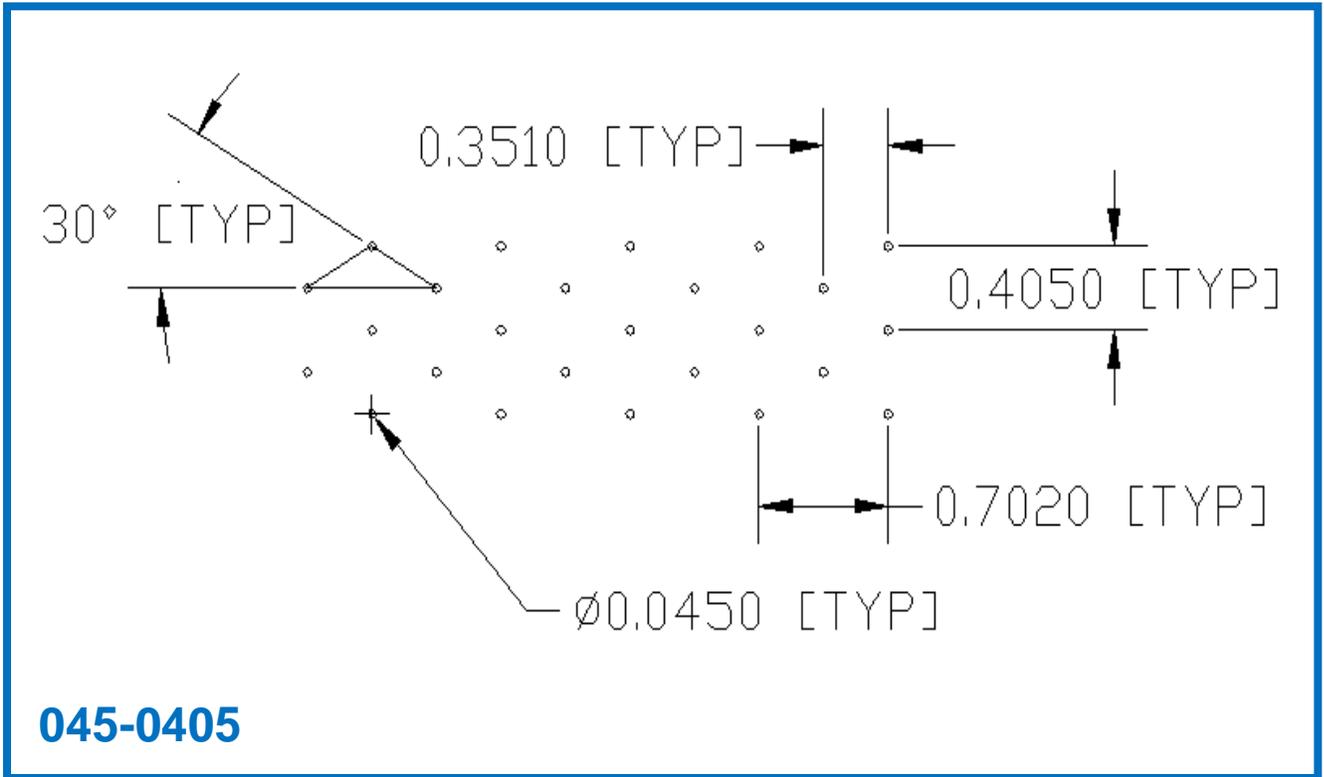
Porolation	18,000 pin holes per sq. foot.	
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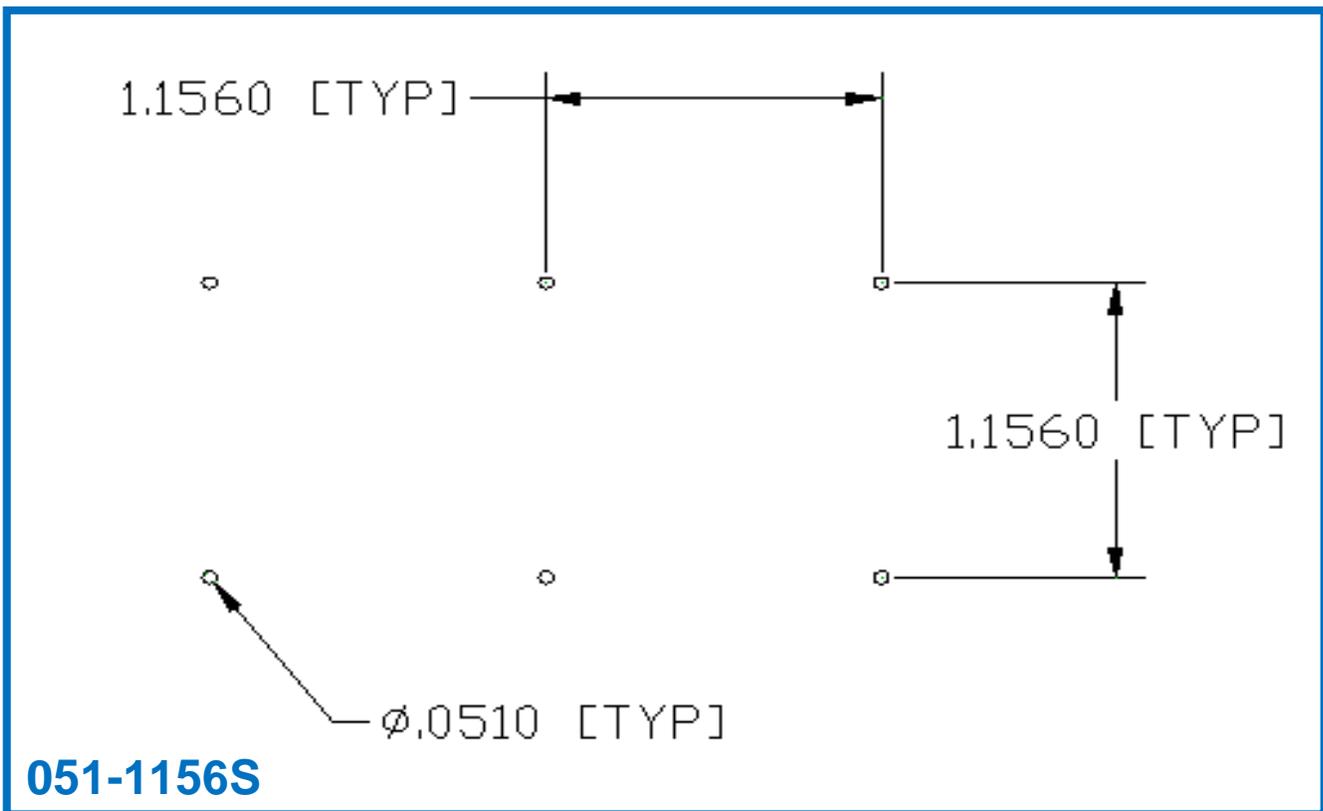
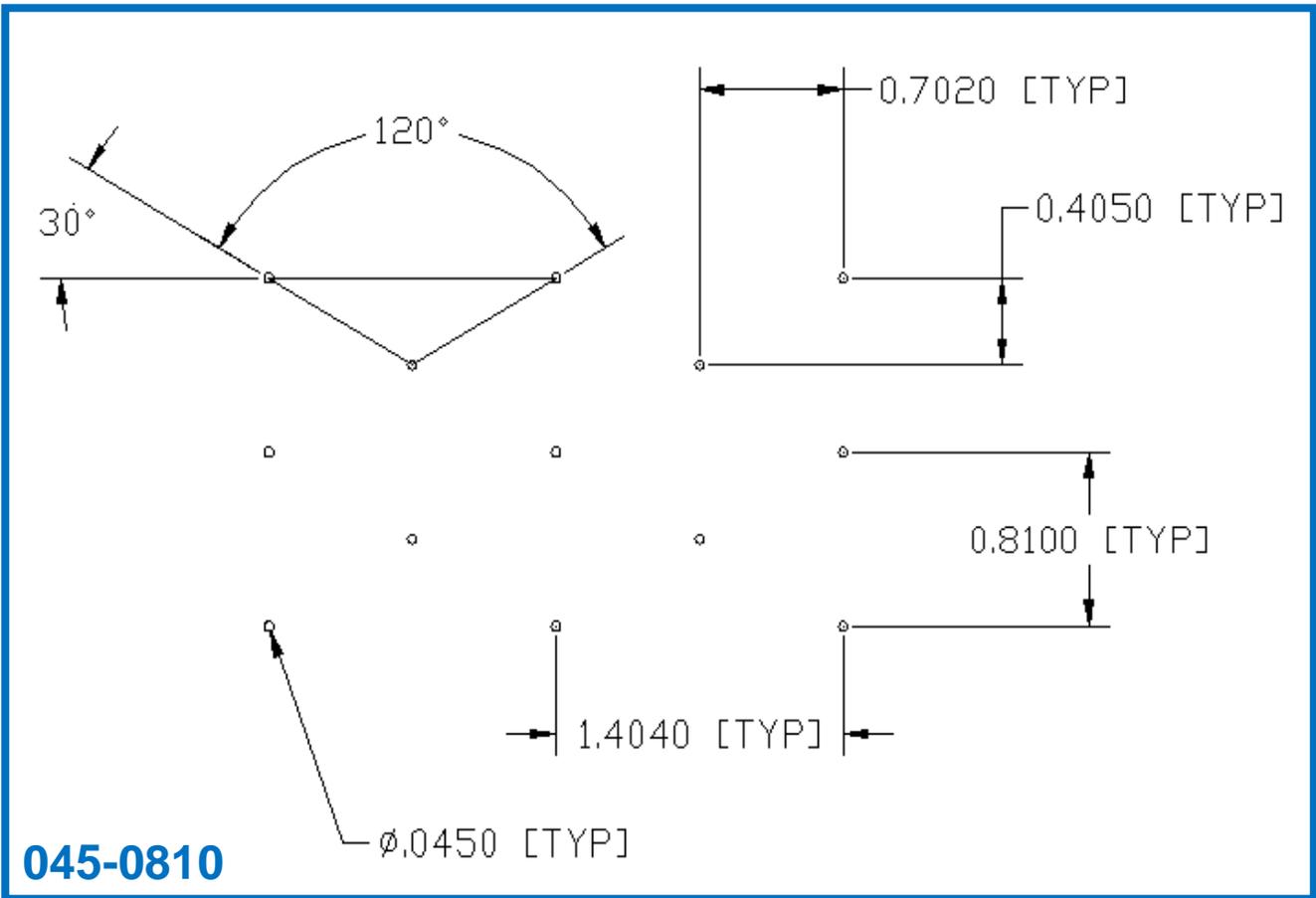
## TAPE PERFORATION PATTERN

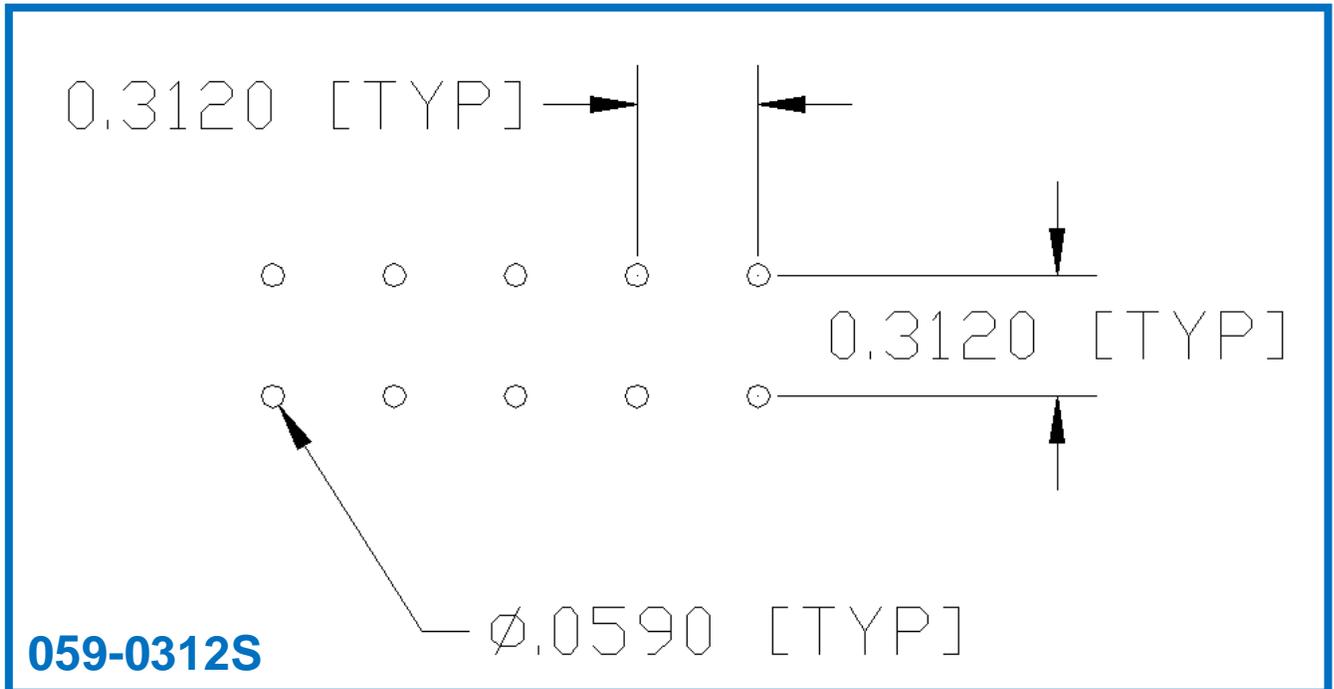
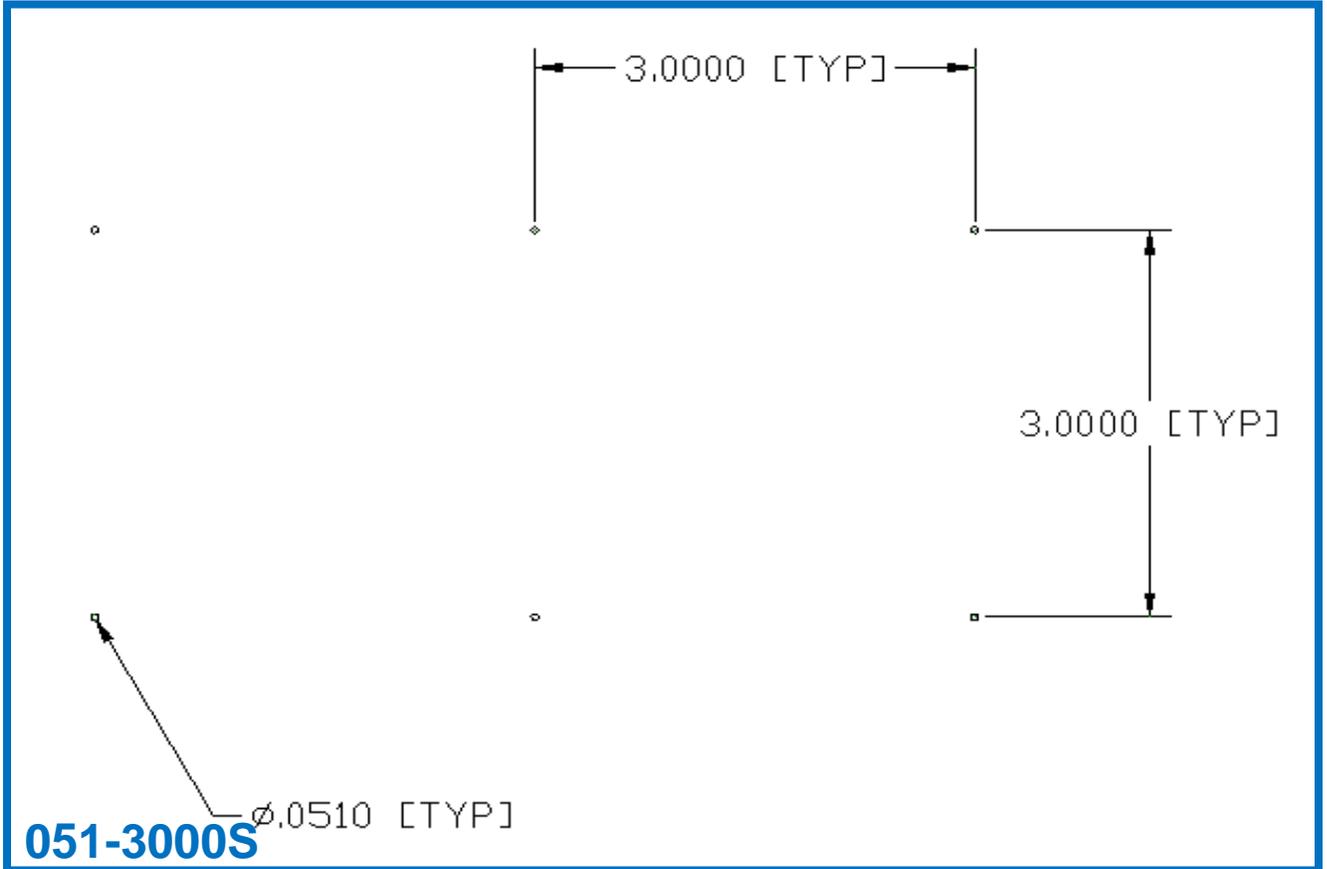
PERFORATION Tape Pattern	0.76 diameter hole on 6.35mm centers per sq. foot.	1.1%
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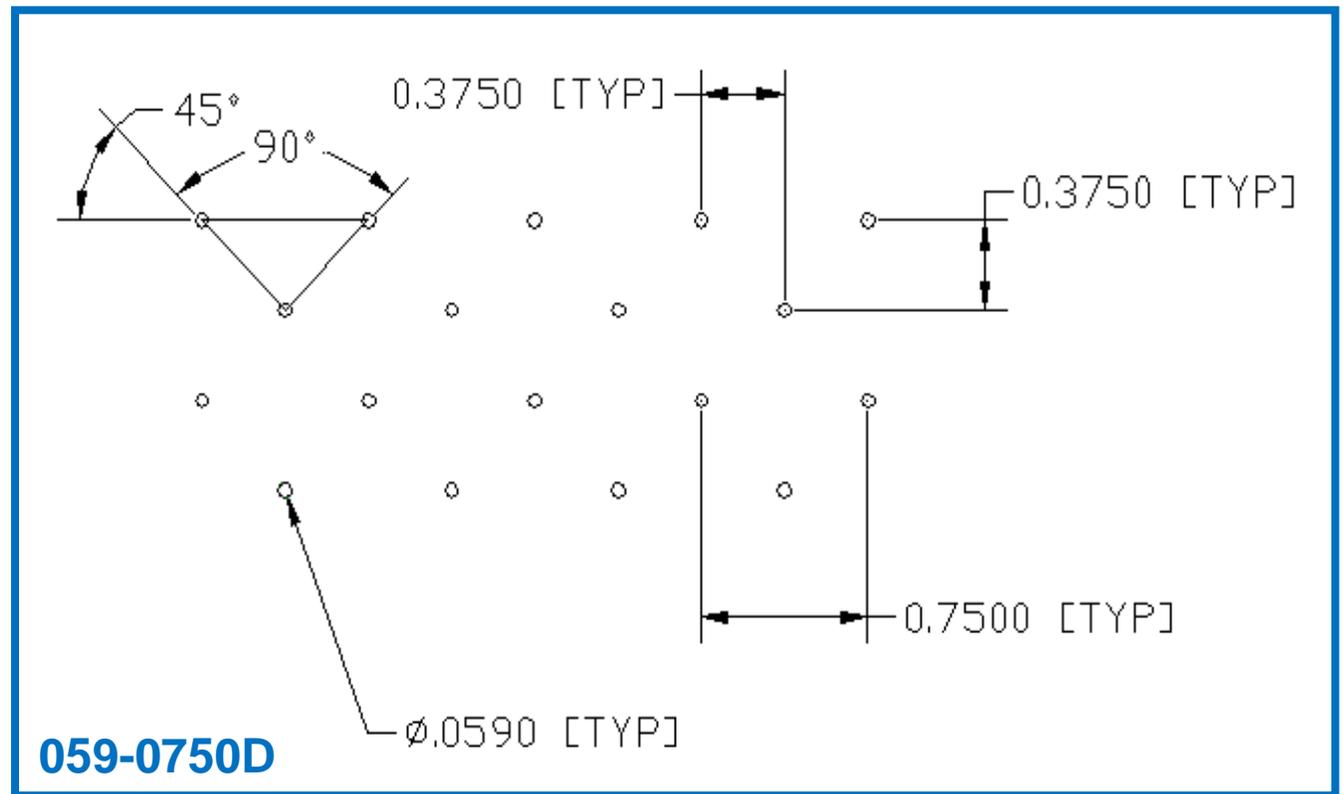
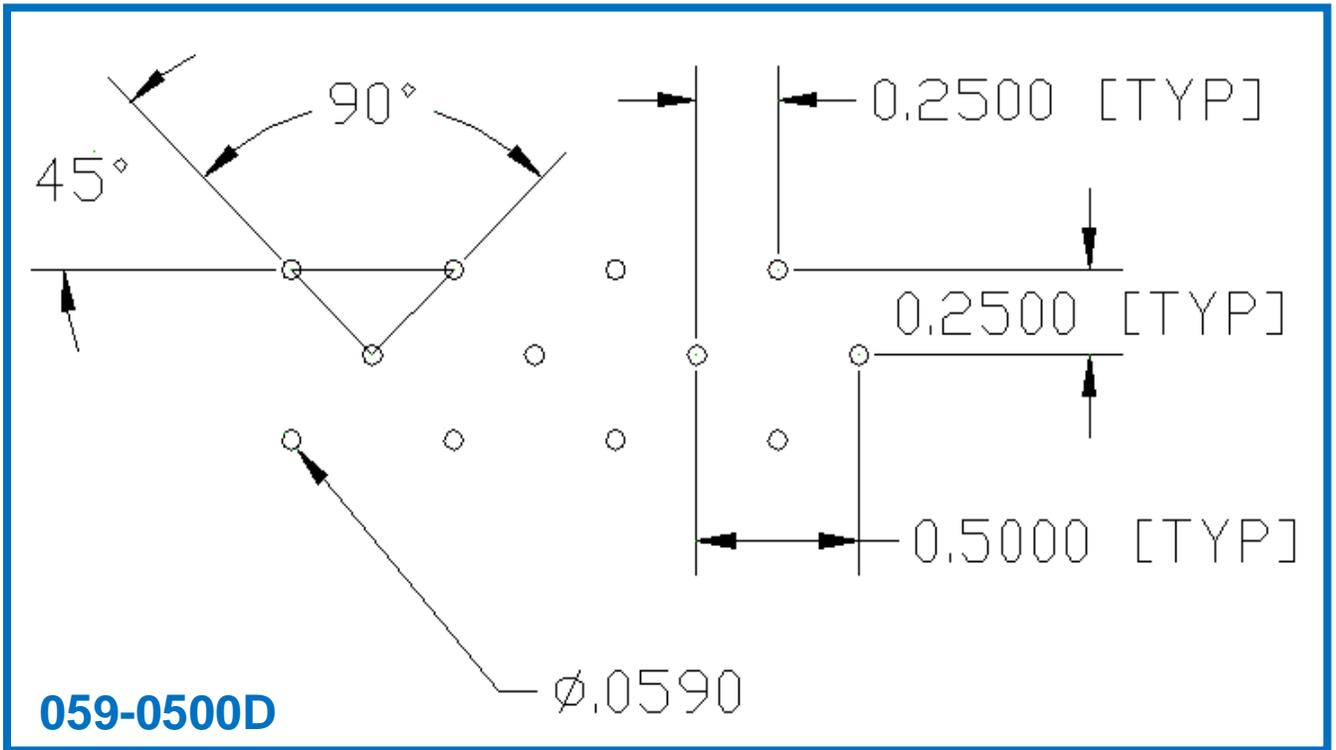
*\*For custom perforation or porolation patterns contact Jim Prince at [Jim.Prince@Sheldahl.com](mailto:Jim.Prince@Sheldahl.com)*

