



PALSUN[®] Technical Guide

Flat Solid Polycarbonate Sheet



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PALSUN® Product Range

Some of the product features below can be combined. Please contact your Palram dealer for further information.

Product	Description
BASIC PALSUN® Basic <i>(Formerly Paltuf)</i>	UV stabilized general purpose polycarbonate sheet
PALSUN® UV1	Co-extruded UV protection on one side for exterior applications
PALSUN® UV2	Co-extruded UV protection on both sides for exterior applications
PALSUN® Embossed*	Embossed surface (E102, prismatic, hair cell)
PALSUN® FR	Sheet with higher fire resistance rating (e.g. UL 94 V-0)
PALSUN® Matte*	Matte finish on one side
UV PALSUN® SG White*	High diffusion for sign grade applications
PALSUN® CS*	Coil stock on rolls (Clear and SG White standard)
PALSUN® Foam	Flat foamed polycarbonate sheet, UV protected on one side
SolarSmart PALSUN® Solar Control	Sheet with integrated heat-blocking layer. This metallic reflective layer that transmits less Infrared radiation and reduces heat buildup.
PALSUN® Smart*	See-through sheet with advanced heat-blocking
PALSUN® Basic FR†	Fire retardant, with elevated Relative Thermal Index (RTI) values
SPECIALTY PALSUN® OG*	Optical grade sheet
PALGARD™	Sheet with abrasion resistant layer on one or both sides
PALGARD™ TG	Transportation grade (meets specific transportation codes)
PALSHIELD™	Containment and bullet resistant glazing

- Notes:
- All the above sheets are supplied with a protective polyethylene (PE) film on both sides (one side upon request), with the UV protected side clearly marked. This film should be removed immediately after installation.
 - For transportation, handling and storage instructions and recommendations, please refer to [Handling and Storage Guidelines for Palram Sheets](#).
 - PALSUN UV Series sheets are backed by a 10 years limited warranty, available upon request.
 - Most PALSUN sheets are available in the transparent, translucent or opaque form, in a variety of colors, either standard or custom ordered.
- * With co-extruded UV protection on one or both sides.
 † Available in 2 mm and 2.36 mm for applications without direct UV exposure.

Selection of the Appropriate PALSUN® Sheet

PALSUN sheets are manufactured in a range of thicknesses from 1.0 mm to a maximum of 20 mm.

PALSUN Basic® Sheets

This series includes products that **do not** feature added UV protection for outdoor use. Intended mainly for indoor use (transparent partitions, interior design applications, industrial shields, and thermoformed items). They are also used in trade show displays, or other temporary structures. Palsun Basic sheets are not recommended for permanent outdoor applications, even in areas with mild UV radiation (Northern Europe, USA, Canada and similar). Use Palsun UV Series products for extended or permanent outdoor applications.

Palsun UV Series Sheets

This series includes products that **do** feature added UV protection for outdoor use. Used for outdoor applications, Palsun UV Series can be cold bent, fabricated or formed, making it ideal for applications such as sign faces, barrel vault roofing, roof (sky) lights, architectural roofing and glazing.

Palsun Specialty Series Sheets


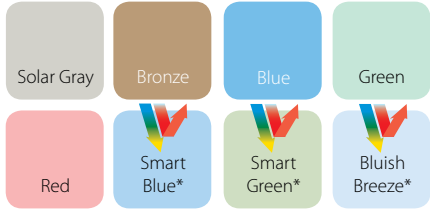
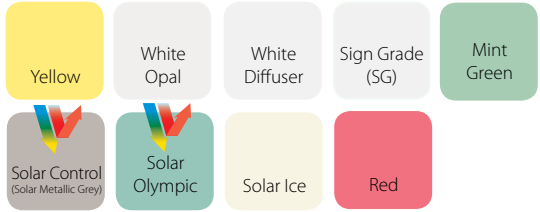

This series includes products that feature either enhanced optical qualities, or a high-performance specialty coating, or are laminated to provide additional performance beyond Basic or UV series products. Products in this series are used for specialized applications in the sign and graphics, transportation, aviation, detention and security industries.

Standard Dimensions*

Width (in.) x Length (in.)	Thickness (in.)
48" x 96" - all thicknesses	0.04", 0.06", and unit values from 0.08" to 0.5".
60" x 96" - all thicknesses	
72" x 96" - all thicknesses	
80" x 120" - all thicknesses	

* Other dimensions are available with a special order, subject to minimum quantity. Monolithic sheet is available up to 20mm thick. Embossed, Matte, Hair Cell and Prismatic are available with minimums.

Colors

Color Group	Description	Colors
Clear	Transmits up to 90% of visible light.	 Clear
Transparent	Low haze colors offering high clarity. Breeze and Smart are SolarSmart™ colors which reduce heat buildup while allowing a clear view through the sheet (see page 9 for more details on SolarSmart products).	 Solar Gray, Bronze, Blue, Green, Red, Smart Blue*, Smart Green*, Bluish Breeze*
Translucent	<p>White Opal: Transmits 11-50% visible light with high light dispersion, produces mild and even lighting.</p> <p>Diffuser: Transmits 50% visible light with high light dispersion, produces diffused and consistent lighting.</p> <p>Sign Grade (SG): Diffuser sheet for illuminated signs and display applications, offering 28% light transmission.</p>	 Yellow, White Opal, White Diffuser, Sign Grade (SG), Mint Green, Solar Control (Solar Metallic Grey), Solar Olympic, Solar Ice, Red
Opaque*	Colors that transmit very little to no light.	 Dark Green, Red Brick, Black, Dark Blue, Cream Ral 9001, Light Grey Ral 7035, Dark Grey, Brown, Off-White

* Subject to minimum quantity. Custom colors and light transmissions are also available in this manner.

** Colors shown above are a reproduction of the actual color. To accurately represent the colors, contact your Palram distributor and request a sample color chip.

SolarSmart™ - Energy Efficiency

SolarSmart™ energy-efficient colors break the historical ratio between light transmission and shading coefficient. SolarSmart™ colors block Infrared energy that causes heat buildup, and transmit “cool light” that help reduce cooling and lighting costs.



Impact Strength

PALSUN sheets are manufactured from polycarbonate, the most versatile, toughest transparent thermoplastic available. PALSUN has 200 times the impact strength of glass, ensuring excellent protection against vandalism, breaking and entering, public disturbances, and even riots.

PALSUN can endure attacks by rocks, clubs, hammers and thrown objects, and still retain its original shape and maintain its integrity with minimal indentations to its surface.

The amount of damage depends on the object mass and energy, and the sheet's thickness. PALSUN sheets will retain these energy-absorbing properties over a wide temperature range (122°F to 212°F).

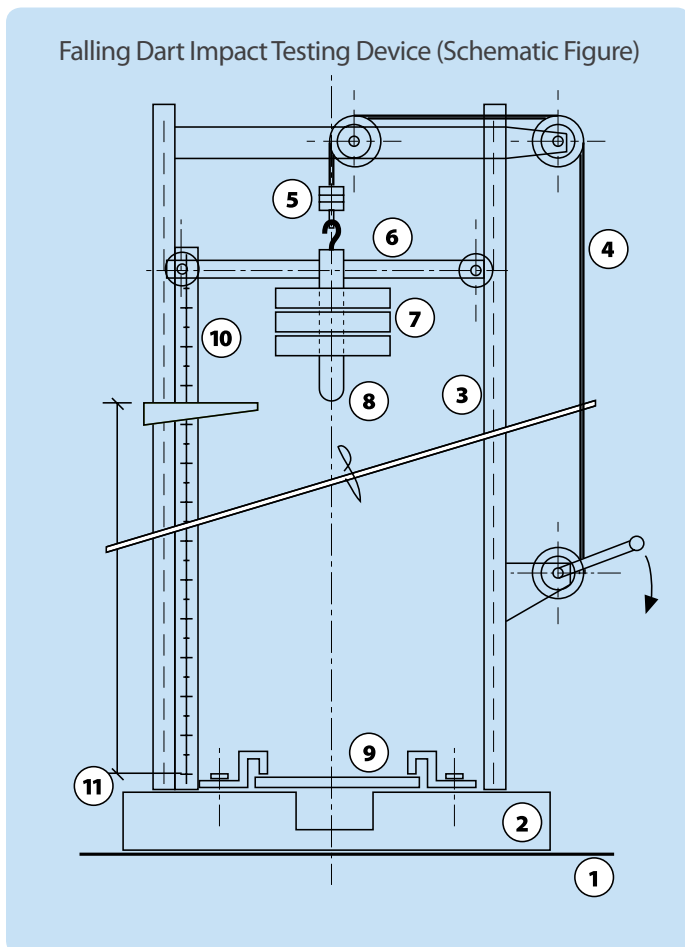
Falling Dart Method

A uniform energy increment is employed during testing. Energy is decreased or increased by uniform increment after testing each specimen, depending upon the result (pass / fail) observed for the previously tested sample. A .79" (20 mm) diameter dart, weighing 17.6 lbs (8 kg), with a rounded tip, is raised to a certain height and released to fall on a suitably sized sample.

Principles: Impact strength is determined by the known weight and height. Adjustment is done by altering height while using a constant mass.

E50: 50% of Impact Failure Energy. The energy that will cause 50% of the tested samples to fail.

N.B.:** No Break. The energy required to break the sample is greater than what the test instrument can deliver.



Typical impact failure energy of PALSUN® sheets*

Thickness mm	Energy at Failure E ₅₀ (Joules)	Type of Failure
2	110	100% ductile
3	150	100% ductile
4	190	100% ductile
5	290	100% ductile
6	400	100% ductile
8 - 18	N.B.**	N.B.**

* According to ISO 6603/1 1985(E): Determination of multi-axial impact behavior of rigid plastics.

Legend

1. Levelled floor
2. Stabilized base
3. Supporting guide rails
4. Lifting mechanism
5. Disengagement mechanism
6. Guidance bar
7. Changeable weight
8. A .79" (20 mm) diameter head falling dart
9. Tested specimen
10. Calibration bar
11. Changeable drop height

Physical Properties

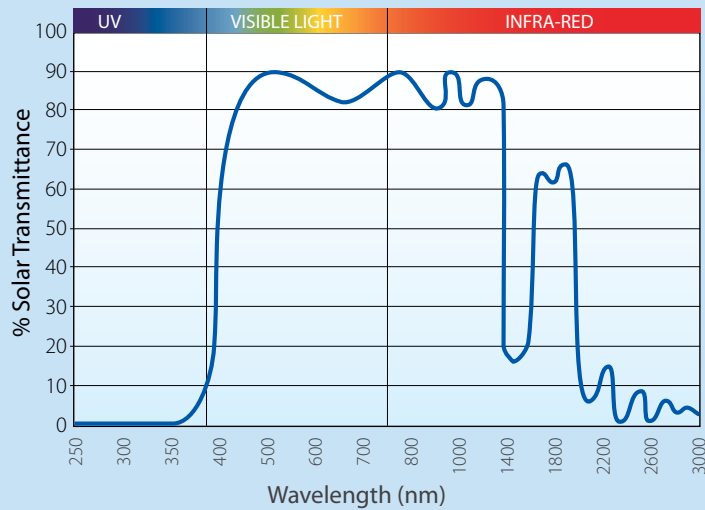
For detailed PALSUN physical property information, please visit:

www.PalramAmericas.com/Products/Flat-Sheets/Palsun/

Optical Characteristics of Transparent Sheets

Ultraviolet (UV) Radiation Blocking - PALSUN sheets completely block out potentially harmful UV radiation and a significant portion of Infrared (IR) radiation. Over the visible light range, a typical 0.125" (3 mm) thick clear PALSUN sheet transmits about 89% (average) of incident light, as seen in the attached graph.

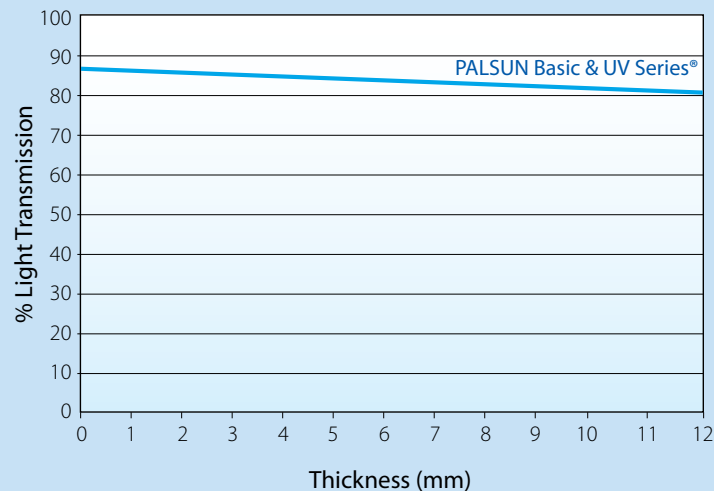
Figure 2:
Solar Transmittance of Clear 3mm PALSUN®



Light Transmission Versus Thickness

Light transmission decreases slightly with increased thickness (see table below).

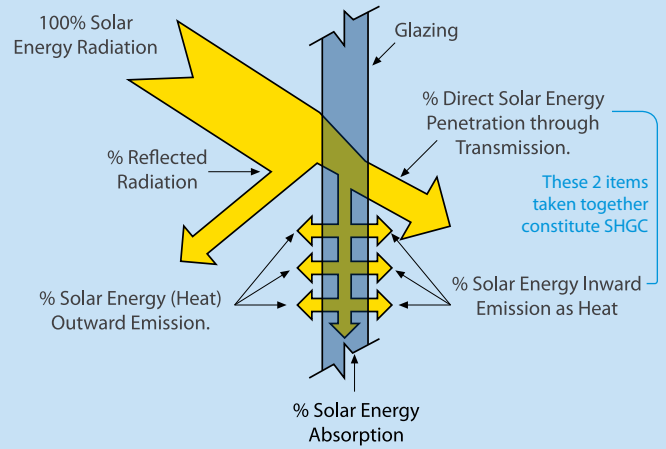
Figure 3:
Light Transmission vs. Thickness
in Clear PALSUN Sheets



Solar Transmission Properties

Solar energy transmission is an extremely important consideration with transparent materials. Geographic location and typical thermal/optical properties of the specific glazing are the main factors influencing solar heat gain. Various types of PALSUN—textured, tinted, opal, diffused, and heat blocking SolarSmart™ sheets—can be used to deliver the exact quantity and quality of light desired. Each of these products transmit different amounts of direct light in varying levels of light diffusion, which may help to spread the light throughout the structure or enclosure. The sheets also vary in their selectivity index (SI) values, which determines how efficiently they keep heat out while letting more “cool light” in (See [next page](#) for more information on SolarSmart™ products). Although colors and tints reduce the percentage of visible light transmitted through the sheets, solar energy is still absorbed by the glazing itself, and in turn transferred by convection and far IR radiation from the heated glazing into the building. PALSUN sheets with embossed or matte surfaces, or diffuser colors, diminish glare and harsh light, preventing damage by direct irradiance. However, solar energy is still transmitted through and increases the solar heat gain inside the structure.

Figure 4: Solar Radiation Schematic Behavior Through Light Transmitting Material



Color*	% Light Transmission ASTM D-1003	%Haze ASTM D-1003	Solar Heat Gain (SHGC) ASTM E-424-71	Shading Coefficient ASTM E-424-71
Clear	90	<1	0.87	1.00
	20	<1	0.45	0.52
Bronze	35	<1	0.56	0.64
	50	<1	0.65	0.75
	20	<1	0.44	0.51
Solar Grey	35	<1	0.56	0.64
	50	<1	0.65	0.75
White Opal	28	100	0.32	0.37
White Diffuser	80	100	0.87	1.00
	70	100	0.68	0.79
Solar Ice	20	100	0.37	0.45
Solar Control	20	67	0.33	0.36
	35	52	0.45	0.52
	50	50	0.54	0.61
Solar Olympic	20	35	0.41	0.47
	35	20	0.52	0.60
Smart Green	50	63	0.63	0.73
	70	42	0.58	0.67
Smart Blue	70	42	0.57	0.65
Bluish Breeze	70	42	0.55	0.63

*Values in the table above relate to 3 mm Sheet. Further information on additional products is available upon request.

Terminology Used in the Table

% Haze (ASTM D-1003): the percentage of transmitted light which, in passing through the specimen, deviates more than 2.5° from the incident beam by forward scattering.

% Light Transmission (ASTM D-1003): Percentage of incident visible light that passes through an object.

% Solar Heat Gain (SHGC): The percent of incident solar radiation transmitted by an object which includes the direct solar transmission plus the part of the solar absorption reradiated inward.

Shading Coefficient (ASTM E424-71): The ratio of the total solar radiation transmitted by a given material to that transmitted by normal glass, whose light transmission is 87%. It can be calculated by: $SC = (1.15 \times SHGC)$





Enjoy sunlight without the heat and harmful UV Radiation



Promoting Energy Efficiency and Climatic Comfort

Studies show that environments with high levels of natural light result are typically more productive and enjoyable.* However, incorporating higher levels of natural light into buildings and structures typically also resulted in higher cooling costs due to infrared heat gain.

SolarSmart technology breaks the traditional engineering correlation between light transmission and shading coefficient, providing architects a whole new realm of possibilities when it comes to the specification of natural light in architectural design.

Unlike commonly-available tinted products, SolarSmart products transmit more natural daylight while reflecting the sun's heat-giving infrared radiation. More natural light and less heat build-up helps improve ambience and climatic comfort, while also supporting energy efficiency goals (energy efficiency is supported by helping to reduce electrical lighting and air conditioning requirements). SolarSmart products allow architects more versatility for specification of color and solar transmission requirements for each project.



Color Specification

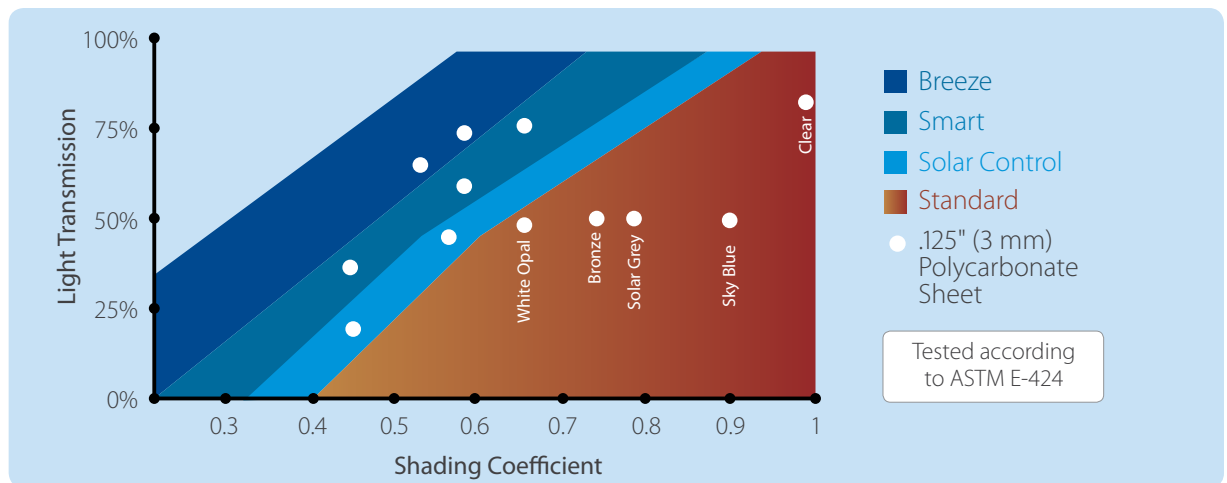
Minimum volume requirements apply, but SolarSmart™ tints can be incorporated into any Palram transparent polycarbonate sheet or panel system, including PALSUN. SolarSmart tints can be blended with any color to tailor the desired appearance and solar properties.

