SABIC
Innovative
Plastics™

Specialty Film & sheet

Lexan*, Valox* and Ultem* Films

Technical Manual

sharing our futures

Index

SABIC Innovative Plastics Specialty Film and Sheet manufactures engineering film products for a wide range of industries and users, including graphic screenprinting, In Mold Decoration, weatherable applications and high temperature electric applications, among others.

Application and product development activities are conducted at SABIC Innovative Plastics' company headquarters in Pittsfield, Massachusetts, USA, the European headquarters in Bergen op Zoom, the Netherlands, andt he China Technology Center in Shanghai, China. It is here, in our state-of-the-art laboratories, that printing, forming, trimming, and injection molding machinery makes it possible for our engineers, designers and technologists to explore and extend the boundaries of film application development and In-Mold Surface technology for our customers.

Around the globe, SABIC Innovative Plastics Specialty Film and Sheet delivers value to customers through innovative products, superior customer responsiveness and hands-on technical assistance.

High Performance Engineering Thermoplastic Film for Electrical, Electronic, Industrial and Consumer Applications

Lexan polycarbonate films offer an unusual combination of features including clarity, dimensional stability, toughness, flexibility, heat resistance, and excellent dielectric performance. The versatile performance and fabricating features of these SABIC-IP products suggest a variety of applications including nameplates, cable wrapping, automotive instrument clusters, membrane switch overlays, metallized films, and many others.

Virtually haze free, with proven qualities for superior performance, Lexan films meet requirements for the full spectrum of film applications. Superior tear strength compared to other films is a practical plus which translates into fewer rejects, fewer production/handling problems, higher quality, and more durable products.

The versatility of Lexan films enables the user to handle a wide range of jobs on conventional equipment where special grades or additional processing techniques may be needed with other films. Information on how to use our products in IMD applications can be found at www.sabic-ip.com/imd.

Because of their excellent property profile plus processing strengths, Lexan films have proven outstanding in many areas. Electrical characteristics, in addition to temperature and dimensional stability, flame resistance and toughness, make Lexan films the logical choice for electrical applications.

In graphic applications, Lexan films are widely used because they permit printing by various methods: screen printing, hot stamping, flexographic, litho, rotogravure, vacuum metallization without pretreatment, and digital printing. Lexan films can also be formed by various methods: embossing, hydroforming, pressure forming, contact heat pressure forming, pressure assist forming, and thermoforming. The combination of ease of printing, forming, and the ability to get clean cuts with steel rule or matched metal trim dies makes Lexan films an excellent choice for the insert material in In Mold Decoration. Learn more at www.sabic-ip.com/imd.

Lexan* Film Polished Grades

Lexan polished films offer 86% to 92% light transmission through all gauges, from 5 to 30 mil (0.125 to 0.750 mm). This makes them the ideal choice for LED/LCD windows and for applications where second surface printing is desirable, such as fascia panels for household appliances, audio/video equipment and automotive dials. Custom colors and optical quality films are available. Lexan films with both surfaces polished can be formed through various techniques and/or selectively textured by screen printing for aesthetic purposes. Screen printing can also provide a mar-resistant finish. Standard grades are available specifically for use with conventional solvent based inks as well as UV cured inks. The following is a partial list of some of the polished film options with a smooth high gloss surface on both sides:

Lexan 8010 film – our standard offering
Lexan T2FOQ film – an optical quality version of 8010 with less inclusions, improved forming consistency, and improved gauge control
Lexan 8020 film – custom colored
Lexan DMX 1HD00 – a coex product with a 1H hardness polycarbonate layer
Lexan SLX 11010 – an excellent choice when chemical resistance or outdoor weathering is needed

Lexan Film Textured Grades

Lexan textured film grades offer a wide range of benefits. First surface textures are anti-reflective and control light diffusion. Textured films are easy to process and can also be formed. They allow for "deadfront" graphics for illuminated instruction or warning lights. In addition, textured first surfaces help to conceal scratches. Clear windows can be wet out using screen printed inks for applications that require a combination of texture and polish. Textured films are suitable for a broad range of applications including automotive dials, audio/video remote control fascias, labels for industrial equipment, control panels for HVAC and office equipment.

Lexan polycarbonate films come in various combinations of textures for customised design flexibility. These textures offer:

- excellent scratch resistance
- an ideal fit for light-emitting devices (LEDs)
- low gloss levels

The following is a partial list of some of the textured films offered:
Lexan 8B35 – Velvet texture on one side with a matte texture on the other
Lexan 8A13 – Polished on one side with a matte texture on the other
Lexan 8A35 – Polished on one side with velvet texture on the other
Lexan SD8B14 – a tight tolerance one side velvet/one side fine matte film for overlay or intermediate layers in security card applications
Lexan SD8B24 – a white version of SD8B14 with excellent opacity to hide security devices in security card applications
Lexan SD8B94 – a laser markable version of SD8B14

Flame Retardant Grades

The family of Sabic Innovative Plastics Flame Retardant (FR) films is UL94 listed and offers a range of surface textures and properties.

These films meet stringent requirements for a wide range of electrical and electronic applications. Polished and textured films are available in this family of films. They can be easily fabricated with conventional converting equipment including forming, embossing, and steel rule die creasing and/or cutting. All FR films offered by Sabic-IP hold their shape when bent which allows for ease of assembly compared to other films. They are also well suited for lamination which provides flexibility to combine shielding and insulation in a single part.

UL file number: E121562USA/E103380NDL

Potential applications include:

- power supply insulation
- disc drive insulation
- bus bar insulation
- TV/monitor insulation
- PC board insulation
- business equipment insulation
- keyboard insulation
- speaker covers
- foil lamination for insulation and shielding
- menu boards
- high voltage internal insulation
- high-temperature PSA tapes
- motor slot-liners and wedges
- transformer wraps
- layer and phase insulation
- speaker cones

The following is a partial list the flame retardant grades available:
FR60 - Polish/polish transparent FR film
FR63 - Polish/matte transparent FR film
FR65 - Matte/velvet transparent FR film
FR700 - Fine matte/velvet black FR film
FR25A - Polish/velvet colored FR film
(Colors include White, black)

Environmental Friendly Flame Retardant Film

The family of Sabic Innovative Plastics environmental friendly FR films is UL94 listed and offers a range of surface textures and properties to cover the current electrical and electronic (EE) flame retardant (FR) brominated polycarbonate (PC) film markets with UL94 VTM-0/V-0 listing at 0.1~0.51 mm. These films have formability, excellent mechanical properties, good dimensional stability at high temperatures and a high flammability rating, making it good for applications such as power supply insulation, disc drive insulation, bus-bar insulation, TV/monitor insulation, PC board insulation, business equipment insulation and has insulation and EMI/RFI shielding when laminated with metal foil.

The following is a partial list of some of the textured films offered:
Lexan* EFR65 - Nature/Black Velvet texture on one side with a matte texture on the other
Lexan* EFR63 - Nature color fine matte texture on one side with a polish on the other
Lexan* EFR95 - Black only, Velvet texture on one side with a fine matte texture on the other

UL file number: E205960

Valox* Film

Valox* FR 1 film is a flame retarded polybutylene terephthalate material offering good temperature resistance, excellent dielectric strength, and ease of fabrication. Valox FR1 offers flame retarded UL94 VTM-0 performance down to 0.125 mm. This material has found use in a wide range of applications in the electronics and graphics industries. Applications include disc drive insulation, business equipment components requiring barrier insulation, and menu boards. With its low moisture absorption and excellent chemical resistance, it is commonly used for laminated EMI/RFI shields.

UL file number: E121562USA/E103380NDL

Potential applications include:
- power supply insulation
- disc drive insulation
- bus bar insulation
- keyboard insulation
- TV/monitor insulation
- PC board insulation
- business equipment insulation
- foil lamination for insulation and shielding
- menu boards

Noryl* EFR735 Film

EFR 735 is halogen-free flame retardant Polyphenylene Oxide film offering UL94 VTM-0 performance down to 0.006" (152 microns) and excellent temperature performance to meet the requirements in a wide range of electrical, electronic and transportation applications. EFR 735 film has outstanding dielectric strength, ease of fabrication such as thermoforming, embossing, clean-edge die-cutting, score and bend. Gauges available are 6mil, 10mil, 17mil and 25mil in Matte/Velvet texture finish.

UL file number: E121562USA

Potential applications include:
- power supply insulation
- TV/monitor insulation
- PC board insulation
- business equipment insulation
- keyboard insulation
- high voltage internal insulation
- layer and phase insulation
- speaker cones

Ultem* Film

Ultem* 1000 film is a high performance thermoplastic polyetherimide material. The combination of Class H high temperature resistance, low moisture absorption and excellent dielectric properties makes Ultem 1000 film a popular choice for a broad range of electrical/electronic applications, including:

- high voltage internal insulation
- high-temperature PSA tapes
- motor slot-liners and wedges
- transformer wraps
- layer and phase insulation
- speaker cones

Ultem 1000 film is thermoformable and can be heat sealed to a wide variety of metals and thermoplastics.

Lexan Film High Performance Grades (HP)

Chemical and abrasion resistant grades

Lexan High Performance films offer exceptional resistance to attack by chemicals and to abrasion, making them suitable for a wide range of applications, including flat membrane switches, anti-reflective computer screens and display windows for audio/video equipment, cell phone and hand held device lenses, washing machine and microwave oven control panels.

HPxxH grades are suitable for second surface printing only and offer optimum abrasion resistance. HPxxS grades are suitable for printing on both surfaces, using UV curing ink on the coated side. Both series are available in grades which provide varying gloss levels for application-specific tailoring. 92, 60, 40, and 12 gloss levels are available.

Chemical, abrasion and UV resistant grades (HP92W, HP12W, and HP92X)

Lexan High Performance Weatherable films feature a proprietary UV-stable coating, which brings long-lasting outdoor performance to a wide range of graphics applications including: warning labels for garden equipment, signage, gas pump point of purchase, and marine graphics.

Abrasion and Fog resistant grades

Lexan High Performance Formable Anti Fog (HPFAF) film offers anti fog performance and anti static performance. It is available in custom colors and is well suited for sport goggle applications and gauges.

Lexan HP92AF film combines the anti fog performance of HPFAF with the abrasion and chemical resistance of HP92S. This product has an anti fog coating on one side and an abrasion resistant coating on the other side. It is useful in medical face shields, goggles, and other applications.

Lexan High Performance Freezer Door Film (HPFDF) combines anti frost performance on one side of the film with an optical adhesive on the other side of the film. This combination along with an NSF splash zone rating make Lexan HPFDF an excellent candidate for application on the reach in freezer cases found in super markets and convenience stores.

Surface Texture Guide

Polished:

Virtually defect-free. Excellent printing surface with true ink color fidelity and optics. Particularly effective for LED/LCD windows. Provides primary substrate finish for screener-applied selective textures.

Fine matt:

Good printing surface, not as smooth as polished.

Matt:

Light diffuser. Hides filaments and eliminates ”hot spots” in back-lit applications. Preferable finish for deadfront graphics. Offers reduced surface reflection and gloss.

Velvet:

Hides scratches, fingerprints and marring for heavy-use applications. Also acts as a diffuser for ”windowed” or back-lit applications.

Suede:

Excellent in very heavy-wear applications.
Resists abrasion while maintaining its attractive appearance.

A Choice of Masking Materials

Polished Lexan films like Lexan 80xx films are available with a choice masking materials:
Stick, a masking with pressure-sensitive adhesive, applied for use when rough handling is expected during processing or shipping. This can be used for applications requiring thermoforming, pressure forming or other forming operations where it is desirable.
Cling, a static-applied masking material for easy removal.

Masking is not available for textured film products.

HP films are available with maskings (on both sides). Typically cling masking is applied on the coated side while a variety of different maskings are applied depending on the gloss (texture) of the coated side. An example is the Y mask, a coextruded masking available for 92 gloss HP films which prevents an increase in tack level due to age or processing even after up to 20 passes of solvent or UV ink printing.