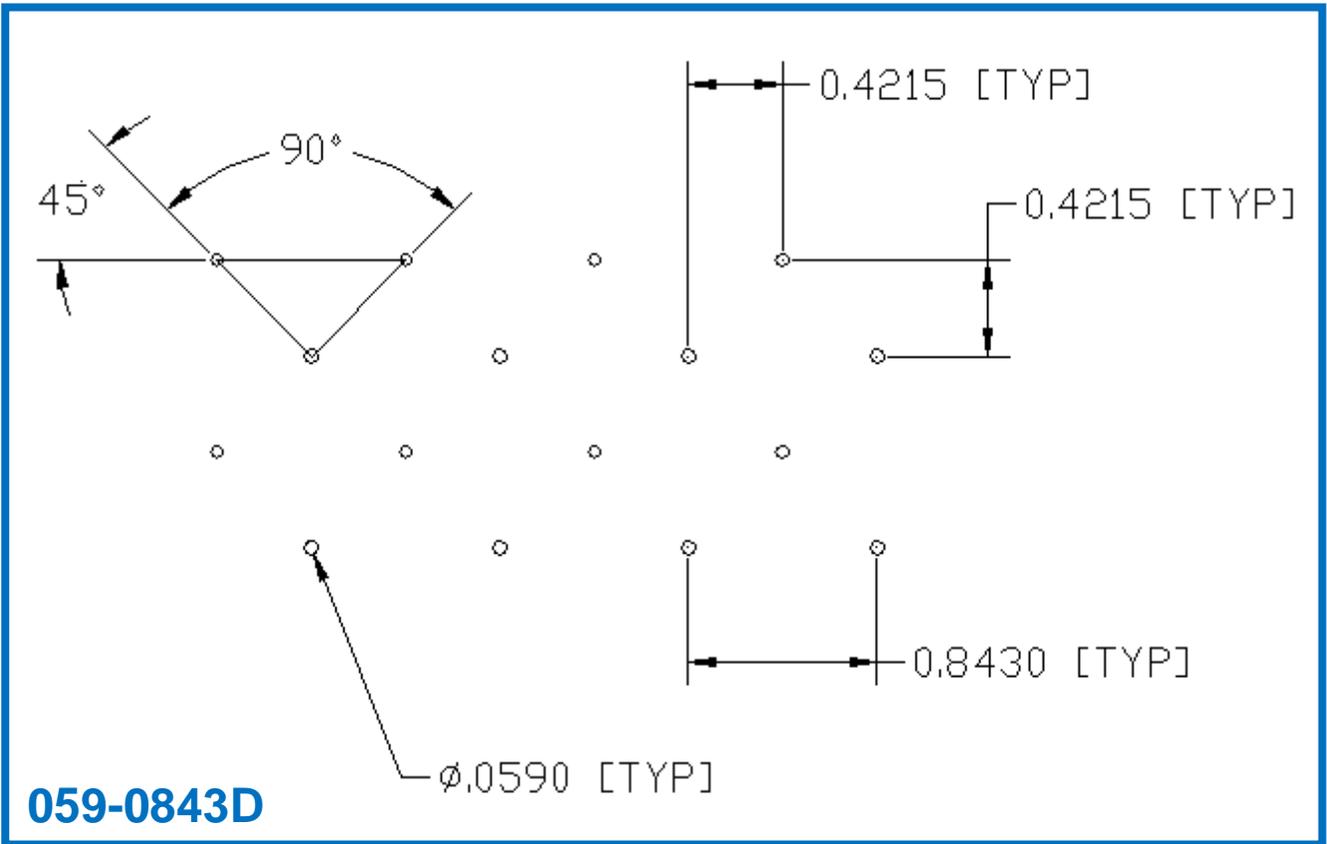






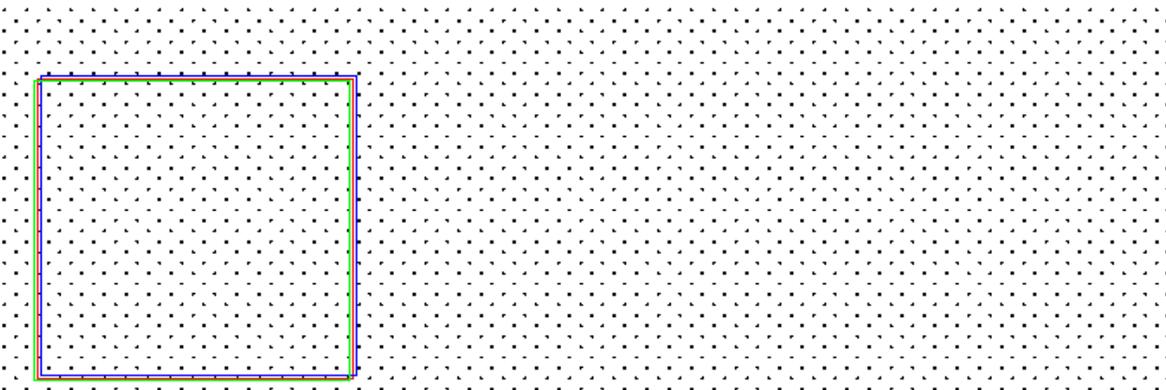






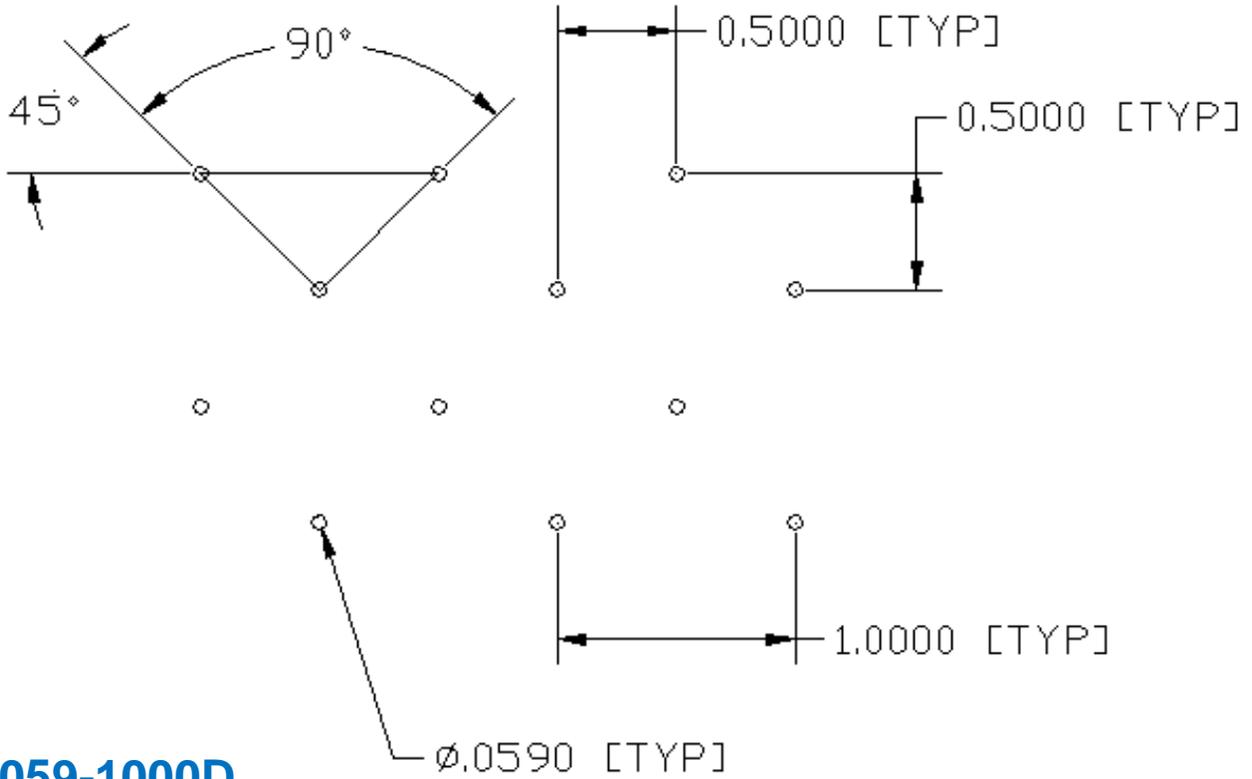
392 TO 421 HOLES PER SQ FT.  
 EFFECTIVE AVG = 406.5  
 HOLES/SQ. FT, THUS  
 2.8229 HOLES' PER SQ.  
 INCH.  
 HOLE AREA = 0.002734  
 SQ. INCHES \* 2.8299  
 == 0.0077363  
 0.774 % OPEN AREA

RED = 7.5+7+196+196=406.5 HOLES  
 BLU = 196+196=392 HOLES  
 GRN = 225+196=421 HOLES  
 [LISTED PER SQUARE FOOT]  
 EFFECTIVE AVG = 406.5 HOLES/SF

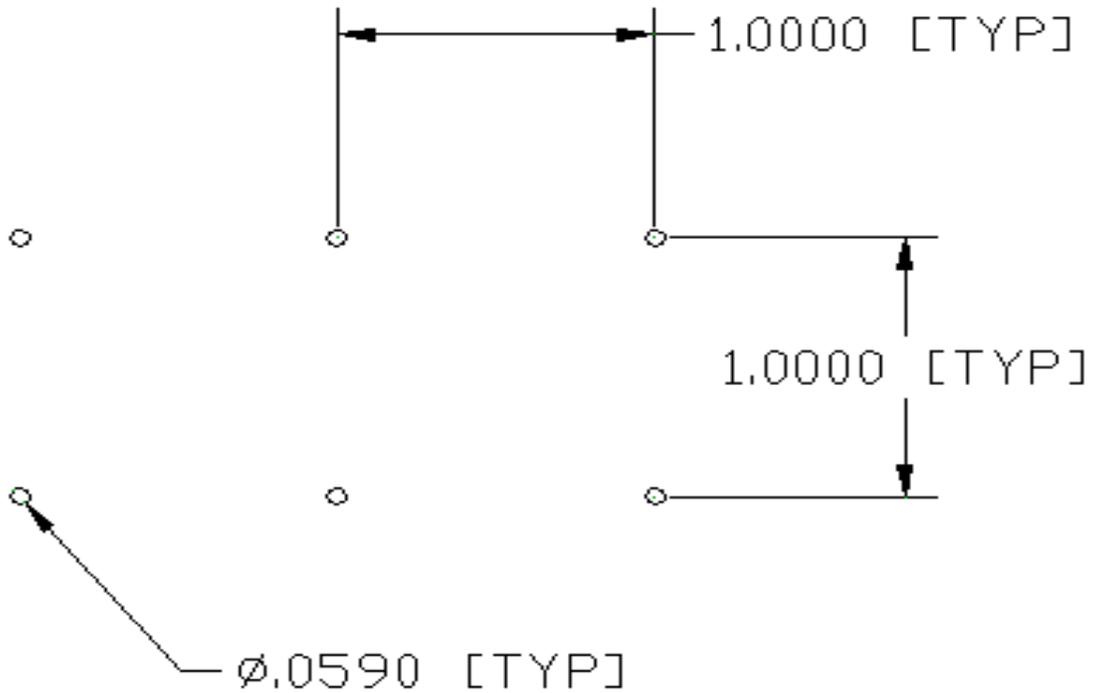


**059-0843D** Explanation

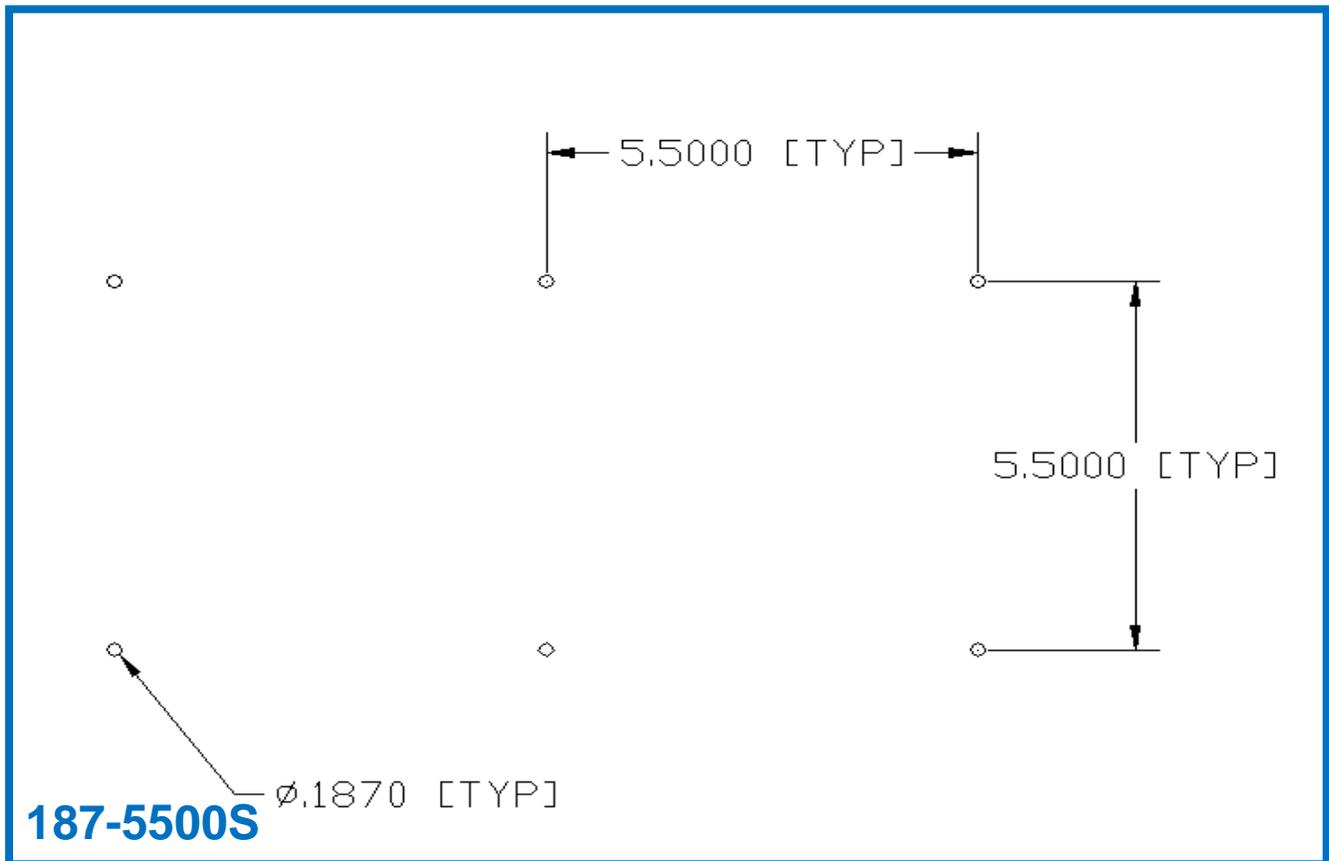
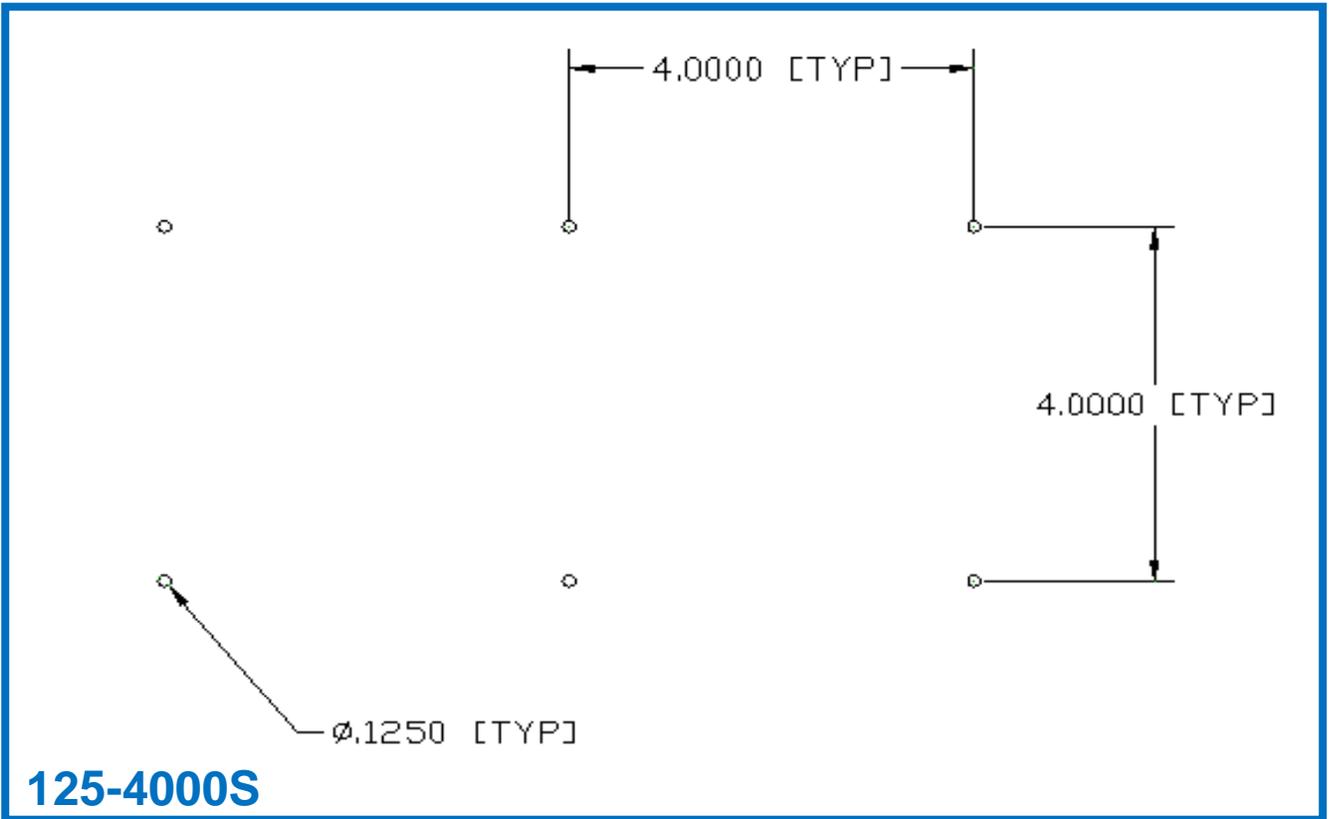
PATTERN: 059-0843D



**059-1000D**



**059-1000S**



## Special Fabrications Overview

Applications for Special Fabrications range from environmental seals used to protect delicate electronic components for long term storage to inflatables for a variety of end uses to large polyimide sheets for satellite solar collectors. We service customers in the military/aerospace, commercial and electronics industries.

Sheldahl has engineered custom fabricated products for over 40 years. Custom products are created from a variety of materials and processes based on customer requirements. The raw materials used may be purchased, manufactured at Sheldahl, or customer supplied. Fabrication methods include heat or pressure forming, punching, cutting, and sewing resulting in unique shapes, forms, and configurations.

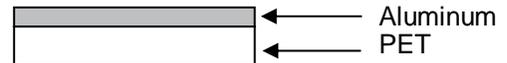
Sheldahl® flexible materials are joined using butt or overlap seams or mechanical fasteners. Overlap seams can be made using pressure sensitive or thermosetting adhesives or by fusion bonding the material to itself. Butt seams are made with Sheldahl® tapes typically using thermosetting adhesives. Using our proprietary adhesive systems and many years of experience we can make these seams into air and moisture tight seals.

Please contact Jim Prince at [Jim.Prince@sheldahl.com](mailto:Jim.Prince@sheldahl.com) for more information or a quotation.

FORMING CAPABILITES	COMBINING CAPABILITES
<ul style="list-style-type: none"> <li>• Slitting</li> </ul>	<ul style="list-style-type: none"> <li>• Laminating / In-Line coating</li> </ul>
<ul style="list-style-type: none"> <li>• Die Cutting</li> </ul>	<ul style="list-style-type: none"> <li>○ Thermoset Adhesives</li> </ul>
<ul style="list-style-type: none"> <li>• Heat Forming</li> </ul>	<ul style="list-style-type: none"> <li>○ Pressure Sensitive Adhesives</li> </ul>
<ul style="list-style-type: none"> <li>• Sheeting</li> </ul>	<ul style="list-style-type: none"> <li>• Sealing</li> </ul>
	<ul style="list-style-type: none"> <li>• Platen Pressing</li> </ul>

## PRODUCT BULLETIN

### Aluminum Coated (One Side) PET



Sheldahl® construction of Polyethylene Terephthalate (PET or polyester) films that are aluminized on one side can be used as either first or second surface mirrors, and are often used in multi-layer insulation (MLI) blankets in low temperature applications. When used as first surface mirrors, these products provide low emittance and low solar absorptance.

