Chapter 60

Polysulfone

General Discussion of Joining Techniques

Amoco Performance Products: Udel (features: transparent, amber tint)

There are many parameters associated with the successful use of the various joining methods for polysulfone. Once the procedure is established for using one of these techniques, the joined parts should be checked periodically to be sure a desirable residual stress level exists.

To optimize the performance of fabricated polysulfone parts, particularly with respect to impact and stress crack resistance, it is recommended that the internal stresses developed during molding, extrusion, forming, joining, etc. be kept to below 1,200 psi (8.3 MPa). The relative amount of residual stress in a part can be estimated by allowing the part to contact a series of solvents that vary in their activity towards polysulfone. These are shown with the corresponding approximate residual stress levels in the table. The approximate level of stress in a polysulfone item is determined as follows. Contact the item with Carbitol Solvent (by immersion or swabbing) for one minute and examine the item. If it is crazed, the residual stress level is 1,800 psi (12.4 MPa) or greater. If it is not crazed, the residual stress is less than 1,800 psi (12.4 MPa). Proceed down the table in similar fashion to find that solvent that induces crazing in one minute. The stress level in the item being tested lies between the stress corresponding to the craze-inducing solvent and the one immediately above it in the table.

It is important to remember that stress can be induced during fabrication, forming, assembly or use and that all such stress can be additive. Thus, to maximize the stress bearing ability of the finished item, stresses arising from other sources should be kept to a minimum.

Table 60.1: Approximate residual stress in polysulfone at a contact time of 1 minute

Solvent	Approximate Residual Stress, psi (MPa)
Carbitol Solvent	1,800 (12.4)
Butyl Cellosolve	1,400 (9.7)
Cellosolve Solvent	1,200 (8.3)
1,1,1-Trichloroethane	600 (4.1)
Ethyl Acetate	<200 (<1.4)
Cellosolve Acetate	<200 (<1.4)

Reference: *Udel Polysulfone Design Engineering Handbook,* supplier design guide (F-47178) - Amoco Performance Products, Inc., 1988.

BASF AG: Ultrason S (features: transparent, amber tint)

Unbreakable connections between Ultrason moldings can be formed by the various welding techniques. Adhesives are resorted to for effecting firm bonds between Ultrason and other materials. Other means of forging unbreakable connections are riveting and beading.

Detachable bonds can be formed by snap-on connectors, screws, and bolts. The threads may be formed during the molding process or may assume the form of metal inserts that are subsequently fixed, e.g. by ultrasonic techniques, in recesses provided for them in the moldings.

Reference: *Ultrason E, Ultrason S Product Line, Properties, Processing,* supplier design guide (B 602 e/10.92) - BASF Aktiengesellschaft, 1992.

Welding

BASF AG: Ultrason S

Ultrason S moldings can be welded together by ultrasonic techniques, which may also be adopted for countersinking metal parts.

Reference: *Ultrason S Resins,* supplier technical report (81527 (8106)) - BASF, 1988.

BASF AG: Ultrason S (features: transparent, amber tint)

The conventional welding techniques adopted for thermoplastics are suitable for the various Ultrason products. The only exception is high-frequency welding, which is unsuitable for thermoplastics with low dissipation factors. If the Ultrason moldings have picked up moisture, which is usually the case, it is absolutely essential to dry them before welding in order to avoid foaming in the zone of the weld during the melting phase.

The welding technique to be adopted depends on the geometry of the muldings and the stress pattern. Allowance must be made for the fact that mulded-in stresses cannot be completely avoided, especially in mouldings with very thick walls produced from Ultrason or any other material. Examples of Ultrason welded to other materials are in the table.

Table 60.2: Welding techniques for joining BASF Ultrason polysulfone to other materials.