Table 1a: Masking information for uncoated films

Designation	Top Mask	Bottom Masking
A	NO MASK	STICK
C	TRUE-CLING	STICK
E	TRUE-CLING	TRUE-CLING
MD	DD	Cling 1 side
ME	DE	Cling 2 sides
MS	DS	Cling/Joggable Mask

Remarks
- Masking is required on all gauges Lexan 8010/FR60

Table 1b: Masking information for uncoated films

Designation	Top (Coated) Mask	Bottom (Uncoated) Masking
B (HP12, HP40, HP60)	STICK	TRUE-CLING
D (HP12, HP40)	NO-MASK	TRUE-CLING
Y (HP92)	COEX	TRUE-CLING
MD	DD	Cling 1 side
ME	DE	Cling 2 sides
MS	DS	Cling/Joggable Mask

Typical Properties

Table 2: Typical Properties

			Lexan Polished/ Textured	Lexan FR	HP	Valox	Ultem
Property	**Test**	**Unit**	**Value+**	**Value+**	**Value+**	**Value+**	**Value+**
Physical							
Specific Gravity	DIN 53479		1.20	1.32	1.20	1.34	1.27
Water Absorption, 24 hours	ASTM D570	% change	0.35	0.28	0.35	0.48	0.48
Pencil Hardness	ASTM D3363	-	B	B	HB-F	B	B
Pencil Hardness	ASTM D3363	-	B	B	HB	B	B
Optical							
Haze	ASTM D1003	%	0.4 Polished	0.6 Polished	0.5 Polished	103 white	n.a.
Light Transmission	ASTM D1003	%	91	91	92	15	n.a.
Refractive index, 25°C	ASTM D524A	-	1.6	1.6	1.5	n.a.	n.a.
Mechanical							
Tensile Strength	ASTM D882						
at yield		psi (MPa)	8,500 (60)	10,000 (70)	8,500 (60)	7200 (50)	14,500 (100)
at break		psi (MPa)	9,000 (65)	8,500 (60)	8,500 (60)	6000 (41)	13,800 (95)
Elongation at break	ASTM D882	%	100	25	100	150	50
Tensile Modulus	ASTM D882	psi (Mpa)	300000 (2500)	319000 (2200)	305000 (2100)	277000 (1900)	421000 (2900)
Tear Strength							
Initiation	ASTM D1004	lb/mil (kN/m)	1.4 (245)	1.7 (298)	1.4 (245)	1.5 (250)	2.2 (365)
Propagation	ASTM D1922	g/mil (kN/m)	30-55 (10-20)	20 (6)	40 (14)	54 (20)	25 (8)
Coefficient of static friction	ASTM D1894	-	-	-	-	0.39	0.72
Coefficient of kinetic friction	ASTM D1894	-	-	-	-	0.35	0.65
Poisson's ratio	ASTM D132-61	-	0.38	0.38	0.38	0.38	0.42
Thermal							
Shrinkage at 302˚F (150˚C)	ASTM D1204	%	1.4	0.9	1.4	0.4	0.33 {170˚C}
DTUL, @ 264 psi (1.8 N/mm2)	ASTM D648	°F (°C)	290 (145)	290 (145)	290 (145)	174 (79)	392 (200)
Vicat Softening Temperature, B	ASTM D1525	°F (°C)	320 (160)	347 (175)	320 (160)	346 (174)	419 (215)
Glass Transition Temperature	ASTM D3417/D3418	°F (°C)	307 (153)	307 (153)	307 (153)	183 (84)	422 (217)
Coefficient of Thermal Expansion	ASTM E831	x 10-5 /°F (x 10-5 /°C)	3.2 (5.8)	3.2 (5.8)	3.2 (5.8)	3.1 (5.7)	2.7 (5.0)
Thermal Conductivity	ASTM D5470	Btu/hr/ft2/°F /in	1.35	1.35	1.35	1.35	1.49
		(W/m.°K)	(0.20)	(0.20)	(0.20)	(0.2)	(0.22)
Brittleness Temperature	ASTM D746	°F (°C)	-211 (-135)	-211 (-135)	-211 (-135)	-211 (-135)	n.a.
Electrical							
Dielectric Strength, 23°C, 10 mil (0.25mm) in oil, short time	ASTM D149	kV/mil (kV/mm)	1.81 (71)	1.5 (59)	-	1.09 (43)	5 (197)
Dielectric Constant	ASTM D150						
at 60 KHz			2.32	2.9	-	3.31	3.2
at 1 KHz			2.3	2.8	-	3.26	3.2
at 1 MHz			2.3	2.8	-	2.8	3.2
Dissipation factor	ASTM D150						
at 60 Hz			0.001	0.0026	-	0.0015	na
at 1 KHZ			-	0.0028	-	0.004	0.004
at 1 MHz			0.006	0.0117	-	0.010	0.005
Volume Resistivity	ASTM D257	Ohm-cm	8.65 E +16	1 E+17	-	1 E+17	2.5 E+15
Surface Resistivity	ASTM D257	Ohm/square	5.24 E+15	1 E+16	-	1 E+16	1.9 E +16
Arc Resistance, Tungsten	ASTM D495	s	70	64	-	21	54
Flammability•							
Oxygen index	ASTM D2683	%	25	33	25	30	47
UL Flammability	UL94		VTM-2, 0.075 mm	VTM-0, 0.075 mm	HB 0.25 mm	VTM-2, 0.075 mm	VTM-0, 0.025 mm
			V-2, 0.250 mm	V-0, 0.250 mm		VTM-0, 0.127 mm	

• These ratings are not intended to reflect hazards presented by this or any other material under actual fire conditions. n.a. not applicable

Density/specific gravity

Physical Properties

Density and specific gravity are often used interchangeably, which is technically incorrect. The difference is the following: density is mass per unit volume of a material at 73°F (23°C); specific gravity is the mass of a given volume of material at 73°F (23°C) divided by an equal volume of water at the same temperature. The conversion is: density (kg/m3) = specific gravity x 0.99756. The often used term "relative density" has the same meaning as "specific gravity". These values are used to determine the area factor, or the amount of coverage for a given thickness.

Table 3: Specific gravity

Lexan	Lexan FR	Valox	Ultem
1.20	1.32	1.34	1.27

In a formula this reads:

Area factor in m^2/kg = 1 / (spec. gravity x thickness (mm))

Convert to ft^2/lb by multiplying the Area factor in m^2/kg by 4.8816.

So for a 10 mil (0.254 mm) stardard Lexan film the approximate coverage is 3.28 m^2/kg or 16.0 ft^2/lb.

Water absorption/moisture

The determination of water absorption by a plastic specimen of defined dimensions is carried out by immersion in water for a specified time and at a specified temperature. The measured results are expressed in either milligrams' absorbed water or as a percentage increase in weight.

All SABIC Innovative Plastics Specialty Film and Sheet's films show very low water absorption. The moisture content may result in changes in dimensions or in properties such as electrical insulation resistance, dielectric losses, mechanical strength and appearance.

Lexan films' optical properties are important for graphic and packaging applications. High light transmission and low haze values make Lexan film one of the highest clarity films available. In applications where optical quality or low stress is important, Optical Quality or OQ grades may be available.

Haze

Haze is a measurement of the amount of perpendicular light transmission lost due to scattering within the film. Haze contributes to difficulty in seeing objects clearly through the film and muting of second-surface printed inks. Lexan polished film's low haze levels ensure clarity and excellent color of second-surface inks.

Yellowness Index

Yellowness Index (YI) is a measurement of the deviation from whiteness (waterwhiteness) of the film in simulated daylight illumination relative to a white standard (magnesium oxide). Low YI values prevent color changes of white and pastel inks printed on the second surface of the film. Special Lexan film products with controlled YI are available. Please contact your local film distributor for more information.

Light Transmission

As shown in Graph 1, most Lexan films transmit 90% of visible light and are somewhat opaque to ultraviolet light. This helps to protect second-surface graphics, package contents and the film itself from degradation caused by ultraviolet radiation from the sun an flouresscent lighting. Long-term, direct solar exposure, however, is not recommended without additional protection to reduce chalking of the film surface. Custom colors and grades are available to block or transmit more or less light at specified wavelengths.

Refractive Index

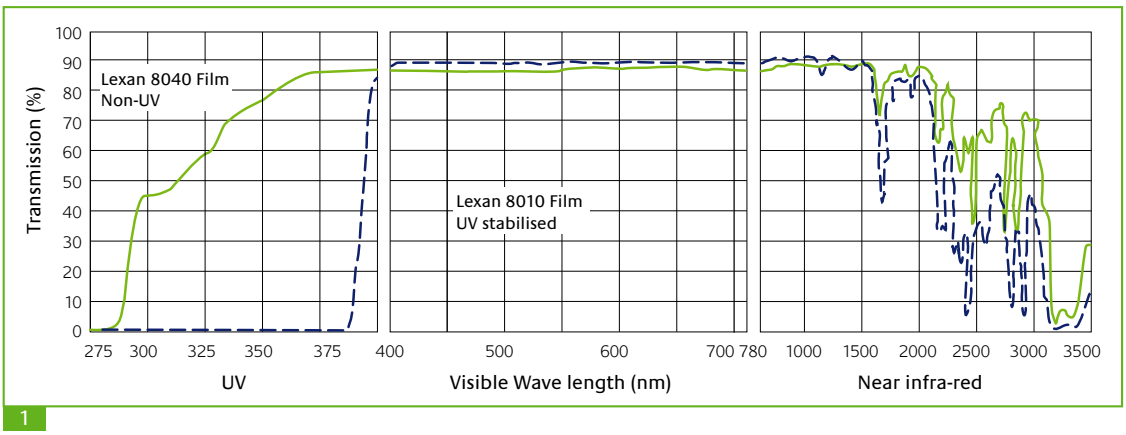
A light beam is transmitted through a transparent specimen at a certain angle. The deviation of the beam, caused when the light passes through the specimen, is the index of refraction, found by dividing sin α by sin β. See figure 2.

Gloss DIN 67350, ASTM D 523

Gloss is associated with the capacity of a surface to reflect more light in some directions than in others. Gloss can be measured in a glossmeter. A bright light is reflected off a specimen at an angle and the luminance or brightness of the reflected beam is measured by a photodetector. Most commonly, a 60° angle is used. Polished materials can be measured at 20° and matte surfaces at 85°. The angle used may also depend on the intended use of the material. The glossmeter is calibrated by using a black glass standard with a gloss value of 100. See figure 3.

Table 4: Gardner Gloss Levels After Screenprinting Flat Black (Min.- Max.)

Film	Angle	Velvet	Matt	Suede
8B35	60°	3.0-4.5	5.0-15.0	
8B36	60°		3.0-12.0	0.0-2.0
8A13	85°		4.0-10.0	
8A35	60°	8.0-14.0		



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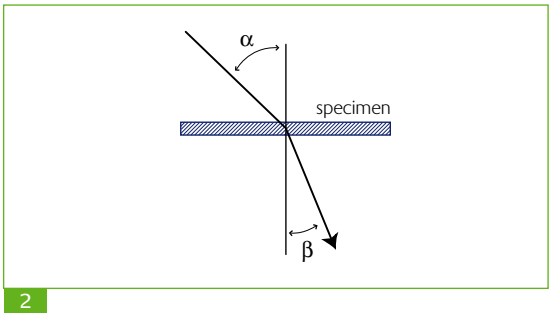

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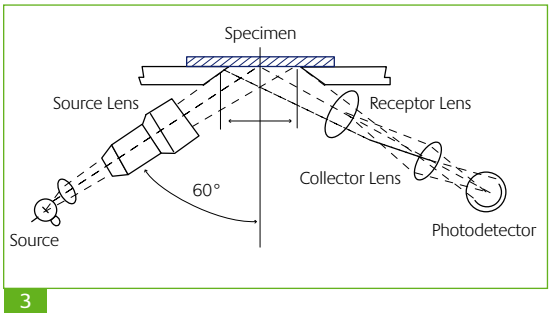

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Table 5:

Property	Test Method	Units	Typical Values									
			HP92H	HP60H	HP40H	HP12H	HP92S	HP60S	HP40S	HP12S	HP92W	HP12W	HP92X
Gloss-Backpainted	ASTM D523	Gardner											
Flat Black													
60°			89	62	34	10	92	62	40	12	92	12	92
85°			-	-	66	38	-	-		45	-	-	-
20°			84	-	-	-	-	-	-	-	80	16	80
Gloss-Clear Over	ASTM D523	Gardner											
White													
60°			167	103	60	25	165	103	64	27	165	24	165
85°			-	-	65	43	-	-	-	45	-	-	-
20°			179	-	-	-	181	-	-	-	160	105	160

Light Diffusion

Light diffusion in accordance with DIN 5036 is a measurement of the amount of perpendicular light transmission lost due to scattering of light. Light diffusion is measured when haze measurement becomes unreliable (>35%). Textures and special filter systems are used to improve light diffusion.

Table 6: Light diffusion of Lexan film

Polished	Texture	Filled
0.00	0.04	0.06

Half Value Angle

This is the angle at which only half of the transmitted light is measured against the 90 degrees luminous transmittance.

Table 7: Half value angle of Lexan film

Polished	Texture	Filled
0°	3°	6°

Tensile strength, elongation and modulus are properties that describe the behaviour of the film in tension. At room temperature, typical values for SABIC Innovative Plastics Specialty Film and Sheet's film are:

These properties are important in pressure-sensitive tape applications and whenever the film is processed in roll form.

Table 8:

	Unit	Lexan	Lexan FR	Valox	Ultem
Tensile strength at yield	psi (N/mm²)	9000 (62)	10100 (70)	7200 (50)	16000 (110)
Tensile strength at break	psi (N/mm²)	9400 (65)	8700 (60)	6000 (41)	1700 (115)
Elongation break	%	100	100	57	60
Tensile modulus	kpsi (N/mm²)	304 (2100)	319(2200)	275 (1900)	363 (2500)

Stress-strain

Stress-strain curves illustrate the ability to withstand short-term loading. A typical curve with general definitions is shown in figure 4

Stresses can be accurately predicted by using basic mechanical engineering equations. These equations, based on Hookes Law, apply to the linear portion of the stress-strain diagram below the proportional (elastic) limit.

Hookes Law states that stress is directly proportional to strain, and is expressed as:

$$E = \frac{\sigma}{\varepsilon}$$

Where: σ = Stress, psi (N/mm²)
E = Modulus of elasticity, psi (N/mm²)
ε = Elongation, mm/mm

Like most thermoplastics, Lexan, Valox, and Ultem exhibit a spring-like behaviour when loaded in tension below the proportional limit. This means that the film will stretch and return to its original dimension as tension is applied and removed. When printing or die cutting from a web in tension, it may be important to consider this dimensional change.

The following formula can be used to compensate for this behaviour to ensure accurate registration:

$$\varepsilon = \frac{F}{A \times E}$$

Where ε = Strain (stretch in inches (mm), per inch (mm) of web)
F = Web tension in pounds (N)
A = Cross-sectional area of web in squar inches (mm²) (width x thickness)
E = Tensile modulus in psi (N/mm²)

The value of "E" will change with temperature.