This product may be ordered with 0.25, 0.5, 1, 2, 3, or 5 mil thick PET that conforms to the requirements of MIL-I-631 and L-P-377. The aluminum coating is nominally 1000 Å thick, and the most common width is 48 inches (1.22 m).

### PRODUCT CHARACTERISTICS

Parameter (independent of film thickness)	Specified Value
First surface mirror solar absorptance ( $\alpha$ )	$\leq 0.14$
First surface mirror hemispherical emittance ( $\epsilon_H$ )	$\leq 0.035$
First surface mirror normal emittance ( $\epsilon_N$ )	$\leq 0.035$
Typical first surface mirror $\alpha/\epsilon$	4 – 5
Aluminum surface resistivity	$\leq 1 \Omega/\text{square}$
Intermittent temperature range	-250° C to 150° C (-420° F to 300° F)
Continuous temperature range	-250° C to 120° C (-420° F to 250° F)

Standard Item Number	Thickness mil ( $\mu\text{m}$ )	Typical Weight ( $\text{g}/\text{m}^2$ )	Perforation Item Number
146477*	0.25 (6)	9	159776
146476*	0.5 (12.5)	17	159777
146468*	1.0 (25)	33	159778
146470*	2.0 (51)	71	159779
146472*	3.0 (76)	104	159780

\*Contact Sheldahl for 5 mil PET construction requirements

## POST PROCESSING – PERFORATION & EMBOSSING

This product may be processed after metalizing to enhance its functionality. To facilitate air passage during launch, the film may be Perforated. Standard perforation patterns are on pages 15 - 23.

Materials may also be embossed or crinkled to provide separation between the layers of an MLI blanket instead of, or in addition to, using fabric spacer layers.

## WARRANTY INFORMATION

Sheldahl warrants that our thermal control materials will meet all acceptance testing criteria for one year from the date of shipment (except Germanium, see product bulletin) if the materials have been stored indoors at standard conditions in their original packaging.

## SHELF LIFE

This product shall meet specified values for a minimum of 12 months after the date of shipment provided that the material is stored in its original unopened container at normal interior temperatures (10° C to 27° C/50° F to 80° F).

The shelf life of the material should be much longer than the warranty period. We recommend retesting any material that is more than one year old (or more than one year since most recent testing) prior to use. This will verify that the material has not been accidentally damaged. Sheldahl offers retest services for a nominal fee.

## SPECIFICATION AND PART NUMBERS

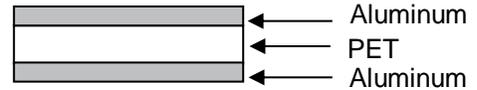
Standard Part Numbers		Thickness	PERFORATION Part Numbers	
Sheldahl Specification	Item Number		Sheldahl Specification	Item Number
G405370	146477	0.25 mil	G405374	159776
G405360	146476	0.5 mil	G405364	159777
G405310	146468	1.0 mil	G405314	159778
G405320	146470	2.0 mil	G405324	159779
G405330	146472	3.0 mil	G405334	159780

Sheldahl manufactures a broad range of vacuum deposited films, laminates and tapes. Ask for additional product bulletins describing other Sheldahl® Materials.

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## PRODUCT BULLETIN

### Aluminum Coated (Two Sides) PET



Sheldahl® of Polyethylene Terephthalate (PET or polyester) films that are aluminized on both sides can be used as first surface mirrors, and are often used in multi-layer insulation (MLI) blankets in low temperature applications. These products provide low emittance and low solar absorptance.

This product may be ordered with 0.25, 0.5, 1, 2, 3, or 5 mil thick PET that conforms to the requirements of MIL-I-631 and L-P-377. The aluminum coating is nominally 1000 Å thick, and the most common width is 48 inches (1.22 m).

### PRODUCT CHARACTERISTICS

Parameter (independent of film thickness)	Specified Value
Solar absorptance ( $\alpha$ )	$\leq 0.14$
Hemispherical emittance ( $\epsilon_H$ )	$\leq 0.035^*$
Normal emittance ( $\epsilon_N$ )	$\leq 0.035$
Typical $\alpha/\epsilon$	4 - 5
Aluminum surface resistivity	$\leq 1 \Omega/\text{square}$
Intermittent temperature range	-250° C to 150° C (-420° F to 300° F)
Continuous temperature range	-250° C to 120° C (-420° F to 250° F)

Standard Item Number	Thickness mil ( $\mu\text{m}$ )	Typical Weight ( $\text{g}/\text{m}^2$ )	Perforation Item Number
146466	0.25 (6)	9	159353
146463	0.5 (12.5)	17	159751
146458	1.0 (25)	33	159773
146460	2.0 (51)	71	159774

Contact Sheldahl for 5 mil PET construction requirements

## POST PROCESSING – PERFORATION & EMBOSSING

This product may be processed after metalizing to enhance its functionality. To facilitate air passage during launch, the film may be Perforated. Standard perforation patterns are on pages 15 - 23.

Materials may also be embossed or crinkled to provide separation between the layers of MLI blankets instead of, or in addition to, using fabric spacer layers.

## WARRANTY INFORMATION

Sheldahl warrants that our thermal control materials will meet all acceptance testing criteria for one year from the date of shipment (except Germanium, see product bulletin) if the materials have been stored indoors at standard conditions in their original packaging.

## SHELF LIFE

This product shall meet specified values for a minimum of 12 months after the date of shipment provided that the material is stored in its original unopened container at normal interior temperatures (10° C to 27° C/50° F to 80° F).

The shelf life of the material should be much longer than the warranty period. We recommend retesting any material that is more than one year old (or more than one year since most recent testing) prior to use. This will verify that the material has not been accidentally damaged. Sheldahl offers retest services for a nominal fee.

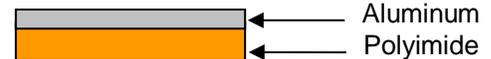
## SPECIFICATION AND ITEM NUMBERS

STANDARD NUMBERS		Thickness	PERFORATION NUMBERS	
Sheldahl Specification	Item Number		Sheldahl Specification	Item Number
G405270	146466	0.25 mil	G405274	159353
G405260	146463	0.5 mil	G405264	159751
G405210	146458	1.0 mil	G405214	159773
G405220	146460	2.0 mil	G405224	159774

Sheldahl manufactures a broad range of vacuum deposited films, laminates and tapes. Ask for additional product bulletins describing other Sheldahl.

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## PRODUCT BULLETIN



### Aluminum Coated (One Side) Polyimide

Sheldahl® polyimide films that are aluminized on one side can be used as either first or second surface mirrors and are often used in multi-layer insulation (MLI) blankets when a wide temperature range is desired. When used as a first surface mirror these products provide low emittance and low solar absorptance. When used as a second surface mirror these products provide moderate absorptance and moderate emittance values, and the polyimide film gives them an amber or gold color.

This product may be ordered with 0.3, 0.5, 1, 2, 3, or 5 mil thick polyimide that conforms to the requirements of ASTM D-5213. The aluminum coating is nominally 1000 Å thick, and the most common width is 48 inches (1.22 m).

### PRODUCT CHARACTERISTICS

Parameter (independent of film thickness)	Specified Value
First surface solar absorptance ( $\alpha$ )	$\leq 0.14$
First surface hemispherical emittance ( $\epsilon_H$ )	$\leq 0.035$
First surface normal emittance ( $\epsilon_N$ )	$\leq 0.035$
Typical first surface $\alpha/\epsilon$	4 - 5
Aluminum surface resistivity	$\leq 1 \Omega/\text{square}$
Intermittent temperature range	-250° C to 400° C (-420° F to 750° F)
Continuous temperature range	-250° C to 290° C (-420° F to 550° F)

Standard Item Number	Thickness mil ( $\mu\text{m}$ )	Second Surface Mirror Properties			Typical Weight ( $\text{g}/\text{m}^2$ )	Perforation Item Number
		$\alpha$	$\epsilon_N$	$\epsilon_H$		
146455	0.3 (8)	$\leq 0.35$	$\geq 0.40$	$\geq 0.40$	11	160478
146454	0.5 (12.5)	$\leq 0.36$	$\geq 0.50$	$\geq 0.52$	19	177735
146446	1.0 (25)	$\leq 0.39$	$\geq 0.62$	$\geq 0.64$	36	160013
146448	2.0 (51)	$\leq 0.44$	$\geq 0.71$	$\geq 0.71$	71	159946
146450	3.0 (76)	$\leq 0.46$	$\geq 0.77$	$\geq 0.77$	109	160824
146452	5.0 (127)	$\leq 0.49$	$\geq 0.81$	$\geq 0.81$	181	174402

## POST PROCESSING – PERFORATION & EMBOSSING

This product may be processed after metalizing to enhance its functionality. The film may be Perforated to facilitate air passage during launch. Standard perforation patterns are on pages 15 - 23.

Materials may also be embossed to provide separation between the layers of an MLI blanket instead of, or in addition to, using fabric spacer layers.

## WARRANTY INFORMATION

Sheldahl warrants that our thermal control materials will meet all acceptance testing criteria for one year from the date of shipment (except Germanium, see product bulletin) if the materials have been stored indoors at standard conditions in their original packaging.

## SHELF LIFE

This product shall meet specified values for a minimum of 12 months after the date of shipment provided that the material is stored in its original unopened container at normal interior temperatures (10° C to 27° C/50° F to 80° F).

The shelf life of the material should be much longer than the warranty period. We recommend retesting any material that is more than one year old (or more than one year since most recent testing) prior to use. This will verify that the material has not been accidentally damaged. Sheldahl offers retest services for a nominal fee.

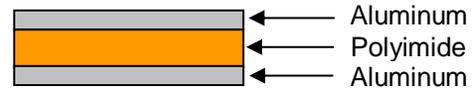
## SPECIFICATION AND ITEM NUMBERS

STANDARD NUMBERS		Thickness	PERFORATION NUMBERS	
Sheldahl Specification	Item Number		Sheldahl Specification	Item Number
G405170	146455	0.3 mil	G405174	160478
G405160	146454	0.5 mil	G405164	177735
G405110	146446	1.0 mil	G405114	160013
G405120	146448	2.0 mil	G405124	159946
G405130	146450	3.0 mil	G405134	160824
G405150	146452	5.0 mil	G405154	174402

Sheldahl manufactures a broad range of vacuum deposited films, laminates and tapes. Ask for additional product bulletins describing other Sheldahl® Materials.

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## PRODUCT BULLETIN



### Aluminum Coated (Two Sides) Polyimide

Sheldahl® polyimide films that are aluminized on both sides can be used as first surface mirrors and are often used in multi-layer insulation (MLI) blankets when a wide temperature range is desired. These products provide low emittance and low solar absorptance.

This product may be ordered with 0.3, 0.5, 1, 2, 3, or 5 mil thick polyimide that conforms to the requirements of ASTM D-5213. The aluminum coating is nominally 1000 Å thick, and the most common width is 48 inches (1.22 m).

### PRODUCT CHARACTERISTICS

Parameter (independent of film thickness)	Specified Value
Solar absorptance ( $\alpha$ )	$\leq 0.14$
Hemispherical emittance ( $\epsilon_H$ )	$\leq 0.035$
Normal emittance ( $\epsilon_N$ )	$\leq 0.035$
Typical $\alpha/\epsilon$	4 - 5
Aluminum surface resistivity	$\leq 1 \Omega/\text{square}$
Intermittent temperature range	-250° C to 400° C (-420° F to 750° F)
Continuous temperature range	-250° C to 290° C (-420° F to 550° F)

Standard Item Number	Thickness mil ( $\mu\text{m}$ )	Typical Weight ( $\text{g}/\text{m}^2$ )	Perforation Item Number
146426	0.3 (8)	11	160090
146424	0.5 (12)	19	160028
146417	1.0 (25)	36	159281
146419	2.0 (51)	71	161411
146421	3.0 (76)	109	161344
146423	5.0 (127)	181	TBD

## POST PROCESSING – PERFORATION & EMBOSSING

This product may be processed after metalizing to enhance its functionality. The film may be Perforated to facilitate air passage during launch. Standard perforation patterns are on pages 15 - 23.

Materials may also be embossed to provide separation between the layers of MLI blankets instead of, or in addition to, using fabric spacer layers.

## WARRANTY INFORMATION

Sheldahl warrants that our thermal control materials will meet all acceptance testing criteria for one year from the date of shipment (except Germanium, see product bulletin) if the materials have been stored indoors at standard conditions in their original packaging.

## SHELF LIFE

This product shall meet specified values for a minimum of 12 months after the date of shipment provided that the material is stored in its original unopened container at normal interior temperatures (10° C to 27° C/50° F to 80° F).

The shelf life of the material should be much longer than the warranty period. We recommend retesting any material that is more than one year old (or more than one year since most recent testing) prior to use. This will verify that the material has not been accidentally damaged. Sheldahl offers retest services for a nominal fee.

## SPECIFICATION AND ITEM NUMBERS

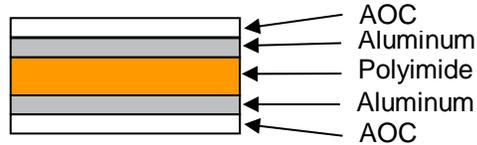
Standard Numbers		Thickness	PERFORATION Numbers	
Sheldahl Specification	Item Number		Sheldahl Specification	Item Number
G402470	146426*	0.3 mil	G402474	160090
G402460	146424*	0.5 mil	G402464	160028
G402410	146417*	1.0 mil	G402414	159281
G402420	146419*	2.0 mil	G402424	161411
G402430	146421*	3.0 mil	G402434	161344
G402450	146423*	5.0 mil	G402454	TBD

*\*If coverlay is required contact Sheldahl.*

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## PRODUCT BULLETIN



### Aluminum Coated (Two Sides) Polyimide with an Acrylic Overcoat

Sheldahl® polyimide films that are aluminized on both sides and protected by AOC can be used as first surface mirrors and are often used in multi-layer insulation (MLI) blankets when a wide temperature range is desired. These products provide low emittance and low solar absorptance. The acrylic overcoat (AOC) provides additional resistance to humidity and salt fog, as may be found around most launch sites.

This product may be ordered with 0.3, 0.5, 1, 2, 3, or 5 mil thick polyimide that conforms to the requirements of ASTM D-5213. The aluminum coating is nominally 1000Å thick, and the most common width is 48 inches (1.22 m).

### PRODUCT CHARACTERISTICS

Parameter (independent of film thickness)	Specified Value
Absorptance ( $\alpha$ )	$\leq 0.14$
Hemispherical emittance ( $\epsilon_H$ )	$\leq 0.05$
Normal emittance ( $\epsilon_N$ )	$\leq 0.05$
Typical $\alpha/\epsilon$	4.0
Aluminum surface resistivity	$\leq 1 \Omega/\text{square}$ (before AOC application)
Intermittent temperature range	-250° C to 205° C (-420° F to 400° F)
Continuous temperature range	-250° C to 205° C (-420° F to 400° F)

Standard Item Number	Thickness mil ( $\mu\text{m}$ )	Typical Density ( $\text{g}/\text{m}^2$ )	Perforation Item Number
146560	0.3 (8)	14	159210
TBD	0.5 (12.5)	22	TBD
TBD	1.0 (25)	39	TBD
TBD	2.0 (51)	74	TBD
146559	3.0 (76)	112	173154
TBD	5.0 (127)	184	TBD

## POST PROCESSING - PERFORATION

This product may be processed after metalizing to enhance its functionality. To facilitate air passage during launch, the film may be Perforated. Standard perforation patterns are on pages 15 - 23.

## WARRANTY INFORMATION

Sheldahl warrants that our thermal control materials will meet all acceptance testing criteria for one year from the date of shipment (except Germanium, see product bulletin) if the materials have been stored indoors at standard conditions in their original packaging.

## SHELF LIFE

This product shall meet specified values for a minimum of 12 months after the date of shipment provided that the material is stored in its original unopened container at normal interior temperatures (10° C to 27° C/50° F to 80° F).

The shelf life of the material should be much longer than the warranty period. We recommend retesting any material that is more than one year old (or more than one year since most recent testing) prior to use. This will verify that the material has not been accidentally damaged. Sheldahl offers retest services for a nominal fee.

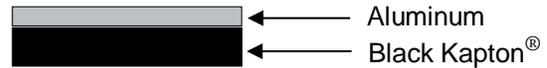
## SPECIFICATION AND ITEM NUMBERS

STANDARD NUMBERS		Thickness	PERFORATION NUMBERS	
Sheldahl Specification	Item Number		Sheldahl Specification	Item number
G411470	146560	0.3 mil	G411474	159210
G411460	TBD	0.5 mil	G411464	TBD
G411410	TBD	1.0 mil	G411414	TBD
G411420	TBD	2.0 mil	G411424	TBD
G411430	146559	3.0 mil	G411434	173154
G411450	TBD	5.0 mil	G411454	TBD

Sheldahl manufactures a broad range of vacuum deposited films, laminates and tapes.

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## PRODUCT BULLETIN



### Aluminum Coated Black Kapton®

Sheldahl® construction of aluminum coated black Kapton® films are used for outer MLI blanket layers when high absorptance, high emittance, or an  $\alpha/\epsilon$  ratio of about 1 is desired.

This product may be ordered on a variety of polyimide substrates: 100CB Kapton® (non-conductive), 100XC Kapton® (semi-conductive), and 160XC or 275XC Kapton® (thick, moderately conductive). The aluminum coating is nominally 1000 Å thick and provides a low emittance back surface. These products are sold in roll form 1.22 meters (48 inches) wide for 100CB or 100XC and 1.09 meters (43 inches) wide for 160XC or 275XC Kapton®.

### PRODUCT CHARACTERISTICS

Parameter	Specified Value		
	100CB	100XC	160XC
Film type	100CB	100XC	160XC
Film surface resistivity *	$\geq 10^{13}$ $\Omega/\text{square}$	$5 \times 10^5$ to $5 \times 10^7$ $\Omega/\text{square}$	300-430 $\Omega/\text{square}$
Intermittent temperature range	-250° C to 400° C (-420° F to 750° F)		
Continuous temperature range	-250° C to 290° C (-420° F to 550° F)		
Kapton® side solar absorptance ( $\alpha$ )	$\geq 0.90$	$\geq 0.90$	0.93 typical
Kapton® side normal emittance ( $\epsilon_N$ )	$\geq 0.82$	$\geq 0.82$	0.84 typical
Aluminum side solar absorptance ( $\alpha$ )	$\leq 0.18$	$\leq 0.22$	$\leq 0.22$
Aluminum side emittance ( $\epsilon$ )	$\leq 0.05$	$\leq 0.05$	$\leq 0.05$
Typical weight ( $\text{g}/\text{m}^2$ )	38	38	61
Film Thickness	1.0 mil	1.0 mil	1.6 mil
Outgassing: Meets NASA guidelines per ASTM E595	TML - WVR $\leq 1.0$ %; CVCM $\leq 0.1$ %		
Standard Item number	146589	146624	162493
Sheldahl Specification number	G414810	G422610	G902120
Perforation Item number	159947	159280	177084

## POST PROCESSING - PERFORATION

This product may be processed after metalizing to enhance its functionality. To facilitate air passage during launch, the film may be Perforated. Standard perforation patterns are on pages 15 - 23.

## WARRANTY INFORMATION

Sheldahl warrants that our thermal control materials will meet all acceptance testing criteria for one year from the date of shipment (except Germanium, see product bulletin) if the materials have been stored indoors at standard conditions in their original packaging.

## SHELF LIFE

This product shall meet specified values for a minimum of 12 months after the date of shipment provided that the material is stored in its original unopened container at normal interior temperatures (10° C to 27° C/50° F to 80° F).

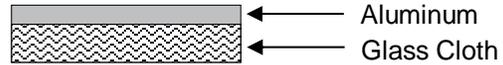
The shelf life of the material should be much longer than the warranty period. We recommend retesting any material that is more than one year old (or more than one year since most recent testing) prior to use. This will verify that the material has not been accidentally damaged. Sheldahl offers retest services for a nominal fee.

## SPECIFICATION AND ITEM NUMBERS

Standard Numbers		Thickness	Perforation Numbers	
Sheldahl Specification	Item Number		Sheldahl Specification	Item Number
G414810	146589	1.0 mil	G414814	159947
G422610	146624	1.0 mil	G422614	159280
G902120	162493	1.6 mil	G902124	177084
G902130	147452	2.75 mil	G902134	TBD

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## PRODUCT BULLETIN

### Aluminum Coated Glass Cloth

Sheldahl® construction of aluminum coated glass cloths are used for outer MLI blanket layers when tear resistance and low solar absorptance with diffuse reflections are desired.

Standard offerings include two types of glass cloth; Beta Cloth and 1080 glass cloth. Beta cloth has been used for several decades for outer blanket layers because it is resistant to atomic oxygen erosion in low earth orbit. It is employed extensively on the Space Shuttle and the International Space Station. The Beta Cloth we aluminize is Silicon free. The 1080 glass cloth is thinner, narrower, and has been used primarily for launch vehicle applications.

### PRODUCT CHARACTERISTICS

Parameter (independent of film)	Specified Value	
	Beta Cloth	1080
Cloth type	Beta Cloth	1080
Intermittent temperature range	-151° C to 315° C (-240° F to 600° F)	-185° C to 260° C (-300° F to 500° F)
Continuous temperature range	-151° C to 260° C (-240° F to 500° F)	-185° C to 200° C (-300° F to 400° F)
Fabric side solar absorptance ( $\alpha$ )	$\leq 0.45$	$\leq 0.85$
Fabric side hemispherical emittance ( $\epsilon$ )	$\geq 0.80$	$\geq 0.80$
Aluminum side absorptance ( $\alpha$ )	$\leq 0.22$	
Aluminum side hemispherical emittance ( $\epsilon_H$ )	$\leq 0.30$	
Weight (g/m <sup>2</sup> )	274 Typical	$\leq 170$
Thickness	0.008±0.001 in.	
Tensile strength (lb./in. of width)	$\geq 90$ Warp $\geq 80$ Fill	$\geq 40$ Warp $\geq 39$ Fill
Tear strength (lb.)	$\geq 4.0$ Warp $\geq 4.0$ Fill	
Width (in.)	51 (1.30 m)	36 (0.91 m)
Standard Item number	146626	146585
Sheldahl Specification number	G423800	G414500

## **WARRANTY INFORMATION**

Sheldahl warrants that our thermal control materials will meet all acceptance testing criteria for one year from the date of shipment (except Germanium, see product bulletin) if the materials have been stored indoors at standard conditions in their original packaging.

