Chapter 58

Polystyrene Modified Polyphenylene Ether

General Discussion of Joining Techniques

GE Plastics: Noryl

NORYL resins lend themselves to a wide variety of bonding, assembly and fastening techniques as shown in the table.

Table 58.1: Joining techniques suitable for use with GE Plastics Noryl polystyrene modified polyphenylene oxide (PPO).

Bonding	Adhesive Solvent
Welding	Heat Sealing Spin Welding Resistance Wire Welding
Mechanical Assembly	Heat Staking Self-Tapping Screws Threaded Inserts Press Fits Induction Heat Insertion
Ultrasonics	Staking Insertion Bonding

Reference: *Noryl Engineering Plastics*, supplier technical report (CDX-80) - General Electric Company.

Welding

GE Plastics: Noryl

Several welding processes, including heat sealing and spin welding, may be used to assemble components made of Noryl resins.

Reference: *Noryl Extrusion Resins*, supplier design guide (CDX-265) - General Electric Company.

Heated Tool Welding

GE Plastics: Noryl

Noryl parts may be bonded together through the use of hot plate or fusion welding. This technique involves taking two mating parts, placing the area to be bonded of each part onto a hot plate, removing the hot plate surface, then forcing the two parts together until the bond has formed.

Reference: *Noryl Design Guide,* supplier design guide (CDX-83D (11/86) RTB) - General Electric Company, 1986.

GE Plastics: Noryl

For best results in heat sealing, use hot plate temperatures of 500°F to 550°F (260°C to 288°C) and 20 to 30 seconds contact time.

Reference: *Noryl Extrusion Resins,* supplier design guide (CDX-265) - General Electric Company.

Modified PPE

The heat soak time was found to be the critical factor in providing heated tool weld strengths approaching that of the parent material. As contact is made with the stops in 4-8 sec, the remaining heating time allows increased material softening without further displacement. At 268°C, to acquire sufficient heat soaked material, it was necessary to have 30-40 sec heating time. Increasing the hot plate temperature would allow a reduction in the heating time. However, an alternative to a PTFE sleeve would be required to prevent the components sticking to the hot plate.

Although the other heating parameters affected the displacement, the influence on tensile strength was minimal. However, in the weld consolidation period, the effect of pressure on strength was substantial. At higher pressures, strength decreased by more than 10 N/mm^2. This was presumably because a greater proportion of the material was squeezed from the joint, thereby reducing the amount of material available at the required temperature. For optimum properties, a low pressure and short time, 0.35 N/mm^2 and 5 sec, would be advantageous in the consolidation stage.

Reference: Watson, M., Murch, M., *Recent Developments in Hot Plate Welding of Thermoplastics,* ANTEC 1989, conference proceedings - Society of Plastics Engineers, 1989.

Vibration Welding

GE Plastics: Modified PPE

Table 58.2: Achievable strengths of vibration welds of M-PPO to itself and other thermoplastics.

Material Family	M-PPO				
Tensile Strength[2], MPa (ksi)	45.5 (6.6)				
Elongation @ Break[2], %	2.5				
Specimen Thickness, mm (in.)	6.3 (0.25)				
Mating Material					
Material Family[1]	ABS	M-PPO	M-PPO/PA	PC	PEI
Tensile Strength[2], MPa (ksi)	44 (6.4)	45.5 (6.6)	58 (8.5)	68 (9.9)	119 (17.3)
Elongation @ Break[2], %	2.2	2.5	>18	6	6
Specimen Thickness, mm (in.)	6.3 (0.25)	6.3 (0.25)	6.3 (0.25)	6.3 (0.25)	6.3 (0.25)
Process Parameters					
Process Type	vibration welding				
Weld Frequency	120 Hz				
Welded Joint Properties					
Weld Factor (weld strength/ weaker virgin material strength)	0.76	1.0	0.22	0.24	0
Elongation @ Break[2], % (nominal)	1.45	2.4	0.35	0.4	

[1]ABS - acrylonitrile-butadiene-stryrene copolymer; M-PPO - modified polyphenylene oxide; M-PPO/PA - modified polyphenylene oxide/ polyamide alloy; PC - polycarbonate; PEI - polyetherimide
[2]strain rate of $10^{-2}s^{-1}$

Reference: Stokes, V.K., *Toward a Weld-Strength Data Base for Vibration Welding of Thermoplastics,* ANTEC 1995, conference proceedings - Society of Plastics Engineers, 1995.