A corresponding necking down or decrease in web width will occur. This can be quantified by using Poisson's ratio, which is the ratio of transverse contraction to elongation of a web under tension. For SABIC Innovative Plastics Specialty Film and Sheet's film this number is 0.38. When multiplied by the strain in the previous formula, this will give the decrease in web width.

Tear Strength

The tear resistance of a film is the force needed to initiate and propagate a tear. The stress is recorded and tear inititiation and propagation resistance is normally expressed in pound force or Newtons. The tear resistance can also be expressed in force per unit of thickness, although comparisons between dissimilar materials and/or thicknesses may not be valid. The tear resistance measured in accordance with ASTM D1004/ ASTM D1925 is shown below.

Table 9:

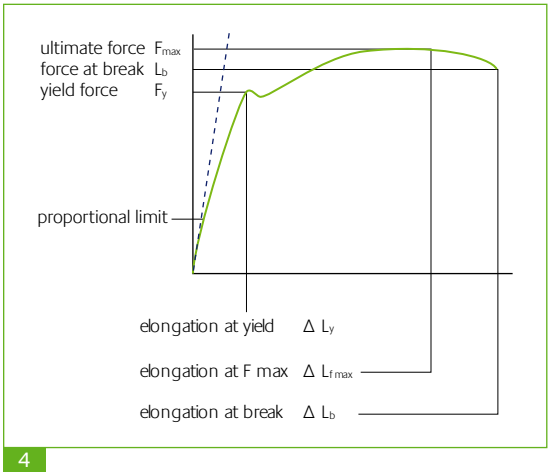
Material	Tear initiation (D1004) lb/mil (kN/m)	Tear propagation (D1925) g/mil (kN/m)
Lexan	1.4 – 1.8 (245 – 298)	30 – 55 (10 - 20)
Valox	1.46 (250)	55 (20)
Ultem	2.1 (365)	24 (8)

Fold Endurance

When tested on the M.I.T. fold endurance tests Lexan Film varies widely with gauge. One-mil (25 micron) film will survive about 12,000 double folds; 5 mil (125 micron) 500 double folds; and 10 mil (250 micron) 200 folds.

Frictional Characteristics

The smooth surface of Valox film makes it appropriate in load bearing surface applications. Valox film also has very low coefficients of static and dynamic friction against metal. The coefficient of static friction of Valox film is 0.39 measured in accordance with ASTM D1894.



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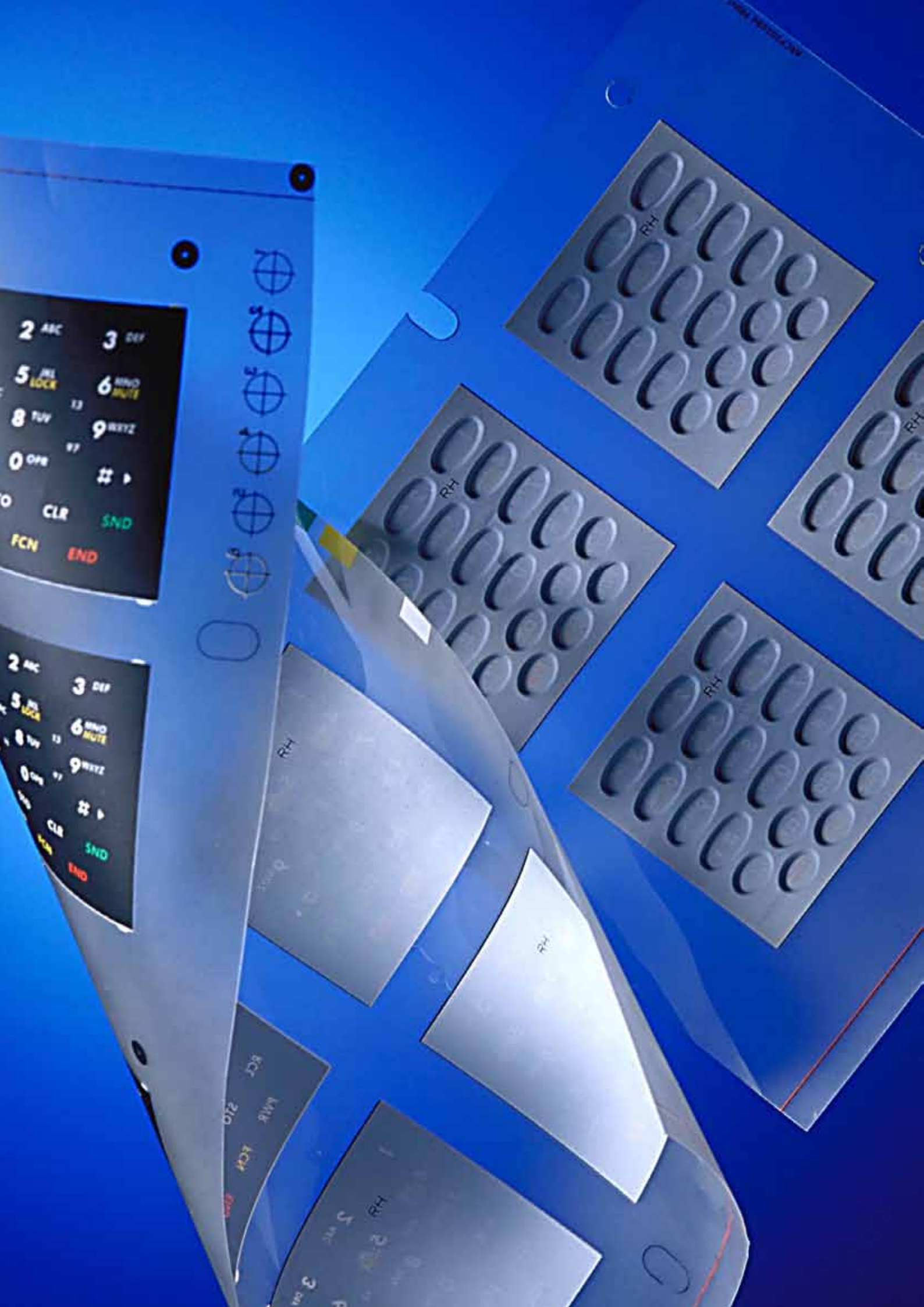
4. Typical Stress-Strain curve


2 ABC
3 DEF
5 JKL LOCK
6 MNO MUTE
8 TUV
9 WXYZ
0 OPR
CLR
SND
FCN
END
RH

Tensile Heat Distortion, DTUL, Vicat

Tensile heat distortion, DTUL and Vicat softening temperature values give an indication of the heat performance of plastics materials. They show the temperatures at which a test specimen will deflect a given distance under a given load in tension, flexure and compression under specified test conditions. The higher the reported value, the higher the material's practical end-use temperature is likely to be.

All thermoplastics undergo mechanical property changes with changing temperature. Amorphous materials such as Lexan polycarbonate change slowly and in an almost linear fashion with increasing temperatures up to 300°F (150°C), where the material begins to soften. Softening continues until it melts at about 420°F (215 °C). Relative thermal stability of Lexan film to 300°F (150°C) makes it a good candidate for high-temperature applications, and the wide softening range allows ease in thermoforming. Following the screen printing of Lexan film, drying temperatures as high as 120°C can be used.

Valox, being a crystalline thermoplastic polyester, shows a more pronounced dependence on temperature. Ill. 5 illustrates tensile modulus as a function of temperature.

RTI and effects of Heat Ageing

RTI, or Relative Thermal Index, is the continuous operating temperature of plastics materials used in electrical applications, as tested by UL. Or "the maximum service temperature at which the critical properties of a material will remain within acceptable limits over a long period of time". The "end of service" life is defined as the time at which a material property has degraded to 50% of its original value after 100,000 hours' continuous exposure. RTI tests are important if the final product is to receive UL recognition. RTI values for various Lexan films are listed in Table 10.

Table 10:

			Relative Thermal index (°C)		
			Mechanical		
Material	Colour	Thickness	Elect.	With Elong.	Without Elong. (tensile)
Valox FR 1	nc	0.075-0.100	-	-	-
	nc	0.125-0.225	125	120	120
	nc	0.250-0.350	125	120	120
	all	0.375-0.600	125	120	125
	all	>=0.635	120	120	140
Lexan FR 6x	cl	0.25-0.35	130	125	130
	cl	0.375-0.74	130	125	130
	cl	>=0.750	130	125	130
Lexan FR 700	bk	0.25-0.35	130	125	130
	bk	0.375-0.74	130	125	130
	bk	>=0.750	130	125	130

Lexan films exhibit polycarbonate's excellent resistance to oxidative embrittlement. After six months at 167°F (75°C) Lexan films showed no measureable change in tensile yield and ultimate tensile strength. The tensile yield point and the ultimate tensile strength of the samples tested increased some 10% during six months at 257°F (125°C). However, the elongation of the same films dropped from an initial average of 97% to a final elongation of 9%. It should be noted that none of the film samples tested were brittle enough to crack by creasing even after the six month aging period.

Degredation of optical properties (decreased light transmission, increased haze and yellowness) can also occur after long-term exposure to high temperatures.

Lexan film should not be exposed on a continuous basis to temperatures exceeding 185°F (85°C).

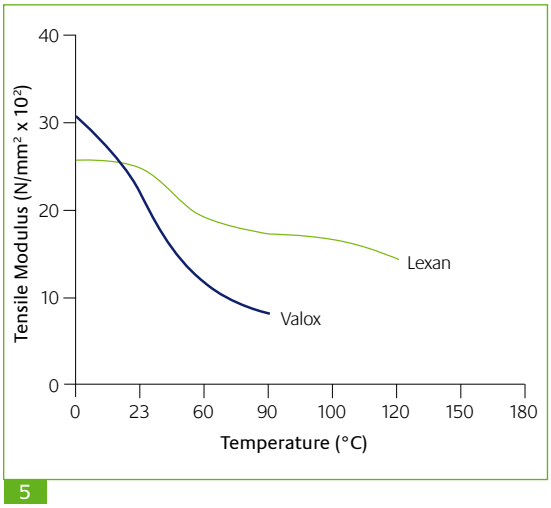
Low temperatures have little effect on Lexan film, which remains ductile down to at least -150°F (-101°C).

Shrinkage

Since Lexan and Ultem films are isotropic and amorphous, they are very dimensionally stable at elevated temperatures. Exposure to temperatures as high as 275°F (135°C) for Lexan and 302°F (150°C) for Utem for short periods (30 min.), results in no detectable change in dimension.

Lexan film from 3 mil to 5 mil (0.075-0.125 mm) will shrink about 0.5% at 302°F (150°C). Heavier gauge film may shrink 1-2% at 302 oF (150°C) depending on gauge. At temperatures above 302°F (150°C), theglass transition temperature, dimensional changes become more pronounced with Lexan films.

When thermoforming, the shrinkage off of the forming tools will vary somewhat depending on the thermoforming tool temperature and cooling time on the tool. For Lexan the shrinkage will range from 0.8% to 0.9%.



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5. Tensile Modulus vs. Temperature

SABIC Innovative Plastics Specialty Film and Sheet's films are characterised by excellent dielectric properties. High dielectric strength and insulation resistance, together with consistent dielectric loss values and superior arc resistance, make them ideal materials for many applications in electronic and electrical components.

Dielectric strength

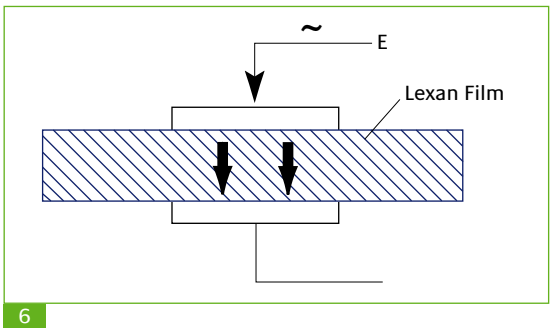
SABIC Innovative Plastics Specialty Film and Sheet's film provides excellent resistance to breakdown in the presence of high voltage AC stress. Table 11 shows the relation of dielectric strength to material thickness as tested according to ASTM D149. All films give similar results and are virtually unaffected by humidity and heat ageing. Absolute resistance to high voltage can be determined by multiplying the dielectric strength in kV/mil (kV/mm) by the material thickness in mils (mm).

Table 11: Dielectric Strength, ASTM D149, kV/mm

Gauge (mm)	Lexan FR	Valox	Ultem
0.05	-	-	6450
0.075	7550	9350	8100
0.1	9000	10800	9500
0.125	10300	12100	10800
0.175	12600	14300	13050
0.25	15650	17100	-
0.375	20050	21000	-
0.5	23850	24200	-
0.625	27300	27050	-
0.75	30500	29650	-

Dielectric constant

Dielectric constant at 60 Hz ranges from about 2.95 to 3.05 over the range of 32 - 257°F (0-125°C) for all Lexan and Valox films. Ultem has a slightly higher dielectric constant of 3.2 over the same range. Water absorption up to equilibrium does not affect this value appreciably.



