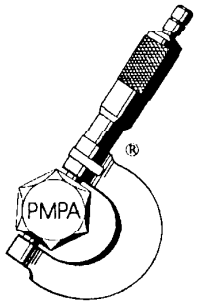
Plastics Machining Manual



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HOW TO USE THIS MANUAL

Even if you are not machining a plastic for the first time, you will find a wealth of information about plastics in this Manual. Each plastic is different. Each was designed for a specific use and as a result has different behavior properties and machining characteristics.

Get acquainted with the information in this Manual. It was compiled from information supplied by plastic producers and processors. The machining data tables were compiled from the experience of those in the screw machine products industry who machined each plastic.

Using this Manual is easy. To find out about machining a particular plastic, just follow these steps:

1. If you know the trade name or the family (generic) name of the plastic, look in the Index to Trade Names to classify it with the family of plastics to which it belongs.

2. Turn to section indicated.

3. Note that a separate plastic's family is covered by each section. Included is data pertinent to that plastic only, along with specific suggestions for tools and tool materials, machining techniques, handling and holding practices, "safe" coolants and cleaners and chip characteristics.

   Each is followed with a feed and speed table compiled from actual shop experience. In many instances you will be able to exceed the figures shown but the figures here provide a starting point.

4. How to inspect, pack and ship the screw machine product is described on page 54.

5. If you have unknown plastics on hand and want to identify them, some simple tests are listed on pages 49 & 50. You don't have to be a chemist to perform them and you can do them in the shop.

6. Page 55 contains a listing of all the references consulted in preparing this Manual. Some of these you may wish to obtain for your own files.

We hope you find this Manual a useful key to machining plastics. Remember it is <u>different</u> but not <u>difficult.</u>

WHAT IS A PLASTIC?

A plastic is a man-made nonmetallic material. It is made by combining elements and chemical compounds under heat and pressure into a form which can be molded or shaped and/or further processed.

The different plastics are the results of different chemical combinations and can be divided into two distinct types -- thermoplastics and thermosets.

A thermoset, when subjected to heat (thermo) takes on a shape (sets) which it retains until destroyed. A thermoset plastic will not soften with heat and is brittle to machine. Phenolics fit into this category.

A thermoplastic differs widely from a thermoset and when subject to heat (thermo) softens and becomes formable (plastic). With proper care, a thermoplastic can be heated and reformed repeatedly. But thermoplastics are not all alike. As heat is applied, some soften gradually as the temperature rises, while others retain their rigidity until the heat being applied reaches their critical temperature and they melt sharply. Each plastic has its own melting temperature.

The term "Polymer" is applied to plastics. All it means is that a plastic is a combination of many smaller units called "Monomers." Monomers are building blocks for plastics and are made up from molecules. The term "Copolymer" means a plastic made up of two or more base monomers or polymers. Many plastics have complicated chemical structures which provide varying properties and machining characteristics.

It is important to know which plastic type you are machining and to know if there are wide machining variations within the type such as with low and high density polyethylene or little machining variations as between the four Delrin grades - 100, 500, 570, 900.

The machining characteristics and other properties of the plastics are detailed in the following pages. We hope these paragraphs help you understand the materials called plastics.

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* - Designates Registered Trademark

** - Designates not commonly machined in bar shapes on automatics

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* Designates Registered Trademark

** - Designates not commonly machined in bar shapes on automatics

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* - Designates Registered Trademark

** - Designates not commonly machined in bar shapes on automatics

INTRODUCTION

Machining plastics is no more difficult than machining metal, but it is different.

While the same machines and tools are used to machine plastics, the way in which they are used determines your success.

The following machining information is compiled to help you become a successful and profitable producer of plastic screw machine products. Information on the characteristics of each plastic, and what you can do to eliminate your problems accompanies the data for each plastic type.

The machining data was compiled from NSMPA members' experiences with plastics and should be used as an example of successful practice or as a starting point. With experience, you may be able to exceed, in some instances, the speeds and feeds.

Remember, machining plastics is different - but no more difficult than machining metals.

NATIONAL SCREW MACHINE
PRODUCTS ASSOCIATION

GENERIC NAME: **POLYAMIDES**

CHEMICAL COMPOSITIONS: Polyamide

Basic Types	Trademarks	Suppliers
6-6*	"Zytel" 42 Nylon	E. I. du Pont de Nemours & Co.
	"Zytel" 101 Nylon Series	E. I. du Pont de Nemours & Co.
6*	"Zytel" 211 Nylon	E. I. du Pont de Nemours & Co.
	"Plaskon"	Allied Chemical Company
	"Spencer"	Spencer Chemical Company
	"Fosta"	Foster-Grant Company
6-10*	"Zytel" 30 Nylon Series	E. I. du Pont de Nemours & Co.
Misc.	"Zytel"	E. I. du Pont de Nemours & Co.

* Tests indicate that the harder the plastic the easier it is to machine. There is a hardness difference between basic nylon types.

Nylon Type	Hardness
6-6	R-118
6-10	R-111
6	R-103

Basic Types Plus Additives

6-6	"Nylatron"	Polymer Corporation
6-6	"Nylafil"	Fiberfil Corporation

STANDARDS AND SPECIFICATIONS

RAW MATERIALS: ASTM D 789-62T Nylon Injection Molding and Extrusion Materials.

U. S. Food & Drug Administration - 21 CFR 121.2502 Nylon satisfactory in food processing equipment. 6-6, 6-10, 66-610 covered.

Federal Specification: L-P-410A covers 6, 6-6, 6-10 and cast 6 nylon.

SUPPLIERS OF STOCK SHAPES

Trademark	Suppliers
"Hyde"	A. L. Hyde
"Cadco"	Cadillac Plastic & Chemical Co.
"Nylon - hollow rod"	Bunnell Plastics
"Nylontron"	Polymer Corporation
"Polypenco"	Polymer Corporation
"Nylux"	Westlake Plastics Company

STOCK SHAPES: Rod, tube, hex, square

Commonly Available Sizes and Probable Lengths Are:

1/16" dia. to 2" dia. - 8'
3-1/8" dia. to 5-3/4" dia. - 6'
2-1/8" dia. to 3" dia. - 6'
6" and over - 2'

Tolerances:

1/4" thru 1"	+.002" -.000"	1-1/8" thru 2"	+.005" -.000"
2-1/8" thru 3"	+.015" -.000"	3-1/4" thru 4-3/4"	+.020" -.000"
5" and over	+.025" -.000"		

Tolerances are on the plus side and vary from .002" to .025" according to this table. Stock ground to size is available. If you are ordering any quantity, order to size - not to tolerance.

NYLON

FORM TOOLS		
Ratio of Tool Width to Machined Diameter	Feed IPR	Speed SFM
1:4	.0025	600
1:2	.0025	600
1:1	.002	550
1.5:1 *	.002	500
2:1 *	.0015	400
2.5:1 *	.0012	350
3:1 *	.001	300

* With Support

BOX TOOLS		
Depth of Cut in Inches	Feed IPR	Speed SFM
.010	.0120	600
1/32	.0100	550
1/16	.0080	500
1/8	.0070	450
1/4	.0065	400
3/8	.0050	400

CUTOFF TOOLS		
Width in Inches	Feed IPR	Speed SFM
1/16	.0025	600
3/32	.0030	550
1/8	.0035	500

GENERAL NOTES
Chips are tough, long, and string-like. Burr removal is a problem. Tool for rigidity and support whenever possible. Keep tools cutting and don't dwell. Moderately abrasive, carbides are recommended. Back out drills frequently. A razor blade can be used for cutoff.

DRILLS		
Dia. (in inches)	Feed IPR	Speed SFM
1/32	.0030	450
1/16	.0045	400
3/32	.0050	400
1/8	.0055	350
3/16	.0062	350
1/4	.0068	320
5/16	.0072	315
3/8	.0088	300
1/2	.010	280
5/8	.012	265
3/4	.012	250
1" and over	.012	180

REAMERS		
Dia. (in inches)	Feed IPR	Speed SFM
1/16	.0080	350
1/8	.0085	340
3/16	.010	330
1/4	.012	310
3/8	.015	280
5/8	.015	265

THREADING		
	Tapping, SFM	Threading SFM
UNF & NF	50-75	75-125
UNC & NC	40-60	60-80

COOLANT
Water soluble. Parafine and Naptha base coolant.

TOLERANCE CONTROL

Nylon, similar to a salt, will absorb moisture and change size as the relative humidity changes. This change can be as great as .020" per inch.

Internal stresses, relieved during machining, will also affect the size of the machined piece. Annealed rods are available which hold machine size satisfactorily.

Nylon is resilient. If squeezed, it will return to the original size once the pressure is removed. Since this is a slow reaction, pieces machined from bars held too tightly in the collet will "grow" in size after machining.

ANNEALING OR STRESS RELIEVING

Nylon bars or product can be stressed relieved or annealed by immersing in hot oil at 350° F. for one-half hour for each one-eighth inch of wall or bar thickness. Give special close attention to the time and temperature when annealing or stress relieving. A slight discoloration may be caused by a pickup of oil on the surface. Cooling to ambient temperature should be in a draft-free area. A cross breeze will cool outside faster than inside and set up external stress.

For applications where the maximum temperature will be 160° or less, acceptable stress relief can be obtained by immersion in boiling water for 15 minutes for each 1/8 inch cross section. In addition, the moisture content is increased tending to stabilize the pieces and increase the size.

COLLETS AND FEEDFINGERS

Use smooth collets and feedfingers taking care to use only the pressure required to prevent the stock from moving. Remember that tool force is relatively light.

TOOLS

High speed tools are satisfactory, but tungsten carbide or diamond tipped tools give the most tool life and will perform best. The abrasive chips cause moderate tool wear. Tools must be kept sharp and chip surface honed smooth for best results.