## **SHELF LIFE**

This product shall meet specified values for a minimum of 12 months after the date of shipment provided that the material is stored in its original unopened container at normal interior temperatures (10° C to 27° C/50° F to 80° F).

The shelf life of the material should be much longer than the warranty period. We recommend retesting any material that is more than one year old (or more than one year since most recent testing) prior to use. This will verify that the material has not been accidentally damaged. Sheldahl offers retest services for a nominal fee.

## **NON-METALLIZED BETA CLOTH**

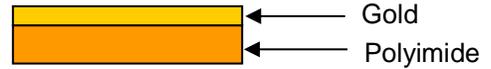
In addition to the products described above, Sheldahl® include two types of uncoated Beta Cloth. Our product number 147252 (F020000) is 250F Beta Cloth which contains Silicon. Product 158646 (F022300) is Silicon free 500F Beta Cloth. Please contact us for more technical information on these fabrics.

Sheldahl manufactures a broad range of vacuum deposited films, laminates and tapes.

The information on this product bulletin is based on data obtained by our research and is considered accurate. However, no warranty is expressed or implied regarding the accuracy of these data and the results obtained from the use thereof. This information is furnished upon the condition that the recipient shall conduct tests to determine the suitability of the product for his or her particular application.

## PRODUCT BULLETIN

### Gold Coated (One Side) Polyimide



Sheldahl® construction of polyimide films that are gold coated on one side are typically used as first surface mirrors in multi-layer insulation (MLI) blankets when a wide temperature range is desired. These products provide extremely low emittance and moderate solar absorptance.

This product may be ordered with 0.3, 0.5, 1, 2, 3, or 5 mil thick polyimide that conforms to the requirements of ASTM D-5213. The gold coating is nominally 900 Å thick, and the most common width is 48 inches (1.22 m).

### PRODUCT CHARACTERISTICS

Parameter (independent of film thickness)	Specified Value
First surface solar absorptance ( $\alpha$ )	$\leq 0.30$
First surface hemispherical emittance ( $\epsilon_H$ )	$\leq 0.03$
First surface normal emittance ( $\epsilon_N$ )	$\leq 0.03$
Typical first surface $\alpha/\epsilon$	10
Gold surface resistivity	$\leq 1 \Omega/\text{square}$
Intermittent temperature range	-250° C to 400° C (-420° F to 750° F)
Continuous temperature range	-250° C to 290° C (-420° F to 550° F)

Standard Item Number	Thickness mil ( $\mu\text{m}$ )	Typical Weight ( $\text{g}/\text{m}^2$ )	Perforation Item Number
146444	0.3 (8)	11	160504
146442	0.5 (12.5)	19	TBD
146437	1.0 (25)	36	159884
146439	2.0 (51)	71	TBD
146440	3.0 (76)	109	TBD
146441	5.0 (127)	181	TBD

## POST PROCESSING – PERFORATION & EMBOSSING

This product may be processed after metalizing to enhance its functionality. The film may be Perforated to facilitate air passage during launch. Standard perforation patterns are on pages 15 - 23.

Materials may also be embossed to provide separation between the layers of an MLI blanket instead of (or in addition to) using fabric spacer layers.

## WARRANTY INFORMATION

Sheldahl warrants that our thermal control materials will meet all acceptance testing criteria for one year from the date of shipment (except Germanium, see product bulletin) if the materials have been stored indoors at standard conditions in their original packaging.

## SHELF LIFE

This product shall meet specified values for a minimum of 12 months after the date of shipment provided that the material is stored in its original unopened container at normal interior temperatures (10° C to 27° C/50° F to 80° F).

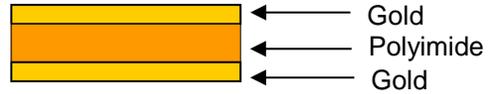
The shelf life of the material should be much longer than the warranty period. We recommend retesting any material that is more than one year old (or more than one year since most recent testing) prior to use. This will verify that the material has not been accidentally damaged. Sheldahl offers retest services for a nominal fee.

## SPECIFICATION AND ITEM NUMBERS

STANDARD NUMBERS		Thickness	PERFORATION NUMBERS	
Sheldahl Specification	Item Number		Sheldahl Specification	Item Number
G404970	146444	0.3 mil	G404974	160504
G404960	146442	0.5 mil	G404964	TBD
G404910	146437	1.0 mil	G404914	159884
G404920	146439	2.0 mil	G404924	TBD
G404930	146440	3.0 mil	G404934	TBD
G404950	146441	5.0 mil	G404954	TBD

Sheldahl manufactures a broad range of vacuum deposited films, laminates and tapes. Ask for additional product bulletins describing other Sheldahl® Materials.

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## PRODUCT BULLETIN

### Gold Coated (Two Sides) Polyimide

Sheldahl® construction of polyimide films that are gold coated on both sides can be used as first surface mirrors, and are often used in multi-layer insulation (MLI) blankets when a wide temperature range is desired. These products provide the lowest possible emittance and moderate solar absorptance.

This product may be ordered with 0.3, 0.5, 1, 2, 3, or 5 mil thick polyimide that conforms to the requirements of ASTM D-5213. The gold coating is nominally 900 Å thick, and the most common width is 48 inches (1.22 m).

### PRODUCT CHARACTERISTICS

Parameter (independent of film thickness)	Specified Value
First surface solar absorptance ( $\alpha$ )	$\leq 0.30$
First surface hemispherical emittance ( $\epsilon_H$ )	$\leq 0.03$
First surface normal emittance ( $\epsilon_N$ )	$\leq 0.03$
Typical first surface $\alpha/\epsilon$	15
Gold surface resistivity	$\leq 1 \Omega/\text{square}$
Intermittent temperature range	-250° C to 400° C (-420° F to 750° F)
Continuous temperature range	-250° C to 290° C (-420° F to 550° F)

Standard Item Number	Thickness mil ( $\mu\text{m}$ )	Typical Weight ( $\text{g}/\text{m}^2$ )	PERFORATION Item Number
146408	0.3 (8)	11	160501
146407	0.5 (12.5)	19	TBD
147286	1.0 (25)	36	TBD
158239	2.0 (51)	71	TBD
146406	3.0 (76)	109	TBD
166185	5.0 (127)	181	166186

## POST PROCESSING – PERFORATION & EMBOSSING

This product may be processed after metalizing to enhance its functionality. The film may be Perforated to facilitate air passage during launch. Standard perforation patterns are on pages 15 - 23.

Materials may also be embossed to provide separation between the layers of MLI blankets instead of, or in addition to, using fabric spacer layers.

## WARRANTY INFORMATION

Sheldahl warrants that our thermal control materials will meet all acceptance testing criteria for one year from the date of shipment (except Germanium, see product bulletin) if the materials have been stored indoors at standard conditions in their original packaging.

## SHELF LIFE

This product shall meet specified values for a minimum of 12 months after the date of shipment provided that the material is stored in its original unopened container at normal interior temperatures (10° C to 27° C/50° F to 80° F).

The shelf life of the material should be much longer than the warranty period. We recommend retesting any material that is more than one year old (or more than one year since most recent testing) prior to use. This will verify that the material has not been accidentally damaged. Sheldahl offers retest services for a nominal fee.

## SPECIFICATION AND ITEM NUMBERS

STANDARD NUMBERS		Thickness	PERFORATION NUMBERS	
Sheldahl Specification	Item Number		Sheldahl Specification	Item Number
G401870	146408	0.3 mil	G401874	160501
G401860	146407	0.5 mil	G401864	TBD
G401810	147286	1.0 mil	G401814	TBD
G401820	158239	2.0 mil	G401824	TBD
G401830	146406	3.0 mil	G401834	TBD
G401850	166185	5.0 mil	G401854	166186

Sheldahl manufactures a broad range of vacuum deposited films, laminates and tapes. Ask for additional product bulletins describing other Sheldahl® Materials.

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## PRODUCT BULLETIN



### Polyester Netting

Dacron® polyester netting is typically used as a spacer material to minimize conductive heat transfer between multilayer insulation (MLI) blanket layers. The netting material is chosen for its low outgassing characteristics and is specially cleaned to assure that it is residue free.

We offer two types of netting; B2A and B4A. The B2A netting is a denser weave and is somewhat easier to handle. The B4A netting is used in applications where minimizing the blanket weight is critical. Both types of netting are supplied in rolls that are 54 inches wide.

### PRODUCT CHARACTERISTICS

Parameter	Specified Value	
	B2A	B4A
Netting type	B2A	B4A
Weight (oz./sq. yd.)	≤0.44	≤0.21
Intermittent temperature range	-250° C to 150° C (-420° F to 300° F)	
Continuous temperature range	-250° C to 120° C (-420° F to 250° F)	
Thickness (in.)	0.007±0.001	0.0065±0.001
Burst strength (psi)	≥15	≥10
Construction (mesh/sq. in.)	190	43
Item number	147298	147096
Previous part number	F022500	F020400

## ALTERNATE LAYER SEPARATION TECHNIQUES

Using polyester netting is the most common way of separating the metallized film layers in MLI blankets. Two other options are available if polyester netting is not used.

### **Nomex**<sup>®</sup>

If the internal blanket temperature is too high for polyester a Nomex<sup>®</sup> scrim can be used. The Nomex<sup>®</sup> netting or scrim is thicker than the polyester netting and weighs more than four times as much as B4A netting.

### **Embossing**

Another approach to separating the blanket layers is to emboss the film. To achieve a small amount of separation between layers, a square tile pattern can be embossed into the film. The material is embossed to a depth of about 75 microns with a series of cross and down web lines every 3 mm (0.125 in.).

Our ShelTherm<sup>™</sup> pattern embosses a series of dimples as deep as two to three millimeters. This pattern is more commonly used on PET films than on polyimide films.

## WARRANTY INFORMATION

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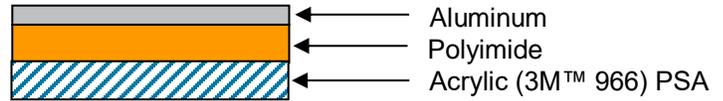
### **SHELF LIFE**

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The shelf life of the material should be much longer than the warranty period. We recommend retesting any material that is more than one year old (or more than one year since most recent testing) prior to use. This will verify that the material has not been accidentally damaged. Sheldahl offers retest services for a nominal fee.

Sheldahl manufactures a broad range of vacuum deposited films, laminates and tapes. Ask for additional product bulletins describing other Sheldahl<sup>®</sup> Materials.

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## PRODUCT BULLETIN

### First Surface Aluminum Coated Polyimide Tape with Acrylic 3M™ 966 Adhesive

Sheldahl® first surface aluminized polyimide tape with acrylic 3M™ 966 adhesive is used whenever a low emittance and low solar absorptance surface is needed. The acrylic 3M™ 966 adhesive is nominally 2.3 mils thick, provides a strong bond with low outgassing, and can be used over a moderate temperature range. These tapes may be bonded to structures to reduce radiative heat transfer. They can also be used on multilayer insulation blankets to close the edges or repair rips in the outer layers.

This product may be ordered with 0.5, 1, or 2 mil thick polyimide that conforms to the requirements of ASTM D-5213. The aluminum coating is nominally 1000 Å thick. Although the standard widths for this tape are 1, 2, 3, and 4 inches, it may be ordered in any width needed. Each roll is 108 feet (33 m) long.

### PRODUCT CHARACTERISTICS

Parameter (independent of film thickness)	Specified Value
Solar absorptance ( $\alpha$ )	$\leq 0.14$
Hemispherical emittance ( $\epsilon_H$ )	$\leq 0.035$
Normal emittance ( $\epsilon_N$ )	$\leq 0.035$
Typical $\alpha/\epsilon$	4 - 5
Adhesion to stainless steel	$\geq 20$ oz./inch of width
Intermittent temperature range	-185° C to 230° C (-300° F to 450° F) <sup>A</sup>
Continuous temperature range	-60° C to 120° C (-75° F to 250° F) <sup>A</sup>

<sup>A</sup> Zero peel strength of acrylic pressure sensitive adhesive is at about -45°C (-50°F).

Standard Item Number	Thickness mil ( $\mu\text{m}$ )	Typical Weight ( $\text{g}/\text{m}^2$ )	Perforation Item Number
146390	0.5 (12.5)	81	TBD
146385	1.0 (25)	98	146386
146389	2.0 (51)	133	166722

## POST PROCESSING – PERFORATION & COVERLAY

This product may be processed after metalizing and combining the adhesive to the film to enhance its functionality. We offer a standard perforation pattern with 0.76 mm (0.03 in.) diameter holes on 6.35 mm (0.25 in.) centers, with a nominal 1.1% open area. We can also place a coverlay on the tape to protect it from accidental damage during handling and application.

## WARRANTY INFORMATION

Sheldahl warrants that our thermal control materials will meet all acceptance testing criteria for one year from the date of shipment (except Germanium, see product bulletin) if the materials have been stored indoors at standard conditions in their original packaging.

## SHELF LIFE

This product shall meet specified values for a minimum of 12 months after the date of shipment provided that the material is stored in its original unopened container at normal interior temperatures (10° C to 27° C/50° F to 80° F).

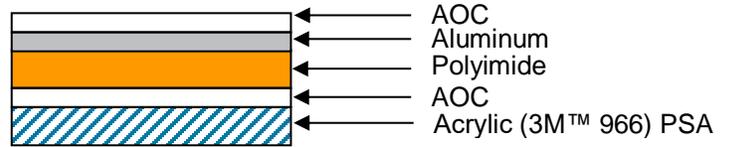
The shelf life of the material should be much longer than the warranty period. We recommend retesting any material that is more than one year old (or more than one year since most recent testing) prior to use. This will verify that the material has not been accidentally damaged. Sheldahl offers retest services for a nominal fee.

## SPECIFICATION AND ITEM NUMBERS

STANDARD NUMBERS		Thickness	PERFORATION NUMBERS	
Sheldahl Specification	Item Number		Sheldahl Specification	Item Number
G401060	146390	0.5 mil	G401061	TBD
G401000	146385	1.0 mil	G401001	146386
G401020	146389	2.0 mil	G401021	166722

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## PRODUCT BULLETIN

### First Surface Aluminized Polyimide Tape with AOC and Acrylic 3M™ 966 Adhesive

Sheldahl® first surface aluminized polyimide tapes with AOC and acrylic 3M™ 966 adhesive are used whenever low emittance and low absorptance surfaces are needed. The acrylic 3M™966 adhesive is nominally 2.3 mils thick, provides a strong bond with low outgassing, and can be used over a moderate temperature range. The acrylic overcoat provides additional resistance to humidity and salt fog, as may be found at most launch sites. These tapes may be bonded to structures to reduce radiative heat transfer. They can also be used on multilayer insulation blankets to close the edges or repair rips in the outer layers.

This product may be ordered with 0.5, 1, or 2 mil thick polyimide that conforms to the requirements of ASTM D-5213. The aluminum coating is nominally 1000 Å thick. Although the standard widths for this tape are 1, 2, 3, and 4 inches, it may be ordered in any width needed. Each roll is 108 feet (33 m) long.

### PRODUCT CHARACTERISTICS

Parameter (independent of film thickness)	Specified Value
Absorptance ( $\alpha$ )	$\leq 0.14$
Hemispherical emittance ( $\epsilon_H$ )	$\leq 0.05$
Normal emittance ( $\epsilon_N$ )	$\leq 0.05$
Typical $\alpha/\epsilon$	3 - 5
Adhesion to stainless steel	$\geq 20$ oz./inch of width
Intermittent temperature range	-185° C to 230° C (-300° F to 450° F) <sup>A</sup>
Continuous temperature range	-60° C to 120° C (-75° F to 250° F) <sup>A</sup>

<sup>A</sup> Zero peel strength of acrylic pressure sensitive adhesive is at about -45°C (-50°F).

Standard Item Number	Thickness mil ( $\mu\text{m}$ )	Typical Weight ( $\text{g}/\text{m}^2$ )	Perforation Item Number
146572	0.5 (12.5)	81	TBD
146570	1.0 (25)	98	TBD
146571	2.0 (51)	133	TBD

## POST PROCESSING – PERFORATION & COVERLAY

This product may be processed after metalizing and combining the adhesive to the film to enhance its functionality. We offer a standard perforation pattern with 0.76 mm (0.03 in.) diameter holes on 6.35 mm (0.25 in.) centers, with a nominal 1.1% open area. We can also place a coverlay on the tape to protect it from accidental damage during handling and application.

## WARRANTY INFORMATION

Sheldahl warrants that our thermal control materials will meet all acceptance testing criteria for one year from the date of shipment (except Germanium, see product bulletin) if the materials have been stored indoors at standard conditions in their original packaging.

## SHELF LIFE

This product shall meet specified values for a minimum of 12 months after the date of shipment provided that the material is stored in its original unopened container at normal interior temperatures (10° C to 27° C/50° F to 80° F).

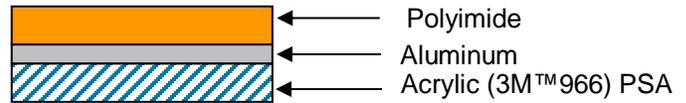
The shelf life of the material should be much longer than the warranty period. We recommend retesting any material that is more than one year old (or more than one year since most recent testing) prior to use. This will verify that the material has not been accidentally damaged. Sheldahl offers retest services for a nominal fee.

## SPECIFICATION AND ITEM NUMBERS

STANDARD NUMBERS		Thickness	PERFORATION NUMBERS	
Sheldahl Specification	Item Number		Sheldahl Specification	Item Number
G411710	146570	1.0 mil	G411711	TBD
G411720	146571	2.0 mil	G411721	TBD
G411760	146572	0.5 mil	G411761	TBD

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## PRODUCT BULLETIN

### Second Surface Aluminum Coated Polyimide Tape with Acrylic 3M™966 Adhesive

Sheldahl® second surface aluminized polyimide tapes with acrylic 3M™ 966 adhesive are used whenever moderate emittance and solar absorptance are needed. The acrylic 3M™ 966 adhesive is nominally 2.3 mils thick, provides a strong bond with low outgassing, and can be used over a moderate temperature range. These tapes may be bonded to structures to reduce radiative heat transfer. They can also be used on multilayer insulation blankets to close the edges or repair rips in the outer layers.

This product may be ordered with 0.5, 1, 2, 3, or 5 mil thick polyimide that conforms to the requirements of ASTM D-5213. The aluminum coating is nominally 1000 Å thick. Although the standard widths for this tape are 1, 2, 3, and 4 inches, it may be ordered in custom widths. Each roll is 108 feet (33 m) long.

## PRODUCT CHARACTERISTICS

Parameter (independent of film thickness)	Specified Value
Adhesion to stainless steel (substrate ≥ 1 mil)	≥ 25 oz./inch of width
Intermittent temperature range	-185° C to 230° C (-300° F to 450° F) <sup>A</sup>
Continuous temperature range	-60° C to 120° C (-75° F to 250° F) <sup>A</sup>

<sup>A</sup> Zero peel strength of acrylic pressure sensitive adhesive is at about -45°C (-50°F)

Standard Item Number	Thickness mil (μm)	Second Surface Mirror Properties			Typical Weight (g/m <sup>2</sup> )	Perforation Item Number
		α	εN	εH		
146528	0.5 (12.5)	≤ 0.36	≥ 0.50	≥ 0.52	81	TBD
146520	1.0 (25)	≤ 0.39	≥ 0.62	≥ 0.64	98	146521
146522	2.0 (51)	≤ 0.44	≥ 0.71	≥ 0.71	133	TBD
146524	3.0 (76)	≤ 0.46	≥ 0.77	≥ 0.77	171	146525
146527	5.0 (127)	≤ 0.49	≥ 0.81	≥ 0.81	243	TBD

## POST PROCESSING – PERFORATION & COVERLAY

This product may be processed after metalizing and combining the adhesive to the film to enhance its functionality. We offer a standard perforation pattern with 0.76 mm (0.03 in.) diameter holes on 6.35 mm (0.25 in.) centers, with a nominal 1.1% open area. We can also place a coverlay on the tape to protect it from accidental damage during handling and application.

## WARRANTY INFORMATION

Sheldahl warrants that our thermal control materials will meet all acceptance testing criteria for one year from the date of shipment (except Germanium, see product bulletin) if the materials have been stored indoors at standard conditions in their original packaging.

## SHELF LIFE

This product shall meet specified values for a minimum of 12 months after the date of shipment provided that the material is stored in its original unopened container at normal interior temperatures (10° C to 27° C/50° F to 80° F).

The shelf life of the material should be much longer than the warranty period. We recommend retesting any material that is more than one year old (or more than one year since most recent testing) prior to use. This will verify that the material has not been accidentally damaged. Sheldahl offers retest services for a nominal fee.

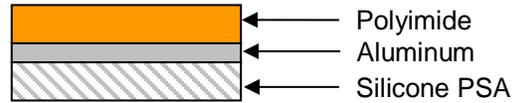
## SPECIFICATION AND ITEM NUMBERS

STANDARD NUMBERS		Thickness	PERFORATION NUMBERS	
Sheldahl Specification	Item Number		Sheldahl Specification	Item Number
G408860	146528	0.5 mil	G408861	TBD
G408810	146520	1.0 mil	G408811	146521
G408820	146522	2.0 mil	G408821	TBD
G408830	146524	3.0 mil	G408831	146525
G408850	146527	5.0 mil	G408851	TBD

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## PRODUCT BULLETIN



## Second Surface Aluminum Coated Polyimide Tape with Silicone Adhesive

Sheldahl® second surface aluminized polyimide tapes with Silicone adhesive are used whenever moderate emittance and absorptance are needed. The Silicone adhesive is nominally 1 mil thick, provides a strong bond with moderate outgassing, and can be used over a wide temperature range. These tapes may be bonded to structures to reduce radiative heat transfer. They can also be used on multilayer insulation blankets to close the edges or repair rips in the outer layers.