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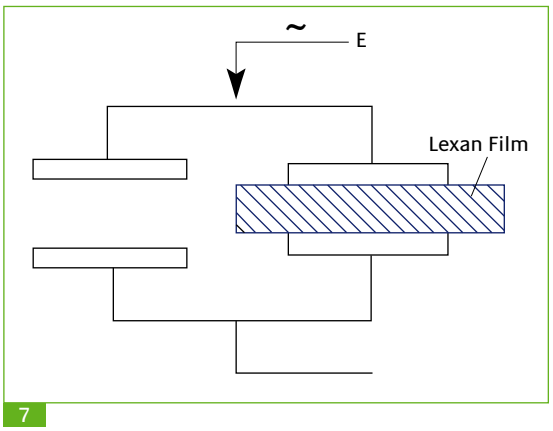

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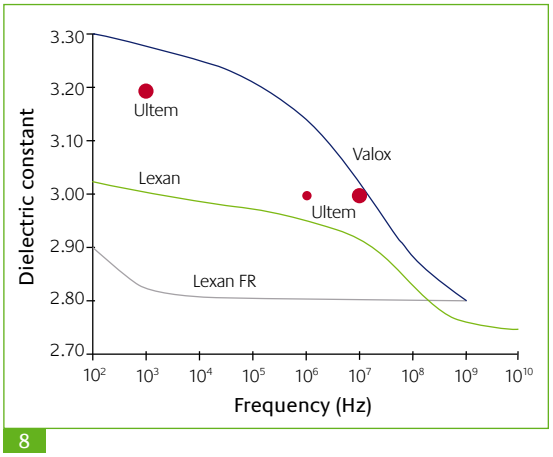

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Dissipation Factor

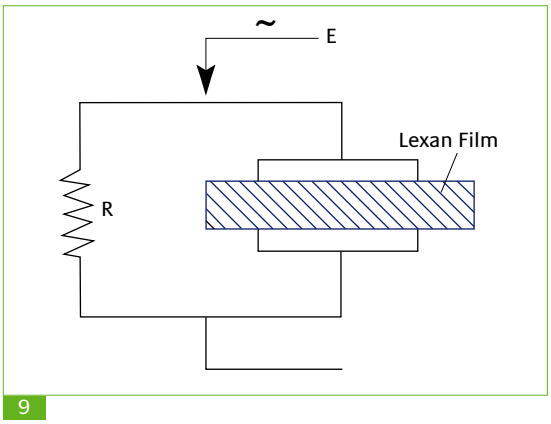
Values for dielectric loss, i.e., dissipation or power factors, are essentially the same across the Lexan film range. From room temperature to 212°F (100°C), the factor is approximately 0.001 (0.1%). It increases gradually to 0.002 at 284°F (140°C) and increases sharply beyond 302°F (150°C). Fig 11 illustrates the effect of frequency on the dissipation factor.

Volume/Surface Resistivity

Lexan films exhibit high resistance to DC current both through and across the surface of the film. Both water absorption up to equilibrium and heat ageing have a negligible effect on these properties.

Arc Resistance

Resistance to high voltage arcing across the film surface varies somewhat with the type of film. Non-flame-retarded grades such as Lexan 8010 generally have better resistance to arc breakdown than the flame-retarded grades.



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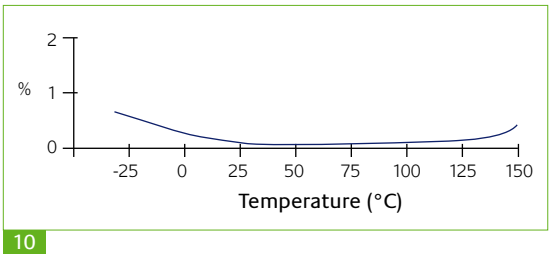

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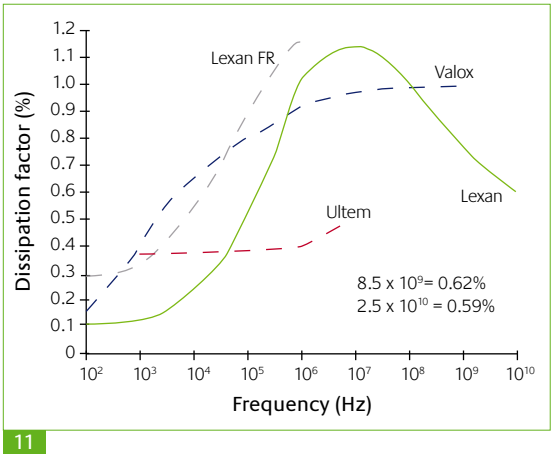

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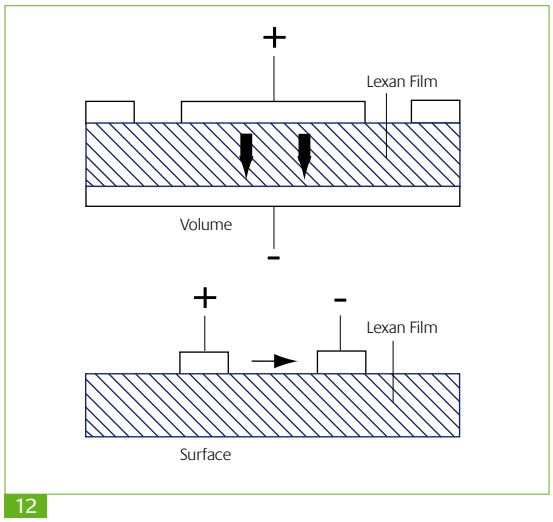

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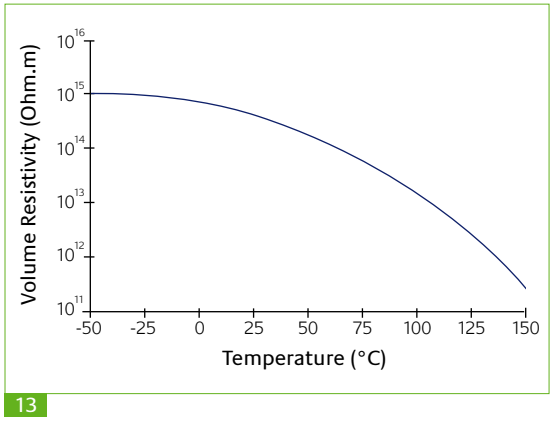

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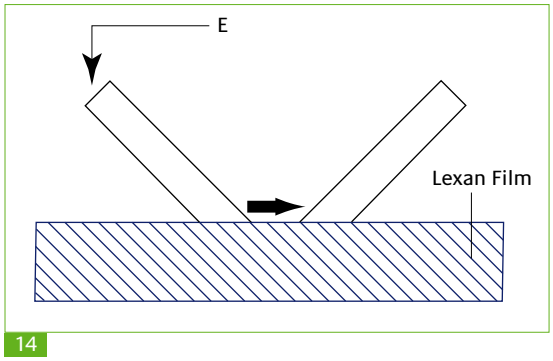

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Performance Level Categories, PLC

PLC, or Performance Level Categories, as defined by UL: "In order to avoid an excessive level of implied precision and bias, material performances for several tests are recorded as PLC, based on the mean test results (rather than recording the exact numerical results)". PLC levels are assigned to electric properties, tested according to UL746A.
Please refer to the following Tables:

Table 12:

Material	Colour	Thickness (mm)	Performance Level Categories (PLCs)				
					H	D	
			H	H	V	4	C
			W	A	T	9	T
			I	I	R	5	I
Ultem 1000	nc	0.05	-	-	-	5	-
Valox FR 1	nc	0.075-0.100	-	-	4	6	2
	nc	0.125-0.225	-	4	6	2	2
	nc	0.250-0.350	4	0	4	6	2
	all	0.375-0.600	4	0	4	6	2
	all	>=0.635	3	0	3	6	2
Lexan FR 6x	cl	0.25-0.35	1	0	-	6	3
	cl	0.375-0.74	0	0	-	6	3
	cl	>=0.750	0	0	-	6	3
Lexan FR 700	bk	0.25-0.35	1	0	-	-	3
	bk	0.375-0.74	0	0	-	-	3
	bk	>=0.750	0	0	-	-	3

Table 13:

Comparative Tracking Index, CTI		PLC level
600	≤ TI	0
400	≤ TI < 600	1
250	≤ TI < 400	2
175	≤ TI < 250	3
100	≤ TI < 175	4
0	≤ TI < 100	5

TI - Tracking Index in Volt

Table 14:

High Voltage Arc		PLC level
0	≤ TR < 10	0
10	≤ TR < 25	1
25	≤ TR < 80	2
80	≤ TR < 150	3
150	≤ TR	4

Tracking Rate, HVTR
TR - Tracking Rate in mm/min

Table 15:

High Current Arc		PLC level
120	≤ NA	0
60	≤ NA < 120	1
30	≤ NA < 60	2
15	≤ NA < 30	3
0	≤ NA < 15	4

Ignition, HAI
NA - Number of Arcs

Table 16:

Hot Wire Ignition, HWI		PLC level
120	≤ IT	0
60	≤ IT < 120	1
30	≤ IT < 60	2
15	≤ IT < 30	3
7	≤ IT < 15	4
0	≤ IT < 7	5

IT - Ignition Time in sec.

Table 17:

Arc Resistance, D495		PLC level
420	≤ TAR	0
360	≤ TAR < 420	1
300	≤ TAR < 360	2
240	≤ TAR < 300	3
180	≤ TAR < 240	4
120	≤ TAR < 180	5
60	≤ TAR < 120	6
0	≤ TAR < 60	7

TAR - Time of Arc Resistance in sec.

Chemical Resistance

At moderate temperatures and low stress levels, SABIC Innovative Plastics Specialty Film and Sheet's film is generally compatible with most substances encountered in home or office environments. However, when stressed in some manner such as by cold-forming, flexing on embossing, some substances will cause the film to craze or stress-crack. Elevated temperatures can initiate or accelerate this type of degradation.

Some organic chemicals such as acetone, toluene and halogenated hydrocarbons will act as solvents to SABIC Innovative Plastics Specialty Film and Sheet's film. Methylene chloride, for example, is often used to solvent-bond SABIC Innovative Plastics Specialty Film and Sheet's films.

A coated film should be used in applications where there is exposure to aggressive or incompatible substances. Tables 18 and 19 offer guide-lines on SABIC Innovative Plastics Specialty Film and Sheet's film's compatibility with general classes of chemicals. Testing is strongly recommended when there may be a question of SABIC Innovative Plastics Specialty Film and Sheet's film's resistance to substances encountered in either processing or end-use.

SABIC Innovative Plastics Specialty Film and Sheet will provide assistance in determining compatibility with specific substances.

Table 18: General Chemical Resistance Overview

Chemical		Amorphous Lexan	Semi -Crystalline Valox
Hydrocarbons			
aliphatic		-/•	•
aromatic		-	+
halogenated	- fully	•/+	-
	- partly	-	-
Alcohols		+	+
Phenols		-	nt
Ketones		-	-
Amides		nt	nt
Amines		nt	nt
Esters		-/•	-
Ethers		-	nt
Acids			
Inorganic	- concentrated	-/•	•/+
	- diluted	•	+
Organic	- concentrated	•	•/+
	- diluted	•	+
Oxidising	- concentrated	-	•/+
	- diluted	+	+
Alkalis			
concentrated		-	-
diluted		-	•
Salts			
acids		+	+
neutral		++	+
alkali		•	+
Automotive fluids			
greases (non-reactive organic esters)		nt	+
oils (unsaturated aliphatic mixtures)		nt	++
waxes (heavy oils)		nt	+
gasoline		-	++
cooling liquid (glycol)		+	++
brake fluid (heavy alcohol)		-	++
detergents, cleaners		+	+
Water hot		-/•	•

Rating: - = Poor •= Fair + = Good ++ = Excellent nt = not tested

Table 19: Chemical Resistance Lexan HP Films

	Lexan HPXXS Film Results		Lexan HP92W Film Results	Lexan HPXXH Film Results	
	As Manufactured•	Post Cured**	As Manufactured•	As Manufactured•	
	1 hr Continuous Surface		1 hr Continuous Surface	Continuous Contact (23 °C)	
Chemical	Contact (23°C)		Contact (23°C)	One hour	Three hours
Acetone	Failed	Passed	Failed (40 - 45 min)	Passed	Failed***
MEK	Failed	Passed	Failed (45 min)	Passed	Failed***
Toluene	Failed	Passed	Passed	Passed	Failed***
Methylene Chloride	Failed	Passed	Failed	Passed	Failed***
Isopropyl Alcohol	Passed	Passed	Passed	Passed	Passed
Cyclohexanone	Failed	Passed	Passed	Passed	Passed
Ethyl Acetate	Failed	Passed	Passed	Passed	-
Xylene	Failed	Passed	Passed	Passed	Passed
40% NaOH	Failed	Passed	Passed	Passed	Passed
Concentrated HCl	Passed	Passed	Passed	Passed	Passed
Gasoline (Regular)	Passed	Passed	Passed	Passed	Passed
Gasoline (Unleaded)	Passed	Passed	Passed	Passed	Passed
Butyl Cellulose	Failed	Passed	Passed	Passed	Passed

• Lexan HPXXS films can be printed on the hardcoated side.
** Post cure: One elliptical focused medium pressure mercury vapour lamp at 120 Watt/cm and a conveyor speed of 6 m/minute.
*** A few small Coating blisters.

Effects of Water

No significant changes have been noted in tensile and elongation properties measured on films immersed in water for several weeks. However, boiling water immersion seriously and rapidly affects the elongation of Lexan films. The tensile yield and ultimate tensile strength values do not change significantly. Long-term immersion in sea water at normal temperatures has no effect on Lexan film. Valox and Ultem films show an improved performance over Lexan films.

Permeability

Plastic films often have specific resistance to gas and moisture vapor passage, which is important in various packaging applications. Permeability is a function of the diffusion rate, the solubility of the gas in the barrier and the barrier thickness. Table 20 gives gas and moisture vapour permeability data for Lexan film at room temperature, gauge 10 mil (0.025 mm).