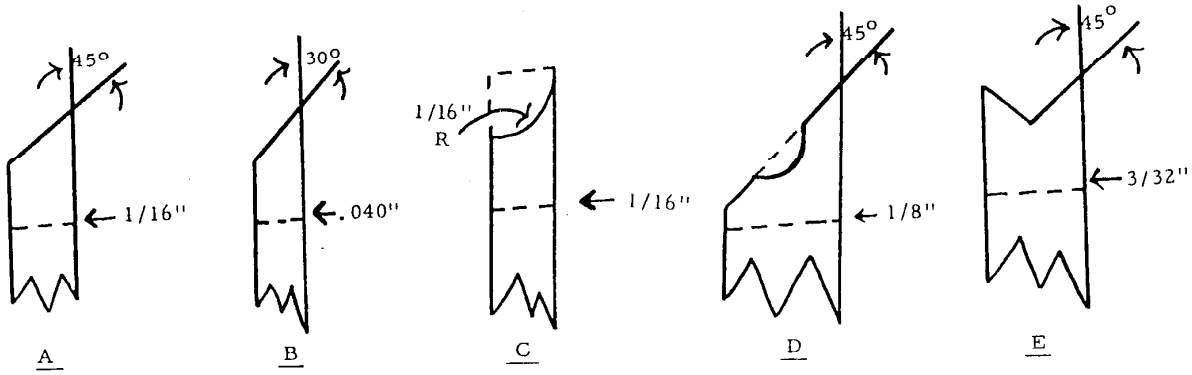
CHIPS

Machining nylon produces long, tough, stringy chips. Chip breakers are seldom effective. A serrated cam to produce a momentary interruption of the feed may help to break up the long ribbon-like chip. Chips may have to be removed regularly from the machine. Every effort should be made to cut the chips free before the part is dropped off.

BURRS

Burrs left on nylon parts present a problem. Dull tools contribute to leaving burrs behind. Nylon burrs can be singed or melted off by passing the part quickly over a flame.

The usual method is to cut off the burrs with a sharp metal edge or with a high speed burr, abrasive disk, or open wheel. Tumbling nylon



parts with dry ice is also effective for removing burrs. The chilled burrs become brittle and break off. Deburring by tumbling is 4 to 6 times longer than for metal. Suggested is the pieces alone or 2/3 seticone or aluminum oxide grit to 1/3 parts by weight.

CUTOFF

Cutting off the machined piece from the bar often results in producing a burr. These burrs can be minimized or eliminated by using sharp tools and forming a "V" to produce a chamfer where the cutoff tool enters. In general, the cutoff blade should be sharp, square to the work, and have minimum overhang and ample side clearance to prevent binding or rubbing. A zero or negative rate is recommended.

Cutoff blade grinds for different conditions are shown on the preceeding page.

Cutoff blade grind "A" is used for general purposes. "B" works well on thin wall jobs. "C" is used where it is essential to avoid a cutoff nib. "D" is used on thick wall or large diameter work. "E" - in addition to parting the stack - also faces off the next piece. Whichever blade is used, be sure the blade does not rub. Also, having the cutoff blade dwell near the terminal point of the cut allows the work to drop free.

For some jobs, a razor blade mounted in a cross slide can be used to cut off burr-free parts. Experimenting will help to develop the best cutoff tool grind for each job.

MACHINING OPERATIONS

Most machining operations can be performed providing the resiliency of nylon is taken into consideration.

TURNING

Single point tools can be used to turn nylon. For heavy cuts use a "V" back or roller rest support. A balanced turning tool is ideal.

FORMING

Nylon can be plunged formed providing the stock is supported to keep it from yielding to tool pressure. Suggested is to keep the cutting surface of the tool no wider than the minimum diameter of the work. Wider tools can be used on supported stock.

Good practice is to reduce the feed rate toward the end of the tool travel to obtain a clean, accurate surface. A front clearance of from 10° to 15° is practical. A negative top rake of 0° to 3° is recommended.

SKIVING

Skiving is ideally suited for forming nylon, particularly for contours too wide for form tools. Less pressure is placed on the nylon rod and closer tolerance is held.

DRILLING

Drilling in nylon produces more heat than any other operation. Extra care must be used to produce good results. In many instances, a heavy feed and slow speed produces excellent results.

Slow spiral, low helix drills with polished flutes should be used whenever possible. A large flute area is necessary to clear the chips. Standard twist drills can be used with the standard 118° included angle. For nylon, the point angle of 90° - 110° and a 10° to 15° lip clearance with a thinned web produces excellent holes. The lip rake should be ground off.

Pullouts will be necessary for all holes over 3 diameters deep. Drills must be pulled out each time the flutes clog with chips. Coolant or air should be directed on the drill at each pullout to remove heat.

REAMING

The soft grades of nylon tend to yield under the pressure from the reamer and undersize holes result. When using a reamer to size a hole, be sure at least .005" remains to be removed on each side (not .005" on the diameter). Harder nylon grades can be reamed to size with lighter cuts.

TAPPING

A 75 percent thread or less is recommended. Oversize taps should be used roughly .002" oversize for small diameter holes and up to .005" oversize for large diameter holes. Standard taps are usually chrome plated .001" or .002". Nitriding also helps.

When thread depth exceeds three diameters, tap flutes should be enlarged to carry off the chips. Two flute spiral taps are satisfactory. Other tapping may require a 3 or 4 flute tap combined with a 75 to 125 SFM speed.

Tearing is minimized if the hole is chamfered and a positive feed is used when cutting the first threads.

Tapping chips and burrs are difficult to remove and usually have to be removed by hand. It may help to reinsert the tap drill to remove tapping chips.

THREADING

External threads can be cut with self-opening die heads or can be chased with chrome plated chasers ground with a zero rake and highly polished. Copious quantities of coolant should be used. Self-opening die heads should be activated by the machine, not the nylon. For single point threading, a diamond tipped tool ground with a zero side rake and a 2° back rake works well. At least two passes should be made and copious quantities of coolant used.

MILLING

With the work supported to prevent deflection, keep milling cutters sharp. Fly cutters and shell mills offer many advantages over conventional milling.

COOLANTS

Nylon is not affected by lubricating oils and greases, aliphatic and aromatic hydrocarbons (including conventional fuels), the common esters, ketones, amides, etc.

Liquid coolant, preferably the water soluble type, should be used. A soap and water solution can also be used.

An air stream properly directed can keep the chips away and cool the tools.

NOTES

GENERIC NAME: **FLUOROCARBONS, HALOCARBONS**

COMMON NAME: Teflon, TFE

CHEMICAL COMPOSITION: Polytetrafluoroethylene (TFE) or Fluoronated Ethylene Propylene (FEP) or Related Compounds.

RAW MATERIALS:

Basic Types	Trademarks	Suppliers
TFE (see above)	"Teflon" TFE	E. I. du Pont de Nemours & Co.
FEP (see above)	"Teflon" FEP	E. I. du Pont de Nemours & Co.
Halocarbon	"Kel - F"	Minnesota Mining & Mfg. Co.
Fluorocarbon	"Kynar"	Pennsalt Chemical Company

SUPPLIERS OF STOCK SHAPES:

Trademarks	Suppliers
"Chemfluor"	Chemplast Corporation
"Fluorosint"	Polymer Corporation
"Fluorocomp"	Liquid Nitrogen Processing Co.
"Cadco"	Cadillac Plastic & Chemical Co.
"Chemlon"	Crane Packing Company
"Rulon"	Dixon Corporation
"Fluororay" (filled)	Raybestos - Manhattan
"Shamco"	W. S. Shamban
"Surf"	Surf Chemical
"Tri - Point"	Tri - Point Industries

STANDARDS AND SPECIFICATIONS:

RAW MATERIALS: ASTM Specification D-2116-T FEP - Fluorocarbon Molding and Extrusion Materials.

D-1457-62T, TFE - Fluorocarbon Resin Molding and Extrusion Materials.

D-1430-58T, Polychlorotrifluoroethylene Molding and Extrusion Materials.

D-1710-60T, Polytetrafluoroethylene Rod.

AVAILABILITY OF STOCK SHAPES:

Please check with more than one plastic supplier since the size and shape of stock available varies according to equipment.

As a rule, the larger the diameter, the shorter the length available. Size increments vary from supplier to supplier. Rounds, tubes, hexes, and squares are usually available.

Sizes and lengths vary and the following table may prove to be indicative of what is available.

Size	Length
1/8" dia. - 3/8" dia.	10'
7/16" dia. - 9/16" dia.	8'
5/8" dia. - 1-3/4" dia.	6'
1 - 7/8" dia. - 3" dia.	3'

Diameters up to 11" are available

Tolerances are on the plus side and vary from plus .001" on 1/8" diameter rod to plus .025" on 5" diameter rod.

FORM TOOLS		
Ratio of Tool Width to Machined Diameter	Feed IPR	Speed SFM
1:4	.0020	500
1:2	.0020	500
1:1	.0015	450
1.5:1 *	.0015	450
2:1 *	.0010	400
2.5:1 *	.0008	400
3:1 *	.0007	350

* With Support

BOX TOOLS		
Depth of Cut in Inches	Feed IPR	Speed SFM
.010	.0080	500
1/32	.0060	500
1/16	.0060	500
1/8	.0055	450
1/4	.0045	400
3/8	.0040	375

CUTOFF TOOLS		
Width in Inches	Feed IPR	Speed SFM
1/16	.0020	500
3/32	.0025	500
1/8	.0028	500

GENERAL NOTES
Do not squeeze in collet. Use lightest pressure required to hold stock in place. Stock is flexible and resilient. Watch for stock slipping back into collet when drilling. Drill rapidly without pullouts. Use a lead screw for threading. Skiving is recommended over forming. Agree with customers in advance on temperature at which measurements will be taken.

DRILLS		
Dia. (in inches)	Feed IPR	Speed SFM
1/32	.0040	500
1/16	.0045	500
3/32	.0050	450
1/8	.0055	450
3/16	.0060	400
1/4	.0065	360
5/16	.0068	345
3/8	.0080	330
1/2	.0080	300
5/8	.0080	300
3/4	.0100	275
1" and over		

REAMERS		
Dia. (in inches)	Feed IPR	Speed SFM
1/16	.006	500
1/8	.008	500
3/16	.008	450
1/4	.008	400
3/8	.010	350
5/8	.012	350
3/4	.012	300

THREADING		
	Tapping SFM	Threading SFM
UNF & NF	40-60	60-80
UNC & NC	30-40	50-60

COOLANT
Water soluble.

TOLERANCE CONTROL

Some fluorocarbons (TFE) have one distinguishing and unusual characteristic. They change size at approximately 68° F. As the plastic warms through 68° F. it increases in volume about 1.4% and in length 0.5%. The same changes take place in a reverse direction as fluorocarbons cool through 68° F. temperature. The transition range is from 60 to 70° F. and fluorocarbons should be held above this range for maintaining a constant size for machining and measuring.

Fluorocarbons should be held at a temperature of 75° F. for at least 48 hours to stabilize them before machining. After machining to size, the products should be held in the same controlled condition until delivery to the customer.

Other than the size change in the 60 - 70° F. temperature range, fluorocarbons are stable under all other environmental conditions encountered in a shop.

COLLETS AND FEEDFINGERS

Smooth collets and feedfingers are used with only a minimum of pressure - just enough to keep the stock from turning - keeping in mind tool force is relatively light, as most fluorocarbons are softer than metals.