Technology Groups

The SolarSmart product range includes three technology groups, each of which have different characteristics and appearance. For more information please refer to the SolarSmart™ Technology brochure.

Efficiency Comparison

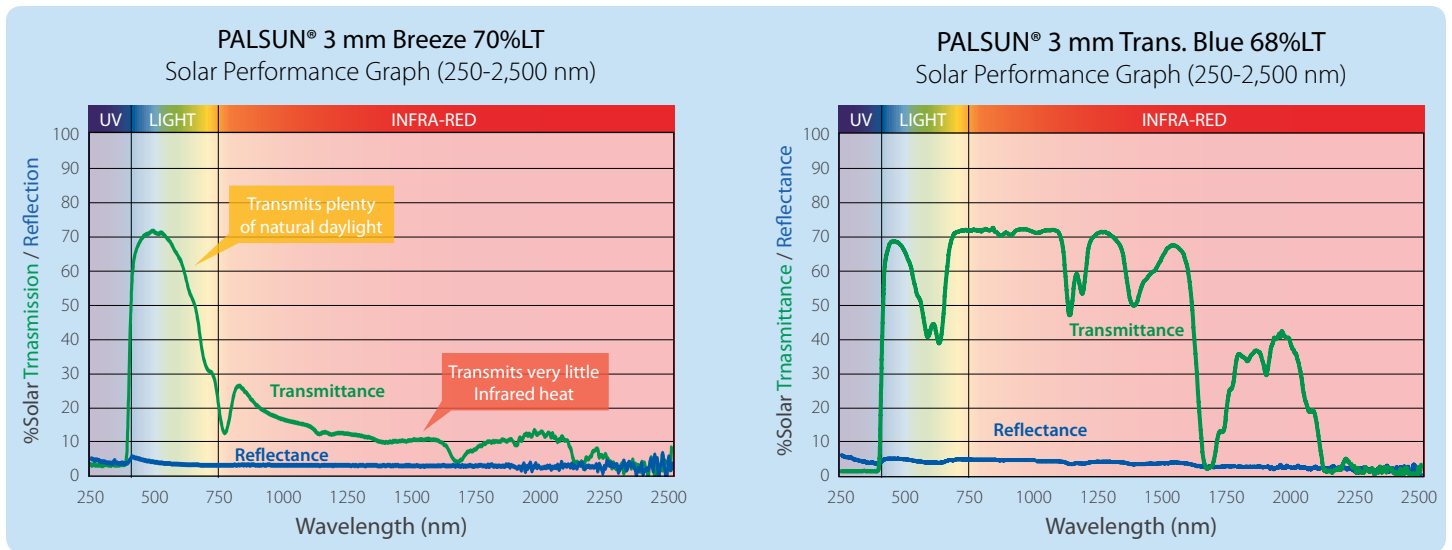
The graph below demonstrates the efficiency of SolarSmart products in comparison with clear and standard colored sheets. The graph shows how SolarSmart™ tints enable higher light transmission while maintaining or decreasing shading coefficient values.



* See Palram's white paper www.PalramAmericas.com/Daylight/

PALSUN® Breeze Offers High Clarity While Also Blocking Heat

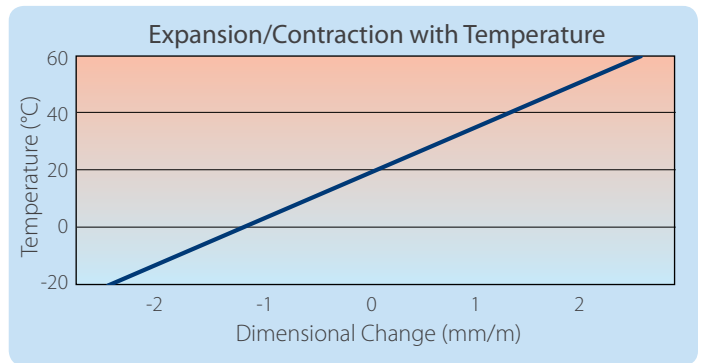
PALSUN glazing with Breeze tint transmits plenty of incident daylight (70%), while absorbing/blocking a large portion of the Infrared radiation, thus significantly reducing heat buildup within the structure. PALSUN Breeze also provides a clear view due to its high transparency, which is uncommon for heat-blocking products.



Thermal Characteristics

Thermal Expansion

The thermal expansion of PALSUN sheets is higher than that of glass. This important factor must be taken into account when mounting the sheets. The graph on the right shows the degree of expansion/contraction as a function of temperature.



Service Temperature

The temperature range over which the characteristics of PALSUN are retained extends from -60° F to +250° F (-50° C to +120° C) for short periods and from -60° F to +210° F (-50° C to +100° C) for long periods. This range of temperatures make PALSUN sheets suitable for use in most climates.

Thermal Insulation

On very hot days, the surface temperature of the sheet might reach up to 140°F (60° C). The U-value characterizes the degree of thermal transmittance offered by a given glazing material, so higher U-values are associated with materials that are poor insulators and result in a greater loss of heat. The following table compares the U-values of glass and PALSUN sheets of equivalent thicknesses. Thicker sheets of a given material will offer greater thermal insulation and be characterized by a lower U-value and reduced heat loss. For any given thickness, the U-value of PALSUN sheet is lower than that of glass. This means that heat loss from the building interior, as well as penetration of heat or cold into a building, will be less if it were glazed with PALSUN than for one glazed with glass. This can result in a significant reduction in energy costs both for heating in winter and air-conditioning during the summer. Note that use of SolarControl sheets will insulate just as well, but will also reduce air-conditioning costs because of Near Infra-Red reflection and reduced heat buildup.

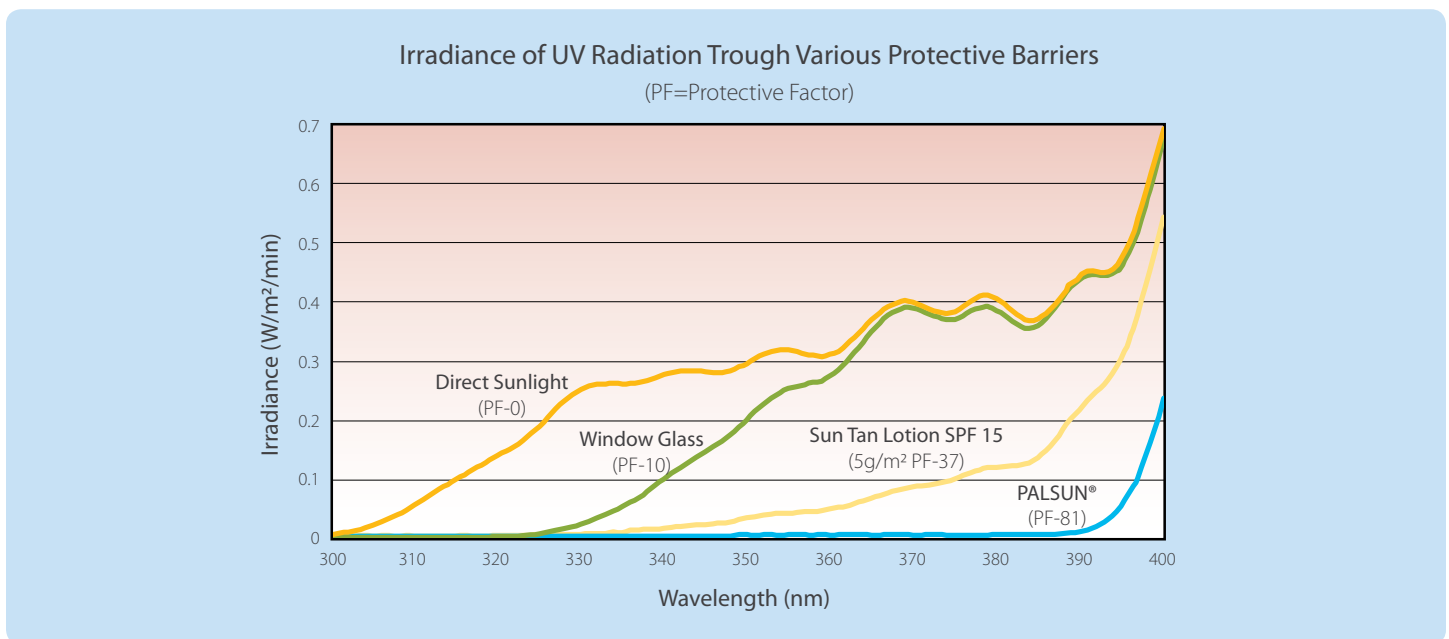
Thermal Insulation of PALSUN® vs. Glass

Thickness	PALSUN U-Value	Glass U-Value
in (mm)	(Btu/hr sq. ft. F)	(Btu/hr sq. ft. F)
0.093 (2.36)	1.00	1.04
0.12 (3)	0.96	1.02
0.20 (5)	0.91	1.01
0.24 (6)	0.89	1.00
0.31 (8)	0.82	0.99
0.39 (10)	0.79	0.97
0.47 (12)	0.78	0.96

Protection from the Harmful Effects of UV Radiation

Exposure to solar ultraviolet (UV) radiation is widely known as a major health concern. The adverse affects were once thought to be associated with solar UV radiation in the 280-315 nm (UV-B) range. However, in recent years it has become apparent that exposure to UV-A (315-400 nm) is also detrimental. In addition to skin cancer, premature aging has been associated with exposure to UV-A. PALSUN sheets block both UV-A and UV-B portions of the UV spectrum. This screening of harmful UV radiation can be observed in the figure below.

A comparison of the UV protection offered by PALSUN and that offered by sunscreen is indicated in the graph below. Note that PALSUN sheet is the most effective barrier against harmful UV radiation—even better than properly applied high SPF sunscreen lotion. The key words in the previous sentence are "properly applied." Improperly applied sunscreen, or worse, no sunscreen will result in undesirable levels of exposure. In addition, note that protection factors are computed on the basis of UV-B exposure. There is as yet no way to compute protection to UV-A exposure. It should also be noted that formulations that only block out UV-B are still being marketed. When playing or swimming below PALSUN, protection is always complete. When swimming, there is no danger that the protection will be washed or wiped away. In the last ten years, it has also been documented that UV exposure can also cause damage to the eyes, specifically to the cornea. Wearing sunglasses manufactured from polycarbonate protects the eyes. However, most people remove their glasses when entering a pool. This is a factor when contemplating a covering for either public or private pools.



Acoustic Properties

Though only about half the weight of an equivalent size glass panel, PALSUN glazing offers similar sound insulation properties along with much higher impact strength. These combined properties make PALSUN glazing the preferred material for see-through sound barriers: lightweight, easy to maintain or replace if necessary, highly transparent and vandal-proof.

The table at right portrays the acoustic performance of PALSUN glazing versus glass.

Acoustic Insulation of PALSUN® Sheets
According to EN 1793

Thickness in.	Thickness (mm)	Sound Reduction dB
.472	12	31
.591	15	33

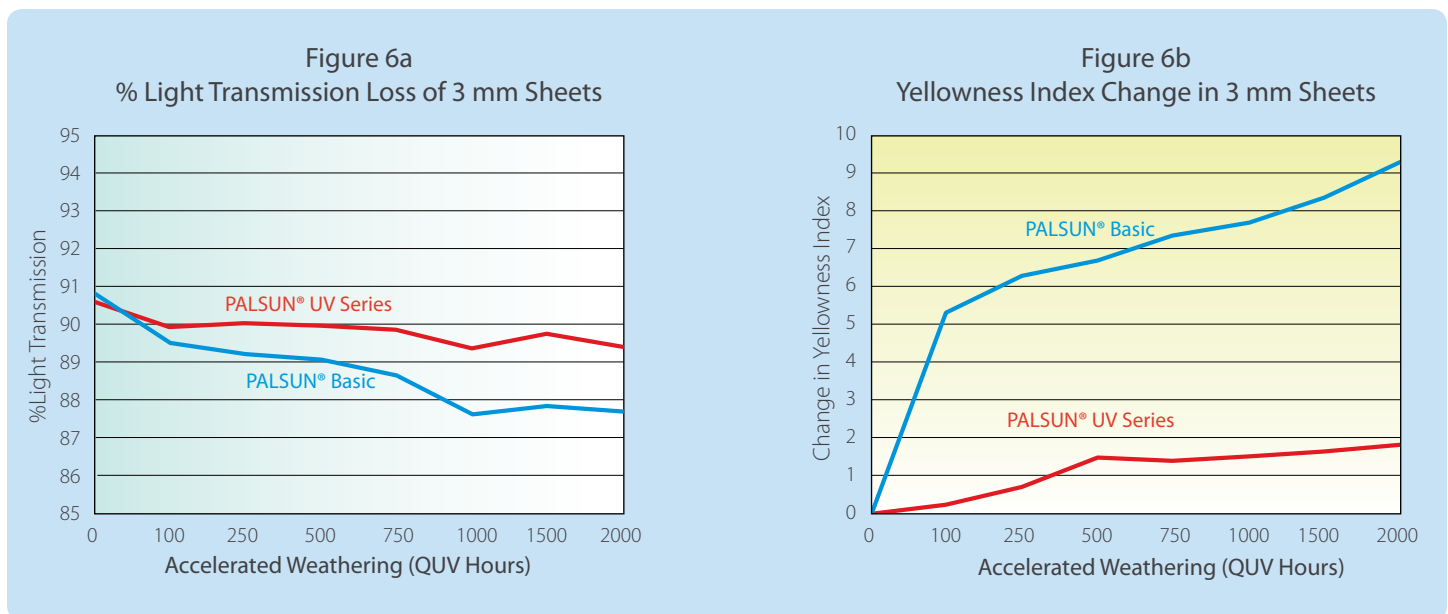
Weather Resistance

Solar UV radiation attacks many polymeric materials. The rate of deterioration and crazing on the exterior surface will vary for different polymers. Further erosion is accelerated by water, dirt, air pollution, chemicals etc. The extent of attack depends on environmental factors such as location, altitude, local weather conditions, air pollution etc. The first initial indication is yellowing, followed by a significant reduction in light transmission and structural strength.

All PALSUN UV Series sheets are manufactured with a co-extruded, UV protective layer on one or two sides (note: excludes Palsun Basic, which is simply UV stabilized). This protective layer assures a long lifetime of service. PALSUN sheets retain their toughness and optical quality under intense UV exposure, with minimal reduction in their properties.

2000 hours of accelerated weathering (UV exposure, QUV - ASTM G154) tests, simulating 20 years of exposure in hot, sunny climates results in a minor decrease in light transmission and a slight increase in Yellowness Index for PALSUN. The changes in UV stabilized PALSUN Basic sheet are greater.

The effect of QUV on 3 mm PALSUN UV Series & PALSUN Basic sheets appears in the graphs below.



Flammability

General

As a thermoplastic, PALSUN eventually melts and burns under the intense heat of a blazing fire. However, PALSUN does not propagate flame, and is solidified and self-extinguished as soon as the direct flame is taken away. PALSUN doesn't produce any toxic fumes or gases when it burns.

PALSUN® FR

PALSUN FR is a fire retardant flat solid polycarbonate sheet with improved flammability ratings. The flame retardant additives make it virtually non-combustible. When flame contacts the sheet, it will only scorch and eventually melt, solidifying quickly when the direct heat source is removed. Drippings do not ignite other combustible materials, as they do not actually burn.

Smoke and heat extraction

In an actual, full-scale combustion, when PALSUN overhead glazing (as in skylights) is exposed to intense heat it will soften at 302 °F-320 °F (150° -160° C) and produce apertures in the glazing, enabling heat and smoke to escape. Reduced temperatures inside the structure help to extinguish the fire.

Flammability Classifications

PALSUN and PALSUN FR are classified as appears in the following table, based on tests executed by certified independent testing laboratories.

PALSUN®	
Standard	Classification*
EN 13501	B, s1, d0
NSP 92501, 4	M1 (1 mm)
NSP 92501, 4	M2 (6 to 12 mm)
BS 476/7	Class 1y
DIN 4102	B1, B2
CSE RF 2/75/A, CSE RF 3/77	Class 1
UL-94	V2 (File e221255)
ASTM E-84	Class A or B

PALSUN® FR	
Standard	Classification*
UL-94	V-0 (File e221255)
ASTM D-2863-87	L.O.I. = 30

* Depends on thickness. For additional information please contact your PALSUN distributor.

General Recommendations for Working With PALSUN®

Handling & Storage

1. PALSUN sheets should be transported and stored horizontally, on a flat, sturdy pallet whose dimensions are equal or larger than the largest of the sheets.

The sheets should be secured to the pallet during transportation and on-site handling. It is recommended to stack the sheets with the longer sheets at the bottom and the shorter on top, leaving no unsupported overhang.

2. When moving a pallet with a forklift, always use forks as long as the sheets' width. Shorter forks used on a wider pallet may cause damage to the sheets.

3. PALSUN sheets leave the factory in packages, wrapped in white, watertight polyethylene. The wrapping should be removed as close to the actual time of installation (or use) as possible.

Storage of the sheets should be in a covered, dry, ventilated place, away from direct sunlight and rain.

4. Avoid extended exposure to direct sunlight, which may cause excessive heat buildup. Long term heating may lead to softening of the protective polyethylene masking, fusing it to the sheet's face and making removal difficult or even impossible.

5. Avoid leaving the sheets stored unwrapped. Dirt may accumulate on the sheets and/or their edges, attracted by electrostatic charges in the sheets, necessitating extra time and labor for cleaning before installation.

6. Whenever necessary to store the pallet in the open, cover it with white opaque polyethylene sheet, cardboard or any other insulating material, taking care to cover the stack completely.

Figure 7: Storing PALSUN® Sheets



Installation

Choice of the Frame

PALSUN sheets can be mounted in most existing frames made of wood, rigid PVC, aluminum or other metals. It is recommended to use neoprene or EPDM packing (never use soft PVC) to secure the sheet in its frame, rather than fixing with screws. Butyl rubber sealing strip or silicone sealant are also permissible. For a list of compatible adhesives and sealants see www.PalramAmericas.com/sealants

Adjusting The Sheet to Frame Dimensions

("c" and "d" refer to the indicated dimension in the diagram shown below).

If sash dimension "c" or "d" is:	Trim sheet by:
11.8" (300 mm)	0.04" (1 mm)
11.8" (300 mm) - 27.6" (700 mm)	0.08" (2 mm)
27.6" (700 mm) - 39.4" (1000 mm)	0.12" (3 mm)
39.4" (1000 mm) - 51.2" (1300 mm)	0.16" (4 mm)
51.2" (1300 mm) - 66.9" (1700 mm)	0.20" (5 mm)
66.9" (1700 mm) - 78.7" (2000 mm)	0.24" (6 mm)
78.7" (2000 mm) - 90.6" (2300 mm)	0.28" (7 mm)
90.6" (2300 mm) - 106" (2700 mm)	0.31" (8 mm)
106" (2700 mm) - 118" (3000 mm)	0.35" (9 mm)

Sheet Thickness Required for Given Sheet Width* and Rabbet Depth. ("a" and "e" refer to the indicated dimensions in the diagram shown below).

