FABRICATION OF ACRYLIC RESINS
IN THE SCHOOL SHOP

by

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INTRODUCTION

A new era of materials, skills and products has been inaugurated with the advent of plastics. As interest develops and more products reach the consumer, it is reasonable to conclude that this material lends itself to educational values in the school and industrial shops and to the recreational aspects of the home workshop.

The purpose of this thesis was to study the acrylic resins and to develop methods and techniques of simple fabrication with the use of power and hand tools usually found in a school shop.

Of the different plastic groups, the acrylic group was chosen because its general properties lend themselves more readily to fabrication with the facilities and machines found in a school shop (9). At the present time Plexiglas and Lucite are the only two brands in the acrylic group. They are thermoplastic and can be formed to most any shape when heated above 220^{o} F. If held in the new shape until cool, they retain that form. On reheating after forming, acrylics return to their original shape. This property is helpful to the operator, since it enables him to salvage parts which may have been improperly formed.

REVIEW OF LITERATURE

It was found after thorough checking of the library facilities and outside sources; i. e., pamphlets supplied by different plastic manufactures, that there is a large amount of information on commerical fabrication. Information on fabrication of plastics in the school shop is limited and not all authorities are in agreement as to the techniques and machines which should be used.

Some of the material which has been written on fabrication of acrylic resins applicable to the school shop will be found under the heading fabrication techniques.

MATERIALS

Acrylics are available in the forms of cast sheets, rods and tubes, and moulding powders. Powders will not be discussed in this thesis because of the lack of suitable equipment in the school shop for forming into suitable shapes. Cast sheets may be obtained in a variety of transparent, translucent and opaque colors (12, 17). Sheet sizes available in different thicknesses are given in Tables 1 and 2.

Larger sheets up to 54 by 78 inches are offered in thicknesses from 0.125 to 0.500 inch, but caliper variations are somewhat larger in these sheets (8, 14).

Caliper tolerances for acrylic sheets vary with the thickness and size of the sheet. The tolerances for sheets in sizes up to 40 by 50 inches are given in Table 3.

Table 1. Cast sheets manufactured in thicknesses from 0.060 to 0.500 inch in the following sizes, in inches.

6 x 12	18 x 18	24 x 60
12 x 12	18 x 24	30 x 36
12 x 18	18 x 36	36 x 36
12 x 24	18 x 60	36 x 42
12 x 36	20 x 50	36 x 48
12 x 48	24 x 24	36 x 60
12 x 60	24 x 36	40 x 50
	24 x 48	

Table 2. Sheets in thicknesses from 0.550 inch to 2.000 inches are manufactured in the following sizes, in inches.

6 x 12	12 x 48	24 x 48
12 x 12	20 x 50	36 x 36
12 x 24	24 x 24	36 x 48
12 x 36	24 x 36	40 x 50

Table 3. Tolerances applying to standard sheets in sizes up to 40 by 50 inches.

Nominal thickness, inch	Tolerance, inch	Approximate weight per sq. ft., pounds
0.060	0.010	0.364
0.080	0.010	0.485
0.100	0.012	0.613
0.125	0.015	0.766
0.150	0.015	0.920
0.187	0.019	1.140
0.220	0.022	1.350
0.250	0.025	1.530
0.312	0.031	1.931
0.375	0.038	2.320
0.500	0.050	3.094

Rods may be obtained in 48 inch lengths in diameters from 0.375 inch up to and including 1.250 inches. Diameters from 1.375 to 2.000 inches are obtainable in lengths of 24 inches.

Tubes are manufactured with outside diameters ranging from 1.500 to 6.000 inches with various wall thicknesses and in lengths of 52.5 inches.

Acrylics are light in weight, having a specific gravity of 1.18 (12). This may be compared to 1.27 for cellulose acetate and phenolic plastics, 2.4 for glass and 2.7 for aluminum. The moisture resistance of acrylics is high. Water absorption is 0.4 per cent by standard tests (12). Acrylics are tasteless, odorless and nonirritating to the skin.

For this work clear Plexiglas sheets 0.060, 0.187 and 0.500 inch in thickness were used. Clear rods 0.750 inch in diameter were purchased cut to 16 inches in length. Rods are not usually furnished in this length, however, the supply house did this for ease of handling and shipping.