Spin Welding

GE Plastics: Noryl

Spin welding is a process by which two round parts of Noryl resin may be joined without the use of adhesives, solvents, or external heating. The spin welding process requires a specific spin time and a certain non-spin pressure hold time. The variables depend upon which grade of Noryl resin is used and the joint design. Typical conditions are a peripheral speed of 40 to 50 feet per second and a pressure of 300 to 400 psi.

Reference: *Noryl Design Guide,* supplier design guide (CDX-83D (11/86) RTB) - General Electric Company, 1986.

GE Plastics: Noryl

Circular parts molded in Noryl resins are easily spin welded. Excellent bonds are possible because the low thermal conductivity of Noryl resins prevents dissipation of heat from the bonding surfaces. Each application will require different welding conditions; however, typical conditions are a peripheral speed of 40 to 50 ft. per min. and a pressure of 300 to 400 psi.

Reference: *Noryl Extrusion Resins,* supplier design guide (CDX-265) - General Electric Company.

Ultrasonic Welding

GE Plastics: Noryl

The assembly of two or more parts through the use of ultrasonics may be employed with Noryl resins. Proper design of the mating surfaces and the incorporation of an energy director or shear joint is necessary.

Tensile shear strengths of up to 3,000 psi may be attained in the bond area through the use of this assembly technique. In most cases the energy director and horn must be oriented in the same direction. Near field design with a high energy input is also recommended.

Each application dictates specific conditions and designs which must be followed. The following may be used as general guidelines:

Equipment: Branson Ultrasonic Assembly Equipment 250-3000 watts.

Ultrasonic Horn - Usually one half wave length at 20 kHz, may be a stepped horn, exponential, catenoidal, rectangular, circular, or booster horn.

Booster: Regulates the amplitude to the horn by a gain factor.

Support Jig: Proper support design is extremely important to insure that a proper weld is achieved.

Air Line Pressure: 30-60 psi

Weld Time: 0.8 to 2.0 seconds

Hold Time: 1-3 seconds

Noryl may be ultrasonically welded to certain other thermoplastic materials. The use of a common solvent can aid in achieving better welding results. Bond strength will be dependent upon the materials used and the welding conditions.

Glass reinforced grades are more difficult to ultrasonically weld due to the lower amount of substrate material located at the joint surface and the difficulty in molding a sharp energy director. Hermetic seals are usually unattainable with glass-filled materials.

Reference: *Noryl Design Guide*, supplier design guide (CDX-83D (11/86) RTB) - General Electric Company, 1986.

GE Plastics: Noryl

Normal ultrasonic welding techniques may be employed with Noryl resins. Tensile shear strengths of 3,000 psi can be attained in the bond area using this fast, effective technique.

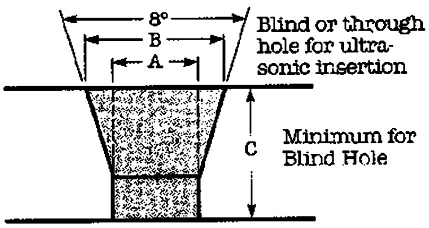
Noryl resins may be ultrasonically bonded to other thermoplastics. In most cases, the application of a common solvent as an activating agent results in better joints for dissimilar material welding.

Reference: *Noryl Extrusion Resins*, supplier design guide (CDX-265) - General Electric Company.

Ultrasonic Inserts

GE Plastics: Noryl

Ultrasonic insertion is a fast and economical method of installing metal inserts into parts molded of Noryl resin. This technique offers a high degree of mechanical reliability with excellent pull-out and torque retention combined with savings resulting from rapid production cycles. If the assembly is properly designed, ultrasonic insertion results in lower residual stress compared to molded-in or pressed-in techniques since a uniform melt occurs and a minimum amount of thermal shrinkage is involved. The figure offers recommended hole designs for inserts used with Noryl resins. Molded-in inserts are not recommended with most Noryl resins due to the coefficient of thermal expansion (CTE) differential between the unreinforced resin grades and the metal insert.



Thread Size	Insert O.D. (inches)	Insert Length (inches)	Dia. A (inches)	Dia. B (inches)	Depth C (inches)
4-40	.171	.250	.136	.164	5/16
6-32	.217	.312	.177	.210	3/8
8-32	.250	.375	.199	.240	7/16
10-24	.296	.438	.234	.280	1/2

Figure 58.1: Recommended hole designs for ultrasonic inserts in Noryl modified polyphenylene oxide resins.