Width* (a)	Thickness	Rabbet Depth (e)
28" (700 mm)	0.12" (3 mm)	0.6" - 0.8" (15-20 mm)
35" (900 mm)	0.16" (4 mm)	0.6" - 0.8" (15-20 mm)
43" (1100 mm)	0.20" (5 mm)	0.6" - 0.8" (15-20 mm)
51" (1300 mm)	0.24" (6 mm)	0.8" - 1.2" (20-30 mm)
59" (1500 mm)	0.31" (8 mm)	0.8" - 1.2" (20-30 mm)
67" (1700 mm)	0.39" (10 mm)	0.8" - 1.2" (20-30 mm)
75" (1900 mm)	0.47" (12 mm)	0.8" - 1.2" (20-30 mm)

*Width refers to the smaller dimension.

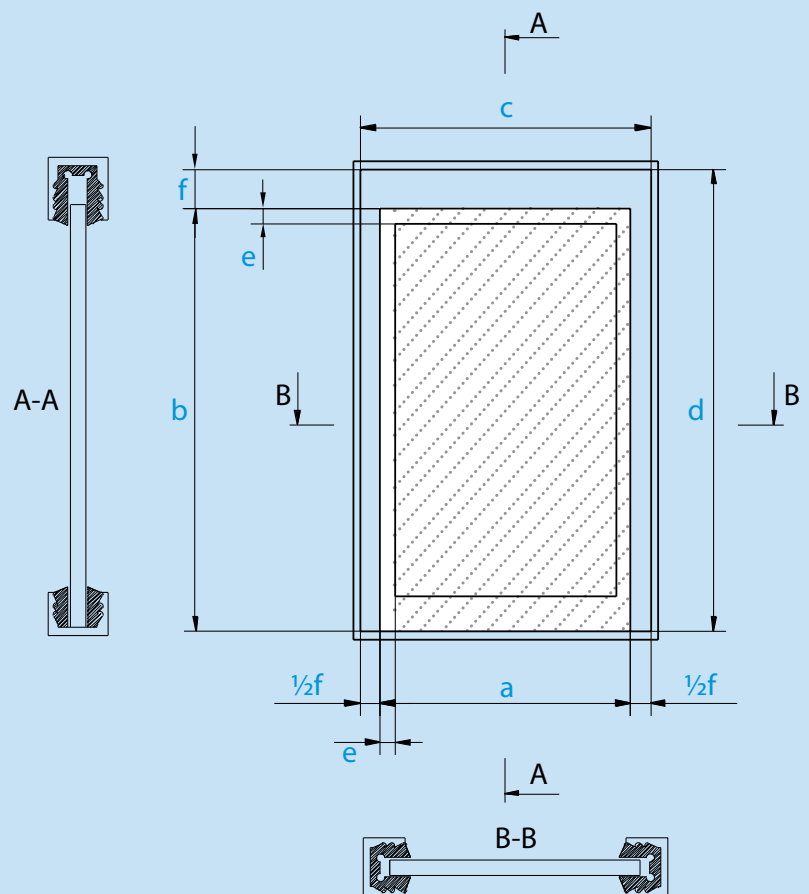
Example Frame

Legend

- a ... Sheet width
- b ... Sheet length
- c ... Sash width
- d ... Sash length
- e ... Edge engagement
- f ... Thermal expansion allowance
- g ... Rabbet depth = $\frac{1}{2}f + e$

Arched Construction

The principals & illustrations shown throughout the Installation Section also apply to arched construction.



Determination of Required Sheet Dimensions

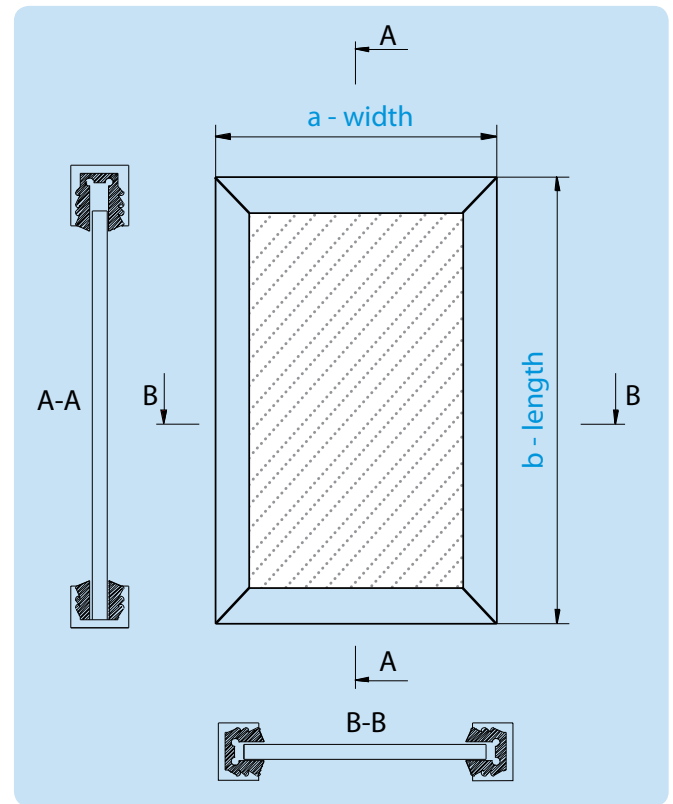
The information below is presented to assist in ordering the required dimensions.

Determination of Sheet Size

Due to thermal expansion, PALSUN sheets need to be accurately cut to predetermined dimensions that are smaller than the dimensions of the frame. At the end of the frame, clearance must be left for expansion. The following tables and diagram help calculate the required sheet dimensions. In addition, there is a table showing the expansion clearance necessary for various sizes of PALSUN sheets.

Determination of Thickness

In order to determine the required thickness, the following table lists the sheet thickness required for a given load and width (at the narrow side of the sheet).



PALSUN® Recommended Panel Width

Wind/Snow Load Chart for Flat 4 Sides Clamped, Single Panel, Single Span

Thickness		Load		Length / Width Ratio (b/a)									
				Ratio 1:1		Ratio 1.25:1		Ratio 1.5:1		Ratio 1.75:1		Ratio 2:1	
in.	(mm)	psf	(kg/m ²)	in.	(mm)	in.	(mm)	in.	(mm)	in.	(mm)	in.	(mm)
.157	4	5	(50)	38.78	(985)	34.45	(875)	32.28	(820)	31.30	(795)	30.91	(785)
		7	(75)	33.86	(860)	30.12	(765)	28.15	(715)	27.36	(695)	26.97	(685)
		10	(100)	30.71	(780)	27.36	(695)	25.59	(650)	24.80	(630)	24.41	(620)
		12	(125)	28.54	(725)	25.39	(645)	23.82	(605)	23.03	(585)	22.64	(575)
		15	(150)	26.97	(685)	23.82	(605)	22.44	(570)	21.65	(550)	21.26	(540)
		17	(175)	25.59	(650)	22.64	(575)	21.26	(540)	20.67	(525)	20.28	(515)
		20	(200)	24.41	(620)	21.65	(550)	20.28	(515)	19.69	(500)	19.29	(490)
.197	5	5	(50)	48.62	(1235)	42.91	(1090)	40.35	(1025)	39.17	(995)	38.58	(980)
		7	(75)	42.32	(1075)	37.60	(955)	35.24	(895)	34.25	(870)	33.66	(855)
		10	(100)	38.58	(980)	34.06	(865)	32.09	(815)	31.10	(790)	30.51	(775)
		12	(125)	35.83	(910)	31.69	(805)	29.72	(755)	28.74	(730)	28.35	(720)
		15	(150)	33.66	(855)	29.72	(755)	27.95	(710)	27.17	(690)	26.77	(680)
		17	(175)	31.89	(810)	28.35	(720)	26.57	(675)	25.79	(655)	25.39	(645)
.236	6	5	(50)	57.09	(1450)	51.18	(1300)	48.23	(1225)	47.24	(1200)	46.26	(1175)
		7	(75)	51.18	(1300)	45.28	(1150)	42.32	(1075)	41.34	(1050)	40.35	(1025)
		10	(100)	46.26	(1175)	40.35	(1025)	38.39	(975)	37.40	(950)	36.42	(925)
		12	(125)	42.91	(1090)	37.99	(965)	35.83	(910)	34.84	(885)	34.06	(865)
		15	(150)	40.35	(1025)	35.83	(910)	33.46	(850)	32.68	(830)	32.09	(815)
		17	(175)	38.39	(975)	34.06	(865)	31.89	(810)	31.10	(790)	30.51	(775)
		20	(200)	36.42	(925)	32.48	(825)	30.51	(775)	29.72	(755)	29.13	(740)

PALSUN® Recommended Panel width - 4 sides clamped (Continued)

Thickness		Load		Length / Width Ratio (b/a)									
				Ratio 1:1		Ratio 1.25:1		Ratio 1.5:1		Ratio 1.75:1		Ratio 2:1	
in.	mm	psf	(kg/m ²)	in.	(mm)	in.	(mm)	in.	(mm)	in.	(mm)	in.	(mm)
.315	8	5	(50)	77.76	(1975)	68.90	(1750)	63.98	(1625)	62.60	(1590)	62.01	(1575)
		7	(75)	67.91	(1725)	60.04	(1525)	56.10	(1425)	54.72	(1390)	54.13	(1375)
		10	(100)	61.61	(1565)	54.72	(1390)	51.18	(1300)	50.00	(1270)	49.21	(1250)
		12	(125)	57.28	(1455)	50.79	(1290)	47.64	(1210)	46.46	(1180)	45.67	(1160)
		15	(150)	54.13	(1375)	47.64	(1210)	44.88	(1140)	43.70	(1110)	42.91	(1090)
		17	(175)	51.18	(1300)	22.64	(1150)	42.52	(1080)	41.34	(1050)	40.75	(1035)
		20	(200)	49.21	(1250)	43.31	(1100)	40.75	(1035)	39.57	(1005)	38.98	(990)
.394	10	5	(50)	80.71	(2050)	80.71	(2050)	80.71	(2050)	78.35	(1990)	77.17	(1960)
		7	(75)	80.71	(2050)	75.20	(1910)	70.67	(1795)	68.50	(1740)	67.52	(1715)
		10	(100)	77.17	(1960)	68.31	(1735)	64.17	(1630)	62.20	(1580)	61.22	(1555)
		12	(125)	71.65	(1820)	63.39	(1610)	59.65	(1515)	57.68	(1465)	56.89	(1445)
		15	(150)	67.32	(1710)	59.65	(1515)	56.10	(1425)	54.33	(1380)	53.54	(1360)
		17	(175)	63.98	(1625)	56.69	(1440)	53.35	(1355)	51.57	(1310)	50.79	(1290)
		20	(200)	61.22	(1555)	54.13	(1375)	50.98	(1295)	49.41	(1255)	48.62	(1235)
.472	12	5	(50)	80.71	(2050)	80.71	(2050)	80.71	(2050)	80.71	(2050)	80.71	(2050)
		7	(75)	80.71	(2050)	80.71	(2050)	80.71	(2050)	80.71	(2050)	80.71	(2050)
		10	(100)	80.71	(2050)	80.71	(2050)	76.97	(1955)	74.61	(1895)	73.62	(1870)
		12	(125)	80.71	(2050)	76.18	(1935)	71.46	(1815)	69.29	(1760)	68.31	(1735)
		15	(150)	80.71	(2050)	71.65	(1820)	67.32	(1710)	65.16	(1655)	64.17	(1630)
		17	(175)	76.77	(1950)	68.11	(1730)	63.98	(1625)	62.01	(1575)	61.02	(1550)
		20	(200)	73.43	(1865)	65.16	(1655)	61.22	(1555)	59.25	(1505)	58.27	(1480)
.551	14	5	(50)	80.71	(2050)	80.71	(2050)	80.71	(2050)	80.71	(2050)	80.71	(2050)
		7	(75)	80.71	(2050)	80.71	(2050)	80.71	(2050)	80.71	(2050)	80.71	(2050)
		10	(100)	80.71	(2050)	80.71	(2050)	80.71	(2050)	80.71	(2050)	80.71	(2050)
		12	(125)	80.71	(2050)	80.71	(2050)	80.71	(2050)	80.71	(2050)	80.71	(2050)
		15	(150)	80.71	(2050)	80.71	(2050)	78.74	(2000)	75.98	(1930)	74.80	(1900)
		17	(175)	80.71	(2050)	78.74	(2000)	74.41	(1890)	72.24	(1835)	71.26	(1810)
		20	(200)	80.71	(2050)	75.79	(1925)	71.26	(1810)	69.09	(1755)	68.11	(1730)
.591	15	5	(50)	80.71	(2050)	80.71	(2050)	80.71	(2050)	80.71	(2050)	80.71	(2050)
		7	(75)	80.71	(2050)	80.71	(2050)	80.71	(2050)	80.71	(2050)	80.71	(2050)
		10	(100)	80.71	(2050)	80.71	(2050)	80.71	(2050)	80.71	(2050)	80.71	(2050)
		12	(125)	80.71	(2050)	80.71	(2050)	80.71	(2050)	80.71	(2050)	80.71	(2050)
		15	(150)	80.71	(2050)	80.71	(2050)	80.71	(2050)	80.71	(2050)	79.72	(2025)
		17	(175)	80.71	(2050)	80.71	(2050)	79.72	(2025)	76.77	(1950)	75.79	(1925)
		20	(200)	80.71	(2050)	80.71	(2050)	75.79	(1925)	73.82	(1875)	72.83	(1850)
.709	18	5	(50)	80.71	(2050)	80.71	(2050)	80.71	(2050)	80.71	(2050)	80.71	(2050)
		7	(75)	80.71	(2050)	80.71	(2050)	80.71	(2050)	80.71	(2050)	80.71	(2050)
		10	(100)	80.71	(2050)	80.71	(2050)	80.71	(2050)	80.71	(2050)	80.71	(2050)
		12	(125)	80.71	(2050)	80.71	(2050)	80.71	(2050)	80.71	(2050)	80.71	(2050)
		15	(150)	80.71	(2050)	80.71	(2050)	80.71	(2050)	80.71	(2050)	80.71	(2050)
		17	(175)	80.71	(2050)	80.71	(2050)	80.71	(2050)	80.71	(2050)	80.71	(2050)
		20	(200)	80.71	(2050)	80.71	(2050)	80.71	(2050)	80.71	(2050)	80.71	(2050)

* For wind load data in N/m² units, multiply value by 10 (e.g. 40 kg/m² = 400 N/m²).

Notes:

- For 2 sides clamped installation please refer to the ratio 2:1 column.
- The table is referring to various ratios of Length (b) and width (a) and valid for both Snow and wind load.
- The table is referring to 4 sides clamped, flat installed Palsun panels.
- The data in the table refer to the short dimension, a.
- Bedding depth shall be minimum 20 mm.
- The values are calculated according to deflection criterion of L/20 of the short span.
- The table is not referring to self-weight deflections which might cause aesthetic issues.
- The table is not referring to the sheet flexibility when vertically installed.

PALSUN® Recommended Panel Width for Curved Installation - Imperial
 Maximum Recommended on Center Distance between Supporting Arches

Thickness		Sheet Curvature Radius (mm)		Max. Recommended on Center Distance between Supporting Arches According to Wind/Snow Loads Below (in.)									
				Uniform Wind/Snow Loads (psf)									
In.	(mm)	In.	Ft.	10	15	20	25	30	40	50	60		
5/32"	4	28	2' - 4"	81	81	81	81	81	75	69	63		
		36	3'	81	81	73	65	59	53	48	40		
		44	3'-8"	81	75	69	63	57	50	42	36		
		52	4'-4"	77	71	65	58	52	47	40	36		
		59	4'-11"	71	65	59	54	48	42	36	36		
		71	5'-11"	65	62	56	52	45	38	33	28		
		79	6'-7"	62	58	53	50	42	35	30	26		
		87	7'-3"	59	55	51	47	39	32	27	24		
		110	9'-2"	53	50	47	44	36	29	24	NA		
		158	13'-2"	48	42	38	34	31	26	18	NA		
236	19'-8"	34	31	29	26	24	18	NA	NA				
13/64"	5	36	3'	81	81	81	81	81	81	75	69		
		44	3'-8"	81	81	81	81	81	75	69	63		
		52	4'-4"	81	81	81	81	77	69	63	57		
		59	4'-11"	81	81	81	77	73	67	61	55		
		71	5'-11"	81	81	77	73	69	61	53	46		
		79	6'-7"	81	77	73	69	61	53	46	42		
		87	7'-3"	77	73	69	65	59	51	44	40		
		110	9'-2"	63	59	55	51	48	42	36	30		
		158	13'-2"	55	51	48	44	40	34	30	20		
		236	19'-8"	48	42	38	34	30	20	450	NA		
1/4"	6	44	3'-8"	81	81	81	81	81	79	75	69		
		52	4'-4"	81	81	81	81	81	75	69	63		
		59	4'-11"	81	81	81	81	75	69	63	57		
		71	5'-11"	81	81	81	77	71	65	59	53		
		79	6'-7"	81	81	77	73	67	61	55	50		
		87	7'-3"	81	77	73	69	65	59	53	48		
		110	9'-2"	67	63	59	55	51	46	40	34		
		158	13'-2"	63	59	55	51	46	40	34	29		
		236	19'-8"	58	54	51	48	43	37	31	21		
		5/16"	8	59	4'-11"	81	81	81	81	81	75	69	63
71	5'-11"			81	81	81	81	77	71	65	59		
79	6'-7"			81	81	81	79	75	69	63	57		
87	7'-3"			81	81	81	77	73	67	61	55		
98	8'-2"			81	81	76	73	68	62	56	50		
110	9'-2"			81	77	72	68	63	57	51	46		
158	13'-2"			77	72	68	64	59	53	48	40		
236	19'-8"			72	66	60	54	50	44	38	31		
13/32"	10			71	5'-11"	81	81	81	81	81	77	71	65
				87	7'-3"	81	81	81	81	79	73	67	61
		110	9'-2"	81	81	81	77	71	69	63	57		
		158	13'-2"	81	81	79	75	70	64	58	52		
		236	19'-8"	81	76	72	68	61	55	50	44		
1/2"	12	87	7'-3"	81	81	81	81	81	81	77	71		
		110	9'-2"	81	81	81	81	81	77	71	65		
		158	13'-2"	81	81	81	81	77	71	65	58		
		236	19'-8"	81	81	81	77	68	62	56	51		

Notes for Tables "PALSUN® Recommended Panel Width for Curved Installation":