One highly recommended bonding agent for acrylics is a mixture of equal parts of monomeric methyl methacrylate and methylene dichloride. Immediately before using this solvent, a small capsule of benzoyl peroxide is added as a catalyst. After the addition of the catalyst, the solvent tends to thicken slowly unless it is refrigerated. This mixture is known as 1-A cement and may be purchased under this name. Methylene dichloride may be used alone as a solvent cement for acrylics. It dissolves the acrylic sheet rapidly and evaporates quickly.

Ethylene dichloride is also used for bonding acrylics. It is considered inferior to 1-A cement. Strong joints may be made with it and it may be kept for a long time without loss of welding properties.

Glacial acetic acid and acetone may be used for cements but are not recommended because joints made with these solvents are often frosted (7).

Ethylene dichloride was selected as the cement to use for this work, since it was not necessary to keep it below room temperature in order to retain its full strength for a long period of time.

FABRICATION TECHNIQUES

Storage and Unmasking

Acrylic sheets are best stored on edge or stacked in small piles with the masking paper in place. Storing at an angle for any considerable period may result in sagging or bowing of the sheets. This is not warping in the usual sense of the word. Such distortions are not due to moisture absorption and are not permanent because if the sheet is tilted at the opposite angle or laid flat it will resume its flat shape.

Direct sun rays should not be allowed to fall on the stored acrylic, since sunlight may cause drying and loss of adhesion of the masking cement particularly at the edges of the sheet.

Masking paper can be lifted from the acrylic sheet at one corner and removed with a slow, steady pull. Unmasking builds up an electrostatic charge on the sheet which will attract dust to the surface, but it can be removed by blotting with a damp, soft cloth.

Principles of Forming

Since acrylics are thermoplastic, they become soft and pliable when heated to 220° F. to 350° F., depending upon the type (12). They can then be bent to almost any shape. When the material cools, it retains the shape to which it has been formed, except for a small contraction caused by the lowering of temperature.

It is not practical to cold form acrylics; i. e., to spring them into a curved form without heating, unless the material is thin and the curve very slight. For example, a 16 inch piece 0.250 inch thick should not be deflected more than 0.250 inch. Acrylics are flexible, but if the outer fiber stress on a curved cold formed piece is over 1,000 psi, tiny fissures called crazing may develop (18).

It is impossible to establish an optimun temperature at which acrylics should be formed. If the material is too cool (below 212° F.) when it is formed, excessive internal strains may be set up and may result in crazing at some later time. If, on the other hand, it is too hot, its surface is very soft and is apt to pick up minor imperfections called mark-off from the form. Finger prints, glove marks and specks of dirt can make deep surface impressions which require extensive polishing later. In some cases it is advisable to heat the sheet somewhat hotter than the required forming temperature, remove it from the oven and allow the surface to cool slightly. In this procedure, the center of the sheet is hot enough to avoid excessive strains, while its surfaces are cool enough to reduce mark-off to a minimum.

Simple bends and slight three-dimensional shapes can be formed with the sheet at a lower temperature than more difficult compound sections require. Thinner material must be heated to a higher temperature than thick material, as the amount of heat that can be stored and the time available for forming the thin sheets are much less than for thick sections. For example, a sheet of 0.060 inch material when heated to 250° F. will cool below its forming temperature in less than a minute when exposed to room temperature, while a piece of 0.250 inch material will still be limp and flexible after three minutes (6).

The application of high or even moderately high pressures is neither desirable nor necessary in the forming of acrylic sheets. Too much pressure tends to increase the extent of mark-off since the power required to form acrylic is much less than that required for even soft metals. Hot acrylic may be handled much like a sheet of pure gum rubber and approximately the same power is required to stretch it (18).

The rate of cooling the formed part should be as slow as is practicable in order to keep internal strains to a minimum. General circulation of air over the formed part is not objectionable, but plunging a formed part immediately into cold water is definitely not recommended.