Reference: *Noryl Design Guide*, supplier design guide (CDX-83D (11/86) RTB) - General Electric Company, 1986.

Ultrasonic Swaging

GE Plastics: Noryl

Ultrasonic swaging is a process of melting and reforming a ridge of Noryl resin to mechanically encapsulate another component of an assembly. This method may be used with Noryl under the following general considerations:

- Low amplitude
- Medium to high pressure
- Rigid fixturing
- Slow to medium carriage speed

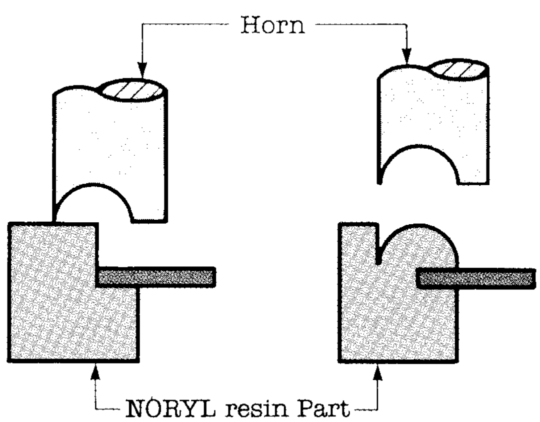


Figure 58.2: Ultrasonic Swaging

Reference: *Noryl Design Guide*, supplier design guide (CDX-83D (11/86) RTB) - General Electric Company, 1986.

Induction Welding

GE Plastics: Noryl

Noryl parts may be joined by a technique known as electromagnetic induction. Heat is generated directly at the interface by a magnetic field which reaches through the materials being joined. With a properly designed coil, the magnetic field energizes sub-micron size metallic particles uniformly dispersed in the bonding agent producing heat effective for joining.

Reference: *Noryl Design Guide,* supplier design guide (CDX-83D (11/86) RTB) - General Electric Company, 1986.

Riveting

GE Plastics: Noryl

Care should be taken when riveting Noryl resin parts to avoid the high stresses inherent in most riveting techniques. Using a shouldered rivet limts the amount of stress imposed on the part. Aluminum rivets also limit the force that can be applied, since the aluminum will deform under high stress.

In general, the rivet head should be 2 1/2 to 3 times the shank diameter, and the flared end of the rivet should have a washer to avoid high, localized stresses. Clearance around the shaft should allow easy insertion but shouldn't be so great as to allow slippage of the joined parts.

Reference: *Noryl Design Guide,* supplier design guide (CDX-83D (11/86) RTB) - General Electric Company, 1986.

Mechanical Fastening

GE Plastics: Noryl

A growing number of products are using housings with lids or covers molded from Noryl resins, especially in the area of small appliances. These lids and housing can be easily designed to incorporate hinge mechanisms, as shown in the figure. Noryl resins should not be considered for living hinges.

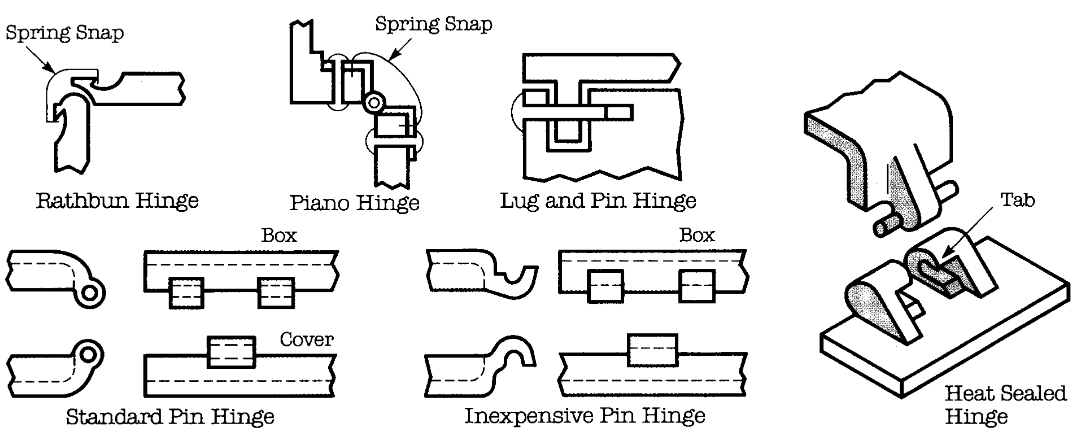


Figure 58.3: Recommended hinge designs for use with Noryl modified polyphenylene oxide resins.