TOOLING

Tool pressure is critical when machining plastics and provision must be made to prevent the deflection of the resilient plastic during each operation. Close chucking or placing a rest diametrically opposite the tool helps. Fluorocarbons are softer than the nylons.

Tools should be centered and a steady rest used since fluorocarbon is resilient. Plunge forming is practical if you do not exceed the ratio of tool width to the machined diameter. A 5° top rake helps and a dovetail form tool with 10 - 15° front clearance helps.

High speed steel tools can be used with fluorocarbons; however carbide tools last much longer and should be used whenever possible. While unfilled teflons are soft and waxy - filled can be tough and abrasive. (See appended machining table.)

All tools should be honed on a diamond wheel with a grit between 240 - 320, and the chip surface must be smooth. Tool clearances should be generous to prevent rubbing the work and generating heat.

Tool pressure can be increased by using a negative back rake angle up to -5° or decreased by using a positive back rake angle up to +5°.

CHIPS

Chips from fluorocarbons are tough and stringy and must be removed from the tool area. Remove chips from the work area with a chip removing rake. Unless removed, the chips will wind around the work and interfere with the tools.

The chips are often stronger than the plastic from which they were cut. This is due to an annealing during the cutting. Chips should be cut free before the parts drop off the bar. A stream of air is helpful is separating parts from the chips as they drop from the bar.

BURRS

Every effort should be made to produce the piece without burrs. Chamfering before cutting is one way. Pickup attachments and back deburring devices help.

In many instances, burrs may have to be removed by hand. Do not attempt to burn or melt off burrs. The gas given off is toxic.

CUTOFF

Cutoff can be made with a variety of tools at feeds up to .006" IPR. Adequate side and front clearance of 10 - 30° should be used to prevent rubbing. A "V" ground into the tool will help eliminate the cutoff burr.

Standard cutoff tools can be used, but in some instances a razor blade held in a cross slide works the best and cuts off a burr-free part. A little experimenting will be necessary.

MACHINING OPERATIONS

Most normal machining operations can be performed on fluorocarbons providing steps are taken to hold the resilient plastic in place so it doesn't deflect from the tool's cutting surface.

TURNING

Single point tools with a slight nose radius, a 20-30° clearance angle and a 5-10° side clearance angle with a zero or 5° top rake, work well.

Often, both a heavy, rough cut and light finishing cut is required to hold the critical dimensions. Keep in mind the temperature should be stabilized before measuring if close tolerances are to be held.

FORMING

Forming and skiving tools can be used to advantage when turning fluorocarbons. Wherever practical, skiving is recommended because little pressure is required, and a smooth finish results from both heavy and light cuts.

Pieces longer than two diameters must be supported to prevent deflection.

DRILLING

High speed twist drills with standard spiral flutes can be used except in deep holes (more than three diameters) where slow spiral fluted drills work best. Use polished flutes.

Point angle and the piece wall thickness are related - as the wall gets thinner the drill point should be flatter and closer to 180°. For large diameter holes in heavy wall parts, an included angle of 90 - 110° with a 15° lip clearance works well. For thin wall parts, an included angle of from 115 - 130° works well. Some applications may require a 180° included angle.

Care must be taken not to push the stock back through the collet.

Holes can be finished to size with a drill providing the drill is accurately machine ground. Pullouts may be necessary to remove chips from the drill flutes.

REAMING

Reaming is not particularly effective with the fluorocarbons. Soft and springy, the work deflects under pressure. When reaming is tried at least .005" must be removed. Boring to size is recommended.

TAPPING

Taps should be .002" oversize, up to 1/2", .005" oversize for larger holes. Taps should be kept sharp and flutes polished.

By chamfering the hole, tearing or raising a burr is minimized. When tapping deep holes, flute area should be increased. Straight fluted or spiral taps can be used with success.

THREADING

Threads can be cut with self-opening die heads and chasers providing an external trip is used to avoid tearing the threads. Grind tangential chasers with a 5 - 10° rake angle. Mount the cutting portion above center.

When using radial chasers, grind the rake angle 0 - 5° and the throat angle 50°. Chasers are not recommended for sintered fluorocarbons.

When single point threading, taking .005" - .010" per pass and no less than .005" in the final pass is often best. A diamond tipped tool lasts longest.

MILLING

Because fluorocarbons flex easily, care must be taken to prevent deforming the holding or supporting device when milling flats or slots. When milling thin sections confine the part in its entirety, leaving only room for the cutter. Square cornered cutters will leave fewer burrs than chamfered cutters.

Use a coolant if undue heat is generated.

GENERIC NAME: **ACETAL**

CHEMICAL COMPOSITION: Polyformaldehyde or related materials

Basic Types	Trademarks	Suppliers
Homopolymer*	"Delrin" Acetal	E. I. du Pont de Nemours & Co.
Copolymer*	"Celcon"	Celanese Polymer Corporation
Filled Homopolymer	"Delrin" AF TFE Fiber Filled Material Formaldafil	E. I. du Pont de Nemours & Co.
	"Delrin" 570 (glass filled)	E. I. du Pont de Nemours & Co.

SUPPLIERS OF STOCK SHAPES:

Trademarks	Suppliers
"Cadco"	Cadillac Plastic & Chemical Co.
"Hyde"	A. L. Hyde Company
"Danco"	Nicholson File Company
"Polypenco"	Polymer Corporation
------	Westlake Plastics Company

STANDARDS AND SPECIFICATIONS:

RAW MATERIALS: ASTM Specification D-2133-62T Copy obtained from ASTM, see address list.

Federal Specification L-P 3928 "Plastic Modling Material, Acetal Injection and Extrusion. Type #1 (Delrin 500), Type #2 (Delrin 150).

Copy of spec may be obtained from General Services Administration, see address list.

* Note: Tests indicate that the harder the plastic, the easier it is to machine. There is a hardness difference between the homopolymer ("Delrin") and the copolymer ("Celcon").

Plastic	Hardness
Homopolymer	M 94
Copolymer	M 80

AVAILABILITY OF STOCK SHAPES:

Please check with plastic suppliers. Contact more than one since size, shape and length vary from supplier to supplier.

As a general rule, the larger the diameter, the shorter the length available.

TOLERANCES ARE ON THE PLUS SIDE AND VARY FROM .001" TO .025" ACCORDING TO THIS TABLE:

		Lengths
3/16" diameter to 1" diameter	+.001 -.000	Up to 10'
Over 1" diameter to 2" diameter	+.005 -.000	8'
Over 2-1/4" diameter to 3" diameter	+.015 -.000	4'
3-1/4" diameter to 4-3/4" diameter	+.187 -.000	4'
5" diameter to 7" diameter	+.250 -.000	2'

FORM TOOLS		
Ratio of Tool Width to Machined Diameter	Feed IPR	Speed SFM
1:4	.0030	600
1:2	.0025	600
1:1	.0025	600
1.5:1	.002	500
2:1 *	.002	450
2.5:1 *	.0015	400
3:1 *	.001	400

* With Support

BOX TOOLS		
Depth of Cut in Inches	Feed IPR	Speed SFM
.010	.0100	600
1/32	.0085	600
1/16	.0080	600
1/8	.0070	550
1/4	.0060	500
3/8	.0045	450

CUTOFF TOOLS		
Width in Inches	Feed IPR	Speed SFM
1/16	.004	600
3/32	.0035	600
1/8	.0030	600

GENERAL NOTES
Chips are powdery. Flags (burrs) may adhere to piece. Use tool angles for free cutting brass. Feeds and speeds approximate brass also. Chips do not break but have less tendency to adhere to workpiece than other plastics. Holds size and produces excellent finishes and cuts with little pressure.

DRILLS		
Dia. (in inches)	Feed IPR	Speed SFM
1/32	.0040	600
1/16	.0045	600
3/32	.0050	550
1/8	.0055	550
3/16	.0060	500
1/4	.0065	500
5/16	.0080	450
3/8	.0100	450
1/2	.012	400
5/8	.012	350
3/4	.011	325
1" and over	.010	300

REAMERS		
Dia. (in inches)	Feed IPR	Speed SFM
1/16	.0055	450
1/8	.0065	450
3/16	.0080	450
1/4	.0080	400
3/8	.010	350
5/8	.012	350
3/4	.015	350

THREADING		
	Tapping SFM	Threading SFM
UNF & NF	75-100	50-75
UNC & NC	50 - 75	40-50

COOLANT
Water soluble or naphtinic oil.

TOLERANCE CONTROL

Delrin is the most metal-like of the plastics and the effect of humidity and temperature changes are slight. Machining Delrin which has been stored under comparable conditions will result in parts within tolerance.

To maintain machined dimensions, acetal plastic stock should be annealed before machining. Use annealed rod for dimensional stability.

ANNEALING AND STRESS RELIEVING

Acetal plastics should be immersed in an inert oil, such as refined mineral oil, petroleum oil or vegetable oil at 300° to 320° F. Temperature in excess of 320° F. may cause a shrinking and deterioration of physical properties. The oil should be agitated.

Recommended immersion time is 15 to 20 minutes for each 1/8 inch of thickness. For parts larger than one inch in diameter, optimum temperature is 300° F. and one hour's time allowed for each inch of thickness.

Cool annealed acetal in a draft-free area or enclosed box until room temperature is reached.

TOOLS

High speed steels work satisfactorily, but tungsten carbide, and diamond tipped tools will be best suited for large quantities of parts. Carbide tools can be used to advantage at faster speeds. Carbide tools will hold sizes consistent on long runs.

Grinding the tool as for non-ferrous metals or free machining leaded steels produce ideal results. A positive rake angle is best.

Little, if any, abrasion has been detected on tools when machining Delrin (Acetals).

CHIPS

Acetals, when machined, produce short or powdery chips. The filter in the coolant system may clog and have to be cleaned or replaced frequently.

Acetal chips should be segregated and disposed of by burning outside in a well ventilated area. Acetal chips can burn without a visible flame and produce a formaldehyde gas. Burning is slow at the rate of 1.1 inches per minute.

COLLETS AND FEEDFINGERS

Use smooth collets or pads.

BURRS

Parts can be cut off relatively burr free. Tools must be kept sharp. If burrs are produced, they can be removed by hand or by using an abrasive slurry in a tumbling barrel. Vibratory finishing is also satisfactory. Care must be exercised not to change overall size.

MACHINING OPERATIONS

Most of the operations normally performed can be performed on acetals.

TURNING

Feed and speed depend upon type of cut and finish desired. Make roughing cuts at highest feed and speed feasible without excessive heat buildup. A fine finish cut is made with a high speed and slow feed.