Heat for Forming

Perhaps the simplest method of forming acrylic sheets depends upon the use of a strip heater, a device which heats the material to forming temperature along the line of the proposed bend. This method lends itself to the rapid production of 90 degree or 180 degree bends for the production of simple boxes, bill clips, tie clips and the like. A strip heater can be simply a blast of hot air, a steam pipe or, more often, an electric heater made from a nichrome wire resistance coil of the type used in many electric heaters and irons. The wire can be insulated with china clay tubing or porcelain beads. A thermostat may be used to control temperature. The acrylic sheet should not be allowed to come in contact with the heated wire, since excessive temperatures will destroy the surface of the material (7).

Another source of heat for acrylic sheets is infrared lamps. The pentration of the infrared rays tends to heat more uniformly than the strip heater (13).

Forms

By skillful manipulation of the heated acrylic sheet it is possible to execute some simple shapes without the use of forms. While designs shaped this way may be clever and highly artistic, it is more often necessary to produce uniform parts by the use of rigid forms.

Built-up wood is probably the simplest and least expensive material for forms. Wooden forms tend to change dimensions with changes in atmospheric conditions and are not recommended for long use. The difference between flat grain and end grain may produce distortions in the finished piece. Therefore, care should be taken in building wooden forms so that the grain of the wood is properly oriented throughout the section.

For simple forming, outing flannel is generally used to cover the form. This material has a soft nap which will not mar the surface of the hot acrylic.

In some types of stretch forming, the surface of the form is covered with a grease which lubricates the hot plastic sheet as it is being drawn and stretched. The grease also acts as an insulating blanket between the hot sheet and the cooler form (11). This insulating effect is very important in producing parts of high optical quality (1).

It is desirable to provide some means of holding the edges of the sheet against the form during cooling. In some cases, rubber bands can be fastened to the form and snapped over the edges of the shaped acrylic.

Cutting

Acrylic sheet up to 0.100 inch in thickness may be cut by a method similar to that used for window glass. A scribe or sharp edge is run across the sheet several times along a straight edge, making a deep scratch. Then, by holding the sheet rigidly under the straight edge on one side of the mark and pressing down the other over the edge of the table, the sheet may be broken along the scratch. This method is not recommended for the long breaks or thick material (10).

Sawing

Acrylic sheet may be cut with any of the saws used for wood or metals. Such saws should be chosen for the type of work to be done. Circular saws are preferred for straight cutting. For cutting large sheets, table saws are used so that the sheet can be held firmly and square. Jig saws are used for cutting curves of small radii, while band saws are particularly suited for curves of larger radii and for straight cuts in thicker material.

In general, the thicker the material or stock, the fewer teeth per inch and the greater clearance will be required. Large diameter circular saws are to be recommended, as the teeth have a chance to cool during each revolution. Similarly, band saws are preferable to circular saws for cutting thick material, for here again the teeth have a chance to cool (3, 16).

Circular saws for cutting acrylics should be hollow or concave-ground. This prevents binding in thicker stock and provides the necessary side clearance with a minimum of chipping in thinner stock. Circular saws should be run at 8,000 to 12,000 surface feet per minute, that is a 12-inch diameter circular blade should run at approximately 3,400 rpm. The plastic piece should be fed rather slowly to prevent overheating. Speed should be reduced as the blade is leaving the cut to avoid chipping of the corners. Wide band saw blades are well suited for long straight cuts, narrow blades for curved cuts. Tooth size should be increased with the material thickness. For light work, a 26 or 28 gauge blade running at speeds of 2,500 to 5,000 feet per minute is very satisfactory (15).

Both band and jig saws should have guides adjusted as close as possible to the work for accuracy of cut. Feed, as in the case of circular saws, should be rather slow.

Since an acrylic sheet contains no fillers, it does not dull the saws excessively. If reasonable care is taken to avoid overheating the material, no coolant need be used.

Turning in Machine Lathe

Acrylic rods may be turned on a machine lathe to produce an excellent semi-matte surface. Work up to 2.50 inches in diameter should turn 700 to 800 rpm. On larger diameters, surface speeds of 500 feet per minute, with automatic cross feeds of 0.004 to 0.005 inch per revolution will cut a clean continuous chip. Heavy feeds are not recommended (18).

Routing

Routers are used for a variety of operations, such as the machining of rabbetted edges to permit flush mountings and the shaping to size of both flat and formed parts.

Routers should have a no-load spindle speed of 10,000 to 22,000 rpm. High speed routing with small cutters under 1.50 inches in diameter will give the smoothest cut. Cutters should be kept sharp and should have a back clearance angle of about 10° and no rake (13).