Reference: *Noryl Design Guide,* supplier design guide (CDX-83D (11/86) RTB) - General Electric Company, 1986.

Snap Fit Assemblies

GE Plastics: Noryl 731 (features: general purpose grade, 119 Rockwell R hardness); **Noryl GFN2** (features: general purpose grade, 106 Rockwell L hardness; material compostion: 20% glass fiber reinforcement); **Noryl GFN3** (features: general purpose grade, 108 Rockwell L hardness; material compostion: 30% glass fiber reinforcement); **Noryl HS1000** (material compostion: 10% mineral filler; process type: injection molding); **Noryl HS2000** (features: 121 Rockwell R hardness; material compostion: 10% mineral filler); **Noryl N190** (features: high impact, flame retardant; process type: injection molding); **Noryl N225** (features: high heat grade, flame retardant, unfilled; process type: injection molding); **Noryl N300** (features: flame retardant); **Noryl SE1** (features: general purpose grade, flame retardant, electronics grade, 119 Rockwell R hardness); **Noryl SE1-GFN2** (features: flame retardant, 106 Rockwell L hardness; material compostion: 20% glass fiber reinforcement); **Noryl SE1-GFN3** (features: flame retardant, 108 Rockwell L hardness; material compostion: 30% glass fiber reinforcement); **Noryl SE100** (features: general purpose grade, flame retardant, 115 Rockwell R hardness); **Noryl**

A method of assembly which works well with Noryl resins is the molded snap-fit. Since no additional components are needed, the mating parts can be assembled rapidly and economically on the assembly line, or at the final use location. The following guidelines should be observed in designing the flexing finger:

1. Do not exceed the recommended dynamic strain limit.
2. After being snapped into place, the flexing finger should be under little or no stress.
3. The snap-fit location should be planned so there are no sharp corners, gates, or knitlines on the flexing finger, which could lead to shortened life.
4. A snap-fit assembly is generally used less than 10 times. If a large number of cycles is expected, fatigue life could be a consideration and a lower strain limit may be required.
5. Designers should remember to consider stress concentration factors.

A tapered beam will provide a more efficient equally stressed flexing finger. Several methods for forming snap-fingers are available. A snap-finger design that does not require a side core in the mold is preferred.

Table 58.3: Maximum recommended dynamic strain limits for snap-fit assemblies using Noryl modified polyphenylene oxide resins.

Resin Used in Snap Finger	% Strain in Snap Finger	Calculated Value of Dynamic Strain (ε_D)
N190, N225, N300	8%	.08
731, SE1, SE100	8%	.08
HS1000, HS2000	8%	.08
SE1-GFN2, GFN2 SE1-GFN3, GFN3	3%	.03

Reference: *Noryl Design Guide,* supplier design guide (CDX-83D (11/86) RTB) - General Electric Company, 1986.

GE Plastics: Noryl

Snap-in fingers design is the simplest and most economical method of assembling two parts. For successful lock-in assembly, use 8% maxiumum strain in the flexing member as the design limit for Noryl resins. The finger should be designed to approach either a stress-free or a predetermined tolerable stress condition when in the locked-in position.

Reference: *Noryl Extrusion Resins,* supplier design guide (CDX-265) - General Electric Company.

Staking

GE Plastics: Noryl

Heat staking is an assembly technique possible with Noryl resins. Depending upon the grade, temperatures will range from 450°F to 550°F. It is similar to ultrasonic staking but the forming head is heated and temperature controlled. The equipment can be shop made or purchased and is relatively inexpensive.

Also, equipment is available which heats the plastic with hot air and then the cold forming head comes down to form the "mushroom." The cold head prevents material from sticking to it in case of overheating of the plastic and eliminates the need for release impregnated forming heads.

Reference: *Noryl Design Guide,* supplier design guide (CDX-83D (11/86) RTB) - General Electric Company, 1986.