FORMING

Plunge forming can be performed if the stock is supported to prevent deflection from the tool. Rough and finish cuts can be taken and close tolerances held. Support all forming cuts when the length is twice the diameter or greater.

CUTOFF

Standard cutoff tool widths and designs can be used. Provide sufficient clearance to eliminate any rubbing. Pieces can be cut off relatively

burr free.

DRILLING

Standard twist drills with polished flutes can be used in acetal. The special plastic drill with polished flutes also works well; however, the leading edges of these drills are usually ground flat and should be modified by changing the drill lip angle to cut rather than scrape.

Coolant should be used if drilling at high speeds. Pullouts should be used to clear flutes and prevent drill overheating. Use plenty of water soluble coolant at all times.

Holes can be drilled to size providing the drills are kept cool. Drills with a 90° included angle also work well and produce holes to size.

TAPPING

Conventional taps with polished flutes can be used to produce close tolerance threads. To ease chips, two fluted taps can be used to advantage. Speeds which do not cause overheating should be used.

REAMING

Hand or collar reamers can be used to produce holes to size with a good finish.

Since acetals are resilient, cuts made with a fixed reamer tend to be undersize unless at least .005" is removed by the reamer.

Straight fluted or spiral reamers with polished flutes and narrow margins are suitable for acetals. A jet of air to cool and clear the chips can be used.

THREADING

Acetals can be threaded using conventional machines and tools. Self-opening die heads with polished chasers can be used. Coolants are not necessary, but a jet of air should be used to clear away the chips.

MILLING

Cutting edges must be kept sharp. Single fluted end mills with lots of chip room generate less heat and should be used. Support the plastic work piece.

When sawing, a slight set to the teeth will prevent rubbing and frictional heat. Use a jet of air to clear the chips.

COOLANTS

Air is the best coolant (not practical on multiples). However, water soluble or other cutting fluids can be used safely with acetal plastics.

SAFETY PRECAUTIONS

Note ARROW under CHIPS.

NOTES

GENERIC NAME: **POLYETHYLENE (A POLYOLEFIN)**

CHEMICAL COMPOSITION: Polyethylenes and Related Materials

RAW MATERIALS:

Basic Types	Trademarks	Suppliers
Polyethylene	"Alathon"	E. I. du Pont de Nemours & Co.
	"Marlex"	Phillips - Grace
	"Bakelite"	Union Carbide Corporation
	"Fortiflex"	Celanese Corporation
		U. S. I.
		Monsanto

DENSITY AND HARDNESS:

	Low Density	Medium Density	High Density
Specific:	0.910 - 0.925	0.926 - 0.940	0.941 - 0.965
Hardness:			
Shore:	D41 - D46	D50 - D60	D60 - D70
Rockwell:	R-10	R-15	R-18

STANDARDS AND SPECIFICATIONS:

STOCK SHAPES:

Trademarks	Suppliers
"Ethylux"	Westlake Plastics Company
"Ultra-Ethylux"	
"Cadco"	Cadillac Plastics & Chemical Co.

Sizes and Lengths: Both low and high density

1/4" diameter to 2" diameter in 8 foot lengths.
2-1/4" diameter to 12" diameter in lengths up to 6 feet.

Tolerances:

1/4" diameter - 1" diameter	+.002" -.000"
1-1/8" diameter - 2" diameter	+.005" -.000"
2-1/8" diameter - 3" diameter	+.015" -.000"
3-1/4" diameter - 4-3/4" diameter	+.020" -.000"
5" diameter and over	+.025" -.000"

GENERIC NAME: **POLYPROPYLENE (A POLYOLEFIN)**

CHEMICAL COMPOSITION: Polypropylene

RAW MATERIALS:

Basic Types	Trademarks	Suppliers
Polypropylene		Chevron
	"Marlex"	Phillips - Grace
		Hercules
	"Bakelite"	Union Carbide Corporation
		Avisun

STOCK SHAPES:

Trademarks	Suppliers
"Cadco"	Cadillac Plastics & Chemical Co.
"Ethylux"	Westlake Plastics Company

Shapes - Sizes: Rounds 1/4" dia. to 15" dia. - 1/4" dia. to 2" dia. - 6ft. lengths
2" and up - 1, 2, 3 ft. lengths

Tolerances: +5% -0 on 1/4" dia. to 2" dia.

FORM TOOLS		
Ratio of Tool Width to Machined Diameter	Feed IPR	Speed SFM
1:4	.004	450
1:2	.0035	400
1:1	.003	380
1.5:1	.0025	350
2:1	.002	325
2.5:1	.0015	310
3:1	.002	300

BOX TOOLS		
Depth of Cut in Inches	Feed IPR	Speed SFM
.010	.015	500
1/32	.012	450
1/16	.010	400
1/8	.0085	375
1/4	.006	350
3/8	.0055	300

CUTOFF TOOLS		
Width in Inches	Feed IPR	Speed SFM
1/16	.004	475
3/32	.0035	450
1/8	.003	425

GENERAL NOTES
Difficult to machine because it is resilient. Chips are ribbon-like and difficult to break and often foul tools. Taps cut oversize. Tapping in collet before feedout is recommended. Burrs require removal by hand. Using tools in combination ie. turning and drilling; forming and drilling is not recommended.

DRILLS		
Dia. (in inches)	Feed IPR	Speed SFM
1/32	.0035	600
1/16	.004	600
3/32	.0042	600
1/8	.0045	450
3/16	.005	425
1/4	.006	400
5/16	.008	350
3/8	.010	300
1/2	.012	280
5/8	.014	260
3/4	.016	250
1" and over	.018	225

REAMERS		
Dia. (in inches)	Feed IPR	Speed SFM
1/16	.012	600
1/8	.010	450
3/16	.009	425
1/4	.0085	400
3/8	.008	350
5/8	.007	300
3/4	.006	280

THREADING		
	Tapping SFM	Threading SFM
UNF & NF	40-80	40-80
UNC & NC	30-40	30-40

COOLANT
Water Soluble.

POLYETHYLENE
POLYPROPYLENE

These plastics are similar in appearance and in machining characteristics to the machinist and will be covered with the same data and machining tables with one exception:

NOTE: Polyethylene is available in three densities - low, medium, and high, with the high density possessing the best machining characteristics.

If any polyethylene is specified, determine if high density can be used, and use it. By machining a bar of each density, the machining characteristics of the high density polyethylene are readily apparent.

TOLERANCE CONTROL

It is somewhat difficult to hold size since these resilient plastics must be supported during turning. Excessive heat buildup during any operation will cause the workpiece to expand and copious quantities of coolants is advised.

Every precaution should be taken to minimize frictional heat.

COLLETS AND FEEDFINGERS

These plastics have a tendency to slip in collets and slide away under pressure. Hold only tight enough to prevent slipping and deforming.

TOOLS

Large rake and relief angles plus high speeds and low feeds produce smooth accurate parts. The plastic should be cut off, not scraped off. Lapped high speed steel tools or carbides can be used with heavy feeds.

CHIPS

Chips present a problem and may have to be removed constantly from the workpiece and tools. Chips tend to melt on tool surfaces. Regardless of feed and speed used, chips will be in long ribbons.

BURRS

Clinging chips and burrs are common and may have to be removed by hand.

MACHINING OPERATIONS

These are resilient plastics and must be supported to prevent deflection from the cutting tool. Heat buildup at the cutting tool should be avoided.

Using tools in combination, that is overlapping, such as turning and drilling, forming and drilling, is not recommended.

TURNING

High speeds and fast feeds are used to turn these plastics. Chips may tend to foul box turning tools. Positive tool rake and adequate side and end clearance is necessary.

FORMING

Plunge forming when workpiece is supported is feasible. Use fast feeds to produce ribbon-like chips.

CUTOFF

Special care must be taken to grind cutoff tools to eliminate cutoff teat and clinging chip. Supporting long work pieces and using a "V" ground cutoff tool helps. (Suggest cutoff tools with 23° angle.)

DRILLING

Drilling presents chip problems. Use the special plastic drills with polished flutes. Use pullouts in deep holes.

Pointed drills (90° included angle) are best for small holes and drills with included angles of not more than 118° for larger holes. Drill angles up to 180° may be necessary for thin walls to prevent spreading of the sides. Polished flutes

and a fast helix will aid chip removal.

Drilling within the collet and before feedout may help produce holes to close tolerances.

TAPPING

Tapping within the collet before feeding out will aid in cutting threads to size.

Use oversize taps .002" to .004". Taps with three polished flutes provide chip clearance.

Chips will remain in tapped holes and may have to be removed by hand.

MILLING

Slots can be milled providing the workpiece is held firmly. Each tooth should cut and feeds and speeds should be adjusted to prevent melting the workpiece and chips.

COOLANTS

Water soluble oils and air are satisfactory.

GENERIC NAME: **POLYCARBONATES AND RELATED COMPOUNDS** **Section V**

CHEMICAL COMPOSITION: Polycarbonates and Related Compounds

RAW MATERIALS:

Basic Types	Trademarks	Suppliers
Polycarbonates	"Lexan"	General Electric Company
Polycarbonates	"Merlon"	Mobay Chemical Company
Basic Types Plus Filler		
Polycarbafil		Fiberfil Corporation

STANDARDS AND SPECIFICATIONS:

STOCK SHAPES:

Lengths:

1/8" diameter to 2" diameter	Up to 8' lengths
2-1/4" diameter to 8" diameter	Up to 3' lengths

Tolerances:

1/4" - 1" diameter	±.001
1-1/4" - 2" diameter	±.005
2-1/2" - 2-3/4" diameter	±.015
3" - 4-3/4" diameter	±.187
5" - 6" diameter	±.250

POLYCARBONATES

FORM TOOLS		
Ratio of Tool Width to Machined Diameter	Feed IPR	Speed SFM
1:4	.0025	500
1:2	.0025	450
1:1	.002	450
1.5:1	.0015	400
2:1 *	.001	375
2.5:1 *	.001	350
3:1 *	.0008	325

* With Support

BOX TOOLS		
Depth of Cut in Inches	Feed IPR	Speed SFM
.010	.010	500
1/32	.009	450
1/16	.007	400
1/8	.006	375
1/4	.005	350
3/8	.004	325

CUTOFF TOOLS		
Width in Inches	Feed IPR	Speed SFM
1/16	.002	500
3/32	.003	500
1/8	.0035	500

GENERAL NOTES
Machining may induce or relieve stresses and cause cracking. Avoid trichlorethylene and carbon tetrachloride. Treat as a mild steel.