Drilling

The drills customarily used for metal can also be used for acrylics. Better results are obtained if drills are specially ground. For thin acrylic sheets, drills ground with a small web and an included angle of 60° to 70° are recommended. They should have zero or little rake and a 12° to 15° lip clearance angle. The lands should be relatively narrow with polished heels and wide flutes to facilitate chip removal. Drills of the slow spiral type are preferred. For material 0.250 inch and thicker and for blind holes, the same type of drill is used, except that it should be ground with a wider included angle, up to 120°. Drills should be run at moderate speeds. Feed will depend on the spindle speed and the diameter of the hole and can best be learned by experience (10).

Tapping and Threading

Acrylics may be tapped and threaded with the tools used for copper and brass. It is preferable to modify standard taps and dies to produce threads with rounded grooves so as to avoid cracking at the apex. During the tapping and threading operations, the material should be kept cool and the taps should be backed out often to clean the threads of chips. A light grade oil is recommended as a lubricant for these operations (10).

Finishing

Acrylics should not be sanded unless it is absolutely necessary. If surface imperfections are too deep to be removed by light buffing, it is best to use the finest sandpaper that will remove the imperfections so as to avoid deep buffing which results in localized heating of the sheet (13).

Usually 320-grit wet paper is as coarse as will be required and after washing this may be followed by 400-grit or finer paper. The sandpaper should be soaked in water a few minutes before using and plenty of water should be used while sanding to reduce the heat caused by friction. The sandpaper should be used with a circular motion and backed by a rubber block or pad. If sanding is confined to too small an area objectionable distortions will result in the surface. Light pressures should be used in sanding (2).

Best buffing results are obtained on very soft, open type cotton buffing wheels. Special buffs may be obtained from reputable buffing manufactures but they are not considered better than the type mentioned.

The acrylic sheet is first buffed on a stitched cotton wheel running at about 2,000 surface feet per minute, to which pumice or similar abrasive has been applied. When most of the scratches have been reduced on the first wheel, the acrylic is buffed on a wheel to which only tallow has been applied. When an unbleached cotton sheeting buff is used, this tallow wheel should operate at 3,200 to 3,600 surface feet per minute.

The acrylic is next brought to a high polish on a soft, loose buff on which no abrasive or tallow is used. This cleaning buff may be a cotton flannel sheeting buff running at 3,500 to 4,000 surface feet per minute (5).

Cementing

The cementing of thermoplastics depends on the intermingling of the two surfaces of the joint so that there is cohesion similar to that in the material itself. This principle differs from that which applies to wood gluing which depends on the adhesion of the glue to each of the two surfaces being bonded. To effect cohesion between pieces of acrylic material, an organic liquid solvent is used which actually attacks the plastic and forms a well defined soft surface layer called a cushion. Most known methods of cementing acrylics are based on this solvent action which permits two surfaces when pressed together to intermingle and finally unite in a true cohesive bond (4). Probably the term welding is actually more descriptive of this process than the term cement, although this latter term is the one most commonly used to describe material making the weld.

In cementing acrylics, most of the joints are made by the soak method. This operation consists of dipping one of the two pieces to be cemented into the solvent and holding it there until a softened cushion is formed on the surface to be cemented. When the piece is removed from the solution, the surface of the cushion is wet with solvent. As this surface is pressed against the dry surface of the other part being cemented, the excess solvent forms a second cushion on this matching edge, shallow but enough to permit the intermingling of the two surfaces.

Satisfactory bonds are affected by a number of factors. The fit of the two parts to be joined must be accurate. It is easier to bond flat surfaces than those that are formed or curved. The two surfaces should have a fairly smooth finish. Generally, it is advisable to polish surfaces of parts to be cemented. In most polishing techniques some type of wax carried abrasive or polishing compound is used. This material, if it remains on the surface of the parts to be cemented, presents a barrier to the solvent. Rather than polishing with a buffing wheel, rough surfaces should be sanded smooth. Unless this is done there will be weak points along the joint.

Before an acrylic sheet is immersed in the soak bath, it is necessary to confine the softening action of the solvent to the area of the joint. Cellophane tape coated with a pressure sensitive adhesive gives satisfactory protection for the sheet surface.