GE Plastics: Noryl

Unlike ultrasonic welding of Noryl resins, staking requires that out-of-phase vibrations be generated between the horn and plastic surfaces. Light, initial contact pressure is therefore a requirement for out-of-phase vibratory activity within the limited contact area. It is the progressive melting of plastic under continuous, but light pressure that forms the head. Adjustment of the flow-control valve and trigger switch may be required to reduce pressure to the desired level.

Optimum staking conditions depend upon part design and the particular Noryl resin used, but typical staking conditions for a 1/8" diameter stud of unfilled resin are:

Pressure: 12 psi
Weld Time: 0.25-0.6 sec.
Hold Time: 1 sec.

Reference: *Noryl Design Guide,* supplier design guide (CDX-83D (11/86) RTB) - General Electric Company, 1986.

GE Plastics: Noryl

Successful ultrasonic staking results in bonded parts with high mechanical performance and low residual stress. Use high ultrasonic amplitude to insure that an "off-phase" condition exists between the horn and surface.

Reference: *Noryl Extrusion Resins,* supplier design guide (CDX-265) - General Electric Company.

Threaded Fasteners

GE Plastics: Noryl

Metal screws and bolts are commonly used to assemble Noryl resin parts or for attaching various components.

Common Bolted Assemblies Are:

Through Nut and Bolt
In this case, the metal assembly puts the Noryl resin part into compression under the bolt and nut. The following guidelines must be observed.

- The Noryl resin parts must go into compression without causing high bending stresses or distortion at the molded part. The loose-fit "gap" should only be large enough to make the assembly a snug-fit.
- Uncontrolled assembly torques with this type of assembly can cause excessive compression forces in the molded parts. The resultant compressive stress due to the assembly torque is the axial force divided by the area under compression. If the resultant compressive stress is beyond the recommended working stresses, either the torque must be controlled to a lower value, or the areas under compression must be increased with a larger screw head or with metal washers.
- Since the areas are usually under moderate stress, lubricants, oils, thread locking compounds, and other substances should be avoided.

Attaching To Metal Part
This is similar to the through bolt and nut design, and excessive compression stress can create problems. If large washers or lower torque are not practical, a shoulder screw or stepped washer is a practical solution.

Reference: *Noryl Design Guide*, supplier design guide (CDX-83D (11/86) RTB) - General Electric Company, 1986.

Tapping and Self-Tapping Screws

GE Plastics: Noryl

When using Noryl thermoplastic resins in injection molded parts, the use of thread-cutting self-tapping screws, such as ASA Type "T" (Type 23) or ASA Type "BT" (Type 25) is recommended. This type of screw cuts its own threads during installation, and has a slot cut out of the bottom to provide a channel in which the chips may accumulate. Thread-cutting screws offer the advantage of low residual stresses in the area around the boss.

General design criteria for using self-tapping screws with Noryl resins are:

- The receiving hole diameter should be equal to the pitch diameter of the screw.
- Boss O.D. should be adequate to resist possible hoop stresses developed during insertion. Usually, a boss O.D. equal to twice the screw diameter is sufficient.
- Thread engagement should be at least twice the screw major diameter. A small increase in thread engagement will result in a significant increase in pull-out strength, however, an increase in screw diameter will result in only a minimal increase in pull-out strength.
- Boss height should not exceed two times the boss O.D. Hole depth should be slightly longer than the screw length, to allow for chip accumulation.
- Repeated assembly operations are not recommended.
- Use minimum torque to keep screw assembly stress within the design limits of the material.

Residual stresses created by screws other than thread-cutting screws are near or exceed the suggested design limits. Boss caps are recommended if self-tapping screws are used for repeated assembly. The advantages of this type of assembly include a 50% increase in pull-out retention, doubled torque retention, minimized hoop stress and greater protection of the boss compared to thread-forming, self-tapping screws.

Reference: *Noryl Design Guide,* supplier design guide (CDX-83D (11/86) RTB) - General Electric Company, 1986.

Bosses

GE Plastics: Noryl

A boss cap is a cup-shaped metal ring which is pressed onto the boss by hand, with an air cylinder, or with a light-duty press. It is designed to reinforce the boss against the expansion force exerted by self-tapping screws, and works well with Noryl resin parts in light duty applications.

Reference: *Noryl Design Guide,* supplier design guide (CDX-83D (11/86) RTB) - General Electric Company, 1986.