Weatherability

Long-term exposure to direct sunlight will cause unprotected SABIC Innovative Plastics Specialty Film and Sheet's film to surface chalk (removable) and yellow. The length of time before a noticeable change occurs depends on the severity of the exposure and the thickness of film, and can be anywhere from several months to several years. Unprotected SABIC Innovative Plastics Specialty Film and Sheet's film is not recommended, therefore, for outdoor applications where the retention of aesthetics and mechanical properties is required. For intermittent outdoor exposure or long-term exposure to fluorescent lighting, all SABIC Innovative Plastics Specialty Film and Sheet's films will show excellent performance.

UV Resistance

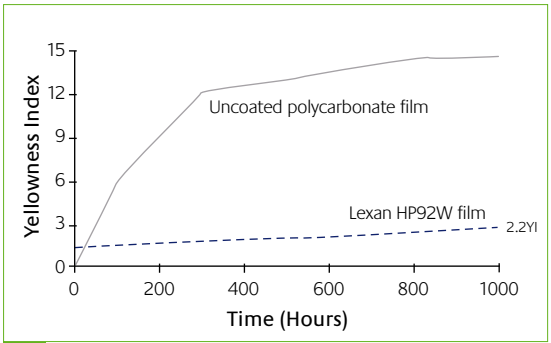
Lexan HP92W and HP92X films utilize a proprietary coating technology developed by SABIC Innovative Plastics. This special coating protects the film from yellowing and hazing, maintaining the appearance of the graphics behind the film. With a yellowness index of less than 2.5 at 1000 hours of QUV testing, Lexan HP92W film is a natural choice for demanding outdoor applications.

Lexan SLX 11010BC film is a clear film of 7 to 10 mil thickness that may be used alone or in a backmolded configuration to provide exceptional weathering, good chemical and scratch resistance and outstanding aesthetics for a wide variety of applications in automotive, telecommunications and outdoor vehicles. It can be printed either first or second surface and retains good aesthetics and performance, even after significant outdoor exposure.

Lexan GS133 film is a laminate of Poly Vinyl Floride (PVF) and Lexan polycarbonate graphic film. With this laminate technology, Lexan GS133 film offers high chemical resistance, formability, and long term resistance to outdoor weathering.

Table 20: Permeability to Gas and Moisture

	Lexan	Unit
Air	85 (1340)	ml/mil/100 in2/24 hr – atm (cc/m² - 24 hrs – atm)
Nitrogen	50 (787)	ml/mil/100 in2/24 hr – atm (cc/m² - 24 hrs – atm)
Oxygen	300 (3500)	ml/mil/100 in2/24 hr – atm (cc/m² - 24 hrs – atm)
Carbon Dioxide	1075 (20000)	ml/mil/100 in2/24 hr – atm (cc/m² - 24 hrs – atm)
Moisture Vapour	8 (85)	g/100 in2/24 hr – atm (cc/m² - 24 hrs – atm)



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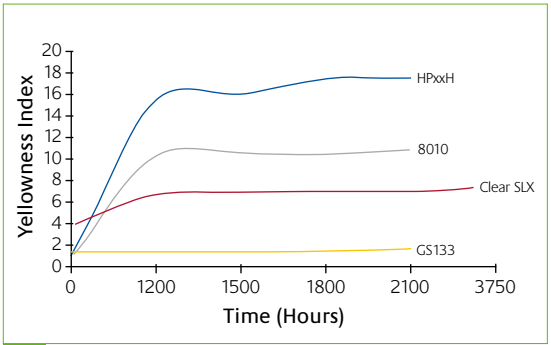

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15. QUV Accelerated Weathering (ASTM G53 - UV313 BB)

16. Xenon Arc Accelerated Weathering

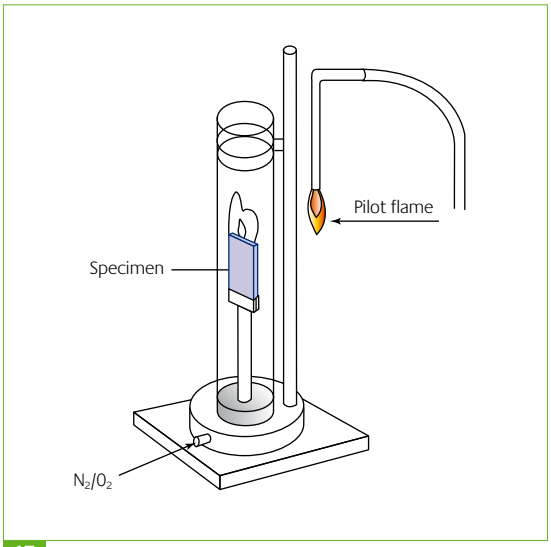
17. xx

Table 21:

Property**	Test	Lexan	Lexan FR	Valox	Ultem
UL Flammability	Bulletin 94	V-2, 0.250 mm	V, 0.250 mm	VTM-0, 0.127 mm	VTM-0, 0.025 mm
	-	VTM-2, 0.125 mm	VTM-0, 0.050 mm	VTM-2, 0.080 mm	-
Oxygen Index	ASTM D2863	25	33	30	47
Flash Point	-	454°C	440°C	-	-
Self-Ignition Temperature	-	575°C	605°C	-	-
FMVSS 302	ISO 3792	pass >0.250 mm	pass >0.250 mm	pass >0.250 mm	pass >0.250 mm
NFPA 258-NBS Smoke	ASTM E662	D (4) = 17	D (4) = 6	-	0
Chamber					
Test (.250 mm)	-	D (max) = 50	D (max) = 36	-	0
Horizontal Burn Rate	ASTM D635	-	-	-	-
Extent of Burn	-	75 mm	36 mm	-	-
Burn Time	-	65 sec.	5 sec.	-	-

** These tests and ratings are not intended to reflect hazards presented by this or any other material under actual fire conditions.
** Updated yellow cards for Sabic Innovative Plastics Specialty Film and Sheet products may be found at **www.UL.com**
UL file number E61257 for the US and E103380 for Europe.

Compared to most other polymers, SABIC Innovative Plastics Specialty Film and Sheet's films are characterised by high inherent flammability resistance. As a result, SABIC Innovative Plastics Specialty Film and Sheet's films are widely used in electrical/electronic, automotive and construction applications. SABIC Innovative Plastics Specialty Film and Sheet'sFR films are formulated to provide further protection against burning and ignition, as shown in Table 21.



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Limiting Oxygen Index ISO 4589 (ASTM D 2863)

The purpose of the oxygen index test is to measure the relative flammability of materials by burning them in a controlled environment. The oxygen index represents the minimum level of oxygen in the atmosphere which can sustain flame on a thermoplastic material.
The test atmosphere is an externally controlled mixture of nitrogen and oxygen with a pilot flame, which is then removed. In successive test runs, the oxygen concentration is reduced to a point where the sample can no longer support combustion. Limiting Oxygen Index or LOI is defined as the minimum oxygen concentration in which the material will burn for three minutes, or can keep the sample burning over a distance of 50 mm. The higher the LOI value, the less the likelihood of combustion.

Table 22: Limiting Oxygen Index

Lexan	Lexan FR	Valox	Ultem
25	33	30	47

UL94 flammability in general

The most widely accepted flammability performance standards for plastic materials are UL94 ratings. These are intended to identify a material's ability to extinguish a flame, once ignited. Several ratings can be applied based on the rate of burning, time to extinguish, ability to resist dripping, and on whether the drips are burning. Each material tested may receive several ratings based on color and/or thickness. When specifying a material for an application, the UL rating should be applicable for the thinnest wall section in the plastic part. The UL rating should always be reported with the thickness: just reporting the UL rating without mentioning thickness is insufficient.

Summary of the UL94 rating categories

HB- slow burning on a horizontal specimen

burning rate < 76 mm/min for thickness < 3 mm

burning rate < 38 mm/min for thickness > 3 mm

V-0- burning stops within 10 seconds on a vertical specimen; no drips allowed

V-1-burning stops within 30 seconds on a vertical specimen; no drips allowed

V-2- burning stops within 30 seconds on a vertical specimen; drips of flaming particles are allowed

5V-burning stops within 60 seconds after five applications of a flame - larger than used in V-testing - for 5 seconds on a test bar.

5VA- plaque specimens may not have a burn-through (no hole) - highest UL rating

5VB- plaque specimens may have a burn-through (have a hole);

VTM-0- this rating category applies to very thin gauge materials. A cylindrical test specimen is used instead of a test bar. The burning and dripping requirements are comparable to the V test.

Table 23:

Material	Color	Thickness (mm)	UL94 Flame Rating*
Ultem 1000	NC	0.025	VTM-0
Valox FR 1	nc	0.08	VTM-2
	nc	0.127-0.51	VTM-0
Lexan FR 6/7	cl	0.05	VTM-0
	cl/bk	0.13	VTM-0
	cl	0.25	V-0

** Not tested, generic value

UL94HB

Where flammability is a safety requirement, HB rated materials are normally not permitted. In general, HB classified materials are not recommended for electrical applications except for mechanical and/or decorative purposes. For applications such as plug housings, requiring a high CTI, HB classified materials can be used.

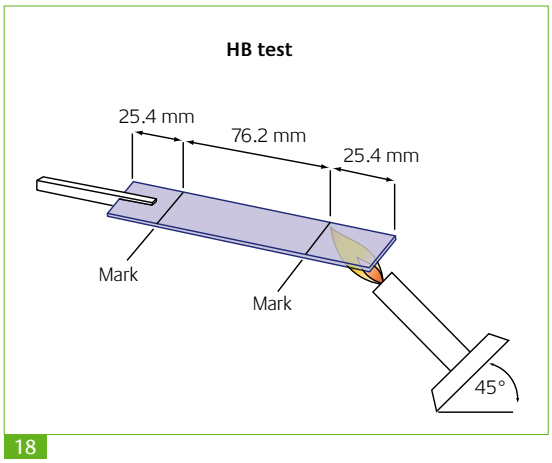
It should be stressed that non-FR materials, (or materials that are not meant to be FR materials), do not automatically meet HB requirements. Although the least severe, UL94HB is a flammability classification and has to be checked by testing.

UL94V-0, V-1 and V-2

The vertical tests take the same specimens as are used for the HB test. Burning times, glowing times and, when dripping occurs, whether or not the cotton beneath ignites, are all noted. Flaming drips - widely recognised as a main source for the spread of fire or flames - distinguishes V-1 from V-2.

18. xxx

19. xxx



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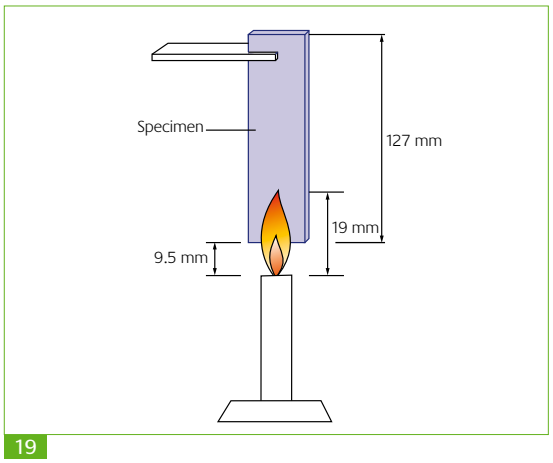

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Printing

Lexan polycarbonate film can be first (front) surface printed and, due to its excellent clarity at any gauge, it is also ideal for second-surface printing. Most inks adhere well to Lexan film without pretreatment or print coat which many other plastic films require. Many printing techniques can be applied to Lexan films including screenprinting, digital printing, sublimation printing, offset printing, and flexographic printing.

Many inks contain aggressive organic solvents that promote adhesion to the film but may contribute to film failure if not removed before further fabrication. Therefore it is suggested to thoroughly dry all inks after printing (preferably at elevated temperatures) to remove all solvents.

Tables 24 through 31 list manufacturers by ink system who carry products those manufacturers recommend for use on Lexan polycarbonate film. This list is by no means all-inclusive and could be subjected to change resulting, for example, from changes in ink formulation by the ink manufacturers. Particular care should be taken in case the Lexan film is to be stressed or bent after printing. In all cases it is recommended to perform end-use testing to determine compatibility with all materials in the system.

Printing Tips

a. Use static eliminators to facilitate sheet handling and reduce dust attraction. (www.stopstatic.com)
b. Keep the printing press and area free of dust and smoke.
c. Web processing - refer to Section, Mechanical Properties, for web stretch information.
d. Drive off solvents as soon as possible. Lexan film can be safely dried at temperatures up to 250°F (120°C)
e. Make sure UV inks are formulated to cure completely according to your requirement.
f. Follow guide-lines for offset printing on synthetic materials; i.e. with low-solvent inks or thin ink film, increase alcohol content of dampening solution, use short lifts to prevent set-off, etc.
g. Work with SABIC Innovative Plastics Specialty Film and Sheet, your film converter, and ink supplier for best results.