Another important factor in successful cementing of plastic parts is the slight time interval which must be allowed between the time the two pieces are placed in contact and the time actual bonding pressure is applied. It is this time interval that the liquid of the cushion surface is being absorbed by the opposing dry surface. It follows that an immediate application of pressure will squeeze out the liquid solvent from the surface of the cushion. A satisfactory interval is from 20 to 40 seconds.

EXPERIMENTAL PROCEDURE

Layout and Unmasking

Layout of parts for the projects shown in Plates I and II was marked in pencil with the masking paper in place. This method was satisfactory except for parts which had to be cut accurately. For accurate layout, it was necessary to roll the paper off the surface and mark the acrylic sheet with a sharp scribe. Marking along a straight edge was first done with a sharp knife which should be held parallel to the straight edge as it has a tendency to crawl away from the guide. The masking paper was cut slightly smaller than the layout and replaced in order to keep the surface finish in good condition.

On removing the masking paper for the finishing operations, small specks or patches of adhesive were left on the sheet. An attempt was made to remove these by washing with mild soap and water. This method proved to be slow and in some cases seemed to spread the adhesive out. It was later found that these adhesive specks could be removed easily by dabbing with the gummed side of a small piece of masking paper.

Sawing

The band saw blade used for cutting was 0.187 inch in width, 10 teeth per inch and 0.025 inch in thickness. The teeth were hardened and set to 0.043 inch. Speed of the blade was calculated to be 4,465 feet per minute.

Saw marks, with the teeth set at 0.043 inch, were too deep for the material to be cemented without sanding or jointing before cementing. By using slower feed speeds, the surface roughness was reduced a great deal but not enough to eliminate the additional sanding operation.

In an attempt to eliminate saw marks, an India oil stone of medium grit was held against each side of the moving blade. The set was ground off in this manner until the flat area extended to the bottom of the tooth gullet. This grinding reduced the set thickness from 0.043 inch to 0.029 inch. For comparison purposes, five sample cuts were made on 0.187 inch sheet before the teeth were ground, and five samples from the same sheet were cut afterwards. Feeds in both cases were kept the same or as near the same as was possible by manual feeding. Average readings of roughness of each sample were taken on an optical comparator for both sets of samples. Roughness readings ranged from 0.0074 inch to 0.0027 inch for cuts made previous to grinding of the teeth, with a range from 0.0015 inch to 0.0007 inch after grinding. The average for the first set of samples was 0.0041 inch, with an average of 0.0011 inch roughness for the second set.

Test cuts were made in 0.187 inch sheet to determine the smallest radius which could be cut without burning or overheating. Surface roughness was greater than on straight cutting, however, burning did not appear until the radius of the cut was less than 0.250 inch.

Saw cuts on 0.187 inch acrylic sheet were made with a 12-inch circular saw blade. This blade was straight ground and had 3.5 teeth per inch.

Speed of the blade was calculated to be 8,200 surface feet per minute. Chipping at the edge of the kerf was excessive and often extended as much as 0.187 inch into the material. Cuts were also made with a hollow ground 14-inch planer saw blade. Speed of this blade was calculated to be 9,720 surface feet per minute. Chipping with the planer blade was less than with the crosscut blade used first. The planer blade could not be used for clear, smooth joints without sanding or jointing the cut before cementing. The ammunition box, shown in Plate II, was assembled from parts cut with the 14-inch planer blade. By close inspection excess material may be detected at the joints. This material was forced to the outside of the joint when too much pressure was applied in an attempt to remove air pockets, which were caused by deep saw marks and chipped areas.

Jointing

Jointing of saw cuts was done on a 6-inch, 3-knife jointer. The speed of the jointer head was calculated to be 4,650 rpm. A smooth dull finish was obtained on the jointer. Jointer marks were reduced by using slow feeds until they were difficult to detect by the naked eye. If the feed is too slow the stock is likely to show signs of burning. Feeds may be slower without burning the material when sharp jointer blades are used. The edges of the vase holder, shown in Plate I, were not finished by polishing or sanding but left as they were after jointing.