Adhesive and Solvent Bonding

GE Plastics: Prevex

Solvent cements which test results show are an effective solvent for bonding modified polyphenylene ether (PPE): ethylene dichloride, methylene chloride, tetrahydrofuran, toluene, trichloroethylene

Solvent cements which test results show do not dissolve modified polyphenylene ether (PPE): acetone, cyclohexanone, dimethyl formamide, ethyl acetate, methyl ethyl ketone, methyl methacrylate, xylene

Table 58.4: Compatibility of generic adhesive groups with modified polyphenylene ether (PPE).

Characteristic Evaluated	Material Evaluated	Compatibility Ratings for Generic Adhesive Groups[a]				
		Acrylics	Urethanes	Cyanoacrylates[b]	Epoxies	Silicones
strength	Prevex PPE	2	5	3	1	5
impact resistance	Prevex PPE	3	2	5	4	5
gap filling	Prevex PPE	2	1	5	3	1
cure time	Prevex PPE	2	5	1	3	3
ease of application	Prevex PPE	3	4	1	3	2

[a] Compatibility rating guide: 1 - excellent, 2 - very good, 3 - good, 4 - fair, 5 - poor. These ratings are generalizations and will differ for specific brands. Chemical compatibiliity should be evaluated prior to adhesive selection to prevent stress cracking.
[b] Stess cracking is a concern with cyanoacrylates. Careful evaluation of chemical compatibility with the substrate is recommended.

Reference: *Techniques: Adhesive Bonding, Solvent Bonding, and Joint Design,* supplier technical report (#SR-401A) - Borg-Warner Chemicals, Inc., 1986.

Adhesive Bonding

GE Plastics: Noryl 731

A study was conducted to test for bond strength on a representative matrix of commonly used plastics and the adhesives best suited to them. For many of the plastics evaluated, the effect of polymer composition on bond strength was evaluated by compounding plastic formulations with each of the most commonly used additives and fillers for that plastic; common grades were used for the remaining resins. The effect of each additive and filler was determined by comparing the bond strength achieved with the specially compounded formulations to that of the neat plastic. In addition, the effect of surface roughening and chemical treatment of the plastic surface on bond strength was examined.

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. Also, limitations on the data due to the variety of additives and fillers used by different companies should not be ignored.

Prism 401 and Super Bonder 414, both cyanoacrylate adhesives, achieved the highest bond strengths on PPO. Loctite 3105, a light curing acrylic adhesive, perfomed the third best. Black Max 380, a rubber toughened cyanoacrylate adhesive, and Depend 330, a two-part no-mix acrylic adhesive, achieved the lowest bond strengths. The addition of an antistatic agent or internal lubricant to PPO was found to cause a statistically significant decrease in the bond strengths achieved by the cyanoacrylate adhesives. However, the addition of antistatic agent was determined to cause a statistically significant increase in the bond strengths achieved by Black Max 380.

Surface Treatments

Prism Primer 770, when used in conjunction with Prism 401, caused a statistically significant decrease in the bond strengths achieved on PPO. Surface roughening caused a statistically significant increase in the bond strengths achieved by Depend 330, but had no statistically significant effect on any of the other adhesives evaluated.

Other Information

PPO can be stress cracked by uncured cyanoacrylate adhesives, so any excess adhesive should be removed from the surface immediately. PPO 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. PPO is incompatible with anaerobic adhesives. Recommended surface cleaners are isopropyl alcohol and Loctite ODC Free Cleaner 7070.

Table 58.5: Shear strengths of modified polyphenylene oxide (PPO) to PPO adhesive bonds made using adhesives available from Loctite Corporation. Values are given in psi and (MPa).[a,b]

Plastic Composition (GE Plastics Noryl 731)		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)
Unfilled resin	7 rms	500 (3.5)	2500 (17.2)	1750 (12.1)	1600 (11.0)	300 (2.07)	950 (6.6)
Roughened	25 rms	500 (3.5)	2500 (17.2)	1750 (12.1)	1600 (11.0)	600 (4.1)	950 (6.6)
Lubricant	9% Polymist F5A	500 (3.5)	1150 (7.9)	1000 (6.9)	1000 (6.9)	300 (2.1)	950 (6.6)
Filler	9% 489 Fiberglass	500 (3.5)	2500 (17.2)	1750 (12.1)	1600 (11.0)	950 (6.6)	500 (3.5)
Antistatic	5% Larostat HTS-904	650 (4.5)	850 (5.9)	600 (4.1)	650 (4.5)	300 (2.1)	950 (6.6)

[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.