Printing Inks Compatible with Lexan Film (as of 2009)

Table 24: Physical Solvent Drying Systems

Manufacturers	
Akzo Nobel Coatings Inc.	www.akzonobel.com
Coates / SunChemical	www.sunchemical.com
JUJO Chemical Co., Ltd.	www.jujo-chemical.co.jp
Seiko Advance Ltd.	www.seikoadvance.co.jp
Teikoku Printing Inks Mfg. Co., Ltd.	www.teikokuink.com www.teikokuink.com/en
Naz-Dar Corporation	www.nazdar.com
Visprox B.V.	www.visprox.com
RUCO Druckfarben	www.ruco.de
ECKART	www.eckart.net.html
Pröll KG	www.proell.de
Sericol Limited	www.sericol.com
Marabuwerke GmbH & Co.	www.marabuwerke.de www.marabu.com

Table 25: Conductive Inks

Manufacturers	
Acheson	www.achesonindustries.com www.achesonelectronicmaterials.com

Table 26: UV Curing Systems

Manufacturers	
Coates / SunChemical	www.sunchemical.com /products.aspx
ECKART	www.eckart.net.html
Visprox B.V.	www.visprox.com
Sericol Limited	www.sericol.com
Polymeric Imaging Inc.	www.polymericimaging.com/2/
Marabuwerke GmbH & Co.	www.marabuwerke.de www.marabu.com/
RUCO Druckfarben	www.ruco.de/
Nor-Cote UK Limited	www.norcote.com/

Table 27: Screen Print / Spray Protective Masking
Use a 1.5 to 2 mil (37 to 50 micron) thickness for ease of removal. Apply over textures prior to forming to limit the increase in gloss

Manufacturers	
Kiwo	www.kiwo.com
Spraylat	www.spraylat.com/home.aspx

Table 28: Coatings and Clear Varnish for Abrasion/Chem Resistance

Manufacturers	
Ernst Diegel GmbH	www.diegel.de/
ECKART	www.eckart.net.html

Table 29: Offset Printing Inks

Manufacturers	
Eastern Marking Machine	www.easternmarking.com/consumables.html#inks

Table 30: Flexographic/Letterpress/Gravure Inks

Manufacturers	
ECKART	www.eckart.net.html
Sicpa Sinclair	www.sicpa.com
Del-Val Ink & Color	www.dvink.com
Custom Printing Inks	www.customprintinginks.com

Table 31: Sublimation Inks

Manufacturers	
Gans Inks	www.gansink.com
Apollo Colors	www.apollocolors.com
Naz-Dar Corporation	www.nazdar.com

Inks for 2nd Surface In Mold Decoration (IMD)

Lexan polycarbonate film can be used in the In Mold Decoration (IMD) process. If the inks will be 1st surface printed then the ink systems found in tables 24 through 30 may be suitable if they meet the durability requirements for the application. If the part will be a second surface IMD application then the ink will become sandwiched between the injection molded resin and the film that the ink is printed on. In this instance the inks must be able to withstand the high thermal and mechanical shear of the injected resin. Table 32 lists ink systems that have been found to be compatible with 2nd Surface IMD.
Learn more about IMD at www.sabic-ip.com/imd.

Table 32: Inks compatible with 2nd surface In Mold Decoration

Manufacturers	Products
Coates / SunChemical www.sunchemical.com	Decomold Ultrabond DMU *** only UV ink system that works without binders
JUJO Chemical Co., Ltd. www.jujo-chemical.co.jp	3300 Series 3200 Series w/ G2S binder
Marabuwerke GmbH & Co. www.marabuwerke.de/ www.marabu.com/	Maramold MPC
Naz-Dar Corporation www.nazdar.com	9600 8400
Nor-Cote UK Limited www.norcote.com/	MSK w/ Seiko binders MSK w/ Proell Aquapress binder
Pröll KG www.proell.de	N2K Noriphan HTR M1 and M2 mirror inks
Seiko Advance Ltd. www.seikoadvance.co.jp/	KKS Super Slow Dry AKE (N) w/ N3A, JT10, or JT20 binder
Teikoku Printing Inks Mfg. Co., Ltd. www.teikokuink.com www.teikokuink.com/en	IPX series w/ IMB 003 binder

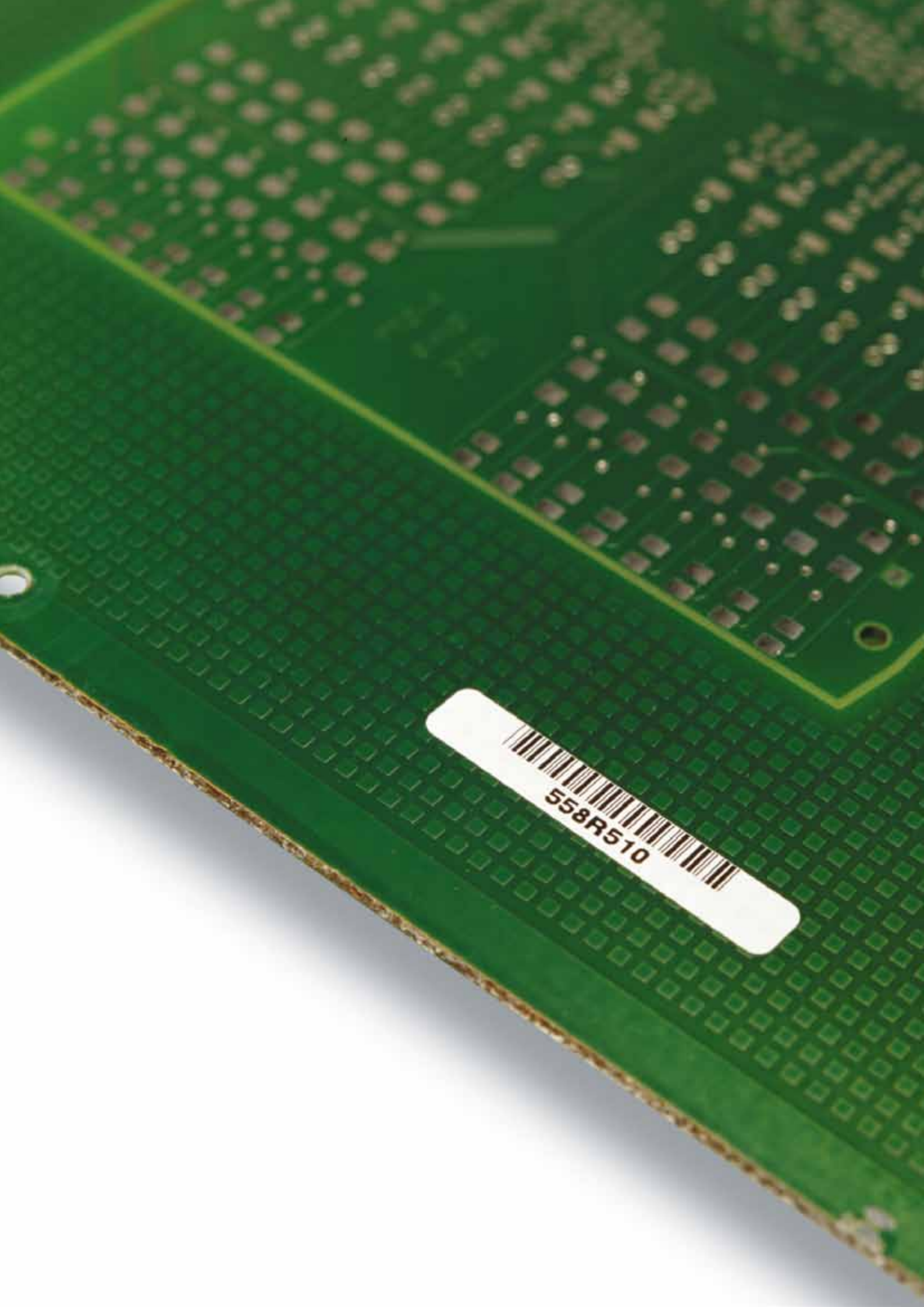
Digital Printing

Lexan polycarbonate film is compatible with digital printing and in many instances can be printed on directly with the digital printing machine without a print receptive pre-treatment. Piezo-head technology is the most popular technology and has been found to be the most compatible with Lexan film. It enables hot-melt inks to be used which solidifies immediately upon contact with the Lexan substrate. The figure below shows a schematic of this technology.

Table 33 lists several companies that manufacture UV ink jet or solvent ink jet printing equipment capable of direct printing on Lexan film. These suppliers offer flat bed and/or roll fed options. Conditions for direct printing on Lexan film will vary from one printer to the next so inquire with the equipment manufacturer about conditions and work with your Sabic-IP representative to trial some Lexan with the equipment manufacturer.

Table 33: Digital Ink Jet Printing Equipment Suppliers

Supplier	
Vutek Inc.	www.vutek.com
Oce	www.oce.com
Inca	www.incadigital.com
Roland	www.rolanddga.com
Mimaki	www.mimakiusa.com
Mutoh	www.mutoh.com
Lotte	www.lotte.co.jp/english/index.html
Gandinnovations	www.gandinnovations.com
HP Scitex Industrial Printers	www.hp.com
Mimaki	www.mimakiusa.com
Durst	www.durstus.com
Inca	www.incadigital.com
Epson	www.epson.com
AGFA	www.agfa.com
Dupont Cromaprint	www.dupont.com
Anhui Liyu	www.ahliyu.com
Digirex	www.digirexdigital.com
Flora	www.floradigital.com
Gerber Scientific Products	www.gspinc.com
Infiniti	www.infinitidigitech.com
Luscher	www.luescher.com
Neolt	www.neolt.it
SkyJet	www.skyair-ship.com
Teckwin	www.teckwin.com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Bonding

Many different adhesive systems, as well as heat sealing, can be used with SABIC Innovative Plastics Specialty Film and Sheet's film. The choice of adhesives will be dictated by the specific application.

Amorphous materials like Lexan and Ultem are easier to bond because of their limited chemical resistance. The solvents in the adhesives make the surface swell and dissolve, resulting in good adhesion. A drawback is the sensitivity of amorphous materials to environmental stress cracking. It takes time for evaporation of solvents or water, in the case of water-based adhesives. This curing process increases the cycle time and limits the handling of components after bonding. The adhesive type primarily determines the characteristics of an assembly. (Table 34)

Table 35 lists a number of adhesive suppliers with adhesives that are compatible with Lexan film. The list is not all-inclusive, and testing is recommended prior to use. Note that some adhesives may have an adverse effect on some inks used on Lexan film.

Table 34: Adhesive Types and Characteristics

Type-Function	Adhesive	Curing	Characteristics
Structural (gap filling)	Epoxies	A+B comp.	chem./moist./heat/creep resist.,
		chemical reaction	stiffness, brittle, low impact
	Polyurethanes	A+B comp.	ductile, flexible, impact, creep, high peel strength
		chemical reaction	
Sealants (gap filling)	Polyurethanes	chemical reaction	ductile, flexible, impact, creep, high peel strength
		moisture	
	Silicones	chemical reaction	impact, flexible, heat resistance, low shear
		moisture	
Contact (not filling)	Polyurethanes	chemical reaction	see above to Polyurethanes
	Cyano acrylates	chemical reaction	fast curing, high peel strength,
		humidity	chem. aggressive, moisture sensitive
Hot melts	EVA	temperature	fast adhesion, low temp. resistance
		chemical reaction	
Solvents (not filling)	MeC12. M.E.K.	physical	easy application, high strength,
	Toluene	evaporation	stress cracking, polluting, toxic

Table 35: Manufacturers with Adhesives Compatible with SABIC Innovative Plastics Specialty Film and Sheetfilm

Manufacturer	Product	
Pressure Sensitive Transfer Adhesives		
3M		www.3m.com
Avery Dennison		www.averydennison.com
Dielectric Polymers		www.dipoly.com
Flexcon		www.flexcon.com/index-flash.htm
Scapa		www.scapaeurope.com www.scapaasia.com www.scapana.com
Mac Tac		www.mactac.com
Henkel		www.henkel.com www.nationaladh.com/Adhesives/
Sun Process		http://sunprocess.com
H.B. Fuller Company		www.hbfuller.com/
One and Two-Part Epoxies/Urethanes		
Henkel		www.henkel.com www.nationaladh.com/Adhesives/
Huntsman		www.huntsman.com/
Rohm & Haas		www.rohmhaas.com
H.B. Fuller Company		www.hbfuller.com/
Hotmelt Adhesives		
3M		www.3m.com
Henkel		www.henkel.com
		www.nationaladh.com/Adhesives/
H.B. Fuller Company		www.hbfuller.com/
Contact Cements		
3M		www.3m.com
Solvent Adhesives		
Local chemical and warehouses distributors	Dichloromethane methylene chloride) Caution: lowers impact	
IMD Adhesion Promoters		
SunChemical	Aqualam	www.sunchemical.com/products.aspx
Seiko Advance	N3A, JT10, JT20	www.seikoadvance.co.jp/
Pröll KG	Aquapress	www.proell.de

Table 36: Overview of assembly techniques for SABIC Innovative Plastics Specialty Film and Sheet's films

Material	Welding	Adhesives	Mechanical Assembly
Lexan	Vibration, Ultrasonic, Induction possible	Generally easy, critical are Cyanoacrylate and Acrylic because of stress cracking	Avoid high stresses at point loadings
Ultem	Vibration, Ultrasonic, Induction possible	Epoxy, PUR(2K), Silicones possible, Acrylic, Cyanoacrylate critical because of stress cracking	All techniques possible
Valox	Vibration, Ultrasonic, Induction possible	Epoxy, PUR, Silicones, Cyanoacrylate possible	All techniques possible Prevent creep

Heat Sealing

Three methods are satisfactory for heat sealing Lexan films: impulse, jaw, and ultrasonic sealing. Preliminary testing indicates that the ultrasonic technique is the most reliable, producing peel strengths of 8.6 lbf per inch (38 N per 25 mm) of width. Speeds for this method range from 6 in/s (150 mm/s) with 0.003 inch (0.075 mm) film to 1.2 in/s (30 mm/s) for 0.020 inch (0.500 mm) film.

Impulse and jaw methods produce bonds ranging from 3-14 lbf per inch (13-62 N per 25mm) of width. As shown in Table 37, the impulse method is more rapid, particularly with the thinner gauges. It should be noted that these times were obtained on laboratory equipment with only single jaw heating. Times on actual production equipment running at normal operating temperatures would be much faster.