This product may be ordered with 0.5, 1, 2, 3, or 5 mil thick polyimide that conforms to the requirements of ASTM D-5213. The aluminum coating is nominally 1000 Å thick. Although the standard widths for this tape are 1, 2, 3, and 4 inches, it may be ordered in widths up to 26 inches. Each roll is 108 feet (33 m) long.

## PRODUCT CHARACTERISTICS

Parameter (independent of film thickness)	Specified Value
Adhesion to stainless steel	≥ 10 oz./inch of width
Intermittent temperature range	-185° C to 260° C (-300° F to 500° F)
Continuous temperature range	-185° C to 150° C (-300° F to 300° F)

Standard Item Number	Thickness mil (μm)	Second Surface Mirror Properties			Typical Weight (g/m <sup>2</sup> )	Perforation Item Number
		α	εN	εH		
146493	0.5 (12.5)	≤ 0.36	≥ 0.50	≥ 0.52	54	TBD
146490	1.0 (25)	≤ 0.39	≥ 0.62	≥ 0.64	71	146491
146492	2.0 (51)	≤ 0.44	≥ 0.71	≥ 0.71	107	TBD
TBD	3.0 (76)	≤ 0.46	≥ 0.77	≥ 0.77	144	TBD
161598	5.0 (127)	≤ 0.49	≥ 0.81	≥ 0.81	217	TBD

## POST PROCESSING – PERFORATION & COVERLAY

This product may be processed after metalizing and combining the adhesive to the film to enhance its functionality. We offer a standard perforation pattern with 0.76 mm (0.03 in.) diameter holes on 6.35 mm (0.25 in.) centers, with a nominal 1.1% open area. We can also place a coverlay on the tape to protect it from accidental damage during handling and application.

## WARRANTY INFORMATION

Sheldahl warrants that our thermal control materials will meet all acceptance testing criteria for one year from the date of shipment (except Germanium, see product bulletin) if the materials have been stored indoors at standard conditions in their original packaging.

## SHELF LIFE

This product shall meet specified values for a minimum of 12 months after the date of shipment provided that the material is stored in its original unopened container at normal interior temperatures (10° C to 27° C/50° F to 80° F).

The shelf life of the material should be much longer than the warranty period. We recommend retesting any material that is more than one year old (or more than one year since most recent testing) prior to use. This will verify that the material has not been accidentally damaged. Sheldahl offers retest services for a nominal fee.

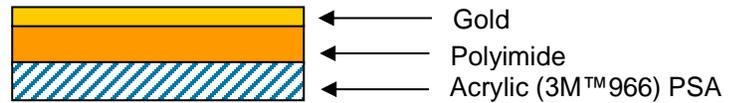
## SPECIFICATION AND ITEM NUMBERS

STANDARD NUMBERS		Thickness	PERFORATION NUMBERS	
Sheldahl Specification	Item Number		Sheldahl Specification	Item Number
G407760	146493	0.5 mil	G407761	TBD
G407710	146490	1.0 mil	G407711	146491
G407720	146492	2.0 mil	G407721	TBD
G407730	TBD	3.0 mil	G407731	TBD
G407750	161598	5.0 mil	G407751	TBD

Sheldahl manufactures a broad range of vacuum deposited films, laminates and tapes. Ask for additional product bulletins describing other Sheldahl® Materials.

The information on this product bulletin is based on data obtained by our research and is considered accurate. However, no warranty is expressed or implied regarding the accuracy of these data and the results obtained from the use thereof. This information is furnished upon the condition that the recipient shall conduct tests to determine the suitability of the product for his or her particular application.

## PRODUCT BULLETIN



### First Surface Gold Coated Polyimide Tape with Acrylic 3M™ 966 Adhesive

Sheldahl® first surface gold coated polyimide tapes with acrylic 3M™966 adhesive are used whenever a very low emittance and moderate solar absorptance surface is needed. The acrylic 3M™966 adhesive is nominally 2.3 mils thick, provides a strong bond with low outgassing, and can be used over a moderate temperature range. These tapes may be bonded to structures to reduce radiative heat transfer. They can also be used on multilayer insulation blankets to close the edges or repair rips in the outer layers.

This product may be ordered with 0.5, 1, or 2 mil thick polyimide that conforms to the requirements of ASTM D-5213. The gold coating is nominally 900 Å thick. Although the standard widths for this tape are 1, 2, 3, and 4 inches, it may be ordered in custom widths. Each roll is 108 feet (33 m) long.

### PRODUCT CHARACTERISTICS

Parameter (independent of film thickness)	Specified Value
Absorptance ( $\alpha$ )	$\leq 0.30$
Hemispherical emittance ( $\epsilon_H$ )	$\leq 0.03$
Normal emittance ( $\epsilon_N$ )	$\leq 0.03$
Typical $\alpha/\epsilon$	15
Adhesion to stainless steel	$\geq 20$ oz./inch of width
Intermittent temperature range	-185° C to 230° C (-300° F to 450° F) <sup>A</sup>
Continuous temperature range	-60° C to 120° C (-75° F to 250° F) <sup>A</sup>

<sup>A</sup> Zero peel strength of acrylic pressure sensitive adhesive is at about -45°C (-50°F).

Standard Item Number	Thickness mil ( $\mu\text{m}$ )	Typical Weight ( $\text{g}/\text{m}^2$ )	Perforation Item Number
146487	0.5 (12.5)	81	TBD
146482	1.0 (25)	98	146483
146486	2.0 (51)	133	TBD

## POST PROCESSING – PERFORATION & COVERLAY

This product may be processed after metalizing and combining the adhesive to the film to enhance its functionality. We offer a standard perforation pattern with 0.76 mm (0.03 in.) diameter holes on 6.35 mm (0.25 in.) centers, with a nominal 1.1% open area. We can also place a coverlay on the tape to protect it from accidental damage during handling and application.

## WARRANTY INFORMATION

Sheldahl warrants that our thermal control materials will meet all acceptance testing criteria for one year from the date of shipment (except Germanium, see product bulletin) if the materials have been stored indoors at standard conditions in their original packaging.

## SHELF LIFE

This product shall meet specified values for a minimum of 12 months after the date of shipment provided that the material is stored in its original unopened container at normal interior temperatures (10° C to 27° C/50° F to 80° F).

The shelf life of the material should be much longer than the warranty period. We recommend retesting any material that is more than one year old (or more than one year since most recent testing) prior to use. This will verify that the material has not been accidentally damaged. Sheldahl offers retest services for a nominal fee.

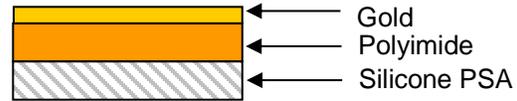
## SPECIFICATION AND ITEM NUMBERS

STANDARD NUMBERS		Thickness	PERFORATION NUMBERS	
Sheldahl Specification	Item Number		Sheldahl Specification	Item Number
G406400	146482	1.0 mil	G406401	146483
G406420	146486	2.0 mil	G406421	TBD
G406460	146487	0.5 mil	G406461	TBD

Sheldahl manufactures a broad range of vacuum deposited films, laminates and tapes. Ask for additional product bulletins describing other Sheldahl® Materials.

The information on this product bulletin is based on data obtained by our research and is considered accurate. However, no warranty is expressed or implied regarding the accuracy of these data and the results obtained from the use thereof. This information is furnished upon the condition that the recipient shall conduct tests to determine the suitability of the product for his or her particular application.

## PRODUCT BULLETIN



### First Surface Gold Coated Polyimide Tape with Silicone Adhesive

Sheldahl® first surface gold coated polyimide tapes with Silicone adhesive are used whenever a very low emittance and moderate solar absorptance surface is needed. The Silicone adhesive is nominally 1 mil thick, provides a strong bond with moderate outgassing, and can be used over a wide temperature range. These tapes may be bonded to structures to reduce radiative heat transfer. They can also be used on multilayer insulation blankets to close the edges or repair rips in the outer layers.

This product may be ordered with 0.5, 1, or 2 mil thick polyimide that conforms to the requirements of ASTM D-5213. The gold coating is nominally 900 Å thick. Although the standard widths for this tape are 1, 2, 3, 4, and 6 inches, it may be ordered in widths up to 26 inches. Rolls no more than 4 inches wide are 108 feet (33 m) long; the 6 inch wide rolls are 54 feet (16.5 m) long.

### PRODUCT CHARACTERISTICS

Parameter (independent of film thickness)	Specified Value
Absorptance ( $\alpha$ )	$\leq 0.30$
Hemispherical emittance ( $\epsilon_H$ )	$\leq 0.03$
Normal emittance ( $\epsilon_N$ )	$\leq 0.03$
Typical $\alpha/\epsilon$	15
Adhesion to stainless steel	$\geq 10$ oz./inch of width
Intermittent temperature range	-185° C to 260° C (-300° F to 500° F)
Continuous temperature range	-185° C to 150° C (-300° F to 300° F)

Standard Item Number	Thickness mil ( $\mu\text{m}$ )	Typical Weight ( $\text{g}/\text{m}^2$ )	Perforation Item Number
TBD	0.5 (12.5)	54	TBD
146498	1.0 (25)	71	TBD
146500	2.0 (51)	107	TBD

## POST PROCESSING – PERFORATION & COVERLAY

This product may be processed after gold coating and combining the adhesive to the film to enhance its functionality. We offer a standard perforation pattern with 0.76 mm (0.03 in.) diameter holes on 6.35 mm (0.25 in.) centers, with a nominal 1.1% open area. We can also place a coverlay on the tape to protect it from accidental damage during handling and application.

## WARRANTY INFORMATION

Sheldahl warrants that our thermal control materials will meet all acceptance testing criteria for one year from the date of shipment (except Germanium, see product bulletin) if the materials have been stored indoors at standard conditions in their original packaging.

## SHELF LIFE

This product shall meet specified values for a minimum of 12 months after the date of shipment provided that the material is stored in its original unopened container at normal interior temperatures (10° C to 27° C/50° F to 80° F).

The shelf life of the material should be much longer than the warranty period. We recommend retesting any material that is more than one year old (or more than one year since most recent testing) prior to use. This will verify that the material has not been accidentally damaged. Sheldahl offers retest services for a nominal fee.

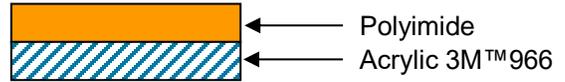
## SPECIFICATION AND ITEM NUMBERS

STANDARD NUMBERS		Thickness	PERFORATION NUMBERS	
Sheldahl Specification	Item Number		Sheldahl Specification	Item Number
G407960	TBD	0.5 mil	G407961	TBD
G407910	146498	1.0 mil	G407911	TBD
G407920	146500	2.0 mil	G407921	TBD

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## PRODUCT BULLETIN



## Polyimide Tape with Acrylic 3M™ 966 Adhesive

Sheldahl® polyimide tapes with 3M™966 adhesive have a variety of uses in satellite applications. The acrylic 3M™966 adhesive is nominally 2.3 mils thick, provides a strong bond with low outgassing, and can be used over a moderate temperature range.

This product may be ordered with 0.5, 1, 2, or 5 mil thick polyimide that conforms to the requirements of ASTM D-5213. Although the standard widths for this tape are 1, 2, 3, and 4 inches, it may be ordered in any width needed. Each roll is 108 feet (33 m) long.

## PRODUCT CHARACTERISTICS

Parameter (independent of film thickness)	Specified Value
Adhesion to stainless steel	≥ 20 oz./inch of width
Intermittent temperature range	-185° C to 230° C (-300° F to 450° F) <sup>A</sup>
Continuous temperature range	-60° C to 120° C (-75° F to 250° F) <sup>A</sup>

<sup>A</sup> Zero peel strength of acrylic pressure sensitive adhesive is at about -45°C (-50°F).

Standard Item Number	Thickness mil (μm)	Typical Weight (g/m <sup>2</sup> )	Perforation Item Number
146397	0.5 (12.5)	81	TBD
146391	1.0 (25)	98	146392
146394	2.0 (51)	133	162496
146396	5.0 (127.5)	238	—

## POST PROCESSING – PERFORATION & COVERLAY

This product may be processed after combining the adhesive to the film to enhance its functionality. We offer a standard perforation pattern with 0.76 mm (0.03 in.) diameter holes on 6.35 mm (0.25 in.) centers, with a nominal 1.1% open area. We can also place a coverlay on the tape to protect it from accidental damage during handling and application.

## WARRANTY INFORMATION

Sheldahl warrants that our thermal control materials will meet all acceptance testing criteria for one year from the date of shipment (except Germanium, see product bulletin) if the materials have been stored indoors at standard conditions in their original packaging.

## SHELF LIFE

This product shall meet specified values for a minimum of 12 months after the date of shipment provided that the material is stored in its original unopened container at normal interior temperatures (10° C to 27° C/50° F to 80° F).

The shelf life of the material should be much longer than the warranty period. We recommend retesting any material that is more than one year old (or more than one year since most recent testing) prior to use. This will verify that the material has not been accidentally damaged. Sheldahl offers retest services for a nominal fee.

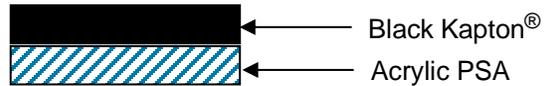
## SPECIFICATION AND ITEM NUMBERS

STANDARD NUMBERS		Thickness	PERFORATION NUMBERS	
Sheldahl Specification	Item Number		Sheldahl Specification	Item Number
G401160	146397	0.5 mil	G401161	TBD
G401100	146391	1.0 mil	G401101	146392
G401120	146394	2.0 mil	G401121	162496
G401150	146396	5.0 mil	—	—

Sheldahl manufactures a broad range of vacuum deposited films, laminates and tapes. Ask for additional product bulletins describing other Sheldahl® Materials.

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## PRODUCT BULLETIN



### Black Kapton® Tape with Acrylic Adhesive

Sheldahl® Black Kapton® tapes are used to seal outer MLI blanket layers when high absorptance, high emittance, or an  $\alpha/\epsilon$  ratio of about 1 is desired. They are also used as high emittance radiator surfaces on areas of the spacecraft that receive little or no direct sunlight.

This product may be ordered on a variety of polyimide substrates: 100CB Black Kapton® (non-conductive), 100XC Black Kapton® (semi-conductive), 160XC or 275XC Black Kapton® (moderately conductive). These tapes can be manufactured with either non-conductive type 3M™ 966 adhesive or with conductive type 3M™ 9703 adhesive. Although the standard widths for this tape are 1, 2, 3, and 4 inches, it may be ordered in custom widths. Each roll is 108 feet (33 m) long.

### PRODUCT CHARACTERISTICS

Parameter	Specified Value		
	100CB®	100XC®	
Film type	100CB®	100XC®	
Film surface resistivity	$\geq 10^{13} \Omega/\text{square}$	$10^5$ to $10^9 \Omega/\text{square}$	
Adhesive type	3M™ 966	3M™ 966	3M™ 9703
Intermittent temperature range	$-185^\circ \text{C}$ to $230^\circ \text{C}$ ( $-300^\circ \text{F}$ to $450^\circ \text{F}$ ) <sup>A</sup>		
Continuous temperature range	$-60^\circ \text{C}$ to $120^\circ \text{C}$ ( $-75^\circ \text{F}$ to $250^\circ \text{F}$ ) <sup>A</sup>	$-60^\circ \text{C}$ to $80^\circ \text{C}$ ( $-75^\circ \text{F}$ – $176^\circ \text{F}$ ) <sup>A</sup>	
Solar absorptance ( $\alpha$ )	$\geq 0.90$	$\geq 0.90$	
Normal emittance ( $\epsilon_N$ )	$\geq 0.82$	$\geq 0.82$	
Adhesion to stainless steel (oz./in.)	$\geq 20$	$\geq 20$	Typical 15
Typical weight ( $\text{g}/\text{m}^2$ )	98	98	
Standard Item number	146586	146622	146676
Sheldahl Specification	G414710	G422410	G431210

<sup>A</sup> Zero peel strength of acrylic pressure sensitive adhesive is at about  $-45^\circ \text{C}$  ( $-50^\circ \text{F}$ ).

## **POST PROCESSING - PERFORATION**

This product may be processed after combining the adhesive to the film to enhance its functionality. We offer a standard perforation pattern with 0.76 mm (0.03 in.) diameter holes on 6.35 mm (0.25 in.) centers, with a nominal 1.1% open area. We can also place a coverlay on the tape to protect it from accidental damage during handling and application.

Contact Sheldahl for perforation item numbers.

## **WARRANTY INFORMATION**

Sheldahl warrants that our thermal control materials will meet all acceptance testing criteria for one year from the date of shipment (except Germanium, see product bulletin) if the materials have been stored indoors at standard conditions in their original packaging.

## **SHELF LIFE**

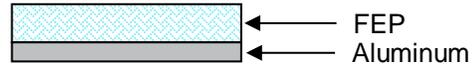
This product shall meet specified values for a minimum of 12 months after the date of shipment provided that the material is stored in its original unopened container at normal interior temperatures (10° C to 27° C/50° F to 80° F).

The shelf life of the material should be much longer than the warranty period. We recommend retesting any material that is more than one year old (or more than one year since most recent testing) prior to use. This will verify that the material has not been accidentally damaged. Sheldahl offers retest services for a nominal fee.

Sheldahl manufactures a broad range of vacuum deposited films, laminates and tapes. Ask for additional product bulletins describing other Sheldahl® Materials.

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## PRODUCT BULLETIN



### Aluminum Coated (One Side) FEP

Sheldahl® FEP films that are aluminum coated on one side is used as second surface mirrors to obtain low solar absorptance and high emittance.

This product may be ordered with 0.5, 1, 2, 5, or 10 mil thick FEP that conforms to the requirements of ASTM D-3368. The aluminum coating is nominally 1,000 Å thick. The most common width is 48 inches (1.22 m).

### PRODUCT CHARACTERISTICS

Parameter (independent of film thickness)	Specified Value
Intermittent temperature range	-185° C to 260° C (-300° F to 500° F)
Continuous temperature range	-185° C to 150° C (-300° F to 300° F)

Standard Item Number	Thickness mil (µm)	Second Surface Mirror Properties			Typical Weight (g/m <sup>2</sup> )	Perforation Item Number
		$\alpha$	$\epsilon_N$	$\epsilon_H$		
146431	0.5 (12.5)	$\leq 0.14$	$\geq 0.40$	$\geq 0.40$	28	TBD
146416	1.0 (25)	$\leq 0.14$	$\geq 0.47$	$\geq 0.48$	54	TBD
146377	2.0 (51)	$\leq 0.14$	$\geq 0.60$	$\geq 0.60$	109	TBD
146383	5.0 (127)	$\leq 0.14$	$\geq 0.75$	$\geq 0.75$	273	TBD
146434	10.0 (254)	$\leq 0.15$	$\geq 0.85$	$\geq 0.85$	546	167303

## POST PROCESSING – PERFORATION & COVERLAY

This product may be processed after metalizing to enhance its functionality. To facilitate air passage during launch, the film may be Perforated. Standard perforation patterns are on pages 15 - 23.

A protective coverlay may be placed on the film to protect the FEP outer layer.

## WARRANTY INFORMATION

Sheldahl warrants that our thermal control materials will meet all acceptance testing criteria for one year from the date of shipment (except Germanium, see product bulletin) if the materials have been stored indoors at standard conditions in their original packaging.

## SHELF LIFE

This product shall meet specified values for a minimum of 12 months after the date of shipment provided that the material is stored in its original unopened container at normal interior temperatures (10° C to 27° C/50° F to 80° F).

The shelf life of the material should be much longer than the warranty period. We recommend retesting any material that is more than one year old (or more than one year since most recent testing) prior to use. This will verify that the material has not been accidentally damaged. Sheldahl offers retest services for a nominal fee.

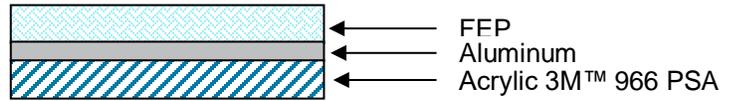
## SPECIFICATION AND ITEM NUMBERS

STANDARD NUMBERS		Thickness	PERFORATION NUMBERS	
Sheldahl Specification	Item Number		Sheldahl Specification	Item Number
G402700	146431	0.5 mil	G402704	TBD
G402000	146416	1.0 mil	G402004	TBD
G400500	146377	2.0 mil	G400504	TBD
G400900	146383	5.0 mil	G400904	TBD
G403800	146434	10.0 mil	G403804	167303

Sheldahl manufactures a broad range of vacuum deposited films, laminates and tapes. Ask for additional product bulletins describing other Sheldahl® Materials.

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## PRODUCT BULLETIN



## Second Surface Aluminum Coated FEP Tape with Acrylic 3M™ 966 Adhesive

Sheldahl® second surface aluminum coated FEP tapes with acrylic 3M™ 966 adhesive are used whenever high emittance and low solar absorptance are needed. The acrylic 3M™ 966 adhesive is nominally 2.3 mils thick, provides a strong bond with low outgassing, and can be used over a moderate temperature range. These tapes may be bonded to structures to control radiative heat transfer. They can also be used on multilayer insulation blankets to close the edges or repair rips in the outer layers.

This product may be ordered with 0.5, 1, 2, or 5 mil thick FEP that conforms to the requirements of ASTM D-3368. The aluminum coating is nominally 1000 Å thick. Although the standard widths for this tape are 1, 2, 3, and 4 inches, it may be ordered in custom widths. Each roll is 108 feet (33 m) long.

## PRODUCT CHARACTERISTICS

Parameter (independent of film thickness)	Specified Value
Adhesion to stainless steel	≥ 20 oz./inch of width
Intermittent temperature range	-185° C to 230° C (-300° F to 450° F) <sup>A</sup>
Continuous temperature range	-60° C to 120° C (-75° F to 250° F) <sup>A</sup>

<sup>A</sup> Zero peel strength of acrylic pressure sensitive adhesive is at about -45°C (-50°F).