GE Plastics: Noryl

There are a multitude of adhesives, and each is usually designed for a broad range of substrates. Below is a brief description of the most common types of adhesives systems recommended for use with Noryl resins.

Single Component - These include various epoxies, cyanoacrylates, urethanes, silicones, nitriles and sulfides. They vary in tensile strength, tack, cure and environmental resistance. Some single component adhesives require a primer.

Two Component - The majority of these are epoxies and urethanes. In some types, the accelerator or catalyst may be mixed into the base. In others, the accelerator may be brushed or sprayed onto one surface while the adhesive is applied to the other. This allows greater open time and ease of assembly.

Hot Melt Systems - These are 100% solids, usually a polymer or polymer blend that is applied as a hot viscous liquid which hardens in minutes to full strength. Polymides, SBR's, SBN's and EVA's are suitable for a variety of applications. They are fast, easy to use and solventless, so they can meet OSHA standards where solvent systems may be a problem.

Transfer Tapes (pressure sensitive) - These are usually 100% adhesive on kraft paper backing, or double-sided adhesive on polyurethane or polyethylene foam tape. Usually the tape is applied to one surface and the backing peeled off so the other substrate can be applied. The 0.020-0.125 in. foam tapes are used generally on irregular surfaces. Tapes offer good shear resistance but generally have poor peel strength. Transfer tapes are widely used in the automotive and appliance industries and when laminating materials.

Reference: *Noryl Extrusion Resins,* supplier design guide (CDX-265) - General Electric Company.

GE Plastics: Noryl

Parts molded of Noryl resins may be bonded to one another as well as to dissimilar materials using a wide range of commercially available adhesives. Because adhesive bonding involves the application of a chemically different substance between two molded parts, the end-use environment of the assembled unit is of major importance in selecting an adhesive. Operating temperature, environments, bond appearance, unit shape, physical properties, production facilities, equipment costs, and production volumes must all be carefully considered. Epoxy or acrylic adhesives are generally recommended due to their versatile product lines and cure rate schedules.

The following factors should be considered when selecting an adhesive:

1. The cure temperature of the adhesive must not exceed the heat deflection temperature of the Noryl resin.
2. Adhesives not tested for compatibility with Noryl resins should be avoided or tested.
3. Adhesive testing for compatibility should consider operational conditions of temperature and stress.
4. Bond strength tests should be conducted on appropriate specimens (i.e. T-peel, impact, tensile shear).

With the exception of holding pressure and cure cycle, the bonding procedures used for solvents can also be used with adhesives. Be sure part surfaces are free of dirt, grease, dust, oil or mold release agents. The surface of the part should be sanded or chromic acid etched before bonding for maximum strength. To insure against misalignment during the cure cycle, apply only "finger-tight" pressure.

Table 58.6: Recommended adhesives for Noryl modified polyphenylene oxide resins.