Material	Suitable technique
Textiles	Ultrasonic welding
(Pretreated) metal foil	Heated tool welding
Other plastics e.g. poly(butylene terephthalate), acrylonitrile/styrene/acrylic copolymers, and acrylonitrile/butadiene/styrene copolymers	Ultrasonic welding

Reference: *Ultrason E, Ultrason S Product Line, Properties, Processing,* supplier design guide (B 602 e/10.92) - BASF Aktiengesellschaft, 1992.

Heated Tool Welding

Amoco Performance Products: Udel (features: transparent, amber tint)

Direct heat sealing requires a hot plate or other suitable heat source capable of attaining 700°F (371°C), covered with a thin film of Teflon. The surfaces to be bonded are pressed against the hot plate set at 700°F (371°C) for about ten seconds and then joined immediately. Because polysulfone contains a small amount of moisture it is desirable to dry it for 3-6 hours at 250°F (121°C) before attempting to heat seal. A suitable jig is necessary for fast, proper alignment of the pieces. A metal jig heated to about 350°F (177°C) is most satisfactory.

Polysulfone can also be joined to metal using the direct heat seal method. To join polysulfone to aluminum, the metal should be heated to 700°F (371°C) and placed directly against the dried polysulfone part. With a typical lap shear sample made in this manner the polysulfone adherend failed, leaving the joint intact, when the sample was tested for tensile shear strength. With cold rolled steel it is first necessary to prime the surface of the metal with a 5-10% solution of polysulfone and bake this for 10 minutes at 500°F (260°C). The primed piece should then be heated to 500-600°F (260-315°C) before adhering it to the polysulfone.

Best results will be obtained when mating parts are flush and in intimate contact with each other. This means that parts should be machined square and surfaces sanded smooth.

Reference: *Udel Polysulfone Design Engineering Handbook,* supplier design guide (F-47178) - Amoco Performance Products, Inc., 1988.

BASF AG: Ultrason S (features: transparent, amber tint)

Heated tool welding is primarily resorted to for joining large parts, e.g. pipes and panels. Ultrason necessitates high tool temperatures, for which conventional adhesive layers are suitable. In heat contact methods, the tool must continuously be cleaned to remove adhering residues. Consequently, preference should be given in any case to contactless heating by radiation. The spacing between the parts to be welded and the heated tool should be about 0.2-0.6 mm.

Owing to the high temperatures involved, a very brief change-over period, if possible less than one second, is required to prevent the surface of the melt from cooling to a temperature below the melting point. Excellent results have been obtained with the following parameters:

- heated tool temperature 380-550°C
- heating-up period 10-90 seconds
- specific joining pressure 2-5 MPa

Reference: *Ultrason E, Ultrason S Product Line, Properties, Processing,* supplier design guide (B 602 e/10.92) - BASF Aktiengesellschaft, 1992.

Hot Gas Welding

Amoco Performance Products: Udel (features: transparent, amber tint)

The Kamweld Products Company of Norwood, Massachusetts, has developed a tool for hot gas welding of polysulfone. This tool is recommended to prospective users of polsulfone sheet who are interested in butt welding or fillet welding. Two potential applications are chemical tank linings and hot air ducts. The welding process consists of heating the polysulfone rod and the ends of the sheet simultaneously and joining them immediately after the surfaces have softened. The welding rate is on the order of 508 mm/min (20 in/min) for 4.0 mm (0.156 in) rod.

Kamweld Model 10-HS-B High-Speed Production Welder, with Model KS-1C High-Speed tool, is recommended for welding polysulfone, using a 3.2 mm (0.125 in) or 4.0 mm (0.156 in) rod. A model KS-2C tool is recommended for 4.8 mm (0.188 in) rod. Polysulfone welding rods can be obtained from Westlake Plastics, Lenni Mills, PA. For best results, the work and welding rods should be dried just prior to the welding operation.

Reference: *Udel Polysulfone Design Engineering Handbook,* supplier design guide (F-47178) - Amoco Performance Products, Inc., 1988.