Standard Item Number	Thickness mil (µm)	Second Surface Mirror Properties			Typical Weight (g/m <sup>2</sup> )	Perforation Item Number
		α	εN	εH		
TBD	0.5 (12.5)	≤ 0.14	≥ 0.40	≥ 0.40	88	TBD
146433	1.0 (25)	≤ 0.14	≥ 0.47	≥ 0.48	115	166631
146372	2.0 (51)	≤ 0.14	≥ 0.60	≥ 0.60	169	TBD
146379	5.0 (127)	≤ 0.14	≥ 0.75	≥ 0.75	333	146380
146537	10.0 (254)	≤ 0.15	≥ 0.85	≥ 0.85	606	TBD

## POST PROCESSING – PERFORATION, EMBOSSING, & COVERLAY

This product may be processed after metalizing and combining the adhesive to the film to enhance its functionality. We offer a standard perforation pattern with 0.76 mm (0.03 in.) diameter holes on 6.35 mm (0.25 in.) centers, with a nominal 1.1% open area. We can also place a coverlay on the tape to protect it from accidental damage during handling and application.

The raw material for these tapes may be embossed prior to coating to provide a more diffuse reflection pattern.

## WARRANTY INFORMATION

Sheldahl warrants that our thermal control materials will meet all acceptance testing criteria for one year from the date of shipment (except Germanium, see product bulletin) if the materials have been stored indoors at standard conditions in their original packaging.

## SHELF LIFE

This product shall meet specified values for a minimum of 12 months after the date of shipment provided that the material is stored in its original unopened container at normal interior temperatures (10° C to 27° C/50° F to 80° F).

The shelf life of the material should be much longer than the warranty period. We recommend retesting any material that is more than one year old (or more than one year since most recent testing) prior to use. This will verify that the material has not been accidentally damaged. Sheldahl offers retest services for a nominal fee.

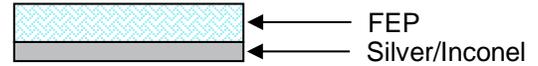
## SPECIFICATION AND ITEM NUMBERS

Standard Part Numbers		Thickness	PERFORATION Part Numbers	
Sheldahl Specification	Item Number		Sheldahl Specification	Item Number
G402800	TBD	0.5 mil	G402801	TBD
G402900	146433	1.0 mil	G402901	166631
G400200	146372	2.0 mil	G400201	TBD
G400800	146379	5.0 mil	G400801	146380
G409200	146537	10.0 mil	G409201	TBD

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## PRODUCT BULLETIN



### Silver Coated (One Side) FEP

Sheldahl® FEP films that are silver coated on one side are used as second surface mirrors to obtain low solar absorptance and high emittance.

This product may be ordered with 0.5, 1, 2, 5, or 10 mil thick FEP that conforms to the requirements of ASTM D-3368. The silver coating is nominally 1500 Å thick. We apply a 275 Å overcoat of Inconel to prevent the silver from oxidizing. This product is manufactured in 4 feet (1.22 m) wide by 10 feet (3 m) long sheets.

### PRODUCT CHARACTERISTICS

Parameter (independent of film thickness)	Specified Value
Intermittent temperature range	-185° C to 260° C (-300° F to 500° F)
Continuous temperature range	-185° C to 150° C (-300° F to 300° F)

Standard Item Number	Thickness mil (µm)	Second Surface Mirror Properties			Typical Weight (g/m <sup>2</sup> )	Perforation Item Number
		α	εN	εH		
146399	0.5 (12.5)	≤ 0.09	≥ 0.40	≥ 0.40	28	TBD
146400	1.0 (25)	≤ 0.09	≥ 0.47	≥ 0.48	54	170769
146374	2.0 (51)	≤ 0.09	≥ 0.60	≥ 0.60	109	146376
146401	5.0 (127)	≤ 0.09	≥ 0.75	≥ 0.75	273	170203
146435	10.0 (254)	≤ 0.10	≥ 0.80	≥ 0.85	546	TBD

RADIATOR SSM

## POST PROCESSING – PERFORATION & COVERLAY

This product may be processed after metalizing to enhance its functionality. To facilitate air passage during launch, the film may be Perforated. Standard perforation patterns are on pages 15 - 23.

A protective coverlay may be placed on the film to protect the FEP outer layer.

## WARRANTY INFORMATION

Sheldahl warrants that our thermal control materials will meet all acceptance testing criteria for one year from the date of shipment (except Germanium, see product bulletin) if the materials have been stored indoors at standard conditions in their original packaging.

## SHELF LIFE

This product shall meet specified values for a minimum of 12 months after the date of shipment provided that the material is stored in its original unopened container at normal interior temperatures (10° C to 27° C/50° F to 80° F).

The shelf life of the material should be much longer than the warranty period. We recommend retesting any material that is more than one year old (or more than one year since most recent testing) prior to use. This will verify that the material has not been accidentally damaged. Sheldahl offers retest services for a nominal fee.

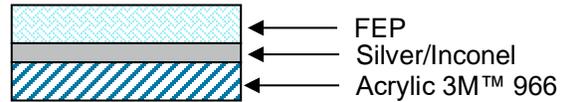
## SPECIFICATION AND ITEM NUMBERS

STANDARD NUMBERS		Thickness	PERFORATION NUMBERS	
Sheldahl Specification	Item Number		Sheldahl Specification	Item Number
G401300	146399	0.5 mil	G401304	TBD
G401400	146400	1.0 mil	G401404	170769
G400300	146374	2.0 mil	G400304	146376
G401500	146401	5.0 mil	G401504	170203
G404000	146435	10.0 mil	G404004	TBD

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## PRODUCT BULLETIN



### Second Surface Silver Coated FEP Tape with Acrylic 3M™ 966 Adhesive

Sheldahl® second surface silver coated FEP tapes with acrylic 3M™ 966 adhesive are used whenever high emittance and low solar absorptance are needed. The acrylic 3M™ 966 adhesive is nominally 2.3 mils thick, provides a strong bond with low outgassing, and can be used over a moderate temperature range. These tapes may be bonded to structures to control radiative heat transfer. They can also be used on multilayer insulation blankets to close the edges or repair rips in the outer layers.

This product may be ordered with 0.5, 1, 2, 5 or 10 mil thick FEP that conforms to the requirements of ASTM D-3368. The silver coating is nominally 1500 Å thick. We apply a 275 Å overcoat of Inconel to prevent the silver from oxidizing. Although the standard widths for this tape are 1, 2, 3, and 4 inches, it may be ordered in custom widths. Each roll is 108 feet (33 m) long.

### PRODUCT CHARACTERISTICS

Parameter (independent of film thickness)	Specified Value
Adhesion to stainless steel	≥ 20 oz./inch of width
Intermittent temperature range	-185° C to 230° C (-300° F to 450° F) <sup>A</sup>
Continuous temperature range	-60° C to 120° C (-75° F to 250° F) <sup>A</sup>

<sup>A</sup> Zero peel strength of acrylic pressure sensitive adhesive is at about -45°C (-50°F).

Standard Item Number	Thickness mil (μm)	Second Surface Mirror Properties			Typical Weight (g/m <sup>2</sup> )	Perforation Item Number
		α	ε <sub>N</sub>	ε <sub>H</sub>		
TBD	0.5 (12.5)	≤ 0.09	≥ 0.40	≥ 0.40	88	TBD
146430	1.0 (25)	≤ 0.09	≥ 0.47	≥ 0.48	115	TBD
146368	2.0 (51)	≤ 0.09	≥ 0.60	≥ 0.60	169	146369
146411	5.0 (127)	≤ 0.09	≥ 0.75	≥ 0.75	333	146412
146534	10.0 (254)	≤ 0.10	≥ 0.80	≥ 0.85	606	169383

## POST PROCESSING – PERFORATION, EMBOSSING & COVERLAY

This product may be processed after metalizing and combining the adhesive to the film to enhance its functionality. We offer a standard perforation pattern with 0.76 mm (0.03 in.) diameter holes on 6.35 mm (0.25 in.) centers, with a nominal 1.1% open area. We can also place a coverlay on the tape to protect it from accidental damage during handling and application.

The raw material for these tapes may be embossed prior to coating to provide a more diffuse reflection pattern.

## WARRANTY INFORMATION

Sheldahl warrants that our thermal control materials will meet all acceptance testing criteria for one year from the date of shipment (except Germanium, see product bulletin) if the materials have been stored indoors at standard conditions in their original packaging.

## SHELF LIFE

This product shall meet specified values for a minimum of 12 months after the date of shipment provided that the material is stored in its original unopened container at normal interior temperatures (10° C to 27° C/50° F to 80° F).

The shelf life of the material should be much longer than the warranty period. We recommend retesting any material that is more than one year old (or more than one year since most recent testing) prior to use. This will verify that the material has not been accidentally damaged. Sheldahl offers retest services for a nominal fee.

## SPECIFICATION AND ITEM NUMBERS

STANDARD NUMBERS		Thickness	PERFORATION NUMBERS	
Sheldahl Specification	Item Number		Sheldahl Specification	Item Number
G400600	TBD	0.5 mil	G400601	TBD
G402500	146430	1.0 mil	G402501	TBD
G400100	146368	2.0 mil	G400101	146369
G401900	146411	5.0 mil	G401901	146412
G409100	146534	10.0 mil	G409101	169383

Sheldahl manufactures a broad range of vacuum deposited films, laminates and tapes. Ask for additional product bulletins describing other Sheldahl® Materials.

The information on this product bulletin is based on data obtained by our research and is considered accurate. However, no warranty is expressed or implied regarding the accuracy of these data and the results obtained from the use thereof. This information is furnished upon the condition that the recipient shall conduct tests to determine the suitability of the product for his or her particular application.

## PRODUCT BULLETIN



## ITO Coated Silver FEP

Sheldahl® of FEP films that are silver coated on one side are used as second surface mirrors to obtain low solar absorptance and high emittance. We then add ITO to the other side to bleed off surface charges without significantly affecting the thermo-optical properties.

This product may be ordered with 0.5, 1, 2, 5, or 10 mil thick FEP that conforms to the requirements of ASTM D-3368. The silver coating is nominally 1500 Å thick. We apply a 275 Å overcoat of Inconel to prevent the silver from oxidizing. Our standard ITO coating has a resistivity between 2K and 10K Ω/square; other values are available upon request. This product is usually manufactured in sheets 4 feet (1.22 m) wide by 10 feet (3 m) long. Roll-to-roll coating is available on a custom basis.

## PRODUCT CHARACTERISTICS

Parameter (independent of film thickness)	Specified Value
ITO surface resistivity	2K to 10K Ω/square
Intermittent temperature range	-75° C to 65° C (-100° F to 150° F)
Continuous temperature range	-75° C to 65° C (-100° F to 150° F)

Standard Item Number	Thickness mil (µm)	Second Surface Mirror Properties			Typical Weight (g/m <sup>2</sup> )	Perforation Item Number
		α	ε <sub>N</sub>	ε <sub>H</sub>		
TBD	0.5 (12.5)	≤ 0.14	≥ 0.40	≥ 0.40	28	TBD
161038	1.0 (25)	≤ 0.14	≥ 0.47	≥ 0.48	54	164644
146648	2.0 (51)	≤ 0.14	≥ 0.60	≥ 0.60	109	160077
146651	5.0 (127)	≤ 0.14	≥ 0.75	≥ 0.75	273	159531
146654	10.0 (254)	≤ 0.15	≥ 0.85	≥ 0.85	546	174229

ITO/GE

## POST PROCESSING - PERFORATION

This product may be processed to enhance its functionality. The film may be Perforation prior to metallization to facilitate air passage during launch or to provide an electrical connection between the silver and ITO coated surfaces. Standard perforation patterns are on pages 15 - 23.

## WARRANTY INFORMATION

Sheldahl warrants that our thermal control materials will meet all acceptance testing criteria for one year from the date of shipment (except Germanium, see product bulletin) if the materials have been stored indoors at standard conditions in their original packaging.

## SHELF LIFE

This product shall meet specified values for a minimum of 12 months after the date of shipment provided that the material is stored in its original unopened container at normal interior temperatures (10° C to 27° C/50° F to 80° F).

The shelf life of the material should be much longer than the warranty period. We recommend retesting any material that is more than one year old (or more than one year since most recent testing) prior to use. This will verify that the material has not been accidentally damaged. Sheldahl offers retest services for a nominal fee.

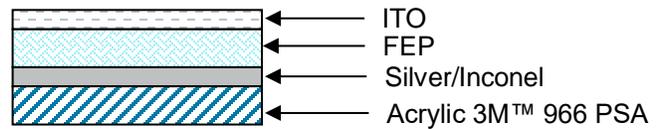
## PART NUMBERS

STANDARD NUMBERS		Thickness	PERFORATION NUMBERS	
Sheldahl Specification	Item Number		Sheldahl Specification	Item Number
G427160	TBD	0.5 mil	G427164	TBD
G427110	161038	1.0 mil	G427114	164644
G427120	146648	2.0 mil	G427124	160077
G427150	146651	5.0 mil	G427154	159531
G427200	146654	10.0 mil	G427204	174229

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## PRODUCT BULLETIN



## ITO Coated Silver FEP Tape with 3M™ 966 Acrylic Adhesive

Sheldahl® ITO coated silver FEP tapes with acrylic 3M™ 966 adhesive are used whenever charge dissipation, high emittance, and low solar absorptance are needed. The acrylic 3M™ 966 adhesive is nominally 2.3 mils thick, provides a strong bond with low outgassing, and can be used over a moderate temperature range. These tapes may be bonded to structures to control radiative heat transfer or used on multilayer insulation blankets to close the edges or repair rips in the outer layers.

This product may be ordered with 1, 2, 5, or 10 mil thick FEP that conforms to ASTM D-3368. The silver coating is nominally 1500 Å thick. We apply a 275 Å overcoat of Inconel to prevent the silver from oxidizing. Although the standard widths for this tape are 1, 2, 3, and 4 inches, it may be ordered in custom widths. Each roll is 108 feet (33 m) long.

## PRODUCT CHARACTERISTICS

Parameter (independent of film thickness)	Specified Value
ITO Surface Resistivity	2K to 10K $\Omega$ /square
Adhesion to stainless steel	$\geq 20$ oz./inch of width
Intermittent temperature range	-75° C to 65° C (-100° F to 150° F) <sup>A</sup>
Continuous temperature range	-60° C to 65° C (-75° F to 150° F) <sup>A</sup>

<sup>A</sup> Zero peel strength of acrylic pressure sensitive adhesive is at about -45°C (-50°F).

Standard Item Number	Thickness mil ( $\mu\text{m}$ )	Second Surface Mirror Properties			Typical Weight ( $\text{g}/\text{m}^2$ )	Perforation Item Number
		$\alpha$	$\epsilon_N$	$\epsilon_H$		
TBD	1.0 (25)	$\leq 0.14$	$\geq 0.47$	$\geq 0.48$	115	TBD
146655	2.0 (51)	$\leq 0.14$	$\geq 0.60$	$\geq 0.60$	169	179478
146656	5.0 (127)	$\leq 0.14$	$\geq 0.75$	$\geq 0.75$	333	146657
147449	10.0 (254)	$\leq 0.15$	$\geq 0.85$	$\geq 0.85$	606	171898

## POST PROCESSING – PERFORATION & EMBOSSING

This product may be processed after metalizing and combining the film to the adhesive to enhance its functionality. We offer a standard perforation pattern with 0.76 mm (0.03 in.) diameter holes on 6.35 mm (0.25 in.) centers, with a nominal 1.1% open area.

The raw material for these tapes may be embossed prior to coating to provide a more diffuse reflection pattern.

## WARRANTY INFORMATION

Sheldahl warrants that our thermal control materials will meet all acceptance testing criteria for one year from the date of shipment (except Germanium, see product bulletin) if the materials have been stored indoors at standard conditions in their original packaging.

## SHELF LIFE

This product shall meet specified values for a minimum of 12 months after the date of shipment provided that the material is stored in its original unopened container at normal interior temperatures (10° C to 27° C/50° F to 80° F).

The shelf life of the material should be much longer than the warranty period. We recommend retesting any material that is more than one year old (or more than one year since most recent testing) prior to use. This will verify that the material has not been accidentally damaged. Sheldahl offers retest services for a nominal fee.

## SPECIFICATION AND ITEM NUMBERS

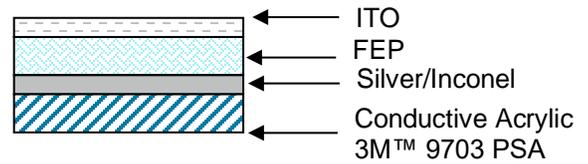
STANDARD NUMBERS		Thickness	PERFORATION NUMBERS	
Sheldahl Specification	Item Number		Sheldahl Specification	Item Number
G427410	TBD	1.0 mil	G427411	TBD
G427420	146655	2.0 mil	G427421	179478
G427450	146656	5.0 mil	G427451	146657
G4274X0	147449	10.0 mil	G4274X1	171898

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## PRODUCT BULLETIN

### ITO Coated Silver FEP Tape with Conductive Acrylic 3M™9703 Adhesive



Sheldahl® ITO coated silver FEP tapes with conductive acrylic 3M™9703 adhesive are used whenever charge dissipation, high emittance, low solar absorptance, and electrical connection between the tape and the spacecraft are needed. The conductive acrylic 3M™9703 adhesive is nominally 2 mils thick, provides a strong bond with low outgassing, and can be used over a moderate temperature range. These tapes may be bonded to structures to control radiative heat transfer or used on multilayer insulation blankets to close the edges or repair rips in the outer layers.

This product may be ordered with 1, 2, 5, or 10 mil thick FEP that conforms to ASTM D-3368. The silver coating is nominally 1500 Å thick. We apply a 275 Å overcoat of Inconel to prevent the silver from oxidizing. Although the standard widths for this tape are 1, 2, 3, and 4 inches, it may be ordered in custom widths. Each roll is 108 feet (33 m) long.

## PRODUCT CHARACTERISTICS

Parameter (independent of film thickness)	Specified Value
ITO Surface Resistivity	2K to 10K Ω/square
Adhesion to stainless steel	≥ 15 oz./inch of width
Intermittent temperature range	-75° C to 65° C (-100° F to 150° F) <sup>A</sup>
Continuous temperature range	-60° C to 65° C (-75° F to 150° F) <sup>A</sup>

<sup>A</sup> Zero peel strength of acrylic pressure sensitive adhesive is at about -45°C (-50°F).

Standard Item Number	Thickness mil (μm)	Second Surface Mirror Properties			Typical Weight (g/m <sup>2</sup> )	Perforation Item Number
		α	ε <sub>N</sub>	ε <sub>H</sub>		
TBD	1.0 (25)	≤ 0.14	≥ 0.47	≥ 0.48	115	TBD
146669	2.0 (51)	≤ 0.14	≥ 0.60	≥ 0.60	169	160550
155410	5.0 (127)	≤ 0.14	≥ 0.75	≥ 0.75	333	149598
166724	10.0 (254)	≤ 0.15	≥ 0.85	≥ 0.85	606	165790

## POST PROCESSING – PERFORATION & EMBOSSING

This product may be processed either before or after metalizing and combining the film to the adhesive to enhance its functionality. By perforating first, there will be an electrical connection from the ITO through the holes to the silver and the conductive adhesive. We offer a standard perforation pattern with 0.76 mm (0.03 in.) diameter holes on 6.35 mm (0.25 in.) centers, with a nominal 1.1% open area.

The raw material for these tapes may be embossed prior to coating to provide a more diffuse reflection pattern.

## WARRANTY INFORMATION

Sheldahl warrants that our thermal control materials will meet all acceptance testing criteria for one year from the date of shipment (except Germanium, see product bulletin) if the materials have been stored indoors at standard conditions in their original packaging.

## SHELF LIFE

This product shall meet specified values for a minimum of 12 months after the date of shipment provided that the material is stored in its original unopened container at normal interior temperatures (10° C to 27° C/50° F to 80° F).

The shelf life of the material should be much longer than the warranty period. We recommend retesting any material that is more than one year old (or more than one year since most recent testing) prior to use. This will verify that the material has not been accidentally damaged. Sheldahl offers retest services for a nominal fee.

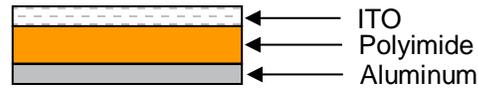
## SPECIFICATION AND ITEM NUMBERS

STANDARD NUMBERS		THICKNESS	PERFORATION NUMBERS	
Sheldahl Specification	Item Number		Sheldahl Specification	Item Number
G430010	TBD	1.0 mil	G430011	TBD
G430020	146669	2.0 mil	G430021	160550
G430050	155410	5.0 mil	G430051	149598

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## PRODUCT BULLETIN



## ITO Coated Aluminized Polyimide

Sheldahl® polyimide films that are aluminized on one side and have an indium tin oxide (ITO) coating on the opposite side are often used as outer layers in multi-layer insulation (MLI) blankets. The ITO coating provides a way to bleed off any electrical charge that may accumulate on the outer surface without significantly affecting the emittance or solar absorptance of the second surface mirror. The aluminum side of these products provides low emittance and low solar absorptance. The ITO side of these products has moderate solar absorptance and emittance (as determined by the polyimide film thickness). This product may be produced in small quantities using a batch process to manufacture sheets or in large quantities using a roll to roll coating process. The product may be perforated prior to coating to provide an electrical connection between the ITO and aluminum coatings.

This product may be ordered with 0.5, 1, 2, 3, or 5 mil thick polyimide that conforms to the requirements of ASTM D-5213. The aluminum coating is nominally 1000 Å thick, and the most common width is 48 inches (1.22 m). Sheets are 48 inches (1.22 m) wide and 10 feet (3 m) wide.