DRILLS		
Dia. (in inches)	Feed IPR	Speed SFM
1/32	.002	450
1/16	.003	450
3/32	.004	450
1/8	.005	400
3/16	.006	400
1/4	.007	400
5/16	.008	375
3/8	.008	350
1/2	.009	325
5/8	.010	300
3/4	.010	270
1" and over		

REAMERS		
Dia. (in inches)	Feed IPR	Speed SFM
1/16	.004	400
1/8	.005	400
3/16	.007	400
1/4	.008	350
3/8	.010	325
5/8	.010	300
3/4	.010	300

THREADING		
	Tapping SFM	Threading SFM
UNF & NF	40-80	50-80
UNC & NC	30-40	30-50

COOLANT

COLLETS AND FEEDFINGERS

Use smooth collets and feedfingers.

TOOLS

Conventional tools and grinds used for mild steels can be used on polycarbonates rod. Even though polycarbonates have a high melting point, care must be used when drilling to prevent excessive heat from building up. Excessive heat will melt the plastic and gum up the flutes of the drill.

Stresses can be induced during machining and surface crazing results.

CHIPS

Discontinuous chips can be produced using high speeds, deep cuts and large rake angle on the tool. Chip breakers help.

Chips are tough, curl about the work, and can foul the tooling.

BURRS

Brittle burrs are formed.

MACHINING OPERATIONS

Most conventional machining operations can be performed.

TURNING

Turning tools should have a 0° rake and a 3° clearance. Boring, threading and roughing tools should have a five degree rake. A coolant is not necessary. When feed is correct, a long spiral chip much like aluminum is produced.

FORMING

Conventional form tools can be used, but work piece must be supported.

CUTOFF

Conventionally ground cutoff tools as used for steel, work well.

DRILLING

Standard twist drills with 118° included angle can be used. No advantage is claimed for special plastic drills. The point angle will affect the quality of the hole.

Recommended drills have a $20 - 32^{\circ}$ helix angle with a $12 - 15^{\circ}$ lip relief. A rake angle of 52°. Speeds range from 300 - 800 SFM and feeds from .010 to .015 IPR.

REAMING

Polycarbonates can be reamed providing enough plastic is removed. Taking .005" is recommended. Use standard reamers designed for steel.

TAPPING

Before tapping, make sure the hole is clean and clear. If too much heat was generated when drilling the hole, the plastic on the surface could become crystalized and difficult if not impossible to tap.

Standard steel working taps and grinds are recommended. Polycarbonates offer considerable resistance to tapping. Tap wear will be excessive unless a coolant is used. A light lubricating oil rather than a cutting fluid is also recommended.

THREADING

Dies and self-opening die heads with chasers can be used to thread polycarbonates without using lubricants or coolants. A jet of air will help clear chips.

MILLING AND SAWING

Regular screw machine milling cutters and

ıetal techniques can be used.

:OOLANTS

:onventional coolants and soluble cutting fluids re compatible with polycarbonates.

For cleaning, use soap and water, detergents and water, ethyl alcohol, kerosene, or gasoline.

Avoid trichlorethylene and carbon tetrachloride since these degreasing agents may crack, craze, or dissolve the surface of polycarbonate pieces.

ENERIC NAME: **ACRYLIC**.

HEMICAL COMPOSITION: Polymethyl Methacrylate and Copolymers

RAW MATERIALS:

Basic Types	Trademarks	Suppliers
Methyl Methacrylate	"Lucite"	E. I. du Pont de Nemours & Co.
Methyl Methacrylate	"Plexiglas"	Rohm & Haas Company
Methyl Methacrylate	"Acrylate"	American Cyanamid Company

STANDARDS AND SPECIFICATIONS:

RAW MATERIALS: ASTM Specification D-788-53T.

STOCK SHAPES:

Trademarks	Suppliers
"Acrylux"	Westlake Plastics Corporation
"Cadco"	Cadillac Plastics & Chemical Co.

Tolerances:

Cast Acrylic Rod only. Diameters 1/4" through 1/2" +.005 -.000; 5/8" through 1" +.010; 1-1/8" through 2" +.015 -.000; 2-1/4" through 3" +.030.

Lengths:

3/8" diameter - 3" diameter .....8' long
3" diameter and over .....3' - 4' long

Note: Specify centerless ground to size stock for screw machine use.

FORM TOOLS		
Ratio of Tool Width to Machined Diameter	Feed IPR	Speed SFM
1:4	.0025	500
1:2	.002	500
1:1	.0015	450
1.5:1 *	.0015	400
2:1 *	.0015	375
2.5:1 *	.001	350
3:1 *	.001	350

BOX TOOLS		
Depth of Cut in Inches	Feed IPR	Speed SFM
.010	.0080	500
1/32	.0060	500
1/16	.0055	450
1/8	.0045	400
1/4	.0040	360
3/8	.0030	320

CUTOFF TOOLS		
Width in Inches	Feed IPR	Speed SFM
1/16	.0030	500
3/32	.0035	500
1/8	.0035	450

GENERAL NOTES
Avoid contact with trichlorethylene and hydrocarbons. To clean use mild soap and water. Brittle chips. Do not combine deep forming with deep drilling and avoid excessively high spindle speeds.

DRILLS		
Dia. (in inches)	Feed IPR	Speed SFM
1/32	.0030	400
1/16	.0040	400
3/32	.0050	400
1/8	.0060	400
3/16	.0065	350
1/4	.0080	325
5/16	.0085	310
3/8	.010	300
1/2	.010	280
5/8	.010	260
3/4	.012	240
1" and over	.010	225

REAMERS		
Dia. (in inches)	Feed IPR.	Speed SFM
1/16	.0060	400
1/8	.0065	400
3/16	.0080	400
1/4	.010	350
3/8	.010	300
5/8	.012	250
3/4	.012	250

THREADING		
	Tapping SFM	Threading SFM
UNF & NF	40-60	60-80
UNC & NC	30-45	40-60

COOLANT
Water soluble.

ACRYLIC POLYMETHACRYLATE (Lucite) - (Plexiglas)

TOLERANCE CONTROL

Acrylics are stable under varying conditions of heat, cold, moisture, and other exposure. With a poor heat conducting factor, acrylics can be machined to close tolerances.

COLLETS AND FEEDFINGERS

Acrylics should be held with smooth collets and feedfingers since the hard surface of the bar is easily scratched. Use rubber or soft pads.

Holding pressure should be only that necessary to keep the bar from turning, keeping in mind tool pressure is light.

TOOLS

Most tools used for cutting ferrous and non-ferrous metals can be used successfully if modified for non-ferrous metal use.

Tools must be kept sharp and a high surface speed coupled with a light feed produces the best work. Tools must be free from nicks and burrs. Deep cuts leave a rough finish which can be improved with a finishing cut at a light feed rate.

Machining acrylics at a higher than room temperature helps eliminate problems. Stock is brittle. For some jobs use warm coolants.

While high speed steel works well, carbide tools are recommended for long runs. The acrylics machine like hard wood or brass, and a little experimenting will soon produce the right technique.

CHIPS

Chips produced range from powder in deep holes to stringy continuous chips in shallow holes.

Improper tool feeds and tool dwell can melt the acrylics and produce gummy chips which will foul the tools and deform the part.

BURRS

Burrs are not much of a problem. Sharp corners have a tendency to chip. Always chamfer corners when possible to do so.

MACHINING OPERATIONS

Acrylics can be readily machined using tools ground for non-ferrous metals. Drilling is the one operation requiring extra attention. Double cutting angle on drills is sometimes helpful.

TURNING

Turning acrylics produces a semi-matte finish if a heavy cut is made (somewhat rough appearing). Light feeds produce a clear transparent finish. Tools should be ground with a zero or negative rake.

A speed of 500 SFM is suggested and feed should be kept constant throughout the cut. Depth of cut is governed by the rigidity of the sections being cut.

FORMING

Depending on support and width of the form tool, plunge forming can be used with excellent results.

CUTOFF

No problem - tool ground same as for brass usually sufficient. When cutting off into a hole, watch for chipping and splinters.

DRILLING

Since acrylics are often transparent, care must be exercised to produce clean holes.

Standard twist drills can be used but tend to grab. Modifying standard drills by dubbing of the cutting edges to a zero rake angle will prevent this. A double angle ground into the point also helps to improve the performance.

The following drill grinds are recommended:

Shallow Holes - (depth to diameter ratios of up to 1-1/2:1) Use a slow spiral twist drill with polished flutes and a point angle of

55-60°. Lip clearance at 15-20°. There should be no chip or colling problem with a shallow hole.

Medium Deep Holes - (depth to diameter up to 3:1) Use a slow spiral twist drill with wide polished flutes to handle the continuous chip. Point angle of 60 - 70° with a 12 - 15° lip clearance. Feed should be controlled to produce a continuous chip without heating the drill point. An air jet helps with chips and cooling drill.

Deep Holes - (depth diameter ratio up to 5:1) Use a slow spiral twist drill with wide polished flutes. The included angle should be 140° or larger. The larger angle produces a shorter cutting edge and a narrower chip. Keep lip clearance between 12 - 15°. Use a slow feed to produce powder-like chips - not strings. A coolant or air jet is necessary. Oil hole drills also help keep the workpiece cool.

REAMING

Not recommended. Drill to size, or use a drill to ream.

TAPPING

Standard metal cutting tools and standard taps can be used. National Coarse Threads are recommended and sharp "V" threads are to be avoided. Coarse pitch threads are best.

The threading tool should be used at 25% slower speeds than for brass for the best results. The tap and hole should be flooded with coolant.

THREADING

Standard metal cutting dies and self-opening die heads can be used. Chasers should be ground with a zero rake. An air jet directed to blow away the chips helps as does a copious amount of coolant.

MILLING AND SAWING

Fast speeds produce light cuts when sawing and eliminate any tendency to chip. Each tooth should produce a light chip. If speed is too high in relation to feed, the teeth will rub and heat up rather than cut free.

Teeth should be ground with a 0 - 10° rake, and hollow ground cutters work best.

COOLANTS

Use soluble oils or mineral oil base coolants. Warm coolant aids machining (see below).

Do not clean with trichlorethylene or any hydrocarbon. Use a mild soap and water.

NOTES

GENERIC NAME: ***POLYVINYLCHLORIDE (PVC)***

CHEMICAL COMPOSITION: Polyvinyl Chloride and Copolymers

RAW MATERIALS:

Basic Types	Trademarks	Suppliers
(Series)	"Geon"	B. F. Goodrich Chemical Co.
(Series)	"Bakelite"	Union Carbide Corporation
(Series)	"Opalon"	Monsanto Company

STANDARDS AND SPECIFICATIONS:

RAW MATERIALS: ASTM Specification, D-1755-60T Poly (Vinyl Chloride) Resins.