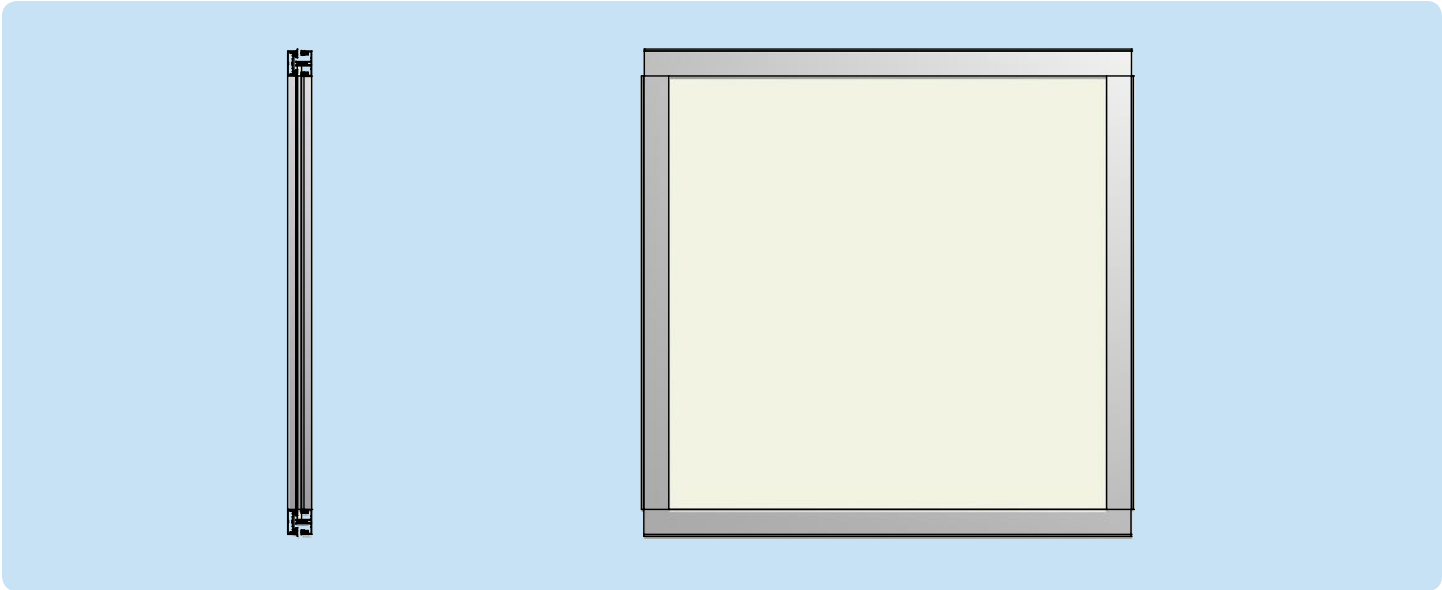
- PALSUN glazing sheets should be installed with their curved edges sustained on the supporting arches, with 5/8" to 1" (15 to 25 mm) edge engagement, depending on the span, in addition to a thermal expansion gap of 3/32" - 1/8" (2-3 mm).
- Thin sheets up to 1/4" (6 mm) can be bent as relatively short glazing panels, 6'7" to 10' length, at 40" to 48" width (2 m to 3 m at 1000 to 1220 mm width). Thick sheets 5/16" (8 mm) and above can be cold curved only as special long panels 13' 2" to 23' (4 m to 7 m), particularly when full width of 6' 9" (2050 mm) or similar is installed.
- Supporting arches and clamps should withstand total maximum permitted loads without difficulty.
- Spans under 20" (500 mm) are generally impractical for an installation method of this type.
- The lowest radius value indicated is the minimal permitted radius for that specific PALSUN sheet.
- Indicated spans are suitable for most common stationary structures, under pressure or uplift loads. Special structures, like mobile pool covers, may use wider spans, subject to preceding approval.

PALSUN® Recommended Panel Width for Curved Installation - Metric
 Maximum Recommended on Center Distance between Supporting Arches

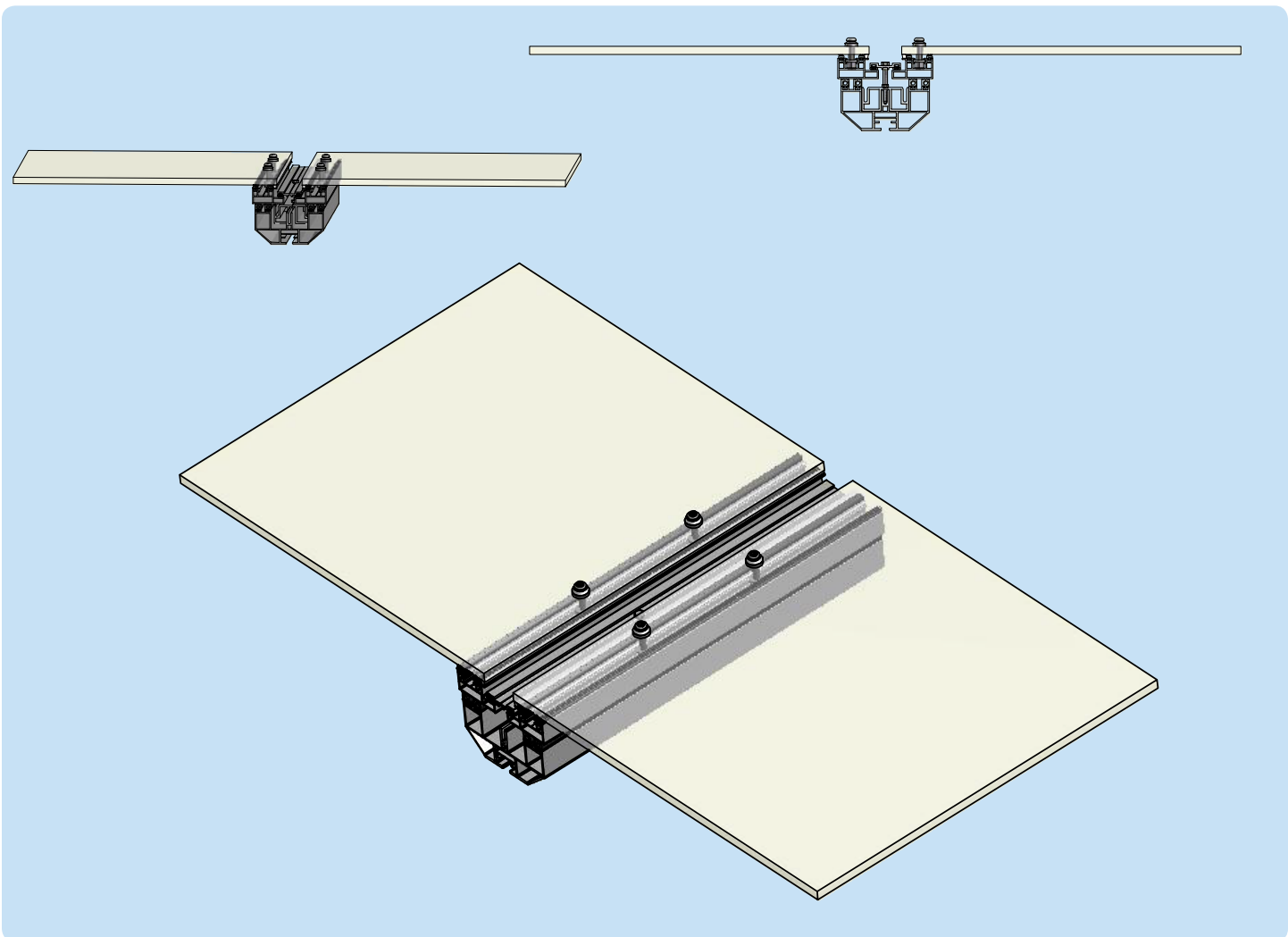
Thickness	Sheet Curvature Radius	Maximum Recommended on Center Distance between Supporting Arches According to Wind/Snow Loads Below (mm)								
		Uniform Wind/Snow Loads (kg/m ²)								
		50	80	100	120	150	200	250	300	
4 mm	700	2050	2050	2050	2050	2050	1900	1750	1600	
	900	2050	2050	1850	1650	1500	1350	1200	1000	
	1100	2050	1900	1750	1600	1450	1250	1050	900	
	1300	1950	1800	1650	1480	1320	1180	1000	820	
	1500	1800	1650	1500	1380	1200	1050	900	750	
	1800	1650	1580	1420	1320	1120	950	820	700	
	2000	1580	1480	1350	1250	1050	880	750	650	
	2200	1500	1400	1300	1180	980	800	680	600	
	2800	1350	1250	1180	1100	900	720	600	NA	
	4000	1200	1050	950	850	780	650	450	NA	
6000	850	780	720	650	600	450	NA	NA		
5 mm	900	2050	2050	2050	2050	2050	2050	1900	1750	
	1100	2050	2050	2050	2050	2050	1900	1750	1600	
	1300	2050	2050	2050	2050	1950	1750	1600	1450	
	1500	2050	2050	2050	1950	1850	1700	1550	1400	
	1800	2050	2050	1950	1850	1750	1550	1350	1150	
	2000	2050	1950	1850	1750	1550	1350	1150	1050	
	2200	1950	1850	1750	1650	1500	1300	1100	1000	
	2800	1600	1500	1400	1300	1200	1050	900	750	
	4000	1400	1300	1200	1100	1000	850	750	600	
	6000	1200	1050	950	850	750	600	450	NA	
6 mm	1100	2050	2050	2050	2050	2050	2000	1900	1750	
	1300	2050	2050	2050	2050	2050	1900	1750	1600	
	1500	2050	2050	2050	2050	1900	1750	1600	1450	
	1800	2050	2050	2050	1950	1800	1650	1500	1350	
	2000	2050	2050	1950	1850	1700	1550	1400	1250	
	2200	2050	1950	1850	1750	1650	1500	1350	1200	
	2800	1700	1600	1500	1400	1300	1150	1000	850	
	4000	1600	1500	1400	1300	1150	1000	850	720	
	6000	1480	1380	1300	1200	1080	920	780	620	
	8 mm	1500	2050	2050	2050	2050	2050	1900	1750	1600
1800		2050	2050	2050	2050	1950	1800	1650	1500	
2000		2050	2050	2050	2000	1900	1750	1600	1450	
2200		2050	2050	2050	1950	1850	1700	1550	1400	
2500		2050	2050	1920	1850	1720	1580	1420	1280	
2800		2050	1950	1820	1720	1600	1450	1300	1150	
4000		1950	1820	1720	1620	1500	1350	1200	1000	
6000		1820	1680	1520	1380	1250	1100	950	780	
10 mm		1800	2050	2050	2050	2050	2050	1950	1800	1650
		2200	2050	2050	2050	2050	2000	1850	1700	1550
	2800	2050	2050	2050	1950	1800	1750	1600	1450	
	4000	2050	2050	2000	1900	1780	1620	1480	1320	
	6000	2050	1920	1820	1720	1550	1400	1250	1100	
12 mm	2200	2050	2050	2050	2050	2050	2050	1950	1800	
	2800	2050	2050	2050	2050	2050	1950	1800	1650	
	4000	2050	2050	2050	2050	1950	1800	1650	1480	
	6000	2050	2050	2050	1950	1720	1580	1420	1280	

* See notes on previous page

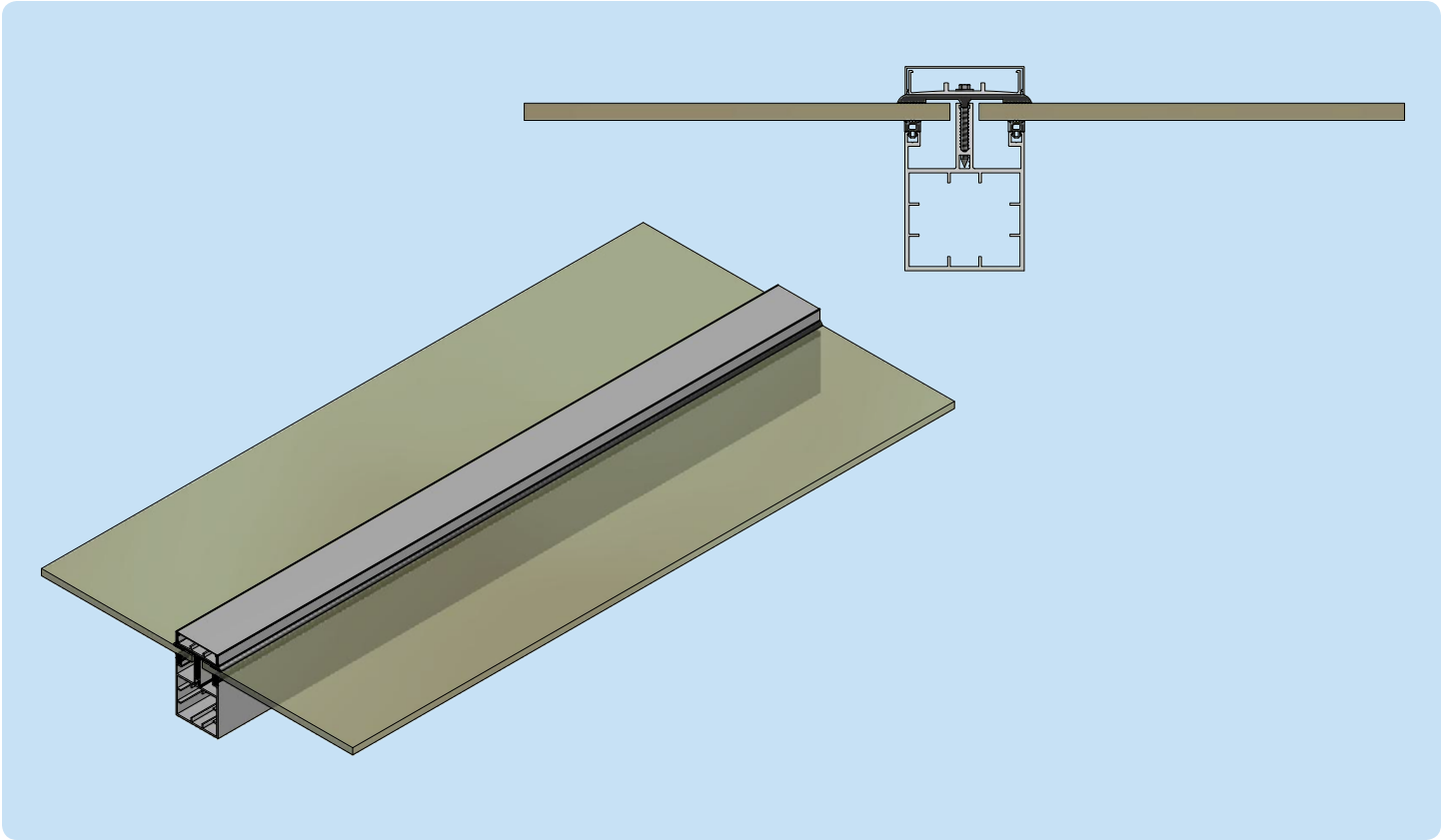
PALSUN® Glazing



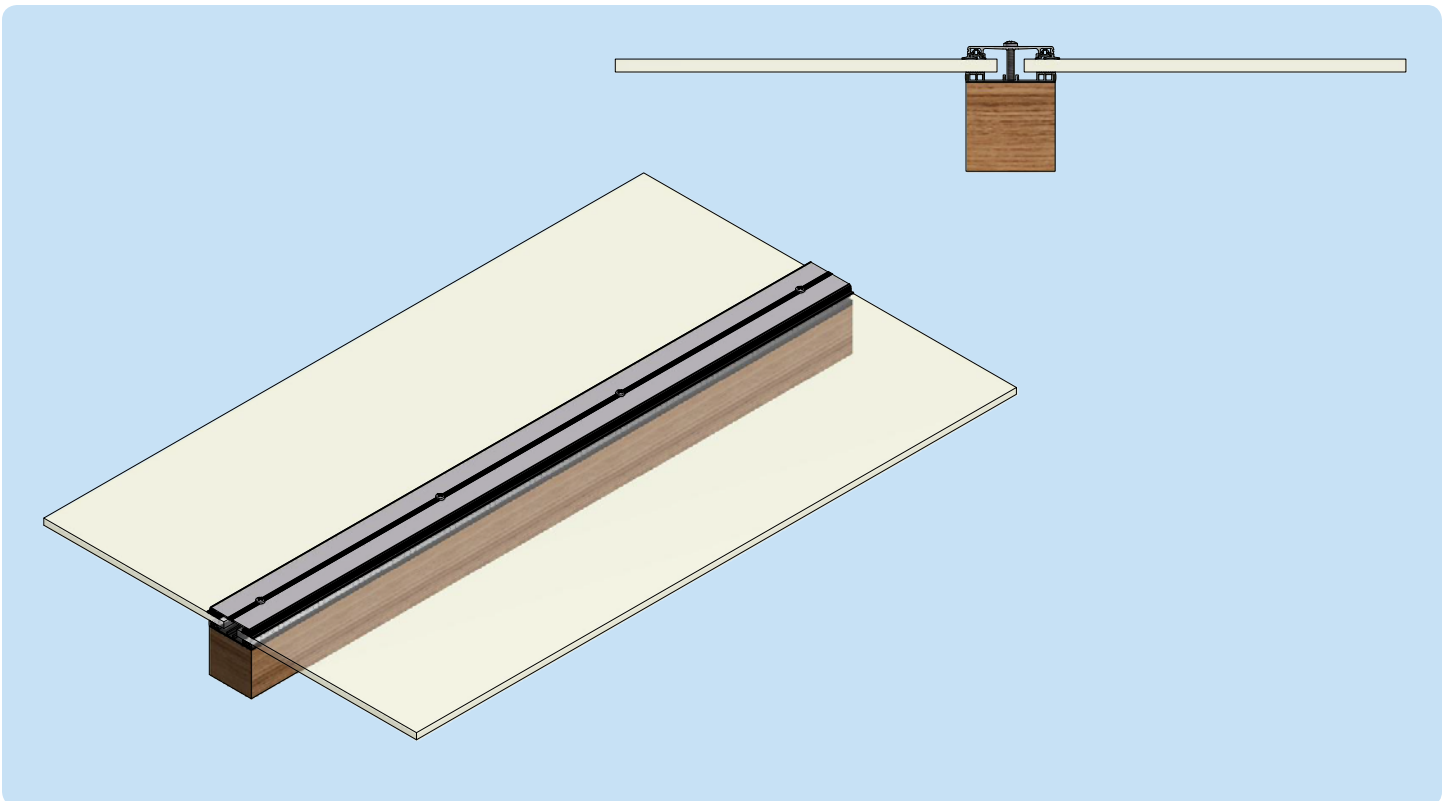
Glazing System Detail (GA-2004)