## PRODUCT CHARACTERISTICS

Parameter (independent of film thickness)	Specified Value
ITO surface resistivity	2,000 to 10,000 Ω/square*
Intermittent temperature range	-185° C to 260° C (-300° F to 500° F)
Continuous temperature range	-185° C to 150° C (-300° F to 300° F)

\* Custom resistance ranges are available upon request

Standard Item Number	Thickness mil (µm)	Second Surface Mirror Properties			Typical Weight (g/m <sup>2</sup> )	Perforation Item Number
		α	ε <sub>N</sub>	ε <sub>H</sub>		
146638	0.5 (12.5)	≤ 0.41	≥ 0.50	≥ 0.52	19	TBD
146631	1.0 (25)	≤ 0.44	≥ 0.62	≥ 0.64	36	160075
146633	2.0 (51)	≤ 0.49	≥ 0.71	≥ 0.71	71	159972
146635	3.0 (76)	≤ 0.51	≥ 0.77	≥ 0.77	109	161050
146637	5.0(127)	≤ 0.54	≥ 0.81	≥ 0.81	181	TBD

## POST PROCESSING - PERFORATION

This product may be perforated prior to metalizing to enhance its functionality. Perforated films facilitate air passage during launch and provide a through hole electrical connection from the ITO to the aluminum surface. Standard perforation patterns are listed on pages 15 - 23.

## WARRANTY INFORMATION

Sheldahl warrants that our thermal control materials will meet all acceptance testing criteria for one year from the date of shipment (except Germanium, see product bulletin) if the materials have been stored indoors at standard conditions in their original packaging.

## SHELF LIFE

This product shall meet specified values for a minimum of 12 months after the date of shipment provided that the material is stored in its original unopened container at normal interior temperatures (10° C to 27° C/50° F to 80° F).

The shelf life of the material should be much longer than the warranty period. We recommend retesting any material that is more than one year old (or more than one year since most recent testing) prior to use. This will verify that the material has not been accidentally damaged. Sheldahl offers retest services for a nominal fee.

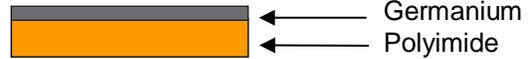
## SPECIFICATION AND ITEM NUMBERS

STANDARD NUMBERS		Thickness	PERFORATION NUMBERS	
Sheldahl Specification	Item Number		Sheldahl Specification	Item Number
G425160	146638	0.5 mil	G425164	TBD
G425110	146631	1.0 mil	G425114	160075
G425120	146633	2.0 mil	G425124	159972
G425130	146635	3.0 mil	G425134	161050
G425150	146637	5.0 mil	G425154	TBD

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## PRODUCT BULLETIN



## Germanium Coated Polyimide

Sheldahl® germanium coated polyimide films are well suited for antenna cover applications due to the coating's unique combination of radio frequency transparency and ability to bleed off static charge. This product may be ordered on a variety of polyimide substrates: Kapton® HN, 100CB Black Kapton® (non-conductive), 100XC Black Kapton® (conductive, nominal  $10^7 \Omega/\text{square}$ ), or 160XC and 275XC Black Kapton® (conductive). The germanium coating is nominally 1000 Å thick, but other thicknesses from 500 to 1750 Å are available. The product is manufactured as sheets 4 feet (1.22 m) wide and 10 feet (3 m) long or Roll-to-Roll up to 48 inches (1.22 m) wide.

## PRODUCT CHARACTERISTICS

Parameter (independent of film)	Specified Value
Germanium surface resistivity	$\leq 10^9 \Omega/\text{square}$ (typical $10^7 \Omega/\text{square}$ )
Transmittance (Kapton® HN only)	$\leq 0.20$
Solar Absorptance ( $\alpha$ ) Black Kapton® Side	0.93 typical
Normal Emittance ( $\epsilon_N$ ) Black Kapton® Side	0.84 typical
Intermittent temperature range	-250° C to 400° C (-420° F to 750° F)
Continuous temperature range	-250° C to 290° C (-420° F to 550° F)
Outgassing: (ASTM – E595)	TML - WVR $\leq 1.0 \%$ ; CVCM $\leq 0.1\%$

Item Number	Thickness mil ( $\mu\text{m}$ )	Ge Coated Surface Properties		Typical Weight ( $\text{g}/\text{m}^2$ )	Substrate
		$\alpha$	$\epsilon_N$		
146663	1.0 (25)	$\leq 0.45$	$\geq 0.72$	36	Kapton® HN
160970	2.0 (51)	$\leq 0.45$	$\geq 0.72$	71	Kapton® HN
160971	3.0 (76)	$\leq 0.45$	$\geq 0.72$	109	Kapton® HN
158816	5.0 (127)	$\leq 0.45$	$\geq 0.72$	181	Kapton® HN
147361	1.0 (25)	$\leq 0.60$	$\geq 0.72$	38	100CB Black
160928	1.0 (25)	0.58 typical	0.86 typical	38	100XC Black
165390*	1.6 (40)	0.60 typical	0.86 typical	63	160XC Black

\*The typical value for the surface resistivity of Ge/160XC Black Kapton® is in the  $10^3 \Omega/\text{square}$  range when measured with Sheldahl test method Q000725.

## WARRANTY INFORMATION

Sheldahl warrants that our thermal control materials will meet all acceptance testing criteria for one year from the date of shipment (except Germanium, see product bulletin) if the materials have been stored indoors at standard conditions in their original packaging.

## SHELF LIFE

This product shall meet specified values for a minimum of 6 months after the date of shipment provided that the material is stored in its original unopened container at normal interior temperatures (10° C to 27° C/50° F to 80° F).

The shelf life of the material should be much longer than the warranty period. We recommend retesting any material that is more than six months old (or more than one year since most recent testing) prior to use. This will verify that the material has not been accidentally damaged. Sheldahl offers retest services for a nominal fee.

Our standard packaging utilizes anti-moisture packaging for our vacuum deposited germanium coated products. The packaging includes interleaving the germanium material with a PET film for batch processed material. In addition, the roll is suspended on round 6" diameter plastic end plates, taped from end-to-end to keep the end plates in place. This interleaved rolled up germanium material is placed in a metallized moisture barrier packaging that has been dry nitrogen purged twice before being sealed within the bag. Sheldahl also requires our customers store the vacuum deposited germanium material in a moisture free environment, such as a nitrogen dry box or re-purging and sealing in the delivered bag after each time the bag is opened.

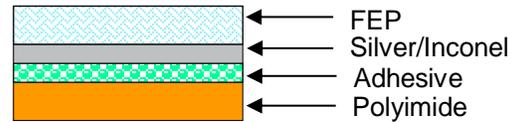
## SPECIFICATION AND ITEM NUMBERS

Standard Numbers		Substrate & Thickness
Sheldahl Specification	Item Number	
G428310	146663	1.0 mil Kapton® HN
G428320	160970	2.0 mil Kapton® HN
G428330	160971	3.0 mil Kapton® HN
G428350	158816	5.0 mil Kapton® HN
G430810	147361	1.0 mil 100CB Black Kapton®
N/A	160928	1.0 mil 100XC Black Kapton®
N/A	165390	1.6 mil 160XC Black Kapton®

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## PRODUCT BULLETIN



## Silver Coated FEP Reinforced with Polyimide

Sheldahl<sup>®</sup> Silver coated FEP film is often used as the outer layer of a MLI blanket. In many applications, the outer layer needs to provide more structural stability than FEP film offers. We offer a family of products of polyimide reinforced FEP sheets. The typical sheet size is 46 inches (1.17 m) wide and 10 feet (3 m) long. The table below provides technical data on just two of the possible constructions. Options available for this product include:

- Choice of FEP film thickness from 2 mil to 10 mil
- Choice of polyimide film thickness from 0.5 to 5 mil or use of 100XC, 100CB, 160XC, or 275XC Kapton<sup>®</sup>
- Choice of adhesive: A528 polyester thermosetting, conductive polyester thermosetting, or acrylic 3M<sup>™</sup> 966 pressure sensitive
- Addition of ITO to the FEP surface
- Addition of aluminum or gold coating to the polyimide surface
- Manufacturing the silver coated FEP wider than the polyimide for access to the silver coating for grounding purposes

## PRODUCT CHARACTERISTICS

Parameter	Specified Value	
FEP Thickness	2 mil (51 $\mu$ m)	5 mil (127 $\mu$ m)
Polyimide thickness	2 mil (51 $\mu$ m)	2 mil (51 $\mu$ m)
Adhesive	A528 Thermoset	A528 Thermoset
Intermittent temperature range	-185° C to 205° C (-300° F to 400° F)	-185° C to 205° C (-300° F to 400° F)
Continuous temperature range	-185° C to 150° C (-300° F to 300° F)	-185° C to 150° C (-300° F to 300° F)
FEP side emittance ( $\epsilon$ )	$\geq 0.60$	$\geq 0.75$
FEP side solar absorptance ( $\alpha$ )	$\leq 0.09$	$\leq 0.09$
Item number	147371	147355

## **POST PROCESSING - PERFORATION**

This product may be processed after combining to enhance its functionality. To facilitate air passage during launch, the laminate may be Perforated. For constructions with ITO, the FEP may be Perforated prior to coating to provide an electrical interconnect between the ITO and the silver coatings. Standard perforation patterns are on pages 15 -23.

## **WARRANTY INFORMATION**

Sheldahl warrants that our thermal control materials will meet all acceptance testing criteria for one year from the date of shipment (except Germanium, see product bulletin) if the materials have been stored indoors at standard conditions in their original packaging.

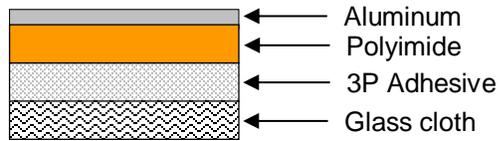
## **SHELF LIFE**

This product shall meet specified values for a minimum of 12 months after the date of shipment provided that the material is stored in its original unopened container at normal interior temperatures (10° C to 27° C/50° F to 80° F).

The shelf life of the material should be much longer than the warranty period. We recommend retesting any material that is more than one year old (or more than one year since most recent testing) prior to use. This will verify that the material has not been accidentally damaged. Sheldahl offers retest services for a nominal fee.

Sheldahl manufactures a broad range of vacuum deposited films, laminates and tapes. Ask for additional product bulletins describing other Sheldahl® Materials.

The information on this product bulletin is based on data obtained by our research and is considered accurate. However, no warranty is expressed or implied regarding the accuracy of these data and the results obtained from the use thereof. This information is furnished upon the condition that the recipient shall conduct tests to determine the suitability of the product for his or her particular application.



## PRODUCT BULLETIN

# Polyimide - Glass Cloth Laminates Using High Temperature (3P) Adhesive

Sheldahl® polyimide - glass cloth laminates are typically used in launch vehicle applications where resistance to very high temperatures is required. These products have been engineered to withstand temperatures as high as 700° F (370° C) when gold coatings are applied.

These products may be manufactured with any thickness of polyimide film, though 0.5 mil film is used most commonly. The laminates can be manufactured with aluminum or gold on the polyimide side, and aluminized laminates may be protected by our AOC coating for corrosion resistance. The table below gives the characteristics of the two most commonly sold constructions. Please contact our engineers for technical data on other constructions.

## PRODUCT CHARACTERISTICS

Parameter	Specified Value	
	VDA x 0.5 mil Kapton® x 3P adhesive x 116 glass fabric	VDA x 0.5 mil Kapton® x 3P adhesive x 112 glass fabric
Construction	VDA x 0.5 mil Kapton® x 3P adhesive x 116 glass fabric	VDA x 0.5 mil Kapton® x 3P adhesive x 112 glass fabric
Intermittent temperature range	-250° C to 315° C (-420° F to 600° F)	-185° C to 260° C (-300° F to 500° F)
Continuous temperature range	-185° C to 200° C (-300° F to 400° F)	-185° C to 200° C (-300° F to 400° F)
Polyimide side normal emittance ( $\epsilon_N$ )	$\leq 0.05$	$\leq 0.06$
Polyimide side hemispherical emittance ( $\epsilon_H$ )	$\leq 0.05$	$\leq 0.05$
Fabric side solar absorptance ( $\alpha$ )	$\leq 0.35$	
Fabric side hemispherical emittance ( $\epsilon_H$ )	$\leq 0.80$	
Thickness (in.)	$\leq 0.0058$	
Weight (g/m <sup>2</sup> )	$\leq 153$	115 typ.
Peel strength (lb./in. of width)	$\geq 1.0$	$\geq 1.0$
Tensile strength, Machine direction (PIW)	$\geq 45$	$\geq 35$ (fabric)
Transverse direction	$\geq 35$	$\geq 32$ (fabric)
Item number	146063	146066
Sheldahl Specification	G103760	G127200

LAMINATES

## **POST PROCESSING - PERFORATION**

This product may be processed after metalizing to enhance its functionality. To facilitate air passage during launch, the laminate may be Perforated. Standard perforation patterns are on pages 15 - 23.

## **WARRANTY INFORMATION**

Sheldahl warrants that our thermal control materials will meet all acceptance testing criteria for one year from the date of shipment (except Germanium, see product bulletin) if the materials have been stored indoors at standard conditions in their original packaging.

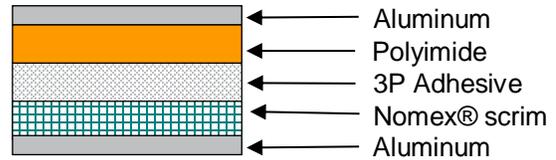
## **SHELF LIFE**

This product shall meet specified values for a minimum of 12 months after the date of shipment provided that the material is stored in its original unopened container at normal interior temperatures (10° C to 27° C/50° F to 80° F).

The shelf life of the material should be much longer than the warranty period. We recommend retesting any material that is more than one year old (or more than one year since most recent testing) prior to use. This will verify that the material has not been accidentally damaged. Sheldahl offers retest services for a nominal fee.

Sheldahl manufactures a broad range of vacuum deposited films, laminates and tapes. Ask for additional product bulletins describing other Sheldahl® Materials.

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## PRODUCT BULLETIN

### Nomex® Reinforced Polyimide High Temperature (3P) Laminate

Sheldahl® reinforced polyimide laminates are often used for the innermost layer of MLI blankets to provide a light weight inner layer that will resist tearing from handling and contact with the spacecraft. This family of laminates uses our proprietary high temperature 3P adhesive to provide superior performance over an extremely broad temperature range.

These products may be manufactured with any thickness of polyimide film, though 0.5 mil film is used most commonly. It can be manufactured with aluminum coated only on the polyimide side, only on the Nomex® side, on both sides, or on neither side. This laminate may also be coated with gold instead of aluminum or we can put our corrosion resistant AOC over the aluminum. The table below gives the characteristics of the two most commonly sold constructions.

### PRODUCT CHARACTERISTICS

Parameter	Specified Value	
Construction	VDA x 0.5 mil Polyimide x 3P Adhesive x Nomex® x VDA	0.5 mil Polyimide x 3P Adhesive x Nomex® x VDA
Intermittent temperature range	-185° C to 260° C (-300° F to 500° F)	-185° C to 260° C (-300° F to 500° F)
Continuous temperature range	-185° C to 200° C (-300° F to 400° F)	-185° C to 200° C (-300° F to 400° F)
Polyimide side solar absorptance ( $\alpha$ )	$\leq 0.14$	$\sim 0.40$
Polyimide side emittance ( $\epsilon$ )	$\leq 0.07$	
Nomex® side absorptance ( $\alpha$ )	$\leq 0.30$	$\sim 0.25$
Nomex® side hemispherical emittance ( $\epsilon_H$ )	$\leq 0.30$	$\leq 0.30$
Typical weight (g/m <sup>2</sup> )	66	66
Peel strength (lb./in. of width)	$\geq 0.4$	$\geq 0.4$
Item number	146071	146078
Sheldahl Specification	G143400	G147900

LAMINATES

## **POST PROCESSING – PERFORATION**

This product may be processed after metalizing to enhance its functionality. To facilitate air passage during launch, the laminate may be Perforated. Standard perforation patterns are on pages 15 - 23.

This laminate may also be micro-Perforated (formerly called porolated). This process puts approximately 18,000 pin-prick size holes per square foot into the material and allows the blanket to vent after launch. Many customers prefer this to perforation because the micro-perforation process does not cut through any of the reinforcing threads.

## **WARRANTY INFORMATION**

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## **SHELF LIFE**

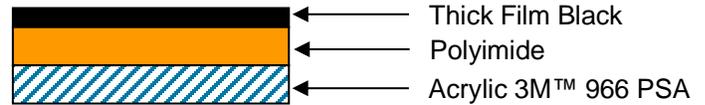
This product shall meet specified values for a minimum of 12 months after the date of shipment provided that the material is stored in its original unopened container at normal interior temperatures (10° C to 27° C/50° F to 80° F).

The shelf life of the material should be much longer than the warranty period. We recommend retesting any material that is more than one year old (or more than one year since most recent testing) prior to use. This will verify that the material has not been accidentally damaged. Sheldahl offers retest services for a nominal fee.

Sheldahl manufactures a broad range of vacuum deposited films, laminates and tapes. Ask for additional product bulletins describing other Sheldahl® Materials.

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## PRODUCT BULLETIN



## Thick Film Black Coated Polyimide with Acrylic 966™ Adhesive

Sheldahl® Thick Film Black provides a high emittance, high solar absorptance surface with an extremely matte finish. In addition, the Thick Film Black coating is electrically conductive to help dissipate electrostatic charge. The Thick Film Black is coated onto polyimide to form a stable, high temperature product that makes an excellent radiator. We add acrylic 3M™ 966 pressure sensitive adhesive to facilitate bonding to your structure to maximize the heat transfer rate. In addition, the matte finish makes this an excellent product to minimize stray light reflections into optical instruments.

This product may be ordered with 0.5, 1, or 2 mil thick polyimide that conforms to the requirements of ASTM D-5213. Although the standard widths for this tape are 1, 2, 3, and 4 inches, it may be ordered in custom widths. Each roll is 108 feet (33 m) long.

### PRODUCT CHARACTERISTICS

Parameter (independent of film thickness)	Specified Value
Adhesion to stainless steel	≥ 20 oz./inch of width
Solar Absorptance ( $\alpha$ )	≥0.85
Normal emittance ( $\epsilon_N$ )	≥0.80
Hemispherical emittance ( $\epsilon_H$ )	≥0.78
Intermittent temperature range	-185° C to 150° C (-300° F to 300° F) <sup>A</sup>
Continuous temperature range	-60° C to 105° C (-75° F to 225° F) <sup>A</sup>

<sup>A</sup> Zero peel strength of acrylic pressure sensitive adhesive is at about -45°C (-50°F).

Standard Item Number	Thickness mil ( $\mu\text{m}$ )	Typical Weight ( $\text{g}/\text{m}^2$ )	Perforation Item Number
146541	0.5 (12.5)	122	146542
146539	1.0 (25)	140	146540
TBD	2.0 (51)	175	TBD

MISC

## POST PROCESSING - PERFORATION

This product may be processed after metalizing to enhance its functionality. To facilitate air passage during launch, the laminate may be Perforated. Standard perforation patterns are on pages 15 - 23.

## WARRANTY INFORMATION

Sheldahl warrants that our thermal control materials will meet all acceptance testing criteria for one year from the date of shipment (except Germanium, see product bulletin) if the materials have been stored indoors at standard conditions in their original packaging.

## SHELF LIFE

This product shall meet specified values for a minimum of 12 months after the date of shipment provided that the material is stored in its original unopened container at normal interior temperatures (10° C to 27° C/50° F to 80° F).

The shelf life of the material should be much longer than the warranty period. We recommend retesting any material that is more than one year old (or more than one year since most recent testing) prior to use. This will verify that the material has not been accidentally damaged. Sheldahl offers retest services for a nominal fee.

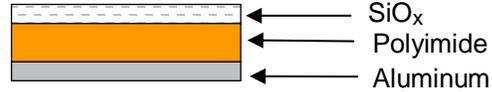
## SPECIFICATION AND ITEM NUMBERS

STANDARD NUMBERS		Thickness	PERFORATION NUMBERS	
Sheldahl Specification	Item Number		Sheldahl Specification	Item Number
G409360	146541	0.5 mil	G409361	146542
G409310	146539	1.0 mil	G409311	146540
G409320	174363	2.0 mil	G409321	TBD

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## PRODUCT BULLETIN



### SiO<sub>x</sub> Coated Aluminized Polyimide

Sheldahl® polyimide films that are aluminized on one side and have a SiO<sub>x</sub> coating on the other side are for protection against Atomic Oxygen. The clear SiO<sub>x</sub> layer has minimal effect on the optical properties of the polyimide and will cause only a minimal increase in polyimide side optical properties. The SiO<sub>x</sub> layer acts as an atomic oxygen absorber and will extend the lifetime of the polyimide film. The aluminum side of these products provide low emittance and low solar absorptance. The SiO<sub>x</sub> side of these products has moderate solar absorptance and emittance (as determined by the polyimide film thickness). This product may be produced economically in small quantities using a batch process to manufacture sheets, or in large quantities using a roll to roll coating process.

This product may be ordered with 0.5, 1, 2, 3, or 5 mil thick polyimide that conforms to the requirements of ASTM D-5213. The aluminum coating is nominally 1000 Å thick, and the most common width is 48 inches (1.22 m). Sheets are 48 inches (1.22 m) wide and 10 feet (3 m) wide.

### Product Characteristics

Parameter (independent of film thickness)	Specified Value
First surface solar absorptance( $\alpha$ )	$\leq 0.14$
First surface hemispherical emittance( $\epsilon_H$ )	$\leq 0.035$
First surface normal emittance( $\epsilon_N$ )	$\leq 0.035$
Typical first surface $\alpha/\epsilon$	4-5
Aluminum surface resistivity	$\leq 1 \Omega/\text{square}$
Intermittent temperature range	-185° C to 260° C (-300° F to 500° F)
Continuous temperature range	-185° C to 150° C (-300° F to 300° F)

Standard Item Number	Thickness mil ( $\mu\text{m}$ )	Second Surface Mirror Properties			Typical Weight ( $\text{g}/\text{m}^2$ )	Perforation Item Number
		$\alpha$	$\epsilon_N$	$\epsilon_H$		
TBD	0.5 (12.5)	TBD	TBD	TBD	19	TBD
175295	1.0 (25)	TBD	TBD	TBD	36	TBD
180027	2.0 (51)	TBD	TBD	TBD	71	TBD
166740	3.0 (76)	TBD	TBD	TBD	109	173333
180028	5.0 (127)	TBD	TBD	TBD	181	TBD

## **POST PROCESSING - PERFORATION**

This product may be processed after metalizing to enhance its functionality. To facilitate air passage during launch, the laminate may be Perforated. Standard perforation patterns are on pages 15 - 23.