BASF AG: Ultrason S (features: transparent, amber tint)

Hot-air welding is suitable for joining large or complicated parts. The air temperature necessary lies between 450 and 500°C, and the diameter of the accessory or "welding rod" should correspond to the wall thickness of the molding. This technique is mostly adopted for manual welding and allows V-seams with joint efficiencies as high as 0.7 to be achieved on unreinforced Ultrason panels.

Reference: *Ultrason E, Ultrason S Product Line, Properties, Processing,* supplier design guide (B 602 e/10.92) - BASF Aktiengesellschaft, 1992.

Vibration Welding

BASF AG: Ultrason S (features: transparent, amber tint)

Vibration welding is resorted to for moldings of extensive area and for joints that lie in one plane or are, at the most, bent in only one direction. The weld must be designed so that the parts to be welded together have ample room to move in the direction of vibration. The amplitude required for heating the surfaces to be joined depends on the frequency of the machine, e.g.

- 100 Hz: 1.0-4.0 mm
- 240 Hz: 0.5-2.0 mm

The welding time should be about 2-10 seconds; and the specific welding pressure, about 1-2 MPa. Joint efficiencies of 0.4 can be achieved for unreinforced Ultrason resins; and 0.2 for products containing 20% glass fibre reinforcement.

Reference: *Ultrason E, Ultrason S Product Line, Properties, Processing,* supplier design guide (B 602 e/10.92) - BASF Aktiengesellschaft, 1992.

Spin Welding

BASF AG: Ultrason S (features: transparent, amber tint)

Spin welding is suitable for Ultrason moldings that have been designed accordingly. The joint efficiencies that can be attained are similar to those achieved in vibration welding.

Reference: *Ultrason E, Ultrason S Product Line, Properties, Processing,* supplier design guide (B 602 e/10.92) - BASF Aktiengesellschaft, 1992.

Ultrasonic Welding

Amoco Performance Products: Udel (features: transparent, amber tint)

Ultrasonics offer a fast, clean, efficient method for bonding polysulfone to itself. Welds can be obtained using a Model J-17 Sonifier Plastics Welder (Branson Sonic Power) with a 0.5 second ultrasonic time. This bonding cycle is much shorter than that of any other method. A standard cylindrical step horn under 40 psig (0.3 MPa) air cylinder pressure has given good results. A holding fixture is necessary to maintain the parts in proper relationship to each other.

Reference: *Udel Polysulfone Design Engineering Handbook,* supplier design guide (F-47178) - Amoco Performance Products, Inc., 1988.

BASF AG: Ultrason S (features: transparent, amber tint)

Ultrasonic welding is recommended for parts with cross-sectional areas of 200 cm^2 or less or for welds of up to 10 cm^2 area. Larger parts necessitate two or more welding operations, which are performed simultaneously or one after the other. The short time required for welding, viz. two seconds, permits extremely rapid cycling. The geometry of the weld must conform to the requirements for ultrasonic welding. The welding parameters depend on the material and the design of the molding, and particularly good results have been achieved with the following settings:

- frequency 20-40 kHz
- amplitude 20-60 µm
- welding time 0.1-2.0 seconds
- specific welding pressure 1-5 MPa

In any event, the parameters should be optimized by systematic variation. The attainable joint efficiency, i.e. the ratio of the strength of the weld to that of the material, lies between 0.3 and 0.6, the actual figure depending on the material and the design of the molding.

Reference: *Ultrason E, Ultrason S Product Line, Properties, Processing,* supplier design guide (B 602 e/10.92) - BASF Aktiengesellschaft, 1992.

Induction Welding

Amoco Performance Products: Udel (features: transparent, amber tint)

Strong bonds can be obtained by magnetic induction heating of an interlayer containing ferromagnetic particles. Systems are supplied by Emabond, Inc. (27 West Forrest Avenue, Englewood, NJ).

Reference: *Udel Polysulfone Design Engineering Handbook,* supplier design guide (F-47178) - Amoco Performance Products, Inc., 1988.