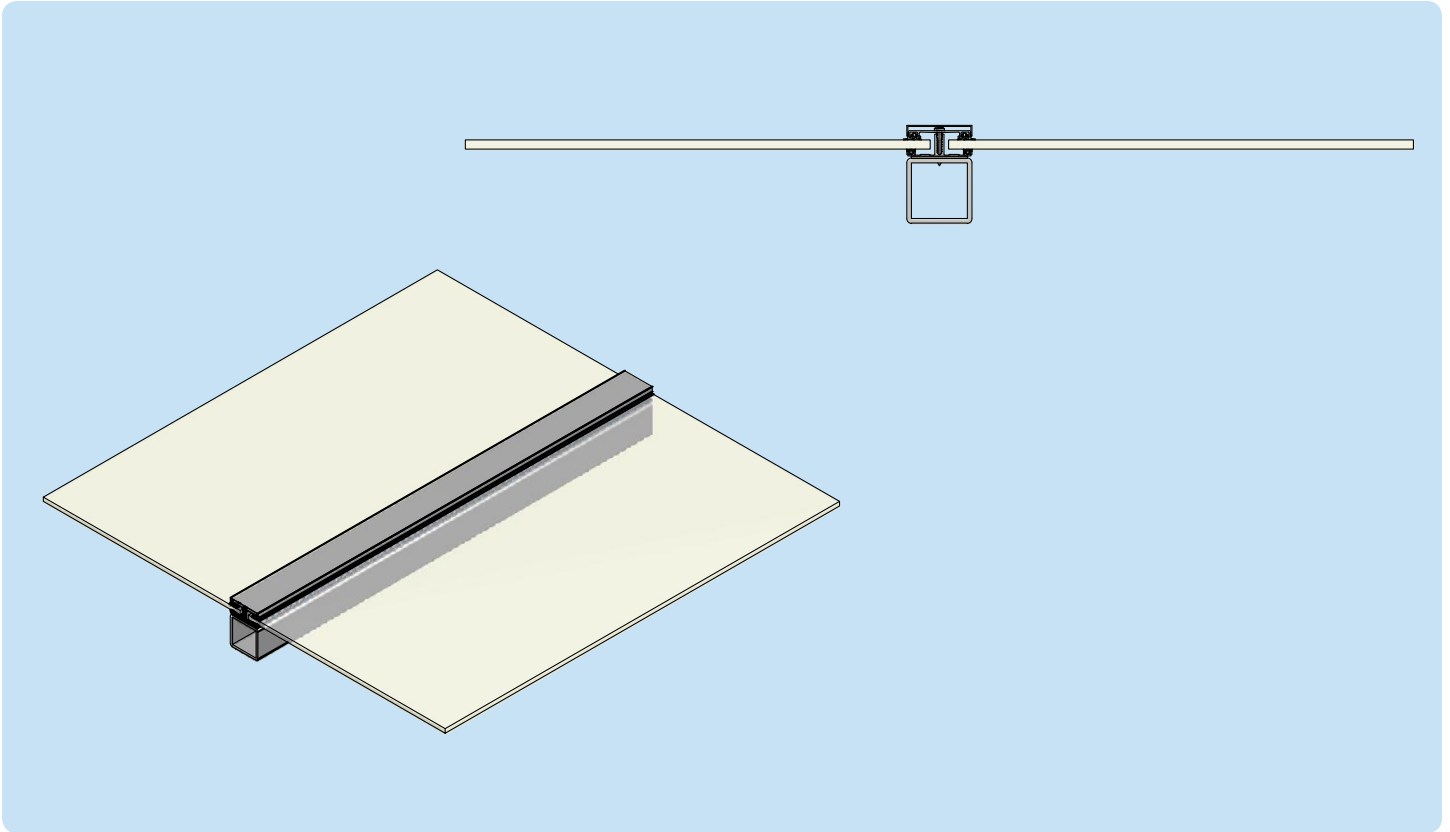
Glazing System Detail



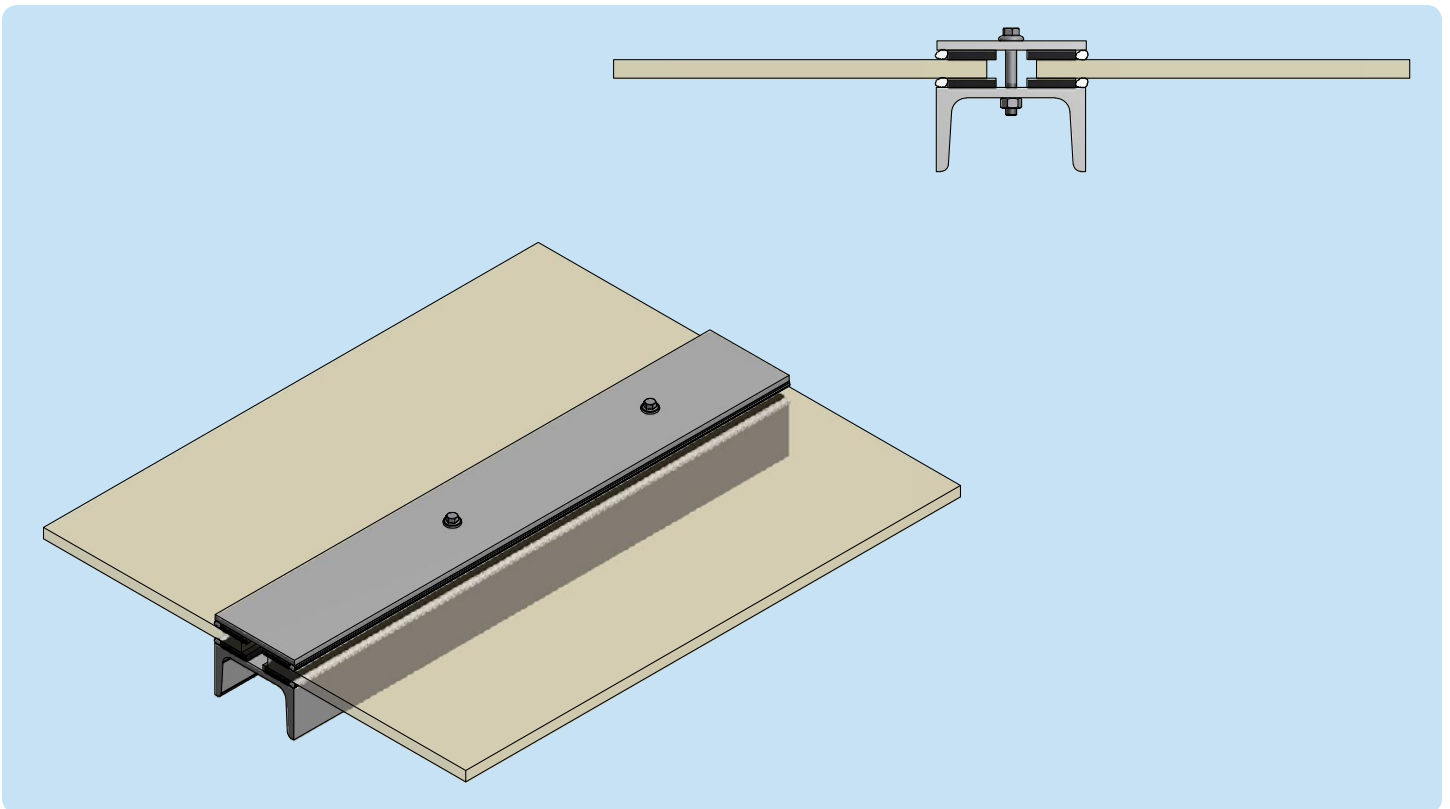
Hybrid Glazing System Detail



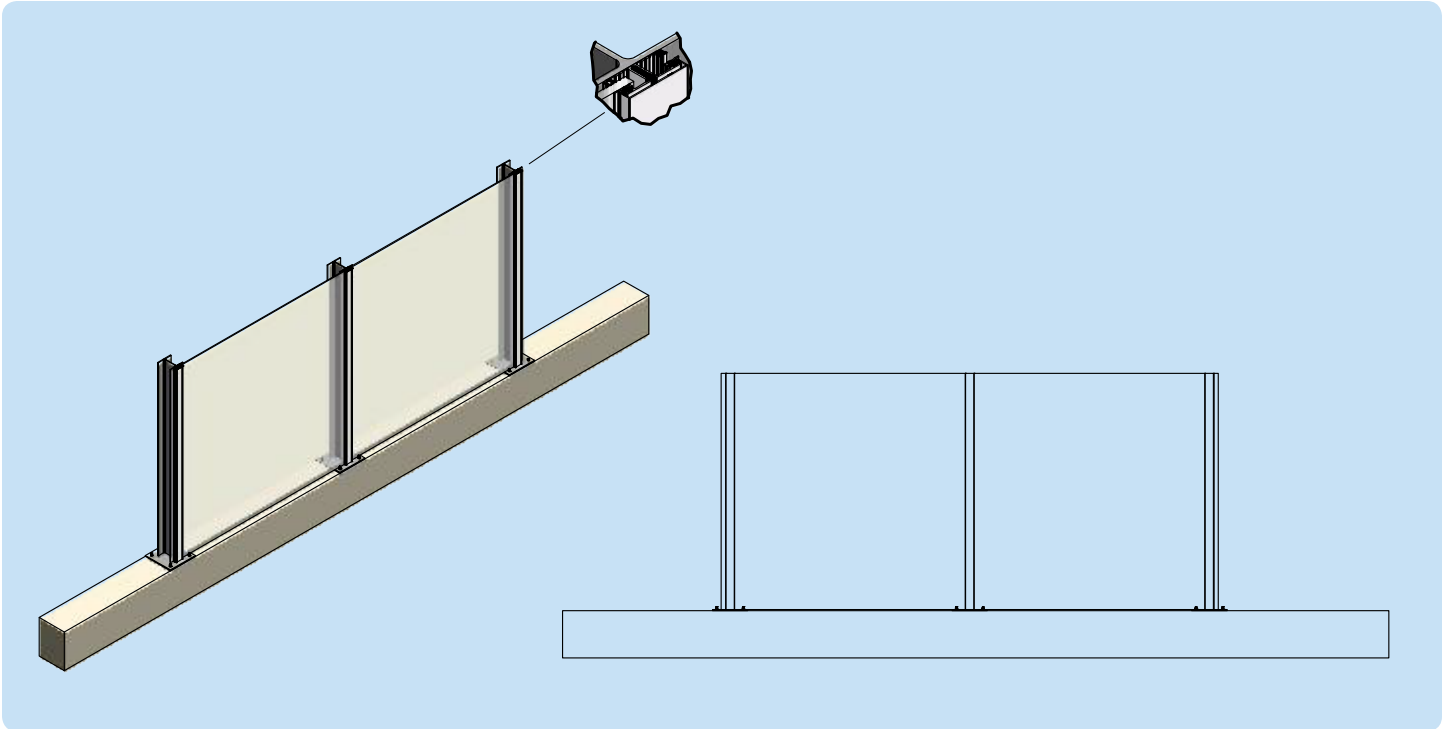
Oriented Glazing System Detail



Wet Glazing Detail



Glazing System Detail



Mechanical Fastening

PALSUN sheets can be fastened with nuts and bolts, providing that several points be kept in mind:

- Never use rivets, as they apply excessive force and could cause cracks in the sheets.
- Always drill a slightly over-sized hole by $\frac{3}{32}$ " - $\frac{1}{8}$ " (2-3 mm) to compensate for thermal expansion.
- Never use soft PVC washers.
- Use EPDM and aluminum washers to distribute the load.
- When using mechanical fasteners, they should be evenly spaced to avoid stress accumulation at particular points.
- With nuts and bolts, tighten moderately and use only rust-free materials.
- Wherever possible, a "floating sheet in frame" is preferable, similar to glass, and without mechanical drilled fasteners.

Treatment of Sheets after Installation

The sheet's polyethylene masking must be removed after it is installed. The masking covers the sheet to protect it during handling, storage, and installation, but once the sheet is installed — **it must be removed within 24 hours of installation.**

PALSUN sheets may be cleaned by carefully following the [instructions on page 29](#).

General Fabrication Guidelines

Tools

PALSUN sheets can be fabricated with standard power or hand tools for wood or metal, as long as they are well sharpened and have the clearance required for machining rigid plastics. Only speed regulated tools should be used. Utilize the highest possible speed that will not melt the sheet during processing, due to the heat buildup.

High-Speed steel tools are adequate in most cases. Carbide-tipped tools are preferred for continuous production lines.

Tools should be set up so just the cutting edges should come into actual contact with the fabricated material, to reduce frictional heat buildup.

Cooling

- Cooling is not required under standard machining conditions.
- When high-speed machining is necessary, clean water or compressed air can be used to cool the material and tool, and remove the machining chips.
- Never use cooling oil or emulsions, as they may damage the PALSUN sheet.
- In order to avoid induced internal stresses generated by overheating, care must be taken to keep heat buildup to an absolute minimum.

Size Regulation

Due to the high thermal expansion rate of PALSUN, which is considerably greater than that of metals, glass or concrete, precision measurement checks should always be done at a fixed reference ambient temperature.

Protective Film (Masking)

The PALSUN polyethylene (PE) protective masking may be left on the sheet during most regular fabrication, to prevent damage to the surface.

Fabrication Markings

When necessary, mark sheets to be fabricated on the protective masking. If, for some reason, it is necessary to mark directly on the sheet, use wax pencils or felt tipped marking pens.

Marking the exposed surface by scratch marks with sharp objects may initiate fractures and induce failure under load.

Sawing & Cutting

A variety of power saws, either table mounted or portable can be used to saw PALSUN. Shearing or punching are also possible. Laser or water-jet cutting are less common but also possible techniques.

Table Mounted or Portable Circular Saws

These types of saw are widely used to saw PALSUN. There are two major workshop types and one portable type:

- A Moving Table, Fixed Blade Bench Saw: is preferable for long, straight sawing.
- Radial Arm Saw: is generally used for "cross-cut" (width) or diagonal sawing.
- Portable Circular Saw: usually restricted for use on site for straight cutting, is slower and not as accurate as table saws. This type of saw may be attached underneath a special bench to function as an on-site, limited operation fixed table saw.

Circular Saw Blades

Should be fine toothed hollow ground, or preferably carbide tipped, triple chipped or alternate bevels (Alt 1 and Alt 2, [see figures 9a & 9b on next page](#), respectively), with minimal blade body contact with the cut material. Such blades can offer clean, good quality cuts.

Generally Accepted Recommendations for Circular Blade Specifications

Property	Units	Sign	Value
Clearance angle		α	10 – 20°
Rake angle		γ	5 – 15°
Alternate double-bevel angle (Alt. 1)		α°	45°
Alternate bevel angle (Alt. 2)		β°	10 – 15°
Cutting speed	ft/min (m/min.)		3,300 - 10,000 (1,000 - 3,000)
Rate of feed	inch/sec. (mm/sec.)		1.2 (30)
Thin gauge: 1/16" - 3/32" tooth pitch (1.5-2.5 mm)	Teeth per inch (Teeth per mm)	t	10 - 12 (2.5 - 6)
Heavy gauge: 1/8" - 1/2" tooth pitch (3.2 - 12 mm)	Teeth per inch (Teeth per mm)	t	3 - 4 (6.5 - 8.5)

- Notes:
- Two possible alternatives (Alt 1 & Alt 2, see figures 9a & 9b below) are supplied by different tools manufacturers as alternate beveled teeth for blades intended for cutting plastics, and both offer satisfactory cuts.
 - For sawing thin gauge sheets of less than 2 mm thickness, it is recommended to batch together 10 - 15 such sheets, with a thicker (3-4 mm) bottom sheet for support.
 - Shearing is the preferable option for cutting a single thin gauge sheet.

Palram Detailed Circular Saw Cutting Recommendations

These recommendations are based on technical experience, particular tests and vast practical experience accumulated during years of work. These recommendations are to be accepted only as general guidelines.

Figure 8: Typical Circular Saw Blade (segment)

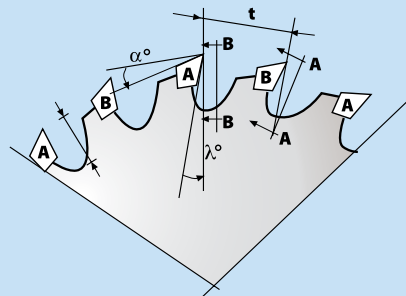


Figure 9a: ALT1 - Alternate Teeth Configuration

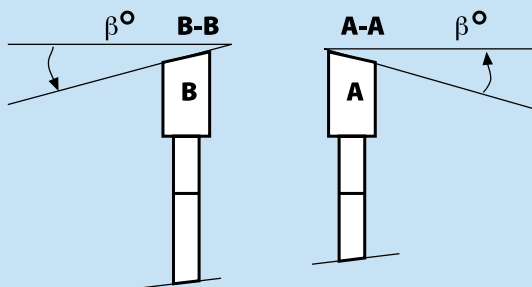
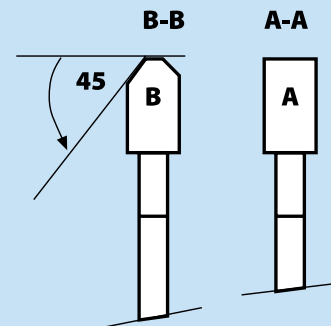



Figure 9b: ALT2 - Alternate Teeth Configuration



Saw Blade Specifications for Cutting PALSUN up to 5 mm Thickness


Property	Units	Value
Clearance angle	inch (mm)	12 (300)
No. of teeth in blade		96
Thickness	inch (mm)	$\frac{3}{32}$ " - $\frac{1}{8}$ " (2.2 - 3.2)
Teeth angles		Rake: 45° Clearance: 15° Alternating: Left - Right
Tooth appearance		
Speed	rpm	1800 - 2400

Band Saw

Band saws can be used for cutting PALSUN sheets of most thicknesses with acceptable results. Band saws are workshop tools. In PALSUN fabrication, they are mostly used to cut formed parts or irregular shapes. It is possible to cut flat sheets in straight lines too, but in limited length and width, due to the tool's limitations.

- Thin gauge sheets are better sawed when stacked to a thickness of 0.4" - 0.5" (10 - 12 mm)
- The preferred band saw blade should have slightly set teeth, with 0.4" - 0.8" (10 - 20 mm) blade widths.

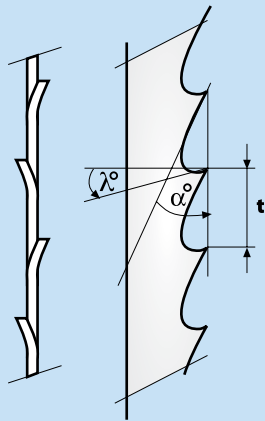
Saw Blade Specifications for Cutting PALSUN 6 mm Thickness and Above

Property	Units	Value
Clearance angle	inch (mm)	14 (350)
No. of teeth in blade		108
Thickness	inch (mm)	$\frac{3}{32}$ " - $\frac{1}{8}$ " (2.2 - 3.2)
Teeth angles		Rake: 10° Clearance: 15° Alternating: Left - Right
Tooth appearance		
Speed	rpm	1800 - 2400

Notes:

1. Teeth shapes sketches are not to scale. They should be considered to serve only as an indication.
2. The PALSUN should be placed on a firm flat base and clamped into position during sawing.
3. When sawing PALSUN, it is recommended to leave the protective masking on.
4. If the cut sheet vibrates during sawing, cardboard sheet padding may be placed beneath it to absorb the vibrations.
5. When sawing thin gauge PALSUN it is recommended not to cut single sheets by themselves. Saw a stack of 5-10 sheets at a time, clamped firmly together to a steady base.
6. Low to moderate feed rate should be used when the sheets approach the blade, or vice versa. A feed rate that is too high can cause gumming, splitting or breaking of the sheet edges.