D-1784-60T. Poly (Vinyl Chloride) Compounds, Rigid.

D-2114-62T Poly (Vinyl Chloride - Vinyl Acetate) Compounds.

D-728-50, Vinyl Chloride Acetate Resin Molding Compounds and extrusion compounds. Nonrigid.

D-729-57, Vinylidene Chloride Molding Compounds.

STOCK SHAPES AND SIZES:

Rounds and other common shapes are available in sizes up to 6 inches in diameter.

Rounds 1/4" dia. to 2" dia. in 10 foot lengths.

2-1/8" dia. to 6" dia. in 5 foot lengths.

Tolerances

Tolerances are on the plus side and range from +.015" on small diameters to +.240" on large sizes.

FORM TOOLS		
Ratio of Tool Width to Machined Diameter	Feed IPR	Speed SFM
1:4	.003	600
1:2	.003	600
1:1	.0025	600
1.5:1	.002	600
2:1	.002	500
2.5:1	.0015	500
3:1	.001	500

BOX TOOLS		
Depth of Cut in Inches	Feed IPR	Speed SFM
.010	.010	600
1/32	.008	600
1/16	.006	600
1/8	.005	600
1/4	.004	500
3/8	.003	500

CUTOFF TOOLS		
Width in Inches	Feed IPR	Speed SFM
1/16	.002	600
3/32	.002	600
1/8	.002	600

GENERAL NOTES
Chips are stringy. Burrs are not a great problem. Support for rigidity and keep tools cutting since PVC will melt under riding tools. PVC is abrasive to tools.

DRILLS		
Dia. (in inches)	Feed IPR	Speed SFM
1/32	.001	250
1/16	.002	250
3/32	.003	250
1/8	.005	250
3/16	.006	300
1/4	.008	300
5/16	.008	350
3/8	.010	400
1/2	.010	400
5/8	.010	350
3/4	.010	350
1" and over	.010	300

REAMERS		
Dia. (in inches)	Feed IPR	Speed SFM
1/16	.010	250
1/8	.010	250
3/16	.010	300
1/4	.010	350
3/8	.010	400
5/8	.015	400
3/4	.015	400

TIIREADING		
	Tapping SFM	Threading SFM
UNF & NF	50-75	75-125
UNC & NC	40-60	60-80

COOLANT
Water soluble.

Section VII

POLYVINYLCHLORIDE (PVC)
(VINYLS)

TOLERANCE CONTROL

Rigid Polyvinylchloride is a stable plastic under all normal conditions encountered in the shop. Rod should be held under stable conditions until machining, and then the parts kept under the same conditions until shipment.

ANNEALING AND STRESS RELIEVING

All thermoplastics should be annealed to remove internal stresses before machining and this applies to PVC as well.

COLLETS AND FEEDFINGERS

Smooth collets and feedfingers should be used. Pressure applied should be just enough to keep the stock from turning. Tool pressure is relatively light.

TOOLS

High speed steel and carbide tools work best. These should be ground with non-ferrous tool angles, but even those won't necessarily produce the best results. PVC is abrasive and will wear the tool chip surface.

CHIPS

Tough and stringy - can be controlled fairly well with proper tool geometry.

BURRS

Can be cut relatively burr-free except for cutoff tool.

MACHINING OPERATIONS

Most conventional machining operations can be performed on PVC, providing the workpiece is adequately supported. With workpiece support, tolerances as close as .0005" can be held.

TURNING

PVC can be turned with tools ground with a negative rake and a turning speed of 300 - 500 SFM with a feed for roughing of .015" IPR and for finishing cuts of .009" IPR. Tools must be held on center.

FORMING

Forming tools can be used when the workpiece is supported. Skiving should be used for long, narrow pieces.

CUTOFF

Cutoff tools should be ground with adequate clearance to prevent rubbing and at an angle to eliminate the cutoff burr. Tools ground for the soft resilient plastics will work fine.

DRILLING

Slightly oversize (.001" - .002") drills should be used. The special plastic drills with a low helix and polished flutes should be used. The cutting angle should be dubbed off to provide a 0° rake angle and adequate lip clearance of $10 - 15^{\circ}$ provided.

Heat buildup both in the hole and in the drill should be avoided. Use pullouts and lots of coolant. If feed is too slow, the drill will gum up with melted PVC. Wet or dry, the feed is critical to successful drilling.

REAMING

A resilient plastic, reaming PVC is not recommended. If necessary for a close tolerance, a spiral reamer with narrow lands should be used and at least .005" stock removed.

TAPPING

Chrome plated (oversize .002" - .005") taps are recommended. Three fluted taps ground with a

negative rake should be used.

THREADING

Chrome plated dies and self-opening die heads can be used. Chasers should be ground with a zero to negative 5° rake. Copious quantities of coolant will flush out the chips and keep the tools cool.

MILLING

With adequate support, milling cutters can cut precise slots. Saws should be hollow ground or have teeth which are set. Adjust speed and feed so each tooth cuts.

COOLANTS

Keep workpiece and tools cool. Whenever heated, PVC emits TOXIC fumes which can permanently damage an individual.

Section VIII

GENERIC NAME: **POLYSTYRENE**

CHEMICAL COMPOSITION: Polystrene and High Impact Grades; Acrylonitrils-Styrene Polymers

RAW MATERIALS:

Basic Types	Trademarks	Suppliers
(Series)	"Styron"	Dow Chemical Corporation
(Series)	"Bakelite"	Union Carbide Corporation
(Series)	"Lustrex"	Monsanto Company
	"Dylene"	Koppers Company
	"Fosta"	Foster - Grant Company
Basic Filled		
	"Styrafil"	Fiberfil Corporation

STANDARDS AND SPECIFICATIONS:

RAW MATERIALS: ASTM Specification D-703-56T, Polystyrene Molding and Extrusion Materials.

D-1431-60, Styrene-Acrylonitrile Copolymer Molding and Extrusion Materials.

D-1892-61T, Styrene-Butadiene Molding and Extrusion Materials.

STOCK SIZES AND SHAPES:

Standard stock shapes are available with the length usually a 6 foot maximum. Diameters available range from .093" through 8". Tolerances - the usual tolerance is either plus or minus .015".

STYRENE

FORM TOOLS		
Ratio of Tool Width to Machined Diameter	Feed IPR	Speed SFM
1:4	.002	300
1:2		
1:1	.0015	300
1.5:1		
2:1	.001	280
2.5:1		
3:1		

BOX TOOLS		
Depth of Cut in Inches	Feed IPR	Speed SFM
.010	.020	500
1/32	.015	500
1/16	.010	450
1/8	.010	450
1/4	.008	400
3/8	.008	400

CUTOFF TOOLS		
Width in Inches	Feed IPR	Speed SFM
1/16	.003	400
3/32	.002	400
1/8	.002	400

GENERAL NOTES
Very brittle. Avoid plunge knurls. Threads tend to peel off. Will soften and distort under heat. Keep surface temperature under 140° F. in drilling - chips will tend to stick and pack in flutes. Use polished fluted drills.

DRILLS		
Dia. (in inches)	Feed IPR	Speed SFM
1/32	.002	80
1/16	.0025	85
3/32	.0028	90
1/8	.003	100
3/16	.003	120
1/4	.004	120
5/16	.004	120
3/8	.004	125
1/2	.005	125
5/8	.005	130
3/4	.006	130
1" and over	.006	130

REAMERS		
Dia. (in inches)	Feed IPR	Speed SFM
1/16	.010	500
1/8	.010	500
3/16	.008	500
1/4	.007	450
3/8	.006	400
5/8	.005	400
3/4	.005	400

THREADING		
	Tapping SFM	Threading SFM
UNF & NF	40-50	40-50
UNC & NC	30-40	30-40

COOLANT
Water Soluble - 10:1 ratio

POLYSTYRENE
Lustrex, Lustron, Styron
Acrylonitrile - Styrene Polymers

TOLERANCE CONTROL

The styrene type of plastics are most stable under ordinary conditions. No particular steps need be taken to store or handle the bar any differently from other materials.

ANNEALING AND STRESS RELIEVING

Most often molded, polystyrenes are subject to internal stresses which can be relieved or additional stresses induced by machining. Strains and stresses are due to localized overheating - especially in the area of the tool.

Polystyrenes are annealed by placing them in an air oven and heating 5 - 9° F. below the distortion point (previously determined with a sample) for about one hour. For pieces thicker than 1/8 inch, longer periods will be necessary.

COLLETS AND FEEDFINGERS

A firm rigid plastic, polystyrene can be held in smooth collets and feedfingers to avoid marking the surface. Light pressure should be used.

TOOLS

High speed steel tools can be used. Carbides are recommended for long runs.

CHIPS

The chips from polystyrene tend to fuse together and gum up tool surfaces. Adequate tooling is a must to keep the chips moving.

BURRS

Polystyrene tends to chip next to a machined surface, and this can be minimized by flooding the machining area with a warm coolant. This plastic is brittle.

MACHINING OPERATIONS

All conventional machining operations can be performed with due caution. Polystyrene when heated, expands but does not conduct heat readily. This means rubbing tools are to be avoided and tools ground with adequate clearances.

TURNING

Turning tools should be ground to produce ribbon like chips. Tools should have a slight (-2°) negative rake and a clearance angle of 10 - 15° and side clearance of about 10°. By setting the cutting edge 1 - 2° above center the tendency of the work to climb is minimized.

Tools must be kept sharp and maximum temperature below 150° F. Copious amounts of coolant may be required. Fast speeds (1300 RPM) and light cuts go together. For inside turning and boring small diameters, speeds may have to be reduced.

FORMING

A limited amount of forming may be performed with care.

CUTOFF

Conventional cutoff tools with liberal clearances can be used.

DRILLING

In drilling polystyrene the problem is removing the chips from the hole. Chips tend to pack in the flutes and fuse together. To cope with this, polished flutes are used with a slow helix. A generous side relief will also help to reduce friction, but the feed and speed used determine drilling success.

Speeds between 75 and 150 SFM are suggested with the following feeds:

Size	Feed (IPR)
Up to 1/8	.001 - .002
1/8 to 1/4	.002 - .004
1/4 to 1/2	.004 - .006
1/2 to 1	.006 - .008

The most satisfactory drills are high speed steel with thinned webs and a 90° included angle for

small holes and a 118° included angle for large holes.

Special plastic drills with a fast helix work well in blind holes.

REAMING

Not recommended if lands rub.

TAPPING

Thread tapping is recommended only for impact (Modified) type styrenes. Use only National Coarse Threads and use speeds 1/2 of those used for drilling. A 75% thread engagement should be maximum. A three-fluted tap helps control the chip problem when cutting threads over 1/4" diameter.