Sanding

The candle holders, shown in Plate II, were made by cementing three pieces of 0.500 inch sheet stock together. After cementing, an attempt was made to smooth up the surface on a belt sander. The finest abrasive belt on hand was number 80-grit. This was coarser than the recommended grit size for the initial sanding. By using very light pressure on the piece against the sanding belt, the surfaces were cut smooth but deep scratches were present. One holder was sanded on the disc sander for a comparsion of the disc and belt sanders. The author found it difficult to sand adjacent surfaces square because more material was removed on the outside area of the surface. This was due to the difference in the surface speed of the disc at the boundaries of the piece being sanded. To remove the sanding marks left by the 80-grit belts, 4/0 waterproof garnet paper and water were used. The 4/0 was followed by using finer grades of garnet paper. The piece was washed in water between each grade of sandpaper. During each step, the deeper scratches left by the proceeding sanding were removed before selecting a finer grit. In the final sanding, 7/0 paper was used.

Buffing

Buffing of the sanded surfaces was done on a wood lathe. Three six inch, loose cotton buffing wheels were used. The wheels were numbered and in all cases the same grit size abrasive was used on the same wheel. Parts were washed between each wheel change so as to remove all abrasive which might be present, before going to the finer grit size wheel. For the first wheel 320-grit abrasive held in wax was used and 400-grit on the second wheel. The final wheel was used dry.

Spindle speeds on the lathe were variable through the following speeds: 1,300, 1,620, 2,200 and 2,800 rpm. Corresponding surface speeds for the spindle speeds named above were the following: 2,200, 2,540, 3,460 and 4,400 surface feet per minute.

Various surface speeds were used with the different grit sizes. For the 320-grit, the surface speed of 3,460 feet per minute with a medium pressure, gave a fast polishing action. The surface speed of 4,400 feet per minute with a light pressure was selected as the best speed for the 400-grit wheel. This same speed was used on the dry wheel with a very light pressure. In all cases the parts had to be moved constantly to avoid overheating.

Heating and Forming

Two 600-watt, filter-type, infrared lamps were used to heat the acrylic sheet before forming. These were flood type and were fitted with 10-inch reflectors. By focusing both lamps on the area, small parts could be heated to easy forming temperatures in about 15 minutes. A thermometer was placed under the material to determine when the forming temperature was reached.

The upright section of the vase holder, shown in Plate I, was made in two sections so as to be able to form it in one heating. The material for the ring was cut slightly longer than necessary, then heated and formed. After removing the ring from the form, it was heated and the tendency for the material to return to its cast shape when hot forced the piece into a circle.

The forms used for shaping the parts on the vase holder, were cut from one-inch white pine, sanded and fastened to a one-inch board to strengthen them in the weaker sections. Cotton flannel was placed over the forms to eliminate any mark-off on the acrylic part during the forming operation. A temperature of

225° F. was first used as the forming temperature, but this was not high enough to allow time for placing the part on the form before it cooled below the forming heat. The part was reheated to 240° F. and this temperature did allow time for placement before too much heat was lost.

Scraps of cotton flannel were used for protection of the hands, while the heated parts were held to the forms and cooled below the forming temperature.

Turning

Regular wood turning tools were used to turn 0.750 inch rod mounted in a wood lathe. It was very difficult to keep lathe tools ground for wood turning from gouging the acrylic material. A scraping cut was used by slightly lowering the tool rest and raising the handle of the tool. Even with conditions in this manner, vibration was excessive and a good finish was difficult to obtain. The tools were then ground with a zero rake angle and a front clearance angle of 8° to 10°. In both cases spindle speeds were varied through the following speeds: 1,300, 1,620, 2,200 and 2,800 rpm. The tools were again held so as to give a scraping action but the vibration was too great and a good finish was not obtained. The lathe table was mounted on a wooden floor and part of the excess vibration could have been due to the poor condition of the floor.

The individual salt and pepper shakers, shown in Plate II, were turned from 0.750 inch rod. A small machine lathe was used since attempts to turn acrylic parts on the wood lathe were unsuccessful. High carbon tool bits were ground with a zero rake angle and a 10° front clearance angle. The top of the tool bit was set level with the center line of the piece to be turned. Spindle speeds were varied through the following speeds: 575, 700, 875, 1,150 and 1,400 rpm. The best surface finish was obtained with the spindle speeds of 875 and 1,150 rpm. With the spindle speed set at 575 rpm, a continous cut was difficult to obtain unless the chip load was rather heavy, however with a heavy chip load setting, gouging often occurred. The highest spindle speed produced a great deal of vibration or chattering, which resulted in a rough finish.