Mechanical Fastening

BASF AG: Ultrason S (features: transparent, amber tint)

The main expedients adopted for detachable connections are screws and bolts and - with certain reservations - snap-on connectors. Bolted connections that must withstand heavy loads and be frequently dismantled are best formed by housing threaded metal inserts in recesses that have been allowed for them in the Ultrason part during the mulding process. These inserts are pressed into the recesses while they are still hot, or - preferably - they are secured by ultrasonic welding. Bolts and other metal parts can also be anchored in the moldings by these means and can be welded in position by normal ultrasonic equipment.

Reference: *Ultrason E, Ultrason S Product Line, Properties, Processing,* supplier design guide (B 602 e/10.92) - BASF Aktiengesellschaft, 1992.

Riveting and Beading

BASF AG: Ultrason S (features: transparent, amber tint)

Unbreakable connections between Ultrason parts and other materials, e.g. sheet metal, can be easily formed by incorporating rivet shanks in the Ultrason part during the molding process. After the metal part has been pushed onto the shanks, the heads of the rivet are formed by a special ultrasonic tool. A similar principle is adopted in beading: the projecting Ultrason bead is plasticized by ultrasonic means and thus formed to enclose, for example, metal parts.

Reference: *Ultrason E, Ultrason S Product Line, Properties, Processing,* supplier design guide (B 602 e/10.92) - BASF Aktiengesellschaft, 1992.

Press Fit Assemblies

Amoco Performance Products: Udel (features: transparent, amber tint)

Because of the inherent dimensional stability and creep resistance of polysulfone, press fitting can be used to advantage as a technique of assembly or installation of accessories. Generally, the amount of interference will be less than that required for other thermoplastics and holding power will be retained to a higher degree. Recommended diametral interference values for a steel shaft in a polysulfone hub have been determined. These values apply to operating environments up to 200°F (93°C) in air and have been derived from standard design formulas. A hoop stress of 2000 psi (13.8 MPa) has been used in the calculations and allowance has been made for creep.