Figure 10: Typical Band Saw Blade Configuration



Recommended Saw Blade Properties

Property	Sign	Units	Value
Clearance angle	α		10 – 20°
Rake angle	γ		5 – 15°
Cutting speed		ft/min (m/min)	1,950 - 3,300 (1,000 - 6,000)
Rate of feed		inch/sec (mm/sec)	$\frac{1}{6}$ (20)
Thin gauge: tooth pitch $\frac{1}{16}$ " - $\frac{3}{32}$ " (1.5-2.5 mm)	t	Teeth per in. (Teeth per mm)	12 - 18 (1.5 - 2.0)
Heavy gauge: tooth pitch $\frac{1}{8}$ " - $\frac{1}{2}$ " (3.2 - 12 mm)	t	Teeth per in. (Teeth per mm)	7 - 10 (2.5 - 3.5)

Notes:

1. A band saw is suitable for cutting curved lines and 3-dimensional, formed parts.
2. For cutting a few formed objects of the same shape, they must be firmly clamped together.
3. A band saw cutting usually yields rougher finished edge, which must be smoothed by sanding and polishing. A belt sander is a preferred tool for such an operation.
4. Palram recommends using a circular saw for better-finished edges, whenever possible.

Portables: Jigsaw or Saber Saw

Portable saws of these types use short movement, reciprocating blades, instead of one-direction orientation, continuous movement blades like those of circular or band saws, and are much slower in operation.

- **Chipping:** Various sized chips are broken off on both edges of the saw line, leaving the cut edges rough and uneven.
- **Gumming:** Chips and splinters from the advancing saw blade overheat during the sawing process, melt and create a mass of cooled down material in front of the blade. The swarf sticks to the edges, leaving an unsightly, rough edge finish, which is difficult to clean.

Jigsaw or saber saw cutting usually results in an inferior finish of the cut edges, worse than the results achieved by a circular saw. Palram recommends sanding and polishing of the cut edges as standard practice. A belt sander is the preferred tool for such an operation.

Gummed material may also stick to the blade itself and cause the blade to seize up.

The same uncontrolled heat that creates gumming may also induce undue internal stresses along the edges of the cut, necessitating cooling of the sheet.

Sawing Tips:

Recommended Remedies:

- Choose the correct tooth size and pitch.
- Select an appropriate saw speed.
- Lower the feed rate.
- Examine the sharpness of the blade.
- Examine the blade alignment.
- Cool the blade with compressed air when long cuts are required.
- Take frequent pauses during long production runs, to let the saw blade cool down.
- Begin sawing with the blade already running at the full recommended speed.

Routing

A versatile technique, enabling diversity of edge fabrications and trimming of PALSUN sheets, notably for parts too large or of irregular shape for a band saw. With sharp two-flute straight cutters, this technique can produce very smooth edges.

- The feed rate should be slow, to avoid excessive heat buildup and shattering.
- As a safety measure, when routing, always guide the sheet with a suitable jig.
- A jet of compressed air can be used to cool the bit and the sheet at the spot of cutting and assist in chip removal.

Static bench routers: Fast, strong and stable, for complex and accurate straight-line fabrications.

Portable routers: Less powerful, for smaller or on site jobs. Also used for trimming and edge fabrications of irregular shapes. Can perform certain small milling jobs like butt shaping on rectangular or round apertures or tongue and groove butt finish on thicker sheets.

Primary Edge Finishing

- Quick and accurate trimming or finishing of straight-edged or curved cut PALSUN sheets.
- Easily produced straightedge corners or curved butts.
- Preparation of varied lap and butt joint fabrications.

Tooling

- **Routers:** Universal, commercially available equipment.
- **Routing cutters:** new metalworking cutters, kept at utmost sharpness.

Recommended Router Bit Properties

Property	Units	Value
Clearance angle		5 - 10°
Rake angle		0 - 10°
Router speed - w/o load	rpm	15,000 - 22,000
Cutting speed	ft./min. (m/min.)	330 - 1640 (100 - 500)
Feed rate	inch/rev. (mm/rev.)	0.004 - 0.07 (0.1 - 0.5)

Routing and milling tips: For clean, smooth routing work ensure cutter's sharpness and accurate alignment before starting work. Compressed air jet cooling following the cutting head improves the router's speed, cut quality and blows the swarf away. Let the tool reach its maximum (unloaded) operating speed before commencing work.

Milling & Joining

A portable router, with suitable cutters, can be used for small milling jobs.

A standard woodworking jointer-planer, preferably with carbide or high-speed blades/cutters, can be used for trimming, resulting in a good quality edge finish.

Avoid excessive stock removal, which may result in shattering or rough edges. A cut of 0.4mm (0.016 in.) or less per pass is recommended.

Finishing Recommendations for Sawing and Cutting

Unintended saw marks, rough or jagged corners, or uneven, drawn edges created by imperfect shearing may result in crazing and cracking, that can develop further to failure under load.

Palram recommends finishing the edges of cut PALSUN sheets to a smooth appearance.

This will ensure that no cracks will develop from the irregularities at the edges.

Smoothing techniques are discussed in "[Finishing](#)" Section on page 28.

Drilling

General Indications

Drill bits: Regular, new high-speed steel twist drills, (Fig. 14a) or new carbide-tipped drills are suitable for drilling holes in PALSUN sheets of various thicknesses, as long as they are sharpened well. They are used mainly for bores up to 1/2" (12 mm) diameter.

Figure 14a: Regular Drill Bit

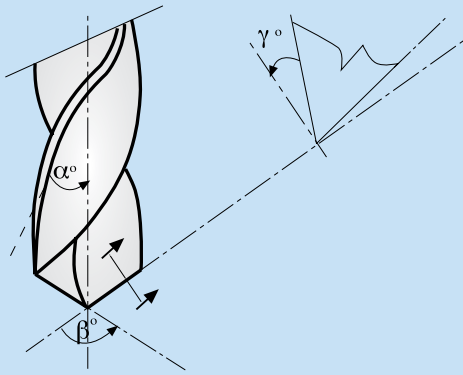
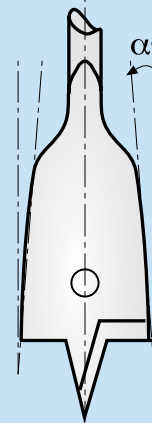


Figure 14b: Flat Chisel Edged Drill Blade



Larger holes may be drilled by flat, chisel edged drill blades with a triangular cutting tip, (Fig. 14b) similar to those used in woodworking, kept sharp. Rake angle should be about 5° to avoid side friction. They are used mainly for bores from 1/2" to 13/16" (12 to 20 mm).

Commercially available hole saws or circle cutters of several types can be used for performing large round apertures.

Speed: Decrease the drill's speed as hole diameter and / or sheet thickness gets larger. Drilling speed may vary due to actual conditions.

Feed rate: May vary due to actual conditions.

Drilling Speed and Feed Rate Change in Accordance with Bore Diameter

Hole Diameter		Drill Speed		Feed Rate	
Inch	mm	rpm		inch/rev	mm/rev
1/8	3	1500 - 1800		0.012 - 0.028	0.03 - 0.07
1/4	6	800 - 1500		0.012 - 0.028	0.03 - 0.07
13/32	10	500 - 1000		0.004 - 0.028	0.01 - 0.07
19/32	15	350 - 700		0.028	0.07
25/32	20	250 - 350		0.028	0.07

Recommended Drill Bit Configurations

Property	Sign	Units	Value
Clearance angle			10 – 20°
Rake angle	γ°		0 – 10°
Drill tip angle	β°		110 – 150°
Helix angle	α°		30°
Cutting velocity		m/min. (ft./min.)	15 - 30 (49 - 98)

Notes: For small gauge sheets (0.04" - 0.08" or 1 - 2 mm.) We recommend using flatter tip drill bits ($\beta = 140 - 150^\circ$) for achieving a cleaner bore with less risk of chipping.

Drilling tips and recommendations

- **Location:** Locate holes no closer to the edges than 2 – 2.5 times the diameter of the pertinent hole, with a 0.4" (10 mm) minimum.
- **Precision:** It is imperative to keep the sheet (or stack of sheets) firmly clamped to a stable workbench (or a similar base) to avoid fluttering during drilling.
- **Cooling:** Usually cooling is not required with regular drills. However, in cases of deep drilling, like putting perpendicular holes through the sheet's edge, or when drilling through a stack of sheets, cooling both the drill bit and the vicinity of the hole with a jet of compressed air is a good practice. It is also recommended, when drilling deep holes, to stop frequently, pull the drill out and clear the hole from swarf and debris with compressed air.
- **Preventing internal stresses:** Producing a clean, smooth bore, keeping heat buildup to the minimum, by the procedure described above, prevents excessive heat buildup, meltdown and gumming of the drilling dust and debris, and possible seizure of the bit. It also prevents undue internal stresses at the vicinity of the hole.
- Honing and polishing the edge of the hole by mechanical or chemical means contributes to keeping the sheet stress-free, preventing cracking.
- **Maintaining the edge:** Carbide tipped twist drill bits are preferable for long or continuous production runs. They are more durable and improve the edge quality.

Finishing

General Comments

Reasons, Means and Targets

The final step in fabrication, finishing improves both the practical and aesthetic properties of PALSUN sheet prior to assembly.

Grinding & Polishing

This is mostly done as a part of edge preparation.

Practical objective: Rough, uneven, untended edges may be starting points for crazing and/or cracks after the PALSUN sheet is installed and subjected to day by day exposure to wind or snow loads, UV radiation and thermal expansion & contraction, not to mention man-made impacts.

Aesthetic objective: Nicely finished, smooth edges are a must for a quality appearance of the finished product, often installed with exposed edges.

Decorating: A type of finishing intended mostly for aesthetic appearance or for display purposes. Executed by painting, printing, films or hot stamping.

Grinding / Sanding

General

A primary stage in edge finishing, rough or jagged edges and cutting tool marks created by a saw, shearing machine or a router, can be removed by grinding.

Grinding / Sanding Recommendations

A belt sander, equipped with a 400-500 grit belt, running at 65 - 100 ft./sec (20 - 30 m/sec), is the preferred option, applying low contact pressure during operation. Wet sanding and waterproof belts are preferable, as they prevents heat buildup, sanding dust accumulation, and prolong sanding belt life.

A reciprocating or orbital sander can also be used, but it can be applied only by the dry sanding method. Manual Sanding can also be used, wet or dry, working with successive grit size abrasive paper (Starting with 100, then 280-grit silicon-carbide, and finally 400-600 grit sandpaper).

Cleaning

General Cleaning Instructions for PALSUN Family of Products

The Palram polycarbonate products can be easily cleaned utilizing a soft sponge or cloth made from 100% cotton, lukewarm water and a mild dish washing detergent. All surfaces should then be rinsed with cold water and dried with a soft cotton cloth to reduce water spotting. In some instances this procedure may be inadequate and require the use of additional cleaning agents. The agents listed below have all been approved for use at room temperature.

Chemical Cleaners:

- Methyl alcohol
- Ethyl alcohol
- Butyl alcohol
- Isopropyl alcohol
- Heptane
- Hexane
- Petroleum ether (BP 65°)
- VM&P Naphtha

Biodegradeable Cleaners:

- Brilliantize - Plastic Cleaner
- Klear to Sea

General Polycarbonate Cleaning Guidelines

- Never use abrasive or high alkaline cleaners on PALSUN sheets.
- Do not use cleaners on PALSUN sheets for an extended period of time. Rinse immediately with clean, cold water.
- Do not apply cleaners in direct sunlight.
- Never use sharp objects, wipers (squeegees) or razors on PALSUN sheets.
- Do not clean with gasoline.
- Always practice safety first and never step directly on PALSUN sheets.
- Always test cleaners in a small inconspicuous area prior to cleaning entire panel to prevent adverse results.
- When using a pressure washer, do not allow the spray tip to come too close to the panel, as it could have enough pressure to penetrate or tear the panel.
- Avoid dry cleaning, as sand and dust particles clinging to the exterior of the panels may scratch the surface.

For additional information, and information specific to Palgard, Palgard TG, and Palshield, see [Palram Polycarbonate care & Maintenance Guide Form 2203](#).

Cold Forming

Cold Curving

1. PALSUN sheets can be cold bent or curved, within their minimal permitted bending radius, without damaging their mechanical performance. The minimal permitted bending radius for a PALSUN sheet is a factor of their thickness and should be calculated in the following manner: 200 x sheet thickness (e.g. for a 5 mm PALSUN sheet, $5 \times 200 = 1000$ mm minimum cold bending radius). Moreover, based on our experience and observations, the internal stresses induced by curving give them extra strength and rigidity in both directions.
2. Rigidity and support spans increase progressively as the curve radius is reduced (down to the minimal permitted radius). A shallow curve should be considered virtually the same as a flat panel, while a deep curve may add significantly to the bridging ability.

Brake Forming

General Notes

1. PALSUN sheets can be cold-bent in a straight line (line bending). Standard metalworking tools, like a brake press, may be used for bending. The bending process results in permanent plastic deformation. The degree and quality of this change depend on the thickness of the PALSUN sheet, the final bending angle required, and the actual tools used.
2. When brake forming of PALSUN is conducted, the internal elastic stresses induced along the bend line reduce the mechanical properties, UV resistance, and chemical resistance of the sheet. Palram recommends using this process for less demanding applications, and protecting the cold bent areas of the sheet from contact with aggressive chemicals or excessive forces.
3. Annealing can reduce the residual stress level induced by the cold bending process, improving the sheet's mechanical properties.
4. The maximum angles that can be obtained using this process depends on the PALSUN sheet thickness, and the extent of the internal elastic strain. Palram recommends a 24-48 hour delay for the sheet to relax after bending. In order to achieve the desired angle, the sheet has to be bent 20-40 degrees in excess of that angle, depending on the angle and sheet thickness. During the stress relaxation period immediately after bending, the bent sheet will expand and regain the required shape.
5. Certain types of sheets are not suitable for either cold or thermal forming, such as PALGARD abrasion resistant sheet. This type is supplied with a tough, scratch-proof finish, which can not be bent and must be installed "as is".

Practical Recommendations & Work Instructions

1. Preparation of the PALSUN Sheets and Tooling for Bending:
 - a. Cut the sheet to its required pre-bending size. Palram recommends leaving the protective film on both sides during the cutting, edge preparation and cold bending operations.
 - b. Sand and polish the sheet's edges to a very smooth finish. Rough edges or the tiniest fissure may initiate cracks and fractures at the vicinity of the bending lines, due to internal stresses induced by the bending process.
 - c. Palram recommends conducting preliminary bending tests on small samples of the same (or varied) thickness of the intended sheet, and try a few different values of excess bending. After arriving at a satisfactory result production can begin.
 - d. It is advised to use special tooling, like blades and anvils, designed for plastic sheet bending. Standard metalworking blades and anvils are not necessarily suitable for bending plastic sheets. For plastics, we recommend using a special bending blade with a straight, rounded edge. The edge radius should be about 0.16" to 0.24" (4-6 mm). The thicker the sheet, the larger edge radius required. The anvil channel outer "banks" (corners) should be rounded. Both blade and anvil are to be smooth and polished, with no projections, irregularities or rough edges. Please note that an anvil channel for plastics bending is different than the one suitable for metalworking. It has a wider, flat bottom and much steeper "banks".

2. Cold Bending Fabrication:

- a. Bending a sheet with an UV protected side (the printed protective film side) on the exterior of the bend gets best results. Therefore, unless otherwise requested, lay the sheet to be bent with the printed side face down.
3. For optimal results, perform the brake forming with an additional 20-40 degrees as explained above, then leave the sheet to relax for 24-48 days. Installation
- a. Cold bent polycarbonate is more sensitive to mechanical or chemical abuse in the vicinity of the bend. Therefore, Palram recommends a design that offers better protection for bent areas from any detrimental influence.
 - b. Avoid putting additional strain on bent parts, like forcing a bent angle in or out to fit into an existing framework.

Thermoforming

Pre-Drying

General Guidelines

- Nearly all types of PALSUN sheets are suitable for various thermoforming (TF) procedures. However, due to native moisture content absorbed after manufacture, the sheets demand a thorough pre-drying process prior to performing thermoforming techniques. During this process, the sheet's temperature will be raised to over 320°F (160°C). Avoiding this preliminary treatment may result in moisture blisters, marring the appearance of the finished product, and/or reduce its properties.
- Higher thicknesses require longer periods in the drying oven.

Typical Pre-Drying Time in Oven for Various Thicknesses*

Sheet Thickness		Drying Time at 260°F (125°C)
mm	Inch	Hours
1	0.04	1.5
2	0.08	4
3	0.12	7
4	0.15	12
5	0.2	18
6	0.24	26
8	0.32	45

Notes: Time for thicker sheets can be calculated through interpolation.



A finished example of thermoformed PALSUN

- The sheets are put into an oven, with the protective film removed from both sides, and arranged 3/4"-1" (20-30 mm) apart, to enable free air circulation. They can be stacked horizontally or vertically—just so they will not be distorted or twisted.
- The pre-drying process should be performed as close as possible to the actual forming. Fully dried sheets taken out of the oven and cooled down to room temperature may be workable within 1 to 10 hours (depending on relative humidity and temperature in the workshop).
- Longer delays may necessitate repeating the pre-drying session. Palram suggests, if possible, is leaving the pre-dried sheets in the switched-off oven until the actual thermoforming process. This method saves energy and time on the thermoforming apparatus.

Guidelines for the Heating Process

- Good quality thermoformed products can only be achieved through a careful and controlled heating process. All parts of the treated sheet should reach even, uniform temperature, achieved by a slow, controlled heating rate, avoiding sudden changes in air circulation and temperature. Such events may result in hot spots and possible distortions. Sheet edges must maintain the same forming temperature as the whole sheet.
- Pre-heating of the clamping frame from 248°F - 266°F (120°C to 130°C) is recommended.
- **Temperature Regulation:** Continuous regulation of the sheet's temperature must be maintained inside the thermoforming device itself. PALSUN sheet (of any type) tends to cool quite quickly, and may need a regulating system for adding or dispersing of excess heat on the spot. The sheet's temperature at the thermoforming zone (or the whole sheet) should be kept between 356°F and 410°F (180°C and 210°C) during the forming process. Forcing the sheet to form at a lower temperature may induce detrimental internal stresses, reducing the sheet's impact resistance and increasing its chemical sensitivity. Internal stresses are invisible and can be detected only by polarized light. Annealing may reduce the stresses, although it is a complicated process and could be inefficient or impossible to perform in most cases.
- **Protective Polyethylene (PE) masking in Thermoforming:** Special masking is available for sheets intended for thermoforming and should be specified in these cases. This type of masking may be kept on the sheet when performing most thermoforming methods and peeled off right before performing the procedure. When using sheets with standard masking, it should be removed prior to the thermal treatment, otherwise it is likely to fuse to the sheet's face.