THREADING

Threading can be done with a single point tool with a light feed and plenty of coolant. On automatic screw machines use standard dies ground as for brass and with a negative rake on the first few threads. Self-opening die heads with chasers ground with a 50° chamfer and 0° rake can be used.

Thread roots and crests should be rounded if possible.

MILLING

Polystyrene can be cut with regular milling cutters. Speeds and feeds should be adjusted to prevent melting and gummy chips.

COOLANTS

Best coolants are air; water; soapy water; one part silicone fluid to six parts water and industrial tallow.

Many common degreasing compounds (perchloroethylene or trichloroethylene) are solvents for styrenes, and even metal parts cleaned in them must not be placed in contact with a styrene.

Avoid all contact with hydrocarbons, kerosene, etc.

NOTES

GENERIC NAME: **CELLULOSICS**

Section IX

CHEMICAL COMPOSITION: Cellulose Acetate, Cellulose Acetate Butyrate, Cellulose Propionate, Cellulose Nitrates

RAW MATERIALS:

Basic Types	Trademarks	Suppliers
Cellulose Acetate Flake	"Plastacele"	E. I. du Pont de Nemours & Co.
Acetate, Propionate	"Porticel"	Celanese Corporation
Cellulose Acetate, Acetate Butyrate	"Tenite"	Eastman Kodak Company
Ethyl Cellulose	"Ethocel"	Dow Chemical Corporation

STANDARDS AND SPECIFICATIONS:

RAW MATERIALS: ASTM Specification D-706-61T, Cellulose Acetate Molding and Extrusion Compounds.

D-707-61T, Cellulose Acetate Butyrate Molding and Extrusion Compounds.

D-1562-60, Cellulose Propionate Molding and Extrusion Compounds.

D-787-61T, Ethyl Cellulose Molding and Extrusion Compounds.

STOCK SHAPES: See above suppliers.

NOTES

Section IX

CELLULOSICS
Cellulose Acetate - Cellulose Nitrate

TOLERANCE CONTROL

Cellulosics are rather stable in the environment conditions encountered in most shops.

COLLETS AND FEEDFINGERS

Smooth surface collets and feedfingers should be used with only enough pressure to keep the stock from turning. Tool pressure is light.

TOOLS

Tools should be carbide or abrasion resistant and ground with greater clearances than for metals. Carbide or diamond tipped tools are best for long runs. Tools should be kept cool. Tools must be kept sharp at all times.

CHIPS

At slow speeds, chips will wind about the work, but at high speeds the chips will tend to be thrown off. Long stringy chips are produced.

MACHINING OPERATIONS

Most operations except reaming can be performed. High speeds should be used along with light cuts to prevent the plastic from overheating and melting.

TURNING

Carbide and diamond tipped tools should be used. High speeds and light feeds. Use adequate clearance to avoid rubbing.

Work should be supported for long cuts.

A jet of air directed at the cut keeps the tool cool.

FORMING

Not recommended unless the workpiece is supported.

Use a jet of air to clear the chips and cool tool.

CUTOFF

Standard cutoff tools designs with adequate clearance at light feeds can be used. A carbide tipped cutoff blade is recommended.

DRILLING

Special plastic drills (low helix angle) work best. Drill point should be 60-90° with a lip clearance of 12 - 18°. Wide polished flutes facilitate chip clearance, prevent friction and eliminate gumming. The web should be thinned.

Air directed on the drill and into the hole helps clear chips. Back out drill frequently to clear chips and cool drill. Watch chip flow.

Speeds should be in the 100-200 SFM range with feeds of .010" - .015" IPR.

For flat bottom holes drill angle can be changed and feed rate adjusted to avoid heat buildup. An excessive feed rate will cause the drill to jam.

High speed steel drills are suited to cellulosics.

Smooth holes can be drilled and reaming is not required.

REAMING

Not recommended, but standard reamers can be used. Suggested is drilling to within .001" and then pushing a hardened polished rod into the hole to obtain a smooth surface.

TAPPING

Conventional four fluted taps can be used but tend to heat during use.

High speed steel taps with 2 flutes are suggested for longer life and greater tapping speed. These also provide more chip room. Cutting edges should cut simultaneously to produce a smooth thread. The cutting edge is ground with a 5° negative rake. A two thread taper lead is sufficient. Either the tap or work should be free to center.

THREADING

Threading die should have three flutes or cutting edges and be ground the same as the taps. A two thread lead is enough.

Self-opening die heads and chasers ground with a 0 - 5° negative rake perform well.

Single point threading is practical with a sharp "V" tool. Cuts of .007" - .010" should be used for the final forming. Deeper cuts can be used for roughing the threads. Low threading speeds keep the thread-like chip close to the work, while faster speeds throw the chip away from the workpiece.

MILLING AND SAWING

Circular saws with set teeth or hollow ground produce smooth cuts in cellulosics.

Feed and speed should be adjusted to prevent saw heating and chips gumming up the teeth.

COOLANTS

Water soluble cutting oils can be used.

NOTES

GENERIC NAME: ***THERMOSET PLASTICS–HIGH PRESSURE AND FILLED LAMINATES***

RAW MATERIALS:

Basic Types	Trademarks	Suppliers
Phenolics (Urea-Formaldehyde)	"Bakelite"	Union Carbide Corporation
	"Beetle"	American Cyanamide Company
	"Durez"	Hooker Chemical Corporation
	"Phenolite"	N V F
High Pressure Laminates	"Micarta"	Micarta Division - Westinghouse Electric Company
	"Formica"	Formica Corporation - American Cyanamide Company
	"Synthane"	Synthane, Incorporated
	"Dilecto"	Budd Company - Polychem Div.
	"Spauldite"	Spaulding Fibre Company
	"Insurok"	Richardson Company
	"Panelyte"	Thiokol Chemical Corporation Panelyte Industrial Div.

A thermoset plastic is a resin plus a lamination of paper, cloth or glass. A filled thermoset plastic has a powder added. These can be very abrasive when cutting tools are used.

Rods are usually formed by rolling a resin soaked or coated paper around a small mandrel. The mandrel is removed and the tube squeezed tightly and baked. Other rods are cut from sheets of laminated plastics. An examination of the end of the rod will either show the layers are spiral or all in one direction.

STOCK SHAPES:

Round tubes and rods are available but can be obtained in oval, elliptical, square, rectangular and in other special shapes. Order rod and tube oversize to allow for a cut when the O. D. or I. D. must be held to close limits.

TOLERANCES:

Rods vary in length with four feet (48") a common length. Special orders may be filled for rods as long as 8 feet (96").

Tolerances can be held since the rods are relatively stable and the resin moisture resistant.

Order either rod or tube larger than required and take off at least .015" when concentricity is required.

THERMOSET PLASTICS–HIGH PRESSURE AND FILLED LAMINATES

FORM TOOLS		
Ratio of Tool Width to Machined Diameter	Feed IPR	Speed SFM
1:4	.002	600
1:2	.002	600
1:1	.0015	600
1.5:1	.001	500
2:1	.001	500
2.5:1	.0005	400
3:1	.0005	400

BOX TOOLS		
Depth of Cut in Inches	Feed IPR	Speed SFM
.010	.010	600
1/32	.008	600
1/16	.007	550
1/8	.005	500
1/4	.004	450
3/8	.002	400

CUTOFF TOOLS		
Width in Inches	Feed IPR	Speed SFM
1/16	.002	600
3/32	.0025	600
1/8	.003	600

GENERAL NOTES
Light feeds - high speeds is the rule for small sizes. Slower speeds for large diameters (5" and over).

DRILLS		
Dia. (in inches)	Feed IPR	Speed SFM
1/16	.006	500
1/8	.008	500
1/4	.010	500
3/8	.010	400
3/4	.010	350

REAMERS		
Dia. (in inches)	Feed IPR	Speed SFM
NOT RECOMMENDED BORE TO SIZE		

THREADING		
	Tapping SFM	Threading SFM
UNF & NF	50	75
UNC & NC	30	50

COOLANT

GLASS FILLED LAMINATES

FORM TOOLS		
Ratio of Tool Width to Machined Diameter	Feed IPR	Speed SFM
1:4	.0015	300
1:2	.0015	300
1:1	.001	250
1.5:1	.001	200
2:1	.00075	200
2.5:1	.0005	200
3:1	.0005	200

BOX TOOLS		
Depth of Cut in inches	Feed IPR	Speed SFM
.010	.008	300
1/32	.007	300
1/16	.006	300
1/8	.004	250
1/4	.003	250
3/8	.002	200

CUTOFF TOOLS		
Width in Inches	Feed IPR	Speed SFM
1/16	.0015	300
3/32	.002	300
1/8	.002	300

GENERAL NOTES

DRILLS		
Dia. (in inches)	Feed IPR	Speed SFM
1/16	.002	300
1/8	.003	300
1/4	.004	250
3/8	.004	200
5/8	.005	175

REAMERS		
Dia. (in inches)	Feed IPR	Speed SFM
1/16	.010	250
1/8	.010	250
3/16	.010	250
1/4	.010	250
3/8	.010	250
5/8	.010	250
3/4	.010	250

THREADING		
	Tapping SFM	Threading SFM
UNF & NF	------	75
UNC & NC	------	50

COOLANT

TOLERANCE CONTROL

Laminated and filled plastics are stable with the paper, cloth and wood filled having a slight affinity for moisture on the surface

Even after machining under quantities of liquid coolant, two hours at 130° F. will dry thermosetting plastics.

ANNEALING AND STRESS RELIEVING

Not necessary.

COLLETS AND FEEDFINGERS

Smooth collets and feedfingers should be used to prevent marking the surface. Pressure can be applied without distorting the bar. Somewhat heavier tool forces are used to cut thermosets, compared to thermoplastics.

TOOLS

Wear resistant carbide and diamond tipped tools are recommended since all molded and filled thermosets (glass base, asbestos base, and graphitized laminates) are highly abrasive. High speed steel tools, if used, will dull rapidly, especially on the filled laminates.

CHIPS

Fine chips are usually produced and if machining dry should be collected to prevent gumming up ways and tool slides.

BURRS

Burrs, while small, will be produced and the surface next to the cut on glass filled laminates may be chipped by the cutting tool. Burrs can be removed with steel wool, by tumbling without a media or using a light slightly abrasive media.

MACHINING OPERATIONS

Most conventional machining operations can be performed but reaming is not recommended. Thermosets are poor conductors of heat and care must be taken to keep tools cool.

Additional care must be used when turning or drilling to assure the stock is not being unwound or peeled by the tool.

Tubing is recommended to eliminate drilling. To assure a concentric hole, bibing should be ordered small enough to remove at least .015" from the I. D. by boring.