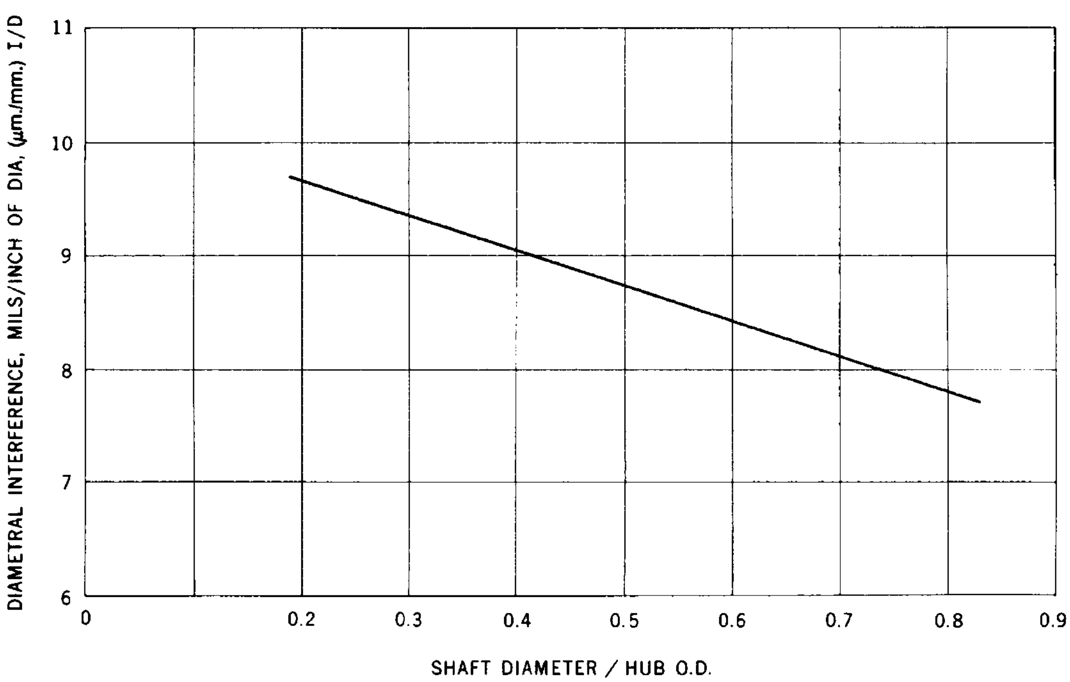

Figure 60.1: Recommended diametral interference for press fits using a polysulfone hub and a steel shaft.

Reference: *Udel Polysulfone Design Engineering Handbook,* supplier design guide (F-47178) - Amoco Performance Products, Inc., 1988.

Tapping and Self-Tapping Screws

Amoco Performance Products: Udel (features: transparent, amber tint)

Standard steel working taps work well with polysulfone. Lubricants or cutting oils are not required, although a light lubricating oil may be used to reduce tap wear. A two or three flute tap may be used at speeds of 35-75 ft/min (178-381 m/sec) with good results.

Reference: *Udel Polysulfone Design Engineering Handbook,* supplier design guide (F-47178) - Amoco Performance Products, Inc., 1988.

Amoco Performance Products: Udel (features: transparent, amber tint)

Self-tapping screws have been tested in polysulfone and found to give satisfactory results. The type "BF" screw manufactured by Parker Kalon Division of General American Transportation Corporation, Clifton, New Jersey, is a suitable brand.

Reference: *Udel Polysulfone Design Engineering Handbook,* supplier design guide (F-47178) - Amoco Performance Products, Inc., 1988.

Molded-in Threads

Amoco Performance Products: Udel (features: transparent, amber tint)

The first three classes of the Unified Thread Standard with a rounded root should be used. Threads should not run to the very end of a threaded section. A clear area of at least 0.031 in. (0.79 mm) should be provided. Pipe threads are not recommended because they induce a severe wedging action.

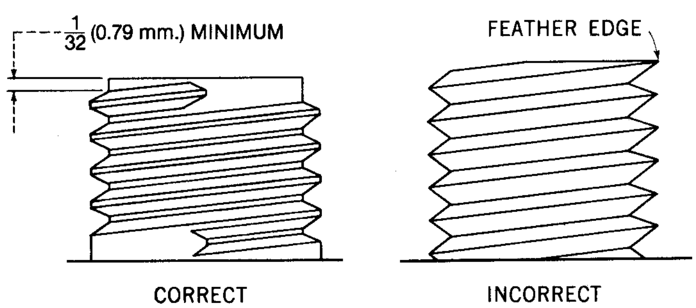

Figure 60.2: Molded-in thread design for polysulfone.

Reference: *Udel Polysulfone Design Engineering Handbook,* supplier design guide (F-47178) - Amoco Performance Products, Inc., 1988.

Threaded Mechanical Inserts

Amoco Performance Products: Udel (features: transparent, amber tint)

Threaded metal inserts provide a convenient means of fastening molded polysulfone articles to other components. In general, inserts installed after molding are preferred over molded-in inserts. They are usually less costly and the high stress accumulation due to differential cooling of the resin and a molded
-in insert is avoided. A variety of inserts can be used with polysulfone. The standard rule that wall thickness around the insert should be at least one-half the insert's major diameter should be followed. It is also possible to install metal inserts with ultrasonic devices. This will usually result in excellent resistance to pull out or stripping combined with a minimum of residual stress. If molded-in inserts are desired, pre-heat the insert as hot as possible prior to molding. This will minimize internal stress on the polysulfone boss.