Table 37: Sealing Time (Seconds)

Method	Thickness (inch (mm))		
	0.001 (0.025)	0.003 (0.075)	0.005 (0.125)
Impulse	2.5	3.5	4.5
Jaw	7	8	9

Jaw sealing requires temperatures of 400°F (205°C) for 0.001 inch (0.025 mm) film and 430°F (220°C) for the two thicker films. Dielectric sealing is not practical with common commercial equipment because of Lexan films' low dissipation factor.

Cleaning

Periodic cleaning using correct procedures can help to prolong service life. For cleaning, it is recommended that the following instructions be adhered to:

Cleaning Procedure for Small Areas - Manual

1. Gently wash film with a solution of mild soap and lukewarm water, using a soft, grit-free cloth or sponge to loosen any dirt or grime.
2. Fresh paint/ink splashes, grease and smeared glazing compounds can be removed easily before drying by rubbing lightly with a soft cloth using petroleum ether (BP65°), hexane or heptane. Afterwards, wash the sheet using mild soap and lukewarm water.
3. Scratches and minor abrasions can be minimized by using a mild automobile polish. We suggest that a test be made on a small area of Lexan film with the polish selected and that the polish manufacturer's instructions be followed, prior to using the polish on the entire sheet of film.
4. Finally, thoroughly rinse with clean water to remove any cleaner residue and dry the surface with a soft cloth to prevent water spotting.

Cleaning Procedure for Large Areas - Automated

1. Clean the surface using a high-pressure water cleaner (max. 100bar or 1,450psi) and/or a steam cleaner. We suggest that a test be made on a small area, prior to cleaning the entire sheet of film.
2. Use of additives to the water and/or steam should be avoided.

Other Important Instructions for All Specialty Film and Sheet Films:

- Never use abrasive or highly alkaline cleaner on Specialty Film and Sheet film materials.
- Never use aromatic or halogenated solvents like toluene, benzene, gasoline, acetone or carbon tetrachloride on Specialty Film and Sheet film materials.
- Use of incompatible cleaning materials with Specialty Film and Sheet film materials can cause structural and/or surface damage.
- Contact with harsh solvents such as methyl ethyl ketone (MEK) or hydrochloric acid can result in surface degradation and possible crazing of Specialty Film and Sheet film materials.
- Never scrub with brushes, steel wool or other abrasive materials.
- Never use squeegees, razorblades or other sharp instruments to remove deposits or spots.
- Do not clean Specialty Film and Sheet film materials in direct sunlight or at high temperatures as this can lead to staining.
- For all mentioned chemicals consult the manufacturer's material safety datasheet (MSDS) for proper safety precautions.

Static Control

Air ionization, liquid treatments and special cleaners are used for static control with SABIC Innovative Plastics Specialty Film and Sheet's films.
A partial listing of suppliers can be found below.

Static Control and Web Cleaners for Lexan Film

Alpha Innovation, Inc	www.stopstatic.com
ElectroStatics, Inc	www.electrostatics.com
NRD	www.nrdstaticcontrol.com
Polymag	www.polymagtek.com
Simco	www.simco-static.com
Teknek	www.teknek.com
R.G. Egan	www.rgegan.com

Die Cutting

SABIC Innovative Plastics Specialty Film and Sheetfilms can be die cut with either steel rule, matched metal and, to a lesser extent, rotary dies. Lexan's shear strength of 10,000 psi (70 N/mm^2), relatively low in comparison to metals, simplifies and eases tool design and processing. In addition, parts may be cut from single or multiple sheets depending on press tonnage, working area and material thickness.

The press tonnage required to die cut Lexan film can be determined by the simple formula:

$$F = \frac{(P)\ (A)}{9807\ \text{N/metric ton}} \qquad F = \frac{\{P\}\ \{A\}}{2000\ \text{lb/ton}}$$

F = press tonnage
P = shear strength of Lexan film
A = cross-sectional area

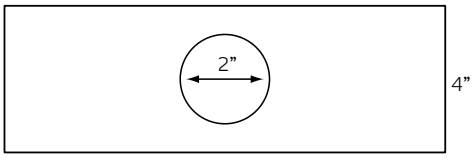
The cross-sectional or shear area can be found by multiplying the total length of the cut by the film thick-ness. For example: (Note: SI and metric examples are not equal)

Figure 20 shows a 4" x 10" rectangle with a 2" diameter circular cutout in the center.

Figure 21 shows a 100 x 300 mm rectangle with a 50 mm diameter circular cutout in the center.

20. (SI)

21. (metric)



Total length of cut = 2L + 2W + πD
= 2 (4") + 2(10") + π(2")
= 8" + 20" + 6.28"
= 34.28"

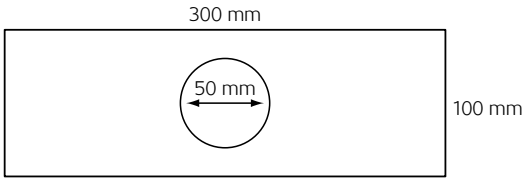
Shear Area = total length x thickness of film
= 34.28" x 0.010"
= 0.343 in^2

Press tonnage

$$F = \frac{(P)\ (A)}{2000} = \frac{(10{,}000\ \text{lb/in}^2)\ (0.343\ \text{in}^2)}{2000\ \text{lb/ton}}$$

F = 1.72 ton

20



Total length of cut = 2L + 2W + π D
= (2) (300 mm)
+ (2) (100 mm) + π (50 mm)
= 600 mm + 200 mm + 157 mm
= 957 mm

Shear area = (total length) x (thickness of film)
= 957 mm x 0.250 mm
= 239.25 mm^2

Press tonnage

$$F = \frac{(P)(A)}{9807} = \frac{70\ \text{N/mm}^2 \times 239.25\ \text{mm}^2}{9807\ \text{N/metric ton}} = 1.7\ \text{metric ton}$$

21

Of the three die cutting methods described earlier, steel rule die cutting is the most popular and least expensive method used. Generally, a 2-point rule (0.0275 inch or 0.7 mm thick) is used to cut SABIC Innovative Plastics Specialty Film and Sheet films up to 0.015 inch or 0.375 mm thick, whereas a 3-point rule (0.04 inch or 1.0 mm thick) is used for films greater than 0.015 inch or 0.375 mm in thickness. When careful make-ready is applied, over 25,000 cuts can be obtained from a steel rule die.

Steel rule dies are manufactured by two different methods: laser and jig. The laser cut die will maintain the most accurate dimensional tolerances (to ± 0.004 in or 0.1 mm), while the jig cut die will provide the least (± 0.016 in or 0.4 mm). In manufacturing a die, a steel rule is fitted into a pre-cut pattern in a wooden die board. Stripping rubber on each side of the rule eases part ejection. Generally, stripping rubber should be no more than 0.12 in (3 mm) above the height of the rule. Figure 22 illustrates a typical steel rule die.

Several different steel rule bevel designs are available, as illustrated in Figure 23.

Although the centre bevel rule is the most common and provides the longest life in terms of wear, cleaner cuts can be attained by using a facet bevel rule.
The longer bevel reduces material displacement, especially with thick material, while the broad tip remains sharp. The flush bevel rule also provides clean cuts, but has a weak tip that is susceptible to roll-over. To maximise both cut quality and rule longevity, the side bevel rule is recommended.
In this case the long bevel side should face the scrap or trim of the piece.

Depending on rule design, size and shape of part and thickness of film, the cut parts will be slightly different in size than the rule: holes will be smaller and cut outs will be larger. Therefore, dies are usually manufactured on either end of the tolerance range. For example, dies to cut holes are made slightly larger than the part size indicated on the print.

SABIC Innovative Plastics Specialty Film and Sheet films can be successfully "kiss cut" with platen presses having close tolerance impression adjustment controls. In kiss cutting, a side bevel is recommended in the die design. The problem of cutting through both the printed SABIC Innovative Plastics Specialty Film and Sheet films and transfer tape or liner can be solved by using a heavier or thicker liner.
For instance, using a 0.006 in. (0.15 mm) liner (3M, 9668) versus a 0.004 in. (0.10 mm) liner (3M 468) will provide a flatter piece and cushion the impact of the steel rule. Obviously the thicker liner will be more difficult to cut through completely, and so the kiss-cutting problem will be reduced.

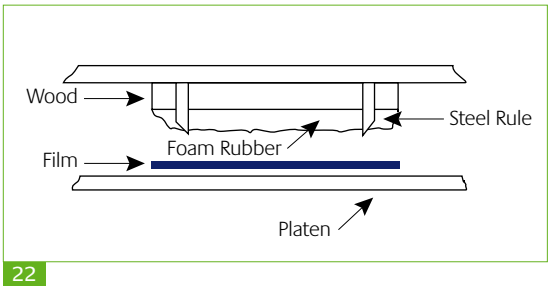
Finally, two other methods are used to die cut SABIC Innovative Plastics Specialty Film and Sheet films; matched metal and rotary. Matched metal dies consist of hardened male and female die halves. Match metal die cutting operates by shearing the film and is used to cut intricate patterns, to maintain tight dimensional tolerances (± 0.001 in. or 0.025 mm), and to cut thicker films on larger volume production runs (100,000+). Clearance between dies should be less than 0.001 inch or 0.025 mm.

In roll-to-roll film processing (i.e. flexographic printing), rotary dies can be used for cutting
SABIC Innovative Plastics Specialty Film and Sheet films. This process offers a high-speed production capability versus steel rule and matched metal die cutting.

Table 38 is a partial list of diemakers for SABIC Innovative Plastics Specialty Film and Sheet films.

Table 38: Diemakers for SABIC Innovative Plastics Specialty Film and Sheet Films

Marbach Werkzeugbau GmbH	www.marbach.com
A&H Formes Ltd.	www.ah-formes.co.uk
Millennium Die Group	www.millenniumdie.com
Atlas Die, LLC	www.atlasdie.com
Independent Die Service	www.wsids.com



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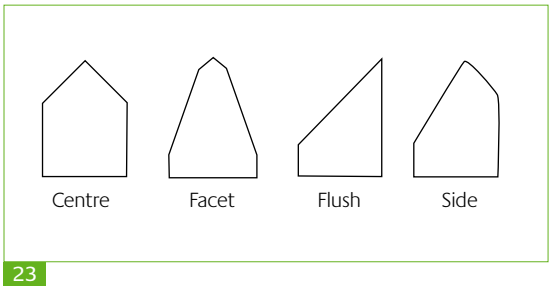

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22. Steel Rule Die

23. Bevel Designs

Embossing

SABIC Innovative Plastics Specialty Film and Sheet films can be embossed to form raised areas for membrane switch keys, or raised letters and design. Thicknesses up to 0.01 in. (0.250 mm) can be readily embossed, and films up to 0.02 in (0.500 mm) can be embossed in certain configurations.

For films over 0.02 in (0.500 mm) thick, thermoforming should be used to create three-dimensional effects. Embossing raised areas for membrane switch keys may significantly decrease switch life. Since switch size and travel, film thickness, embossed height and working environment can all be factors, product life cycle testing is strongly recommended.

A wide variety of embossed configurations is possible with SABIC Innovative Plastics Specialty Film and Sheet-films, as shown in Figure 24.

Die Design

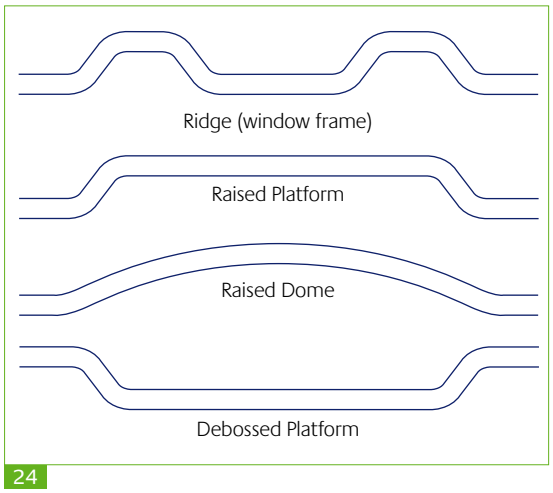
Dies for embossing can be matched male/female or either male or female with a rubber counter die. Materials include metals such as zinc, magnesium, brass, aluminium and steel, as well as polyester/fibreglass and silicone rubber. Sharp detail usually requires the use of metal dies.
Dies should be designed so the clearance between the male and female sides is approximately equal to the film thickness. Minimum draft angles of 3° should be designed into both male and female walls, as shown in Figure 25.

To keep localised stresses in the embossed overlay to a minimum, embossing dies should contain no sharp corners at points in contact with Lexan film. Radii at all internal corners will reduce stress concentration and help prevent failure from fatigue or impact. As a rule of thumb, radii should be equal to, or greater than, the thickness of the film. In other words, a 0.01 in. (0.250 mm) thick Lexan film should contain a 0.01 in. (0.250 mm) minimum radius at any corner (Figure 26).

Heated platens with temperatures as high as 290 F (143 C) may also be used to reduce stresses from embossing and to obtain more emboss detail.

Embossing Press

Several types of press can be used to emboss SABIC Innovative Plastics Specialty Film and Sheet films. The most popular of these is the platen press, which also can be used in steel rule die cutting.