## **WARRANTY INFORMATION**

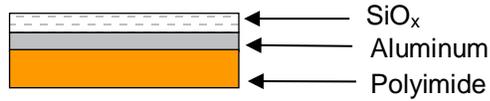
Sheldahl warrants that our thermal control materials will meet all acceptance testing criteria for one year from the date of shipment (except Germanium, see product bulletin) if the materials have been stored indoors at standard conditions in their original packaging.

## **SHELF LIFE**

This product shall meet specified values for a minimum of 12 months after the date of shipment provided that the material is stored in its original unopened container at normal interior temperatures (10° C to 27° C/50° F to 80° F).

The shelf life of the material should be much longer than the warranty period. We recommend retesting any material that is more than one year old (or more than one year since most recent testing) prior to use. This will verify that the material has not been accidentally damaged. Sheldahl offers retest services for a nominal fee.

## PRODUCT BULLETIN



## Aluminum Coated Polyimide Film Overcoated With SiO<sub>x</sub>

Sheldahl® SiO<sub>x</sub> overcoated aluminized polyimide films are used when precisely tailored emittance characteristics are desired. These products maintain the low solar absorptance of aluminum coatings and allow the emittance to be controlled to a value between 0.11 and 0.26. This yields an absorptance to emittance ratio between 0.5 and 1.

The coatings can be put on any thickness of polyimide desired (0.3, 0.5, 1, 2, 3, or 5 mil). The product can be manufactured in sheets that are four feet (1.2 m) wide and ten feet long (3 m). We can also produce tapes with Silicone or acrylic adhesive that are 100 feet long and up to four inches wide. Please contact us for information on constructions (film thickness, adhesive, or SiO<sub>x</sub> properties) other than those described below.

### PRODUCT CHARACTERISTICS

Parameter	Specified Value	
	"Low" Emittance	"High" Emittance
Product description	"Low" Emittance	"High" Emittance
Polyimide thickness	0.5 mil (12.5 μm)	0.5 mil (12.5 μm)
Intermittent temperature range	-185° C to 260° C (-300° F to 500° F)	-185° C to 260° C (-300° F to 500° F)
Continuous temperature range	-185° C to 150° C (-300° F to 300° F)	-185° C to 150° C (-300° F to 300° F)
Typical coated side solar absorptance (α)	0.12	0.13
Typical coated side emittance (ε)	0.11	0.26
Standard Item number	146545	TBD
Sheldahl Specification	G410460	G410760
Item number if combined with Silicone PSA	146518	146517
Sheldahl Specification if combined with Silicone PSA	G408760	G408660
Item number if combined with acrylic PSA	146581	175835
Sheldahl Specification if combined with acrylic PSA	G414260	TBD

## **WARRANTY INFORMATION**

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## **SHELF LIFE**

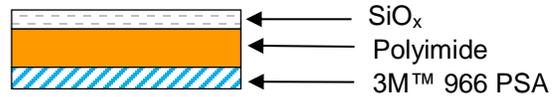
This product shall meet specified values for a minimum of 12 months after the date of shipment provided that the material is stored in its original unopened container at normal interior temperatures (10° C to 27° C/50° F to 80° F).

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## PRODUCT BULLETIN



### SiO<sub>x</sub> coated Polyimide Tape with 3M™ 966 Acrylic PSA

Sheldahl® coated polyimide tape with 3M™ 966 adhesive has a variety of uses in satellite applications. The SiO<sub>x</sub> layer provides protection against Atomic Oxygen. The acrylic adhesive provides a strong bond with low outgassing and can be used over a moderate temperature range.

This product may be ordered with 0.5, 1, or 2 mil thick polyimide that conforms to the requirements of ASTM D5213. The SiO<sub>x</sub> coating is nominally 1300 Å thick. The standard widths for this tape are 1, 2, 3, and 4 in. Each roll is 108 ft. (33 m) long.

Parameter (independent of film thickness)	Specified Value
Adhesion to stainless steel	≥ 20 oz./inch of width
Intermittent temperature range	-185° C to 230° C (-300° F to 450° F) <sup>A</sup>
Continuous temperature range	-60° C to 120° C (-75° F to 250° F) <sup>A</sup>

Standard Item Number	Thickness mil(μm)	Typical Weight (g/m <sup>2</sup> )	Perforation Item Number
TBD	0.5 (12.5)	81	TBD
180103	1.0 (25)	98	180099
TBD	2.0 (51)	133	179953

MISC

## **POST PROCESSING - PERFORATION**

This product may be processed after metalizing to enhance its functionality. To facilitate air passage during launch, the laminate may be Perforated. Standard perforation patterns are on pages 15 - 23.

## **WARRANTY INFORMATION**

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## **SHELF LIFE**

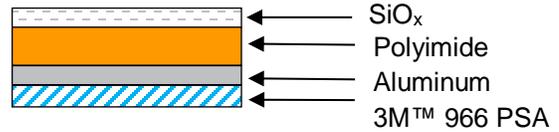
This product shall meet specified values for a minimum of 12 months after the date of shipment provided that the material is stored in its original unopened container at normal interior temperatures (10° C to 27° C/50° F to 80° F).

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## PRODUCT BULLETIN



### SiO<sub>x</sub> Coated Aluminized Polyimide Tape

Sheldahl® polyimide tapes that are aluminized on one side and have a SiO<sub>x</sub> coating on the other side are used for protection against Atomic Oxygen. The clear SiO<sub>x</sub> layer has minimal effects on the optical properties of the polyimide and will cause only a minimal increase in polyimide side optical properties. The SiO<sub>x</sub> layer acts as an atomic oxygen absorber and will extend the lifetime of the polyimide film. The SiO<sub>x</sub> side of these products has moderate solar absorptance and emittance (as determined by the polyimide film thickness). The acrylic adhesive provides a strong bond with low outgassing and can be used over a moderate temperature range.

This product may be ordered with 0.5, 1, or 2 mil thick polyimide that conforms to the requirements of ASTM D5213. The SiO<sub>x</sub> coating is nominally 1300 Å thick. The standard widths for this tape are 1, 2, 3, and 4 in. Each roll is 108 ft. (33 m) long.

Parameter (independent of fil thickness)	Specified Value
Adhesion to Stainless Steel	≥ 20 oz./inch of width
Intermittent temperature range	-185° C to 260° C (-300° F to 500° F)
Continuous temperature range	-60° C to 120° C (-75° F to 250° F) <sup>A</sup>

<sup>A</sup> Zero peel strength of acrylic pressure sensitive adhesive is at about -45°C (-50°F).

Standard Item Number	Thickness mil (µm)	Second Surface Mirror Properties			Typical Weight (g/m <sup>2</sup> )	Perforation Item Number
		α	□ <sub>N</sub>	□ <sub>H</sub>		
TBD	0.5 (12.5)	TBD	TBD	TBD	81	TBD
180104	1.0 (25)	TBD	TBD	TBD	98	TBD
10934	2.0 (51)	TBD	TBD	TBD	133	TBD

## **POST PROCESSING - PERFORATION**

This product may be processed after metalizing to enhance its functionality. To facilitate air passage during launch, the laminate may be Perforated. Standard perforation patterns are on pages 15 - 23.

## **WARRANTY INFORMATION**

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## **SHELF LIFE**

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## **Application and Handling of Thermal Control Materials**

Application of thermal control materials and fabrication of multilayer insulation (MLI) blankets should take place in an enclosed, controlled area. The floors should be non-dusting and the walls and ceilings free of flaking, chipping or other particle producing features. The area should be cleaned daily when fabricating operations produce visible contamination. Personnel should wear smocks, clean room head covering and, under certain circumstances, face masks. We recommend wearing nylon or powder free vinyl gloves when handling thermal control materials. Food and drink should not be permitted in the controlled area.

Vacuum deposited coatings are fragile and can be damaged by even moderate abrasion. Table tops should be covered with Tedlar or polyester and kept free of dirt, grit, and other contamination. If films do become contaminated, a light dusting with a soft camel hairbrush is acceptable. We suggest using Rymplecloth (purified wiping cloth) saturated with isopropyl alcohol to remove contaminants after brushing. A glass, polycarbonate, or acrylic sheet should be used as a cutting surface for thermal control materials. A new blade should be used for each cut to minimize tears and wrinkles.

Thermal control materials should be covered or stored in the original shipping container when not in use to prevent the accumulation of dust or dirt on the film surface.

Thermal Control materials having ITO coatings require extreme care when handled. Three-cornered folds, sliding the ITO coating on table surface, excessive handling, folding, and slight surface scratches can severely degrade the electrical continuity of the ITO.

### **Warranty Information**

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The shelf life of the material should be much longer than the warranty period. We recommend retesting any material that is more than one year old (or more than one year since most recent testing) prior to use. This will verify that the material has not been accidentally damaged. Sheldahl offers retest services for a nominal fee.

## Pressure Sensitive Adhesives

Our tapes bond best to clean, dry surfaces. Typical surface cleaning solvents include an isopropyl alcohol/water mixture and heptane. Follow the solvent manufacturer's precautionary warnings and suggested handling procedures.

Bond strength depends on the amount of adhesive to surface contact developed. Firm application pressure develops better adhesive contact and thus improves bond strength. After application the bond strength will increase as the adhesive flows onto the surface. At room temperature approximately 50% of the ultimate bond strength will be achieved after 20 minutes, 90% after 24 hours, and 100% after 72 hours. In some cases bond strength can be increased and ultimate bond strength can be achieved more quickly by exposure to elevated temperatures [e.g. 150°F (65°C) for one hour].

The ideal temperature range for applying tapes is 70°F to 100°F (21°C to 39°C). Initial tape application to surfaces at temperatures below 50°F (10°C) is not recommended because the adhesive becomes too firm to adhere readily. However, once properly applied, low temperature holding is generally satisfactory.

## Test Methods

All thermal control materials are subjected to rigorous quantitative testing and 100% visual inspection for workmanship before being shipped. Our consistent use of test methods and statistical analysis of the test data assures that product quality remains at the highest standards. Sheldahl is ISO 9001 certified.

Where possible we use test methods that are based on industry standards so that our customers can reliably reproduce our test results. The chart below shows how we test the various product types.

	Solar Absorptance ( $\alpha$ )	Emittance ( $\epsilon$ )	Surface Resistivity $\Omega$ /square	Coating Adhesion	Adhesion to steel Oz./in width	Peel Strength Oz./in width
Test method	Q000199	Q000341 ( $\epsilon_N$ ) Q000154 ( $\epsilon_H$ )	Q000322 Q000331 Q000379 Q000725	Q000084		
Industry test method	ASTM E-490 ASTM E-903	ASTM E-408 Methods A & B	ASTM D-257 ASTM F-390	ASTM D-1000 Mil M 13508	ASTM D-1000 ASTM D-3330	ASTM D-903
Metal x substrate	X	X	X*	X		
Metal x substrate x metal	X	X	X	X		
ITO x substrate x metal	X	X	X*	X		
Substrate x adhesive					X	
Metal x substrate x adhesive	X	X	X	X	X	
Substrate x metal x adhesive	X	X	X	X	X	
Substrate x fabric laminate						X
Metal x substrate x fabric laminate	X	X	X	X		X
Substrate x fabric x metal laminate	X	X	X	X		X

\* Surface resistivity not measured on aluminum or silver coating on FEP.

**Note:** Optical properties, resistivity, and metal adhesion of tapes are measured prior to combining with adhesive.

## Optical Properties

### Solar Absorptance Testing



Sheldahl measures solar absorptance using a Perkin-Elmer Labsphere 950 UV-VIS-NIR spectrophotometer.

In this instrument the light reaches the sample at an 8° angle of incidence, enters a 150 mm diameter Labsphere integrating sphere with Spectralon™ coating, and data is recorded every 2nm from 250 nm to 2500 nm. The Labsphere has a photomultiplier tube (PMT) detector for the UV/Vis range (up to 900 nm) and a PbS detector for the NIR range (860-2500 nm). Specular samples are measured against specular reference mirrors and diffuse samples are measured against diffuse standards. The reference standards are calibrated against NIST traceable standards.

Solar absorptance ( $\alpha$ ) is computed by numerical integration of the spectral reflectance weighted by the solar spectrum as described in NASA Reference Publication 1121, NASA SP-8005, and ASTM E-490. We perform the integration by averaging the reflectivity at 25 wavelengths at the center of spectral bands representing 4% of the solar output. For terrestrial solar energy applications, air mass 1.5 can be used.

### Emittance Testing

Room temperature emittance testing is currently done two different ways. A good approximation of total hemispherical emittance ( $\epsilon_H$ ) is obtained from a Lion Research Corporation emissometer. The instrument responds to the IR energy between 3 and 30 microns emitted from a sample through a potassium bromide window into a detector. This method conforms to ASTM E-408, Method B.

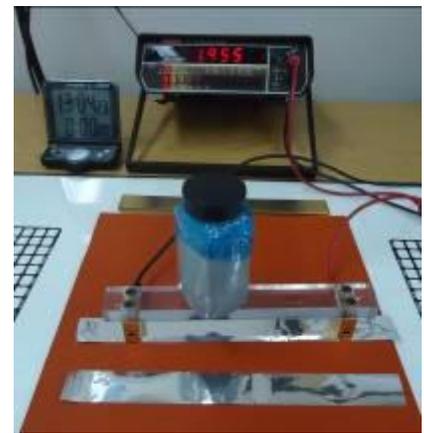




We can also test total normal reflectance on the AZ Technology Temp 2000A. A calculated normal emittance value can be provided by testing on the AZ Technology Temp 2000A Reflectometer in the Relative Mode. This meets ASTM-E408 Method B.

## Electrical Properties

There are several methods for measuring surface resistivity of our products. The test methods are based on ASTM D-257 and yield similar results. The surface resistivity of roll to roll and sheet goods is most often measured using a system with two probes that are each one inch wide and are placed six inches apart. In this case, the surface resistance is one sixth of the reading on the ohm meter. The surface resistance of the material being tested in the image at the right is 0.38  $\Omega$ /square. This test approach is described in Q000331. Q000379 is similar, except that the probes are only one inch apart and the surface resistance equals the value on the meter.



When small test samples are available, or we cannot cut a test sample for surface resistivity testing we use a four point probe as described in Q000322.

The surface resistivity of highly resistive products (e.g., germanium or 100XC Kapton®) may be measured on two machines. The first is a Pinion meter. This is a self-contained four point probe and it returns the order of magnitude of the surface resistivity. The second machine is an ETS 870A (shown at right) that uses a pair of concentric ring probes. The ETS 870A meter provides a resistivity readout that is accurate to several significant digits. These tests are described in our test method Q000725.



## Physical Properties

We have the capability to test many of the physical characteristics of the materials we use and produce. The most common testing of physical properties are the measurements of coating adhesion, adhesion of tapes to stainless steel, and peel strength of laminates. In addition, we can measure the tensile strength and elongation of films as well as the tear resistance of films and laminates. Using an outside laboratory we can test the outgassing properties of products and raw materials.

## Metal Adhesion Testing

Q000084 describes testing metal adhesion to film with a “scotch®-tape” test. The tape is selected and inspected per ASTM D-1000 to assure consistent bond strength to the metal coating. As shown in the figures below, the tape is pressed onto the coating using a calibrated force, pulled off at moderate speed at a high angle, and then examined for evidence of coating removal. The results are reported in levels of adhesion ranging from No Removal to Level 6 with more than 25% removal.



## Adhesion to Stainless Steel Testing



All tapes sold by Sheldahl are tested for bond strength. This test is done by applying the tape to a clean stainless steel substrate using a prescribed pressure and then measuring the force required to remove the tape using an Instron instrument. Our test methodology is in accordance with ASTM D-1000 and ASTM D-3330. We can also test adhesion to aluminum plates if desired.

## Peel Strength

We test the peel strength of laminates in much the same way we test the adhesion of tapes to metal plates. We begin by attempting to initiate a peel of the laminate. Some laminates are bonded so well that we cannot initiate a peel, and the test stops. If we can initiate a peel, the laminate is mounted in the Instron and then pulled apart while the Instron measures and records the force required. This test follows the methodology of ASTM D-903.

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## Glossary

- 3P Adhesive** - The Sheldahl high temperature and low outgassing adhesive made with polyimide/polyamide/polyester based resin is used in laminates for applications requiring performance at extreme temperatures.
- A528 Adhesive** - The Sheldahl low outgassing polyester based thermosetting adhesive used in laminates for standard temperature applications.
- Absorptance** - The ratio of the light absorbed by a material to the total incident light. (See also Solar Absorptance)
- Abrasion** - The wearing away of a surface by such means as rubbing, scraping or erosion.
- Acrylic Overcoat (AOC)** - A thin protective coating put on aluminum coated substrates.
- Adhesion** - The atomic or molecular attraction at the interface of two materials. Adhesion keeps a vacuum coating and substrate together.
- Adhesive** – A material used to attach similar or dissimilar materials to each other. (See also Pressure Sensitive Adhesive)
- Angstrom** - A unit of length, used especially in expressing the length of light waves, equal to  $10^{-10}$  m,  $3.9 \times 10^{-9}$  inches.
- Blackbody** – An idealized substance that is completely opaque and non-reflecting in all directions and at all wavelengths.
- Black Kapton<sup>®</sup>** - A carbon filled polyimide made by DuPont. The material has both high absorptance and high emittance.
- Blister** - An elevation of the surface of the adherent, somewhat resembling in shape a blister on the human skin; its boundaries may be indefinitely outlined and it may have burst and become flattened. It may be caused by insufficient adhesive, inadequate curing time, temperature, or pressure; or trapped air, water or solvent vapor.
- Blocking** - Undesirable adhesion between touching layers of similar or dissimilar materials.
- Blush** - Whitish surface appearance where moisture has condensed before solvent is all evaporated; or as a result of moisture or impurities bleeding from the substrate.
- Combining** - The process of adding PSA, coverlay, or release to substrate.
- Coverlay** - Protective layer of tape with a low tack adhesive to allow easy removal from the product to which it was combined.
- Desiccant** - Substance which can be used for drying purposes because of it's affinity to water.
- Dielectric** - A nonconductor of electricity, an insulator.
- Dielectric Strength (Breakdown Potential)** - The potential per unit thickness of the dielectric to cause puncture when electrodes are in contact with the material and the voltage is increased at a specific rate.
- Embossing** - A technique to produce a rough or raised pattern on the surface of a material. Material may be embossed to produce a diffuse surface or to provide separation between surfaces with minimum contact as may be desired in multilayer insulation blankets.
- Emittance** – A material's ability to radiate heat energy. A perfect blackbody has an emittance of 1 at all wavelengths.
- FEP** – Fluoro ethylene propylene (Example: Teflon<sup>®</sup> Type A)
- ITO** – Indium Tin Oxide, a sputtered transparent conductive coating.
- Laminate (Noun)** - A product made by bonding together two or more layers of material with an adhesive.
- Laminate (Verb)** -To unite layers of material with adhesive.
- MLI** – Multi-Layer Insulation. A term used to describe a thermal control blanket.

**Outgassing** – The process of emitting volatile substances from a material.

**Perforation** - A process that punches many regularly spaced holes in a material.

**PET** – Polyester or Polyethylene Terephthalate (Example: Mylar<sup>™</sup>, Melinex<sup>®</sup>)

**PI** – Polyimide (Example: Kapton<sup>®</sup>, Apical<sup>®</sup>, Upilex<sup>®</sup>)

**Porolation** – A process also called micro-perforation that punches approximately 18,000 pin-prick sized holes per square foot in a material.

**Pressure Sensitive Adhesive (PSA)** - A dry thin adhesive with a paper or polypropylene backing. PSAs require only pressure to adhere to a surface.

**PTFE** – Polytetra fluorinated ethylene

**Reactive Sputtering** - A sputtering process that uses a small amount of gas to form compounds on the substrate.

**Reflectance** - The ratio of the light reflected from the surface of the total incident light.

**Roll** - A continuous length of films of any width typically one hundred to several thousand feet long.

**Roll to Roll Coating** - A process for handling continuous lengths of a material in a vacuum chamber.

**Scrim** - A loosely woven cloth which is attached or laminated to a substrate or product to give it strength.

**Solar Absorptance** – The fraction of the sun's energy that is incident on a surface that it absorbs. This is computed by measuring the absorptance at many wavelengths and performing a weighted integration based on the sun's spectral output. We normally report solar absorptance based on the solar spectrum in vacuum. We can also compute solar absorptance based on the sun's spectrum as modified by passing through the earth's atmosphere.

**Sputtering** - A deposition process by which atoms and/or molecules of atoms are ejected from the surface of a target after bombarding it with ions.

**Substrate** - The base layer(s) upon which a process is to be performed (i.e., Polyimide, Polyester, FEP).

**Surface Resistivity** - An electrical resistance parameter for thin conducting layers. The surface resistivity is given by the bulk resistivity divided by the film thickness and is independent of the cross sectional area of the layer measured.

**Temperature Range, Continuous** – Listed in our individual Product Bulletins, it is our engineer's best judgment of recommended temperature ranges that a material can withstand without degradation. Continuous exposure is described as periods of hours or longer. Sheldahl recommends users verify material selections are appropriate for their mission environment.

**Temperature Range, Intermittent** – Listed in our individual Product Bulletins, it is our engineer's best judgment of recommended temperature ranges that a material can withstand without degradation. Intermittent exposure is described as periods of seconds or minutes. Sheldahl recommends users verify material selections are appropriate for their mission environment.

**Thermal Conductivity** -Ability of a material to conduct heat.

**TFB** – Thick Film Black, a Sheldahl<sup>®</sup> brand matte black coating that may be modified to also serve as a conductive black adhesive.

**Transmittance** - The ratio of the light transmitted through a material to the total incident light. (See Absorptance)

**VD** – Vacuum Deposited

**VDA** – Vacuum Deposited Aluminum

**Vapor Deposition** – A process where a material, usually metal, is deposited in the absence of air. The material condenses onto cooler surfaces including the substrate.



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# The Red Book

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