Table 60.3: Post molding threaded inserts for use with polysulfone

Manufacturer	Trade Name	Type	Internal Thread	Manufacturer's Part Code	Pilot Hole & Drill Size	Counter Bore
Groov-Pin Corp., 1125 Hendricks Causeway, Ridgefield, New Jersey 07657	"Tap-Lok"	thread cutting	6-32	C-Series, coarse external thread	0.1935" (#10) (4.91 mm.)	7/32"x1/16" (5.56 mm.x1.59 mm.) deep
	"Tap-Lok"	thread cutting	10-32	C-series, coarse external thread	0.226" (H) (6.76 mm.)	19/64"x1/16" (7.54 mm.x1.59 mm.) deep
Boots Aircraft Nut Div., Townsend Company, Newton Avenue, Norwalk, Connecticut 06851	"Banc-Lok"	expansion	6-32	N-series	0.187"(3/16") (4.75 mm.)	--
	"Banc-Lok"	expansion	10-32	N-series	0.246" (D) (6.25 mm.)	--
Phelps Manufacturing Div., Heli-Coil Corporation, Danbury, Connecticut	"Dodge"	expansion	6-32	--	0.187"(3/16") (4.75 mm.)	--
	"Dodge"	expansion	10-32	--	0.246" (D) (6.25 mm.)	--

Reference: *Udel Polysulfone Design Engineering Handbook,* supplier design guide (F-47178) - Amoco Performance Products, Inc., 1988.

Bosses

Amoco Performance Products: Udel (features: transparent, amber tint)

Locate bosses at the junction of two surfaces, such as a corner, if possible. Boss outer diameter should be twice the diameter of the hole. Boss height should not exceed twice the boss outer diameter.

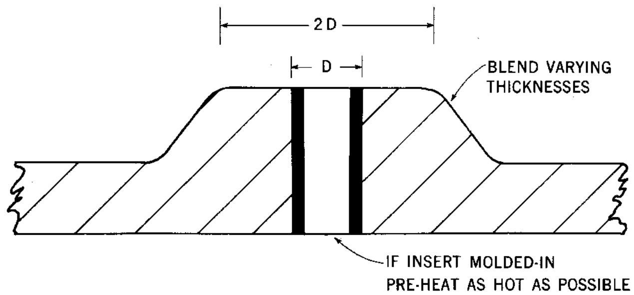

Figure 60.3: Boss design for polysulfone.

Reference: *Udel Polysulfone Design Engineering Handbook,* supplier design guide (F-47178) - Amoco Performance Products, Inc., 1988.

Adhesive and Solvent Bonding

Amoco Performance Products: Udel (features: transparent, amber tint)

For solvent bonding of polysulfone, a 5% solution of resin in methylene chloride can be used. Also available is a gelled methylene chloride cement, designated (Zip Strip), made by Star Bronze Co. (Box 568, Alliance, Ohio 44601). This cement is formulated to provide several minutes of open time after application.

Best solvent bonds are achieved by applying the minimum solvent needed to wet the surfaces to be joined. A convenient way of accomplishing this when edge joining is to use a capillary medicine dropper to apply a thin film of solvent along each edge. The two pieces should then be assembled in a jig and placed in a cold press for five minutes at 500 psi (3.5 MPa). At this point the joint should be clear and bubble-free. The presence of bubbles indicates an excess of solvent and/or insufficient pressure. Squeeze-out indicates too high pressure or excess solvent.

To use a solvent for bonding metal to polysulfone it is first necessary to adhere a layer of 3-5 mil (0.076-0.127 mm) polysulfone film to the metal. In the case of aluminum, the film can be bonded directly to the metal at 700°F (371°C) using a set of nip rolls. With steel, priming is necessary and the temperature should be 600°F (315°C). The metal can then be solvent fused to polysulfone as previously described.

The strength of this joint will improve over a period of several weeks as the residual solvent evaporates. Properly prepared joints using either heat or solvent fusion techniques have surpassed the strength of the polysulfone adherends. Solvent bonding is not recommended where bond areas will come in contact with even weak environmental stress cracking agents. Solvent bonding to other plastics is possible using a mutual solvent and the same procedure described above.