The same tool bit was ground with a 5° negative rake angle and spindle speeds were varied the same as before. Better finishes were again obtained with spindle speed settings at 875 and 1,150 rpm. A 0.005 inch setting was used in both cases for the automatic cross feed.

Cementing

Ethylene dichloride was used as the solvent cement for the projects shown in both Plates. To confine the softening action of the cement to the joint area, the surrounding parts were masked with scotch tape. This tape was applied very carefully, so as to keep the cement from seeping under the edges. When joint areas were small both parts were soaked with the solvent. The author used a medicine dropper to apply the solvent to the joint areas. This worked rather well, for difficult joints were reached easily with enough solvent. On large joint areas, only one of the surfaces was soaked with the solvent for about one minute before the two pieces were assembled. The two pieces were held together for 15 to 20 seconds to allow the second cushion to form before applying pressure. A machinist vise was used to clamp the pieces together with just enough pressure to force out air bubbles. Cemented parts were left in the vise for four hours and no parts were worked until 24 hours after cementing.

Masking of the areas around the joint was a very slow and tedious task. By using only enough solvent to make a clear joint and removing any excess softened material, which was forced out of the joint, masking in some cases was eliminated. The edge strips on the tray, show in Plate II, were not masked for cementing. The correct amount of solvent can be determined by experience, however, if the pieces are a true plane, the amount of solvent may be decreased slightly. In order to detect poor fitting joints, water was placed on one surface and a slight pressure was applied to see if all air pockets could be forced out. This technique was not used until after the two center strips on the tray were cemented. Poor joints were obtained on these two which are shown by the frosted areas in them.

The lamps, shown in Plate I, were made by cementing three .750 inch rods together. Two rods were held horizontal in wooden jigs and cement was placed along the joint. When sufficient time was allowed for the solvent to form a shallow cushion on each rod, a light pressure was applied. After this joint had cured, a third rod was cemented to the two rods. Clear joints were obtained by this method and very little dissolved material was forced out of the joints.

A 0.187 inch steel rod was used to clamp the acrylic rods end to end and to the base of the lamp. This eliminated the tendency for the rods to slip on the cement cushion when clamped in a bench vise.

Routing

The frosted V-grooves in the lamp base and in the vase holder, show in Plate I, were made by using a three wing V-cutter in a regular woodworking router. The side strips on the tray, shown in Plate II, were cut with this same cutter. The router had a spindle speed of 18,000 rpm and the cutting angle on the cutter was not changed.

In order to obtain a smooth frosted finish with a router, it was found that the feed must be kept slow, but at no time can the piece be stopped during the cut or burning will occur.

Drilling and Tapping

A vertical drill press, with variable spindle speeds of 612, 1,258, 2,420 and 5,000 rpm was used for drilling in acrylic sheet. Test holes were drilled with high carbon steel drills which were ground to the following angles: flute angle 17°, lip angle 59° and lip clearance angle 12°. Feeding was done by hand. Considerable gouging was encountered even with very slow feeds. The acrylic sheet was clamped in a machinist's vise and backed by a block of hard wood.

Drills were then ground to the following specifications: lip angle 70°, flute angle or rake angle zero and lip clearance angle 8°. The material was held and backed the same as in the previous test. During the drilling operation, the drill was withdrawn every few seconds to facilitate chip removal and to reduce overheating of the material. Results were better than with drills ground as in the first case, however, with the spindle speed constant, results were different with different size drills.

To determine spindle speeds for different size drills, drills of the following sizes were used: 0.187, 0.500 and 0.750 inch. The best results were obtained by using the following spindle speeds for the different size drills: 0.187 inch drill at 1,258 rpm, 0.500 inch drill at 612 rpm and 0.750 inch drill at 612 rpm.

Regular steel taps were used for tapping the lamps to receive the fixture screw. Clean threads were cut easily, however, it was necessary to withdraw the taps frequently to remove the chips.