Hot-Line Bending

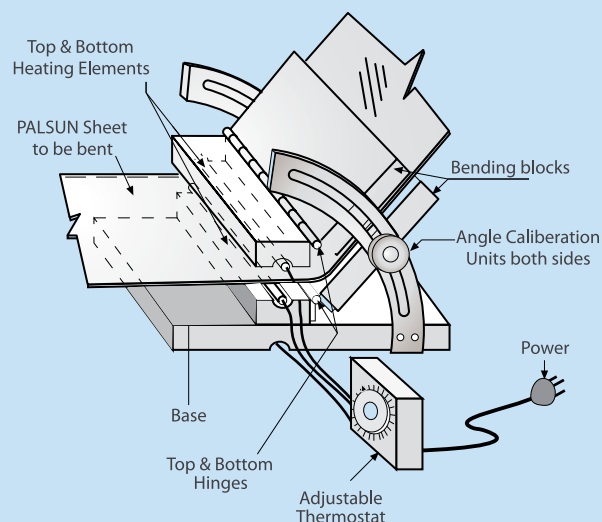
General Guidelines

1. **Description:** A simple bending technique, used for forming local, straight line, one axis bent parts (such as corners, boxes, and machine guards). This type of bending is usually preferable (if possible) to cold line-bending.
2. **The process:** A bending device with localized heaters on one or two sides of the sheet to be bent is used. The "sandwiched" two-sided heating method is preferable, since it retains the same temperature on both sides of the sheet. A one-sided heater method requires turning the sheet over a few times during the heating period, in order to maintain optimal temperature on both sides.

Steps & Indications

- One-sided heating method may suffice for sheets up to 0.12" (3 mm). Thicker sheets or more demanding cases require using two-sided heating. Keeping control of the sheet's temperature limits of 31-332° F (155-167° C) is of the utmost importance.
- Forcing the bend at lower temperatures will render the sheet fragile at the bend. This simple bending process enables working with regular sheets, without pre-drying. Experimenting with small samples before final execution is highly recommended.

Figure 15: Heat bending device



- **PE Masking:** When preparing for bending of regularly clad sheets, peel off the masking on both sides of the sheet along the bend line about 4" (100 mm) on each side. It is possible to process the sheet with the masking on, up to 0.2" (5 mm) thickness. For sheets of 6 mm thickness or more the PE masking should be removed along the bending line, as described above. Always test a few samples before proceeding to production.
- **Heaters:** Linear IR (Infrared) or resistance wires strip heating elements are used, preferably with heat reflectors. The width of the heated zone depends on the number of elements used, the spacing between them depends on their specific thermal output and the distance from the target sheet.
- **Bending process:** When the sheet has reached the required temperature, the heaters are to be switched off. The sheet, held in pivoted clamps, preferably equipped with a caliper, is then bent to the required angle, secured there until it cools down and sets..
- **Note:** It is recommended to perform the bend a few degrees tighter than the required angle, as the angle may increase as the sheet cools. The desired angle may be reached after a few trials.
- **Cooling** is to be done in ambient air, taking care to avoid sudden drafts. This can cause distortion of the final product.
- The minimum hot-line bending radius is three times the thickness of the bent sheet. Larger radii can be achieved by widening the heated zone.

Forming - Notes for Consideration

Local hot line bending (or any other localized heating) induces internal stresses in the finished part, reducing the chemical resistance of the element at the bending line zone. Such treatment is therefore recommended for use in less demanding environments.

Localized heating and cooling expansion/contraction characteristics are unpredictable in many cases. Short elements (up to 3.0' or 1.00 m) usually remain flat. Longer elements may distort to a concave shape (the outer edges are longer than the line-bent side due to uneven contraction).

This phenomenon can be corrected or reduced by simple jigs or frames, which hold the part in the right position during the cooling period. Annealing (see page 38) may also correct this problem. It is always advised to fabricate experimental test samples to check feasibility of the bending operation.

PALSUN® Thermoforming Tips

- Consistent part-to-part uniformity is better ensured if the sheet blanks prepared for the thermoforming process are cut from the basic sheet always at the same direction.
- Best results in thermoforming are achieved when parts are heated to temperatures just above the HDT 300 °F (150 °C).
- Thermoforming parts below the HDT temperature induces internal stresses.
- Secure the cooling area for thermoformed parts against undue drafts. Uneven cooling may result in warping and/or curling of parts.
- Assure precise and systematic control over oven temperature and heating time.
- PALGARD (abrasion resistant) and PALSUN FR (fire retardant) are not recommended for use in thermoforming. The bending and stretching involved during the process will permanently damage the sheets.

Drape Forming

Description

A simple technique, using a single positive (male) or negative (female) mold, on which a heated PALSUN sheet is placed. The sheet, softened by appropriate thermal processing, sags and conforms to the shape of the mold under its own weight, or by slight mechanical pressure applied by hand. Drape forming is generally used to achieve simple, uniaxial, large curvature thermal forming.

The Process

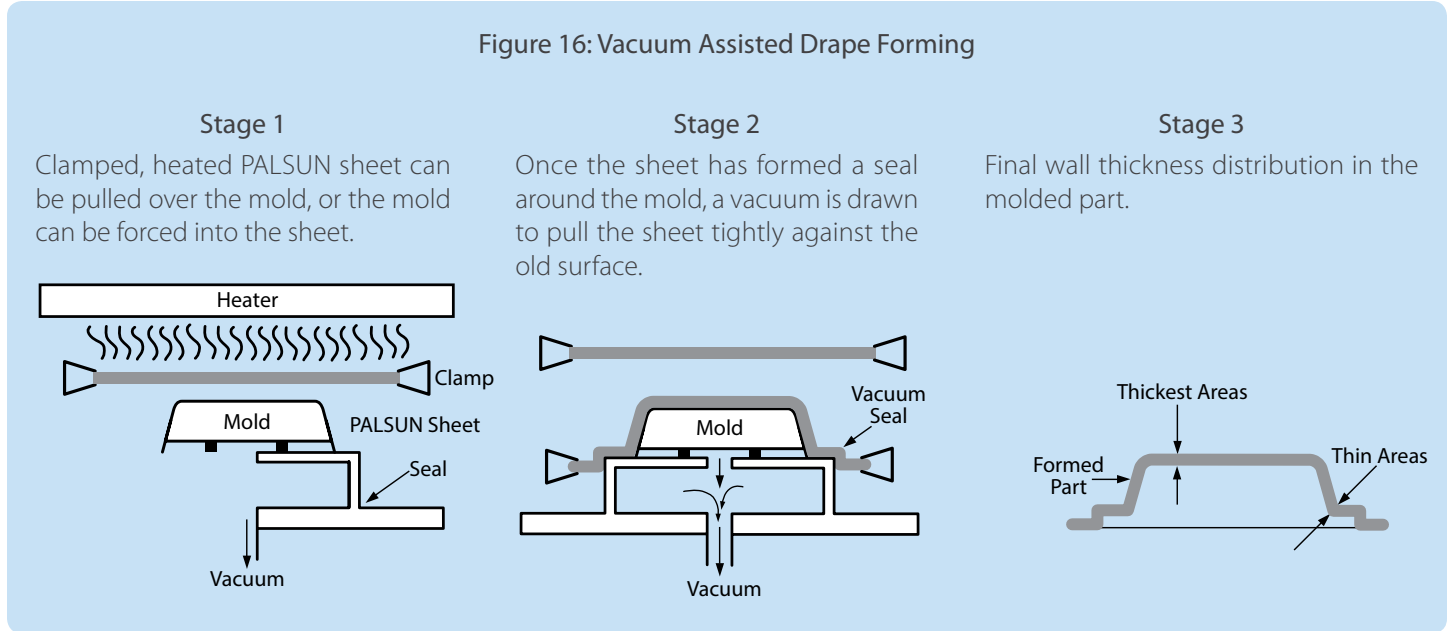
Two main techniques, differing by the position of the mold during the first stage.

1. 1st Method: The sheet (without masking) is placed on top of the mold in its basic, flat state. Both sheet and mold are then slid into a hot-air circulating oven and heated to about 150-155°C (300-312°F). When the sheet (and mold) reaches the required temperature it sags and drapes over the heated mold. Both are then pulled out of the oven and quickly helped, by gloved hands, to conform more precisely to the mold. It is then allowed to cool down.
2. 2nd Method: The sheet is placed into a hot-air circulating oven (without masking), and heated to about 300-312°F (150-155°C). When the sheet reaches the required temperature it is quickly pulled out of the oven and placed on top of the mold. There the sheet sags, aided quickly by the gloved helping hands, and takes the accurate shape of the mold. For better results we recommend pre-heating the mold to about 175-210°F (80-100°C) before putting the heated sheet on top.

Vacuum Assisted Drape Forming

This technique can be assisted by vacuum and is then very similar in detail to the male (positive) straight vacuum forming.

Figure 16: Vacuum Assisted Drape Forming



Notes for Consideration

(These notes exclude the vacuum assisted drape forming)

1. There is no need for pre-drying in this technique, due to the lower operating temperature it requires.
2. The lower operating temperature leaves the exterior surface harder, helping to keep it mar free, with better optical quality.
3. The emphasis on quick operation during the final finishing touch to the heated sheet derives from the rapid cooling and setting properties of the PALSUN sheet once taken out of the oven.

The Molds

1. **Regular molds:** Can be made of metal (steel, aluminum or other) or wood, as long as it can withstand the temperature inside the oven without visible distortion. The upper surface is usually covered by heat resistant felt, which will not mar the exterior sheet surface facing the mold face.
2. **Premium molds:** Finished products requiring premium optical quality (like visors, police shields, vehicles safety glazing etc.) need molds with very smooth, glossy, heat resistant upper surface. They can be made of polished steel, aluminum, glazed ceramics or glass.

Drape Forming

General Guidelines

Vacuum forming is the most versatile and widely used thermoforming process. The equipment required is simpler and less costly to operate than most pressure or mechanical thermoforming techniques. Good results are quite easily attained with pre-dried sheets and decent vacuum-forming equipment.

Reduction in Thickness: The Vacuum forming procedure generally stretches parts of the processed sheet to smaller thickness at varied areas (according to the system chosen). Always take this into consideration when choosing the primary sheet thickness.

Molds:

Prototype or Limited Production Molds can be prepared of smoothed plaster, hardwood, reinforced epoxy or polyester resins (or a combination).

High quality finish or full production run molds for yielding quality results or quick release operation tools have to be heated to working temperatures of 248°F - 266°F (120 - 130 °C). Higher mold temperature (within the limits) results in a better finish. Polished aluminum or steel are the preferred materials.

Mold Corners: Design the mold with rounded corners, with radii at least as large as the processed sheet thickness, to avoid excess thinning or webbing during forming.

Mold Release: Good release of the molding can be achieved by designing the mold with a draft angle of at least 4 to 6 degrees on the upright walls. Allow for a molding shrinkage of up to 2%.

Air Evacuation Through the Mold: Vacuum forming operates on suction principle, creating vacuum underneath the processed sheet. Suction is obtained through small holes put into the mold face. To prevent marking the molding, holes diameter on the exterior should not surpass 0.8 mm (0.031 in.). On the interior side of the mold the hole could be enlarged, to speed up air evacuation.

Male (positive) or Female (negative) Molds: Vacuum forming can be performed on male or female molds, using different equipment and technique, with different results.

Male Mold Forming: A heated sheet is lowered over a protruding mold and stretched down to the bottom, then air is evacuated through the mold and creates vacuum, which "sucks" the stretched sheet until it clings to the mold face. (Actually similar to vacuum assisted drape forming).

Female Mold Forming: A heated sheet is placed over the cavity of the negative mold, then air is sucked through the mold. The vacuum "sucks" the sheet until it clings to the inner face of the mold.

Male Mold: Its use results in thicker bottom and thinner walls. The internal finish of the final product is better. This type of mold is suited for deeper drawing (up to 4:1 depth to diameter ratio). It usually has a single protrusion, in a simple or more elaborately shaped forming. This is a relatively complex and slow technique and as a result, requires a longer production cycle.

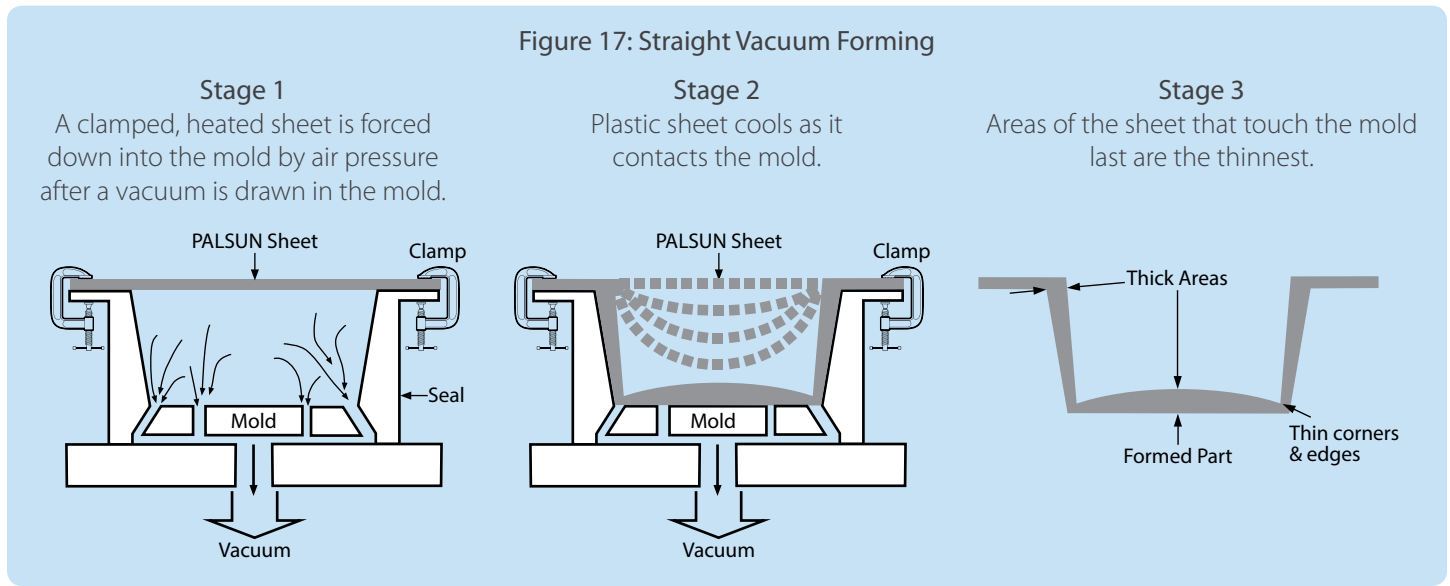
Female Mold: Its use results in thinner bottom and thicker walls and edges. The exterior finish of the final product is better. It can be used in a single cavity (simple or elaborate), especially suitable for multi-cavity, smaller spacing moldings. Its use results in edges thinning during deep draw, thus most suitable for simple, shallow, quick release designs, with a relatively fast production cycle.

Automatic Vacuum-Forming Machines: These are preferable in use, gripping the sheet on all sides during the process. It is notably important when working on 0.04" or 0.08" (1 or 2 mm) thick sheets. Thin sheets tend to shrink up to 5% during the thermal processing and the cooling period, and must be firmly held in a fixed size frame. When a sheet is inserted into the vacuum-forming machine, verify that the UV protected side is properly oriented to suite the finished product. Vacuum forming usually requires pre-drying of the sheets. It can also be carried out without pre-drying, in shallow molds and careful treatment. In the case the sheet temperature should not exceed 320° F (160 °C). Uneven heating, resulting in localized hot spots, over 320-330° F (160-165 °C), may cause bubbles to appear at the overheated zone.

Various Vacuum Forming Techniques

- 1. Straight Vacuum Forming:** In straight vacuum forming, the PALSUN sheet is clamped in a frame and heated until it reaches an elastic state. It is then placed over the female mold cavity, and air is then sucked out of the cavity by vacuum. The atmospheric pressure forces the hot sheet against the contours of the mold. When the PALSUN sheet has cooled down sufficiently, the formed part can be removed from the mold. Thinning at the upper edges of the part usually occurs with relatively deep female molds. The hot sheet being drawn first to the mold center causes thinning. The sheet area at the edges of the mold stretch the most, thus becomes the thinnest section of the formed item. Straight vacuum forming is normally used for simple, shallow designs. See the figures below.

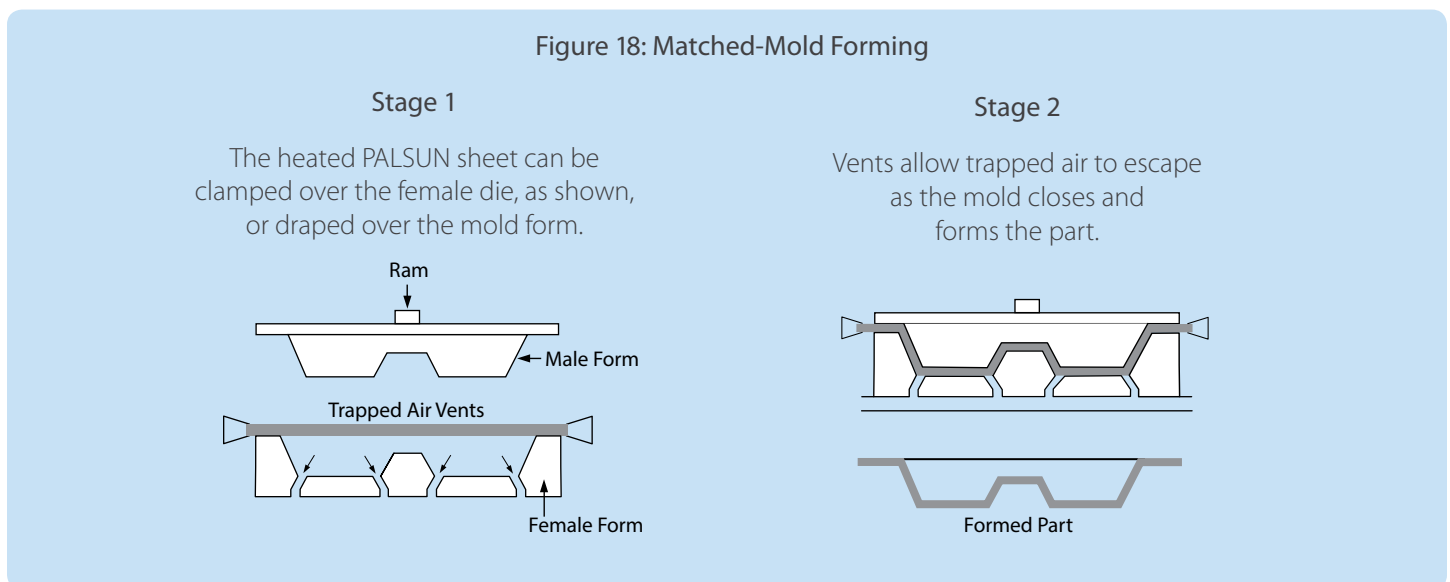
Figure 17: Straight Vacuum Forming



Other Thermoforming Techniques: Other, more specialized, thermoforming techniques use vacuum along with other power assistance, and others depend on different mechanical principles. These techniques were developed for typical applications or to achieve certain results:

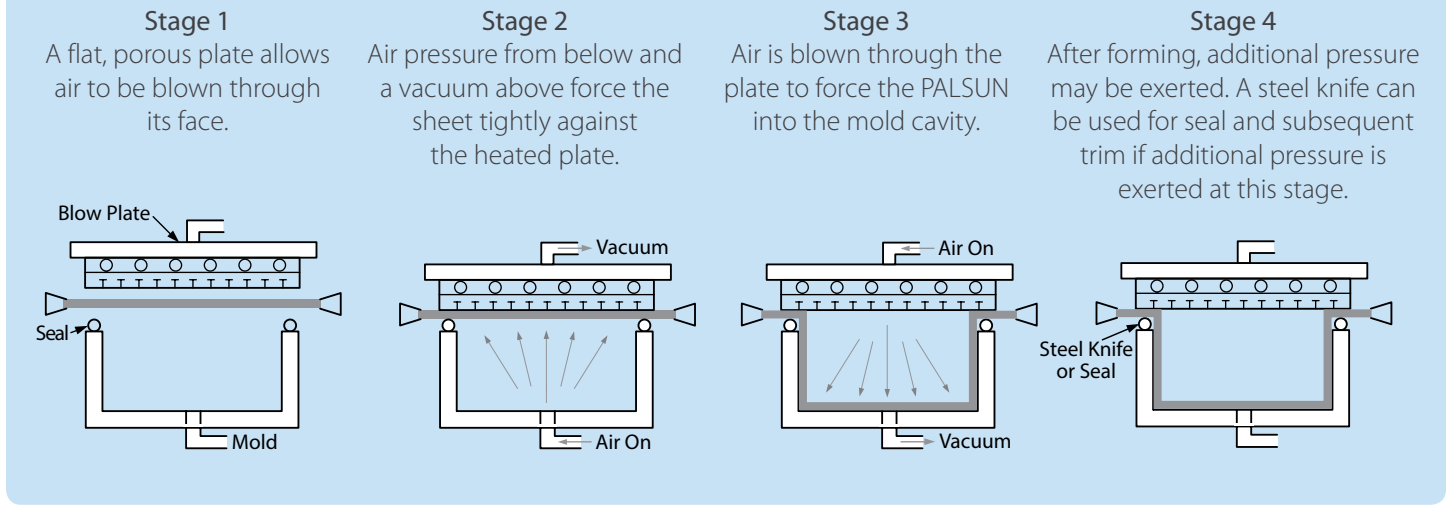
- 2. Matched Mold Forming:** A heated sheet is placed between two matching male/female heated molds, which are then pressed to each other. Trapped air pockets are vented by vacuum through holes in the molds. System enables very good detailing of surfaces, but is relatively costly due to need of accurate tooling and closer tolerance.