Best results will be obtained when mating parts are flush and in intimate contact with each other. This means that parts should be machined square and surfaces sanded smooth.

Reference: *Udel Polysulfone Design Engineering Handbook,* supplier design guide (F-47178) - Amoco Performance Products, Inc., 1988.

BASF AG: Ultrason S

Ultrason S moldings can be bonded together with solvents such as N-methyl-2-pyrrolidone (NMP) and dichloromethane or their blends. Allowance must be made for the fact that these solvents may give rise to environmental stress cracking in parts subjected to load. The solvents can be made more viscous by adding 3-15% of polysulfone. In any event, sufficient time must be allowed for the solvent to evaporate. Some epoxy and silicone adhesives are also suitable for bonding.

Reference: *Ultrason S Resins,* supplier technical report (81527 (8106)) - BASF, 1988.

BASF AG: Ultrason S (features: transparent, amber tint)

Various adhesive systems allow unbreakable bonds to be formed between Ultrason articles or between Ultrason and other materials. Examples are epoxy resins, polyurethanes, phenolic resins, and silicone adhesives. The system is selected to meet the requirements imposed, e.g. resistance to heat, moisture, chemicals, etc. Some solvents initiate environmental stress cracking in Ultrason, or any other amorphous thermoplastic for that matter. As a consequence, prior experiment is essential in each case to determine the suitability of an adhesive system. The surfaces to be bonded should be degreased, roughened, or otherwise treated to ensure good adhesion.

Ultrason can also be bonded with solvents such as N-methyl-2-pyrrolidone (NMP), N,N-dimethylformamide and dichloromethane. Allowance must be made for the fact that these solvents may give rise to environmental stress cracking in parts that are subjected to mechanical stress. Their viscosity can be raised by adding 3-15% of Ultrason. In any event, the bonds must be allowed sufficient time to dry, i.e. for complete removal of the solvent.

The strength of the bonds depends not only on the adhesive but also on the geometry of the joints. Good results are obtained with tongue-and-groove joints. If the overlap is sufficiently long, these joints can transmit more than 60% of the assembly's strength.

Reference: *Ultrason E, Ultrason S Product Line, Properties, Processing,* supplier design guide (B 602 e/10.92) - BASF Aktiengesellschaft, 1992.

Adhesive Bonding

Amoco Performance Products: Udel

A study was conducted to test for bond strength on a representative matrix of commonly used plastics and the adhesives best suited to them. The block-shear (ASTM D 4501) test was chosen as the test method because it places the load on a thicker section of the test specimen that can withstand higher loads before experiencing substrate failure. In addition, the geometry of the test specimens and the block-shear fixture helps minimize peel and cleavage forces in the joint. How well the block-shear test method reflects the stresses that an adhesively bonded joint will experience in real world applications should be considered.

Loctite 3105, a light curing acrylic adhesive, consistently achieved the highest bond strengths on polysulfone. Prism 401, a surface insensitive cyanoacrylate adhesives achieved the second highest bond strengths on polysulfone. Prism 401, when used in conjunction with Prism Primer, achieved the lowest bond strengths on polysulfone.

Surface Treatments
The use of Prism Primer 770, in conjunction with Prism 401, caused a statistically significant decrease in the bondability of polysulfone.

Other Information
Polysulfone is extremely sensitive to stress cracking caused by exposure to uncured cyanoacrylate adhesives, so any excess adhesive should be removed from the surface immediately, and cyanoacrylate accelerators should be used whenever possible. Polysulfone is compatible with acrylic adhesives, but can be attacked by their activators before the adhesive has cured. Any excess activator should be removed from the surface immediately. Polysulfone is incompatible with anaerobic adhesives. Recommended surface cleaners are isopropyl alcohol and Loctite ODC Free Cleaner 7070.