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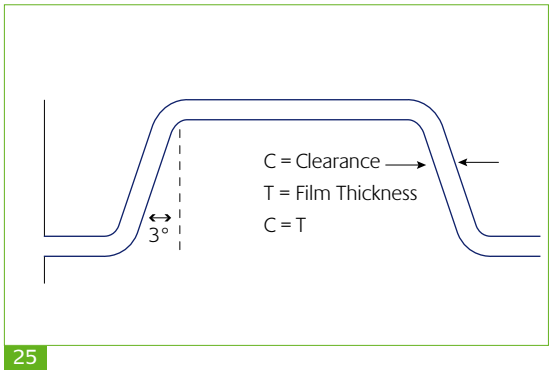

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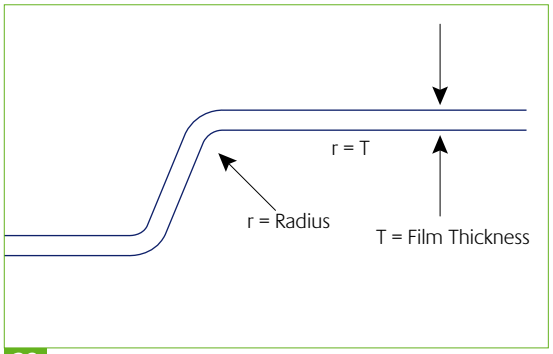

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Part Design

The following design recommendations for embossed parts will help to minimise stress and maximise key life in membrane switch applications.

a. **Embossed Width**
The width of ridge-type embossing should be equal to, or greater than, five times the film thickness. If adhesive and liner are not zoned away from the embossed area, their thickness must be added to the film thickness when determining width (Figure 27).

b. **Embossed Height**
The height of an embossed area should be no greater than 2.5 times the material thickness (excluding adhesive and liner), with material thickness included in the measurement (Figure 28). Greater embossed heights can be attained, but are not recommended for membrane switch keys.

c. **Embossed Spacing**
Spacing between embossed areas should not be less than 0.06 in. (1.5 mm) to minimise distortion of the sheet after embossing (Figure 29)

d. **Inks/Adhesives**
Inks used on SABIC Innovative Plastics Specialty Film and Sheetfilm that is to be embossed should be compatible with the material and also somewhat flexible. The ink coating will be stretched and bent, and may fracture slightly. This is an important consideration in back-lit applications, and may require special handling by the printer.

Adhesives should be zoned away from the embossed area wherever possible to facilitate embossing. If adhesive is required in the embossed area, it should be carried on a polyethylene liner instead of on paper.

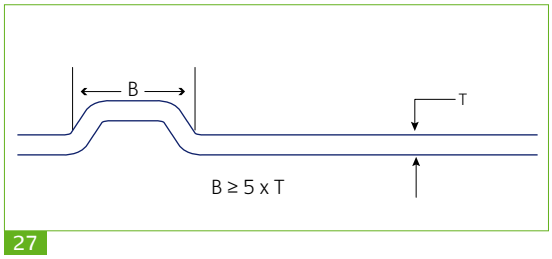
Thermoforming

Lexan film's high melt strength makes it ideal for thermoforming. Recommended forming techniques are pressure forming and vacuum forming, with or without plug-assist over female molds, along with drape-forming over male molds. The following guide-lines should be followed for successful forming.

27. xxx

28. xxx

29. xxx



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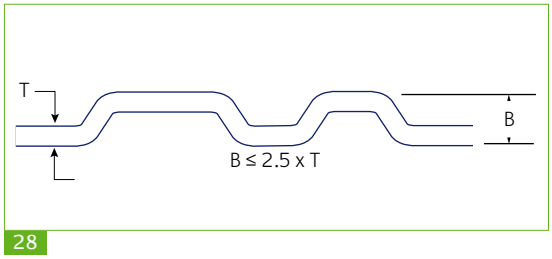

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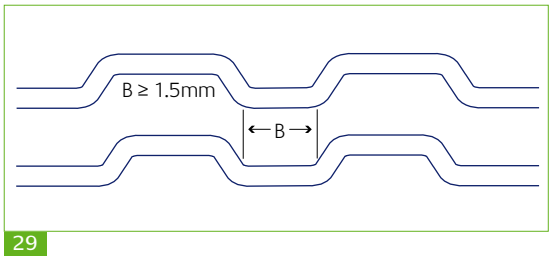

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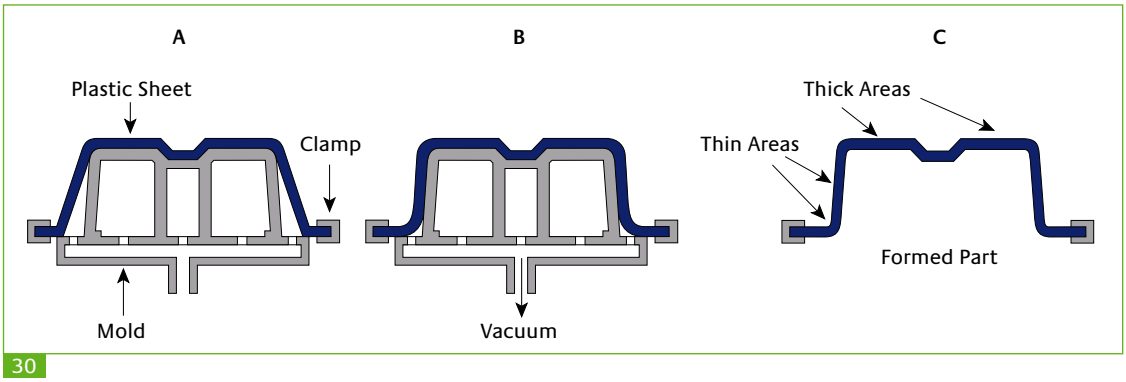
Mold Design

Male molds as shown in Figure 30 are preferred for deep draws and interior detail appearance parts. Good material uniformity can be maintained in depth of draw ratios between 1:1 and 2:1. A draft of 3-5 degrees per side and a micro roughening surface finish gives easy parting from the male mold and will avoid air entrapment.

Female molds like the example shown in Figure 31 are recommended when exterior detail is important. Unless plug-assisted or mechanically formed, parts made on female molds will generally be limited to a maximum depth: draw ratio of 1:4 with a draft of between 2-3 degrees per side.

Because of the high tensile strength of Sabic Innovative Plastics Specialty Film and Sheet film undercuts will be troublesome when forming film 0.02 in. (0.500 mm) and 0.03 in. (0.750 mm) thick. If they cannot be avoided, split molds with sliding sections solve the problem of removing the part after forming. Figure 32 shows an example of a tool with a cam as well as a removable insert that allows for an undercut.

Recommended tooling materials are steel and cast aluminium for attractive, durable surface finishes, maintenance of close tolerances, and rapid heating and cooling. Materials such as silicone, hardwood, fibreglass, melamine and phenolic are only for prototype or limited-production work.



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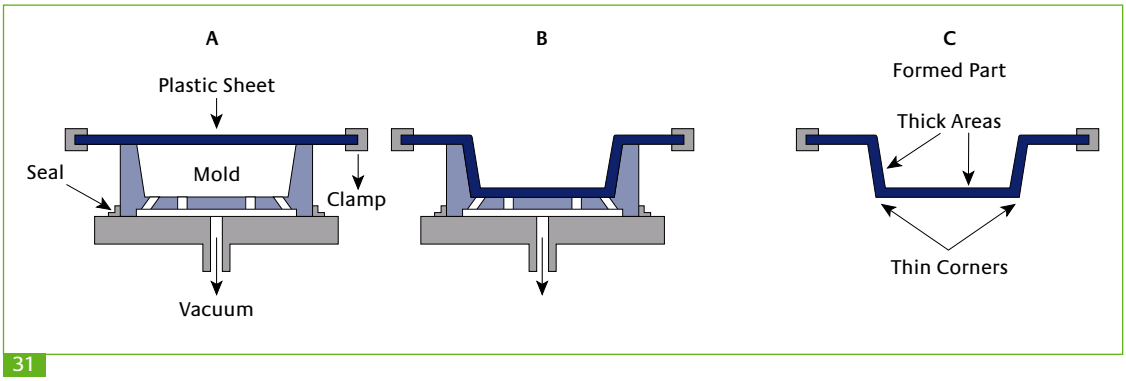
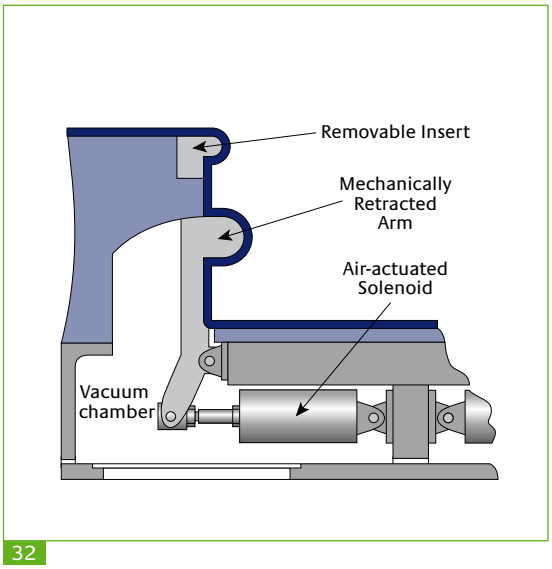
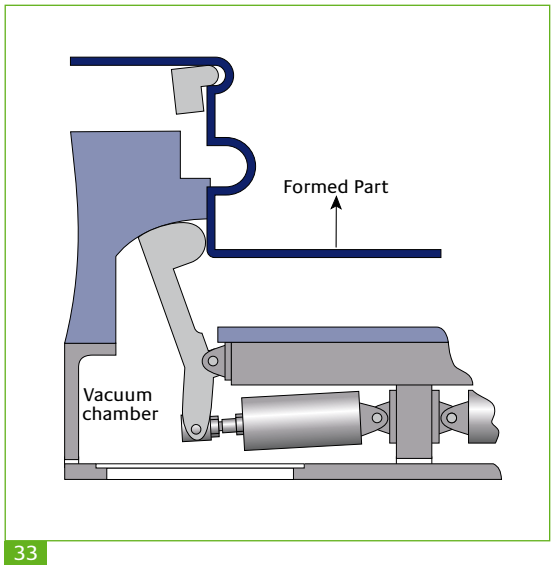


31



32

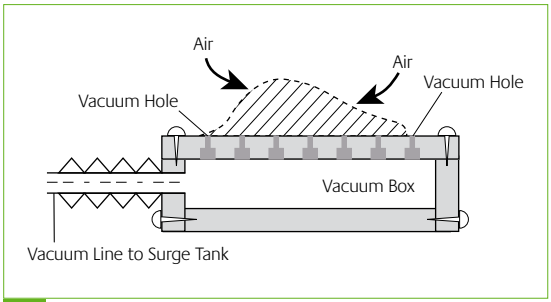


33

Vacuum holes of 0.02 in. (0.50 mm) diameter and/or shims that supply adequate vacuum flow are recommended for male and female molds. Where fine detail is required, vacuum holes should be spaced as close as 0.25 in. (6.4 mm). On large flat surfaces, 1 to 3 inches (25 to 75 mm) spacing is adequate. Back drilling with larger drills (i.e. > 0.25 in. or 6 mm) is suggested to speed up evacuation.

Mold Temperature

Optimal forming of SABIC Innovative Plastics Specialty Film and Sheetfilms requires heated molds. Mold heating can facilitate making deep-drawn parts with plug-assist, producing superior surface quality and minimised formed-in stresses. Mold temperature affects the appearance of the formed part, length of the forming cycle and size of the finished part. Minimum mold temperatures of 194°F (90°C) are recommended, 248-257°F (120-125°C) when appearance is critical. Oil and electrical systems are recommended for mold heating when forming SABIC Innovative Plastics Specialty Film and Sheet film.



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Drying

Despite the low moisture absorption (0.35%), which contributes to the excellent dimensional stability of SABIC Innovative Plastics Specialty Film and Sheetfilm parts, drying of film stock is essential. A circulating oven set at 257°F (125°C) is recommended for drying sheeted film stock. Residence times are indicated in Table 39.

Table 39: Drying Time for Sheeted Lexan Film at 257°F (125°C)

Gauge in. (mm)	Time (min.)
0.01 (0.250)	15
0.015 – 0.02 (0.375-0.500)	20
0.02 – 0.03 (0.500-0.750)	30

Web-fed forming of SABIC Innovative Plastics Specialty Film and Sheetfilm rollstock up to 0.03 in. (0.750 mm) may be accomplished without pre-drying. Care must be taken to allow the film to reach forming temperature gradually to avoid bubbling in the web. Sandwich style heating units are recommended to be four times the length of the forming station dimension (i.e. 12 in. tool = 48in tunnel or a 300 mm tool = 1200 mm tunnel).

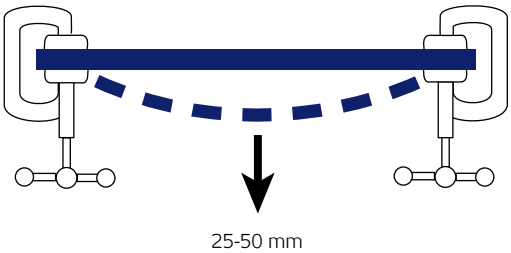
Forming Temperatures

Normal processing temperatures for SABIC Innovative Plastics Specialty Film and Sheetfilm range between 374 - 410°F (190-210°C). For optimal gauge versus temperature parameters see Table 40.

Table 40: Gauge Versus Forming Temperature

Gauge in. (mm)	Temperature °F (°C)
0.01 (0.250)	374 - 383 (190 - 195)
0.02 (0.500)	383 - 392 (195 - 200)
0.03 (0.750)	392 - 410 (200 - 210)

Sandwich heaters (top and bottom) are preferable so that both sides of the film can be heated simultaneously. See Figure 34 for optimum sag appearance. This recommendation avoids overheating one side and underheating the other which might create strains and stresses, excessive sag and degradation of material on the heater side.



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34. Forming Tool with Undercuts

35. Optimum Appearance Sag

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