Figure 18: Matched-Mold Forming



3. **Trapped-Sheet Contact-Heat Pressure Forming:** The process is based on similar principles as vacuum forming, except that both air pressure and a vacuum assist are used to force the PALSUN sheet into a female mold. It uses lower working temperature, and has a quicker production cycle. Other benefits are better dimensional control and finer finish. The figures below describe the steps in the process.

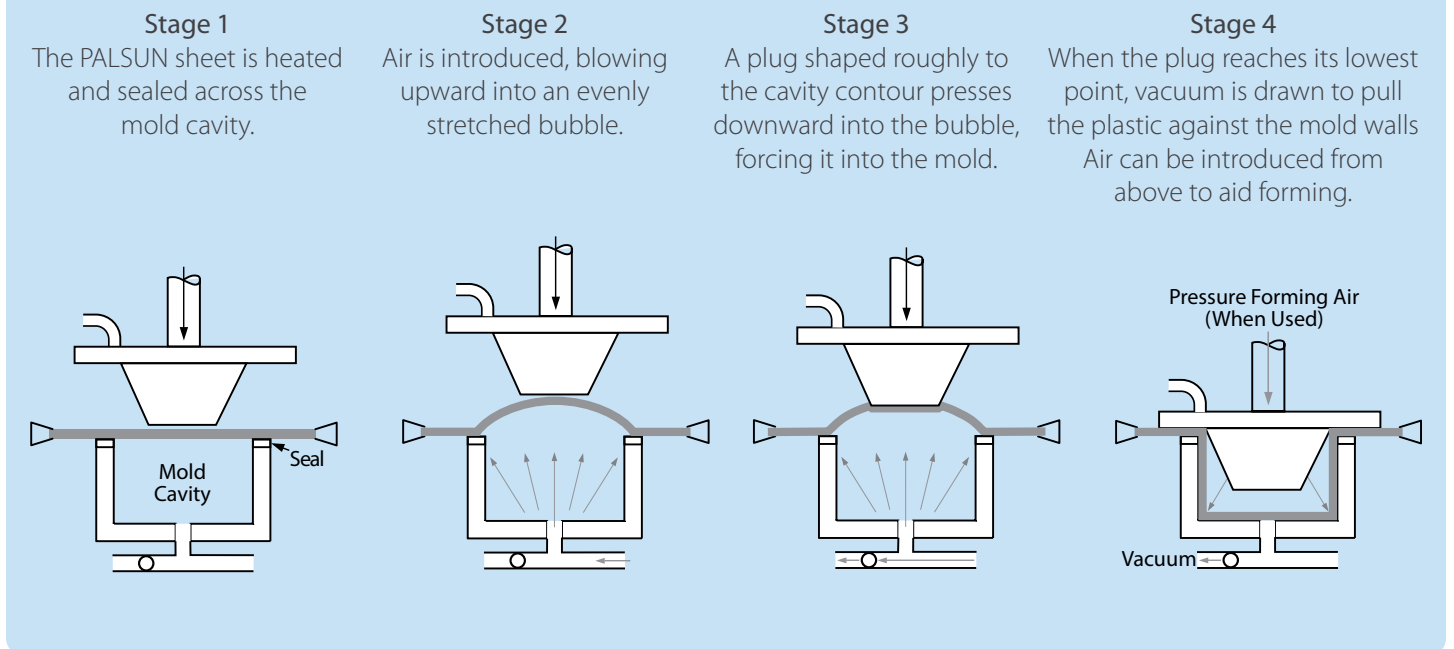
Figure 19: Trapped-Sheet Contact-Heat Pressure Forming



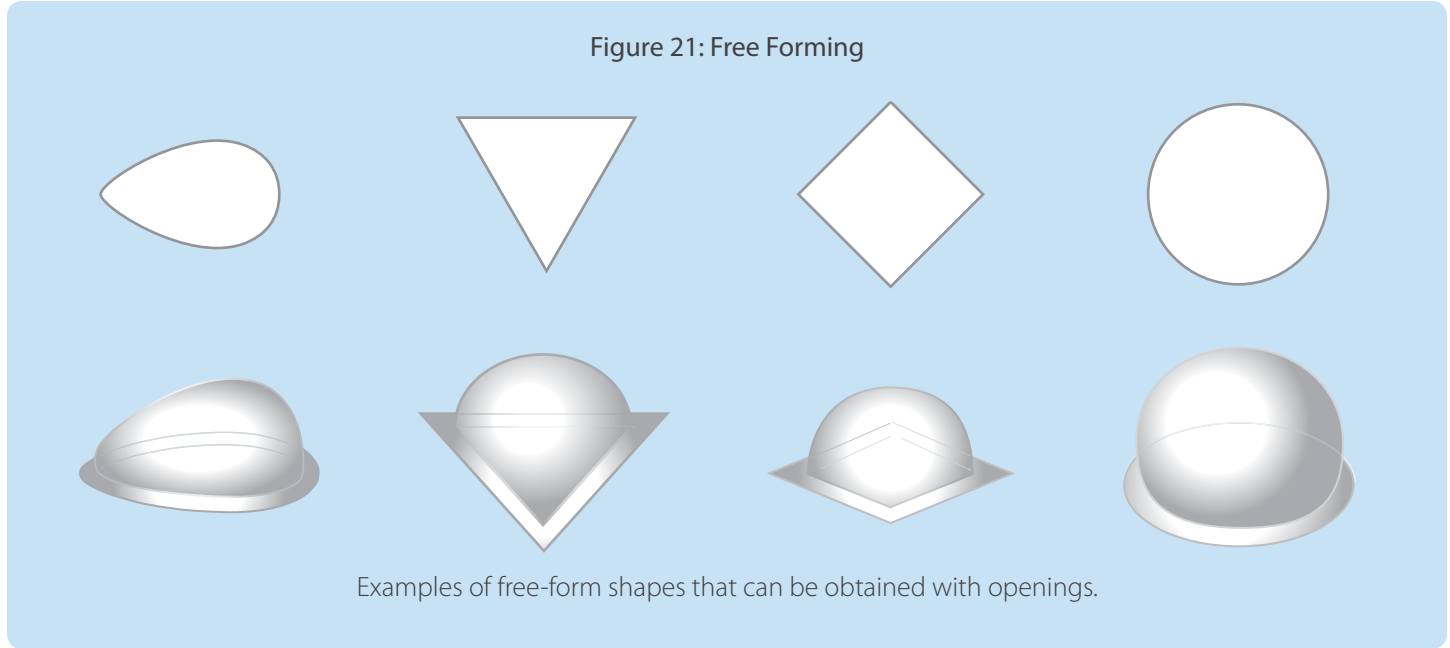
4. **Plug Assisted Forming:** Available in varied pressure/vacuum systems for deeper drawings and better control over wall thickness.

5. **Pressure-Bubble Plug-Assist Vacuum Forming:** The pressure-bubble plug-assist vacuum forming technique is used when a sheet is to be formed into deep articles that must have good thickness uniformity. The framed sheet is heated, then controlled air pressure is used to create a bubble. (See the figures below.) When the bubble is stretched to a predetermined height, the male plug-assist (normally heated) is lowered to force the stretched sheet into the cavity. Plug speed and shape can be varied for improved material distribution.

Figure 20: Pressure-Bubble Plug-Assist Vacuum Forming



6. High air-pressure blows-up a heated sheet through a shaped aperture, resulting in Free Forming, a smooth, free form bubble shape, without touching mold's face. Both interior and exterior surfaces remain smooth and blemish-free.



7. **Mechanical Forming:** This method uses no molds, only mechanical means like bending, stretching or holding to form parts of relatively simple design.

Troubleshooting Tips for Thermoforming

Please consult the Faults & Remedies for Thermoforming Table (next page) at the end of this manual.

Forming – Annealing

Cold fabrication, or various thermoforming systems of the PALSUN sheets, may induce detrimental internal stresses, which may eventually cause failure, and have to be relieved by annealing. Annealing is achieved by heating the fabricated objects evenly in an air-circulating oven up to 248°F to 266° F (120 to 130 °C), and leaving them inside for about an hour for every 3 mm thickness. (Example: 6 mm thick formed part- 2 hours of “baking”.) After the “baking” period, the parts should be left to cool down slowly to the ambient temperature. It is preferable to let it cool inside the closed oven.

Fault and Remedies in Thermoforming Practice

#	Recognized Fault	Probable Cause	Proposed Treatment	Hot Line Bending	Drape Forming	Vacuum Forming	Free Blown
1	Bubbles in sheet	Moisture content too high	Pre-drying	+	+	+	+
2		Working temp. too high	Decrease working temp.	+		+	+
3	Hair fissures, fragile parts	Part overheated	Decrease heating period			+	+
4		Mold under-heated	Increase mold temp.			+	
5		Late extraction of part	Diminish cooling cycle			+	
6		Vacuum speed too high	Reduce vacuum rate			+	
7		Mold corners too sharp	Round sharp corners			+	
8		Basic sheet size too small	Increase sheet size			+	
9		Erratic heating	Prevent hot or cold spots			+	
10		Webbing	Mold lead inadequate	Check spacing-min. depth x 2			+
11	Vacuum speed too high		Reduce vacuum rate			+	
12	Basic sheet size too large		Clamp/mold spacing <50 mm			+	
13	Blurred or partial detailing	Vacuum too weak	Seal leaks/add vacuum holes			+	
14		Sheet rigid, under-heated	Extend heating period or temp.			+	
15	Product sticks to mold	Mold overheated	Decrease mold temperature			+	
16		Product release delayed	Shorten release period			+	
17		Draft angle too steep	Enlarge draft angle up to 4-6°			+	
18		Irregular finish of mold	Treat mold to consistent finish			+	
19	Marked zones on product	Suction holes misplaced	Install new, better placed holes			+	
20		Sheet overheated	Decrease heating period/ temp.	+	+		
21	Exterior flaws / roughness	Dirt/ grime on sheet / mold	Wipe/Vacuum-clean mold/sheet		+	+	
22		Suction holes misplaced	Install new, better placed holes			+	
23		Mold/ brace under-heated	Extend pre-heat of mold/brace			+	
24	Inconsistent shape of part	Irregular heating/ cooling	Prevent drafts, fix faulty heater	+	+	+	+
25		Product release delayed	Shorten release period			+	

Printing

PALSUN is suitable for all printing methods which are applicable to rigid sheets. It has been tested and approved by leading digital printer manufacturers, achieving excellent results in all parameters. Clear PALSUN sheets match the high clarity of other thermoplastic sheets, yet offer far better adhesion properties and ease of printing with no requirement for any further surface treatment.

Direct Digital Printing

Wide format (Roll-to-roll) and flatbed printers use various ink and ink curing technologies to allow high quality printing at relatively high speeds. High quality digital printing depends on various factors:

- Printer capabilities
- Ink technology and quality
- Type of printing substrate and quality
- Machine operator experience level

PALSUN is suitable for use with UV curing and solvent-based digital inks, and for IR drying when water-based inks are used. PALSUN will retain its clarity or tint, even after intense UV curing.

Protective Film Masking

The protective polyethylene film masking helps prevent surface abrasion and stains. However, removing the protective film may cause an increase of static electric charge, which can affect ink coverage. Therefore, after peeling the film away from the sheet, the static electricity that has built up in the sheet should be discharged using an ionized gun or a suitable device provided by the printer manufacturer.

Cleaning PALSUN® and Preparing for Printing

The surface should be clean before printing. Carefully inspect each panel to ensure there is no: dust, fingerprints, residue or other foreign substances that may affect ink coverage or adhesion. If needed, the PALSUN should be cleaned with a damp rag, or with isopropyl alcohol.

Ink Adhesion

PALSUN is suitable for all types of inks: aqueous, solvent based, and UV curable. This suitability is affirmed by major printer OEM's, including HP, AGFA, Canon, EFI, Mutoh, and more. For compatibility information and recommendations, please consult the printer manual or contact the printer manufacturer.

Ink Drying

There are two main technologies used for ink drying in digital printing:

IR (Infrared) – PALSUN's short and long term service temperatures are 248°F (120°C) and 212°F (100°C) respectively, which make it highly suitable for printers with IR drying tunnels.

UV (Ultraviolet) – PALSUN is immune to long term UV exposure and is suitable for UV curing.

Print Head Adjustment

The distance between the print head and the substrate can have a significant affect on print quality. Manufacturer specifications, combined with operator experience, should determine print head distance from the substrate.

The suggested starting distance should not be more than 2 mm from the print head to the substrate.

Chemical Resistance

PALSUN sheets are compatible with many materials and chemicals, show limited resistance to others, and are incompatible with a third group, with which contact may be devastating. The mechanism of chemical attack on polycarbonate sheets differs significantly from the mechanism of corrosion of metals. Corrosion of metals results in a gradual loss of surface material as a result of electrolytic action by the relevant chemicals. In the cases where chemical attack on polycarbonate sheet occurs, all or a portion of a range of effects can be observed. Ethylene chloride, chloroform, tetrachloroethane, m-cresol, pyridene and other chemicals can cause partial dissolution of polycarbonate. Swelling agents include benzene, chlorobenzene, tetralin, acetone, ethyl acetate, acetonitrile and carbon tetrachloride. Additional effects include color change and/or whitening. These effects may not always lead to product failure, especially for non-loaded sheets. Nevertheless, the level of measured mechanical properties will be reduced. The most critical effect of chemical attack is stress cracking or crazing, which may range in size from being visible to the naked eye to being only observable under a microscope. Stress cracks will always result in sheet failure which will emanate from areas of greatest stress (screws, fixings, bends, etc.).

Polycarbonate sheets are generally not recommended for use with acetone, ketones, ethers, and aromatic and chlorinated hydrocarbons in addition to aqueous or alcoholic alkaline solutions, ammonia gas and its solutions and amines.

Polycarbonate is resistant to mineral acids, many organic acids, oxidizing and reducing agents, neutral and acid salt solutions, many greases, waxes and oils, saturated, aliphatic and cycloaliphatic hydrocarbons and alcohols, with the exception of methanol. The resistance of polycarbonate to water may be described as good up to approximately 140°F (60°C). At higher temperatures, degradation occurs, the extent of which depends on time and temperature. Polycarbonate should therefore not be exposed for long periods of time to hot water. However, brief contact with hot water has no effect. For example, polycarbonate tableware can be washed over 1000 times in a dish washing machine with no adverse effects being observed.

The table that appears on the following pages lists the resistance of polycarbonate sheet to a number of commonly encountered chemicals and other corrosive media at room temperature. (Information on chemical resistance at higher temperatures will be supplied upon request). Where the chemical resistance varies with concentration, the results of tests at different concentrations is presented. The information on chemical resistance is based on our research and experience. (Note that information on compatible adhesives and sealants can be found at www.PalramAmericas.com/sealants. It serves as a basis for recommendation. PALRAM Industries does not guarantee chemical resistance unless specific separate documentation is supplied.

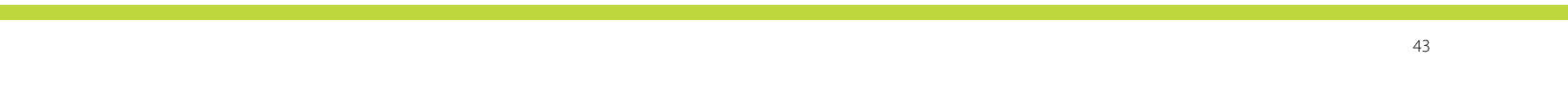
For chemicals and corrosive media not indicated in the list, please contact your PALRAM representative. They will place you in contact with the PALRAM R&D & Technology Department.

For detailed PALSUN / polycarbonate chemical resistance information, please visit: www.PalramAmericas.com/tech

Adhesives and Sealants

Adhesives and sealants are a special class of substances often required during installation or fabrication of PALSUN. The guidelines for their use, appearing below, must be followed.

1. Use only sealants, adhesives, rubber packing, sealing strips & gaskets that are compatible with PALSUN and approved by Palram. An updated list of compatible adhesives and sealants can be found in the “[Recommended Adhesives and Sealants for Palram Polycarbonate Products](#)” which is available from www.PalramAmericas.com/sealants. EPDM rubber sealing strips and gaskets are the preferred choice, (though the use of neoprene is permitted) due to a longer life expectancy and durability.
2. Use of sealants, adhesives and other sealing products not included in the recommended list “[Recommended Adhesives & Sealants for Palram Polycarbonate Products](#)” must receive the Manufacturer’s explicit approval.
Important: Soft PVC gaskets and/or sealing strips are absolutely forbidden for use, as they are detrimental and may cause sheet failure.
3. Use of materials that are not on the list, and/or which have not received the Manufacturer’s explicit approval, may harm the sheets and void all warranties and any responsibility of the Manufacturer for the performance of PALSUN.
4. See [Milling & Joining section on page 26](#) for additional specific details.





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