Table 60.4: Shear strengths of polysulfone to polysulfone adhesive bonds made using adhesives available from Loctite Corporation. Values are given in psi and (MPa).[a,b]

Plastic Material Composition		Loctite Adhesive					
		Black Max 380 rubber toughened cyanoacrylate (200 cP)	**Prism 401** surface insensitive ethyl cyanoacrylate (100 cP)	**Prism 401/ Prism Primer 770** polyolefin primer for cyanoacrylate	**Super Bonder 414** general purpose cyanoacrylate (110 cP)	**Depend 330** two-part no-mix acrylic	**Loctite 3105** light cure acrylic (300 cP)
Polysulfone	Udel courtesy of Amoco Perf. Products	650 (4.5)	1600 (11.0)	150 (1.0)	700 (4.8)	900 (6.2)	3050 (21.0)

[a] All testing was done according to the block shear method (ASTM D4501).
[b] For more information on data presented in this table, contact Loctite Corporation at 800-562-8483 (1-800-LOCTITE). Request the "Design Guide for Bonding Plastics."

Reference: *The Loctite Design Guide for Bonding Plastics,* supplier design guide (LT-2197) - Loctite Corporation.

Amoco Performance Products: Udel (features: transparent, amber tint)

A number of adhesives have been found suitable for joining polysulfone to itself or to other materials. Some of these are recommended only for relatively low temperature applications. Others give bonds that retain their integrity at temperatures approaching the continuous service temperature of polysulfone itself. Two adhesives recommended for applications up to 180°F (82°C) are EC-880 and EC-2216. Both of these are manufactured by the 3M Company.

EC-880 is a one-part, solvent based adhesive useful for bonding neoprene and other types of rubber as well as canvas, fabric and felt to polysulfone. Although not considered a structural adhesive, it is also useful for bonding polysulfone to itself in applications where there is no external stress applied to the bond. To use this adhesive, a thin, even coat should be applied to each surface and allowed to dry until quite tacky, usually between 5 to 15 minutes. Surfaces are then pressed together to insure intimate contact.

EC-2216 is a room temperature curing epoxy useful as a structural adhesive for bonding polysulfone to itself. This adhesive is a two-part paste which is mixed immediately prior to use. Pot-life is 1.25 to 2.5 hours, depending on the volume that is mixed. Optimum strength is obtained after 3-7 days at 75°F (24°C). Other suitable cure cycles are 2 hours at 150°F (66°C) or 45 minutes at 200°F (93°C).

Other recommended structural adhesive systems for bonding polysulfone to itself or to metal in high temperature applications are BR-92 resin with either dicyandiamide curing agent or curing agent "Z", all made by the Bloomingdale Division of American Cyanamid Company. Both adhesive mixes are spreadable pastes. The use temperature range for the BR-92 systems is -100°F to 300°F (-73°C to 149°C). Elevated temperature cure is needed with BR-92 to achieve good strength and chemical resistance. With dicyandiamide, mix 10 parts per 100 parts of BR-92 and cure for 2 hours at 300°F (149°C).

With curing agent "Z", mix 20 parts per 100 parts of BR-92 and cure for 20 minutes at 240°F (116°C) and 30 minutes at 300°F (149°C) for optimum strength. Laboratory tests show BR-92 with Curing Agent "Z", cured only for 30 minutes at 250°F (121°C), to have good resistance to several chemical environments at 200°F (93°C), including 20% sodium hydroxide, 5% sodium hypochlorite, 20% phosphoric acid, 20% sulfuric acid, 20% hydrochloric acid, steam [215°F (102°C)], and Prestone II ethylene glycol based antifreeze.

Many epoxy resins and hardeners are listed as potential carcinogens. With proper precautions, these materials can be safely handled.

Reference: *Udel Polysulfone Design Engineering Handbook,* supplier design guide (F-47178) - Amoco Performance Products, Inc., 1988.