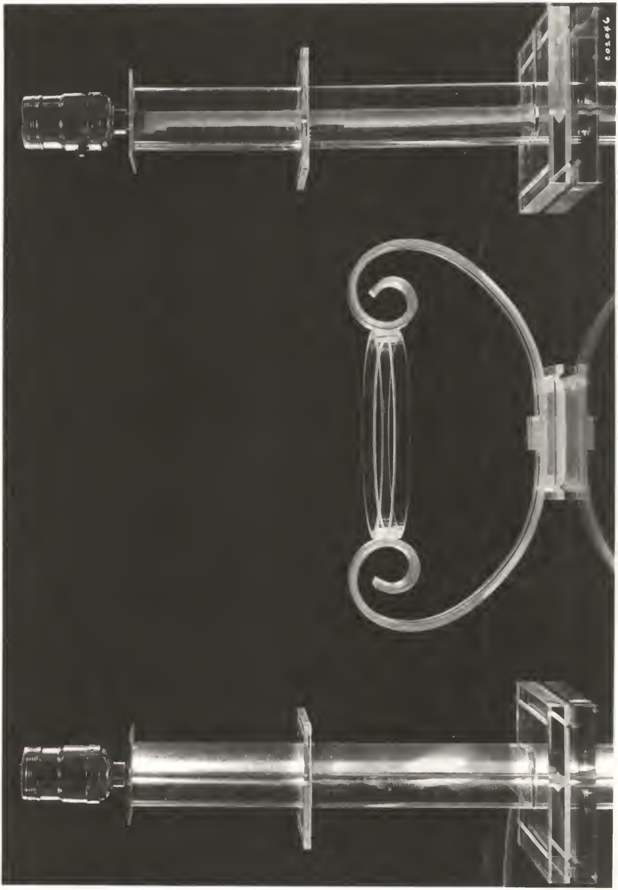
Etching

The etchings on the tray and ammunition box, shown in Plate II, were done with an electric hand grinder. A very small dental burr was used running at 22,000 rpm. The pattern was placed on the top side of the sheet with the masking paper replaced for surface protection. The etching was cut in the lower side of the sheet. The etching should be done with the hand grinder held vertically over the pattern, otherwise there is a tendency for the pattern to be distorted. This is due to the thickness of the sheet. By using the pattern as a guide for placement of principle parts, then completing the etching freehand, the author was able to eliminate much of this distorted effect. Light etching lines were used to copy the design. To bring out areas of the design, deeper and wider cuts were used. To produce shadow areas, light sketchy lines were cut. Fast movement of the tool produced cleaner lines and reduced the tendency of the burr to crawl.

EXPLANATION OF PLATE I

Table lamps and vase holder made from acrylic sheets and rods.

PLATE I



EXPLANATION OF PLATE II

Serving tray and small projects made from acrylic sheets and rods.

PLATE II

SUMMARY OF RESULTS

Layout on acrylic sheet material can be done more accurately by using a sharp scribe and marking directly on the sheet.

Acrylic sheets were cut readily by the use of ordinary band and circular saws, however, for smoother cuts in thin sheets the set should be reduced as much as possible without burning the material.

Wood jointers gave a smooth dull finish by using very slow feeds.

The belt sander produced a better finish than the disc sander on acrylic stock.

Highly polished surfaces were obtained by using loose cotton buffing wheels. Surface speeds were reduced as the grit size was increased.

Infrared lamps were used very successfully to heat small acrylic parts for forming.

Attempts to turn acrylic rods in a wood lathe were unsuccessful. Acrylic rods were turned in a machine lathe by using a 5° negative rake angle and a 10° front clearance angle on the tool bit.

Joints made with ethylene dichloride were as strong as simple projects would usually require.

Smooth V-grooves were obtained without altering the router cutter and without changing the spindle speed.

Holes were tapped very readily in acrylic material by occasionally withdrawing the tap. Clearer drilled holes were obtained by grinding metal drills with a zero rake angle, an 8° clearance angle and a 70° lip angle.

Fast, fine cuts made with a small cutter, such as a dental burr, proved to be the best for etching acrylic sheet.

Acrylic resins may be fabricated in the school shop with the use of woodworking equipment. Designs should be kept simple until the individual has learned how acrylic plastic responds to the different machine operations.

It would seem that a more through study should be made in this type of work.

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