Adhesive*	Type	CureTime/ Temperature	Available From
Permabond 910	Methyl Cyanoacrylate	30 sec/RT	Permabond Intl. Co.
Permabond 101	Ethyl Cyanoacrylate	30 sec/RT	Permabond Intl. Co.
Permabond 105	Ethyl Cyanoacrylate	30 sec/RT	Permabond Intl. Co.
Permabond 102	Ethyl Cyanoacrylate	30 sec/RT	Permabond Intl. Co.
Permabond 240	Ethyl Cyanoacrylate	30 sec/RT	Permabond Intl. Co.
Super Bonder 420	Ethyl Cyanoacrylate	30 sec/RT	Loctite Corp.
Super Bonder 495	Ethyl Cyanoacrylate	30 sec/RT	Loctite Corp.
JR-228	Epoxy	2 hr/2°F	Bacon Industries
FFA-2	Epoxy	3 1/2 hr/200°F	Bacon Industries
FFA-5	Epoxy	1 hr/160°F	Bacon Industries
No. 2214 (Regular)	Aluminum Filled Epoxy (1 Part)	40 min/250°F	3M
No. 2214 (Hi Temp.)	Aluminum Filled Epoxy (1 Part)	40 min/250°F	3M
No. 2214 (Hi Flex.)	Epoxy (1 Part)	40 min/250°F	3M
No. 1838	Epoxy (2 Part)	24 hr/RT	3M
No. 2216	Epoxy (2 Part)	24 hr/RT	3M
PR1201QG (Class 1)	Polysulfide Epoxy	24 hr/RF	Products Research
RTV 103	Silicone	RT	General Electric
RTV 108	Silicone	RT	General Electric
RTV 102	Silicone	RT	General Electric
RTV 116	Silicone	RT	General Electric
RTV 157	Silicone	RT	General Electric
PB 4801	Synthetic Rubber	5 min/RT	3M
Numel 400	Hot Melt	apply to heated parts	Gulf Chemicals
Numel 610	Hot Melt	RT	Gulf Chemicals
#1050	Hot Melt	RT	Williamson Adhesives
#7820	Hot Melt	RT	Williamson Adhesives
B3579-5	Acrylic	4-24 hrs/RT	Lord Corp.
Versilok 506	Acrylic	4-24 hrs/RT	Lord Corp.
Versilok 510	Acrylic	4-24 hrs/RT	Lord Corp.
Depend	Acrylic	4-24 hrs/RT	Loctite
Ethylene dichloride	Solvent	1-24 hrs/RT	chemical supply houses
Chloroform	Solvent	1-24 hrs/RT	chemical supply houses
Methylene chloride	Solvent	1-24 hrs/RT	chemical supply houses
Trichloroethylene	Solvent	1-24 hrs/RT	chemical supply houses
85% methylene chloride/ 15% trichloroethylene	Solvent	1-24 hrs/RT	chemical supply houses

*There are many adhesives that have not been evaluated. General Electric is constantly reviewing and testing to keep information up to date.

Reference: *Noryl Design Guide*, supplier design guide (CDX-83D (11/86) RTB) - General Electric Company, 1986.

Solvent Bonding

GE Plastics: Noryl

Solvent bonding (or welding) is characterized by the use of a chemical agent which dissolves the outer skin of the Noryl resin sufficiently to allow it to be joined together with another Noryl part. The end result of the process after the solvent has evaporated is a true Noryl to Noryl bond, with no intermediate material.

Parts fabricated with Noryl resins may be bonded together through the use of several commercially available solvents, solvent blends and solvent solutions containing varying percentages of Noryl resin. Other thermoplastic resins may be bonded to Noryl with the proper solvent.

Table 58.7: Solvent combinations to control evaporation rate for Noryl modified polyphenylene oxide (PPO) resin.

Noryl to Noryl	When the total surface area is less than 1 square foot, and/or the open time is less than 60 seconds.	TCE/MeCl$_2$ 1:1 or TCE/DCE 1:1 by volume for faster evaporation (approx. 15 seconds)
		TCE for medium evaporation (30 seconds)
		TCE/MCB 4:1 for slow evaporation (approx. 45 seconds)
	When more open time is needed or a large area is used:	Use TCE/MCB 1:1 (toluene may be substituted for MCB)
		Use TCE/MCB 4:1, and about 5-25% Noryl weight/vol. If more open time is required, increase MCB by about 10 parts at a time up to a maximum of 60 parts.
Noryl to ABS/PVC	TCE/MCB/THF	1:1:2 by volume
Noryl to ABS	TCE/MEK	4:1 by volume
	TCE/XYL	1:1 volume
Noryl to PVC	XYL/MEK	1:1 by volume mixtures
Noryl to CPVC	THF or THF/TCE	by volume mixtures

Key to Solvent Names

DCE	1:2 Dichloroethylene
CH_2C1_2	Methylene Chloride, Dichloromethane
MEK	Methyl Ethyl Ketone, 2-Butanone
MCB	Monochlorobenzene, Chlorobenzene
TCE	Trichloroethylene, 1:1:2 Trichloroethylene
XYL	Xylene, Xylol, o, m, p-Xylenes, Dimethyl Benzene
TOL	Toluene, Toluol
THF	Tetrahydrofuran

Reference: *Noryl Design Guide,* supplier design guide (CDX-83D (11/86) RTB) - General Electric Company, 1986.

GE Plastics: Noryl

Noryl resin may be solvent cemented to itself or numerous other plastics using a number of commercially available solvents, solven mixtures or solvent solutions which use Noryl resins. Numerous Noryl resin applications currently use solvent bonding.

Reference: *Noryl Extrusion Resins,* supplier design guide (CDX-265) - General Electric Company.