TURNING

Watch the rotation of the stock to be sure the tools don't unwind or peel off the laminations. This can happen with poorly produced rod or tube.

Paper or cloth filled laminates can be turned with high speed steel tools at about 600 - 800 SFM. By using carbide or diamond tipped tools this speed can be doubled.

Tools must be kept sharp, rounded nose, and have a 30-60° clearance angle. A negative rake is best. Rough cuts followed with a finishing cut to remove .010" - .015" works very well.

Glass filled laminates are turned with carbide or diamond tipped tools only. Speed is 150 - 200 SFM and feed at .010" IPR. Use 30 - 35 clearance angle, a 13° side rake and 0° top rake. Use as large a nose radius as the job will allow. The tools should be placed on the centerline for best performance and finish.

FORMING

Carbide form tools can be used with high speeds and light feeds to form thin wall flanges for both paper and glass filled laminates.

CUTOFF

Cutoff can be done with blades from 1/32" to 5/16" in width depending on the size and wall thickness of the product. Feeds from .002" IPR to .006" IPR can be used.

DRILLING

Paper and cloth filled laminates can be drilled with high speed steel twist drills ground with

plenty of lip clearance. Carbide tipped (Carboloy) drills are best for long runs. Polished flutes aid chip removal.

Drills should be the "slow twist" design with polished flutes to remove the chips as rapidly as possible.

Drills should be run at the fastest speed not to burn. Drill will produce smaller holes and oversize drills may be required. 3/32" - 1/4" drills may produce holes .003" undersize. 1/4" to 1" drills may produce holes .004" undersize.

When drilling the center of a rod (with the laminations) be careful not to split the rod. A pilot hole will be helpful. Drilling can be done with a diamond tipped boring bar comparable to a half round drill. A stream of air aids in removing the chips. Be sure to use a starting hole.

REAMING

Reaming is not recommended.

TAPPING

Paper and cloth filled laminates can be tapped with chrome plated and ground taps which are .003" - .004" oversize. An oil emulsion will help clear chips.

When tapping glass filled laminates, a blast of air should be directed into the hole to remove the abrasive powder-like chips.

Keep taps sharp to prevent tearing threads.

THREADING

Cutting threads in paper, cloth and glass filled laminates is very satisfactory, and threads can be ground. The strength of the thread is related to the strength of the resin used in the laminate.

COOLANTS

Thermoset plastics can be cut dry or with a stream of air to blow away the chips and cool the tool. Water soluble oils or parafin based cutting fluids are also used.

NOTES

TO KEEP IN MIND WHEN ORDERING PLASTICS

Plastic rods are produced by casting or extruding. The larger the diameter the shorter the length produced. Small diameter rods can be produced 8 feet or more in length and larger diameters, 5 to 8 inches, can be produced in lengths of about 2 to 3 feet.

Unless ordered to a specific size, plastic rod may be delivered in the "as produced" condition. The variations in diameter in "as produced" rod may be unsatisfactory for screw machines.

Most plastics used in automatic screw machines are centerless ground to produce the tolerance limits necessary for holding with a uniform pressure using smooth collets. The centerless grinding is an extra operation but is necessary to insure a uniform dimension.

If a large quantity of rod will be required for a job, it can, in many instances, be produced to the exact size without requiring the extra expense of grinding to size.

The industry practices do not include producing each plastic to the same tolerance limits so each plastic must be examined separately and the supplier asked for the specific tolerance limits.

Plastic rod for screw machine products should be stress relieved before use. This is necessary to avoid product distortion after machining.

Anyone machining plastics should be aware of the fact that the same plastic is available in different densities (see Polyethylene). To obtain the best machining characteristics, always order the highest density available and compatible with the customer's use. Test samples of high and low density will quickly show which density to use.

Section XII

HOW TO IDENTIFY PLASTICS

(Refer to Chart on page 53)

The chart is to help you identify some of the basic types of plastic materials, using ordinary techniques and simple available tools. Please note that thermosetting plastics, phenolics and epoxies differ from the thermoplastic materials in that once set or hardened by heat they cannot be resoftened or melted by heating.

Common tests used to identify plastic materials are burning or heating in a test tube and checking the odor given off. These tests are intended for easy identification of basic polymer types.

In any method for testing to identify unknown plastic material, it often helps to compare the unknown with a known sample by running simultaneous tests and comparing the results. Identification can often be speeded up this way.

The test data given is based on information furnished by E. I. du Pont de Nemours & Co., Inc., and by the editors of Materials Engineering Magazine. The test data is believed to be reliable and is based on accumulated experience. Results as indicated are not guaranteed.

BURNING TEST

Most plastics have definite characteristics when exposed to flame. These are flamability, color and nature of flame, presence or absence of smoke, melt behavior and odor.

Cut a small strip of plastic, about 3 inches long, if possible. Hold one end with pliers or tweezers and bring the other end to a Bunsen burner flame which has been regulated to make it non-luminous. A match may be used. Always be careful to avoid drips of molten plastic.

Hold the sliver just to the edge of the flame until it takes fire, or for ten seconds. Note the character of the flame and cautiously smell any odor produced after distinguishing.

Care must be taken when smelling for odor since some polymers may produce toxic gases.

If such danger is suspected, smell only for a short time and indirectly by waving a hand gently through the emitted vapor or gas. Do this test in a well-ventilated room.

The presence of cellulose or glass filler or plasticizers will affect the burning characteristics and odor of resin.

To use the chart, first note if the plastic burns and if it does, does it keep burning when removed from the flame or does it stop burning. This characteristic indicates whether the left or right side of the chart is applicable.

USING A TEST TUBE FOR THE ODOR TEST

Although the odors from heating a plastic in a test tube are similar to those encountered in the burning test, they are much stronger and more distinctive. Identification by odor may frequently be accomplished by this test when it has been indefinite in the burning test.

Following are some examples of how characteristic the behavior may be.

Cellulose nitrate, upon heating in a test tube, fumes strongly and emits a cloud of brown nitric acid.

Cellulose butyrate will evolve a combination of acetic and butyric acids, and after standing a few minutes, a rancid butter odor will be discernible.

The chlorine-containing polymers emit the sharp pungent hydrochloric acid odor.

Delrin acetal resin will produce a formaldehyde odor. Nylon produces a very characteristic odor similar to that of burnt wool.

HOW TO IDENTIFY PLASTICS

	Materials	Burns, But Extinguishes No Flame on Removal of Flame Source				Continues to Burn After Removal of Flame Source				Remarks
		Odor	Odor	Color of Flame	Drips	Odor	Color of Flame	Drips	Speed of Burning	
Thermoplastics	Acetals	---	---	---	--	Formaldehyde	Blue, no smoke	Yes	Slow	---
	Acrylics	---	---	---	--	Fruity	Blue, yellow tip	No (cast) Yes (molded)	Slow	Flame, may spurt If rubber modified
	Cellulosics									
	Acetate	---	Vinegar	Yellow	No	Vinegar	Yellow	Yes	Slow	Flame may spark
	Ethyl Cellulose	---	---	---	--	Burnt Sugar	Yellow, blue edges	Yes	Rapid	---
	Fluorocarbons									
	FEP	Faint odor of burnt hair	---	---	--	---	---	--	--	Deforms; no combustion, but drips
	PTFE	Faint odor of burnt hair	---	---	--	---	---	--	--	Deforms; does not drip
	CTFE	Faint odor of acetic acid	---	---	--	---	---	--	--	Deforms; no combustion, but drips
	Nylons									
	Type 6	---	Burnt wool	Blue, yellow tip	Yes	---	---	--	--	---
	Type 6/6	---	Burnt wool or hair	Blue, yellow tip	Yes	---	---	--	--	More rigid than type 6 nylon
	Phenoxies	---	Acrid	Yellow	No	Acrid	Yellow	Yes	Slow	Black smoke with soot in air
	Polycarbonates	---	Faint, sweet aromatic ester	Orange	Yes	---	---	--	--	Black smoke with soot in air
	Polyethylenes	---	---	---	--	Paraffin	Blue, yellow tip	Yes	Slow	Floats in water
	Polypropylenes	---	Acrid	Yellow	No	Sweet	Blue, yellow tip	Yes	Slow	Floats in water; more difficult to scratch than polyethylene
	Polystyrenes	---	---	---	--	Illumating gas	Yellow	Yes	Rapid	Dense black smoke with soot in air
	Vinyls - Rigid	---	Hydrochloric acid	Yellow with green spurts	No	---	---	--	--	Chars, melts
	ABS/PVC	---	Acrid	Yellow, blue edges	No	---	---	--	--	Black smoke with soot in air
	PVC/Acrylic	---	Fruity	Blue, yellow tip	No	---	---	--	--	---
Thermosets	Epoxies	---	---	---	--	Phenol	Black smoke	No	Slow	Black smoke with soot in air
	Phenolics	Formaldehyde & phenol	Phenol & wood or paper	Yellow	No	---	---	--	--	May crack

Section XIII STORING AND HANDLING PLASTIC ROD

Label Each Lot

Since many plastics are similar in appearance, but possess widely differing properties, it is essential that each lot be identified.

The use of tags, separate racks or bins is suggested.

Handling Rod

Since most plastics are softer than metals, care must be taken to prevent chips and other metal particles from inbedding in the surface.

Inside or Outside Storage

Plastics thermal coefficient of expansion may be ten times that of metal. The temperature and moisture content of the surrounding air affect plastics, and the bars should be stored for at least 48 hours near the machine or in the same area prior to machining. It is essential to stabilize the rod prior to machining to prevent size changes after machining.

Cover

Any clean storage area can be used, and clear plastics should be covered to prevent scratching or marring their surface.

Plastics are resistant to oil but with prolonged exposure, will stain. A light protective cover of paper will prevent oil mist from accumulating on the plastic.

Support

Thermoplastic rod can be stored in either a vertical or horizontal position.

Handling Machined Pieces

Thin walls often characterize machined plastic pieces and care must be used not to pile heavy tote pans, etc. on top of machined pieces.

Shipping Machined Plastics

Machined plastic pieces can be shipped in open or sealed containers without special precautions.

Some plastics, nylon for example, absorb or give up moisture constantly and this can change the "as-machined" dimensions. To counteract, some shops seal the pieces in plastic bags to maintain the "as-machined" condition and dimensions until delivery is made and the customer accepts the shipment.

Should extremely close tolerances be required, shipping conditions and receiving inspection conditions, should be agreed upon with the customer.

The following books, booklets, brochures and magazine articles, were read as background material for this manual. Those who may want additional information on a specific plastic can use this as a reference list.

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