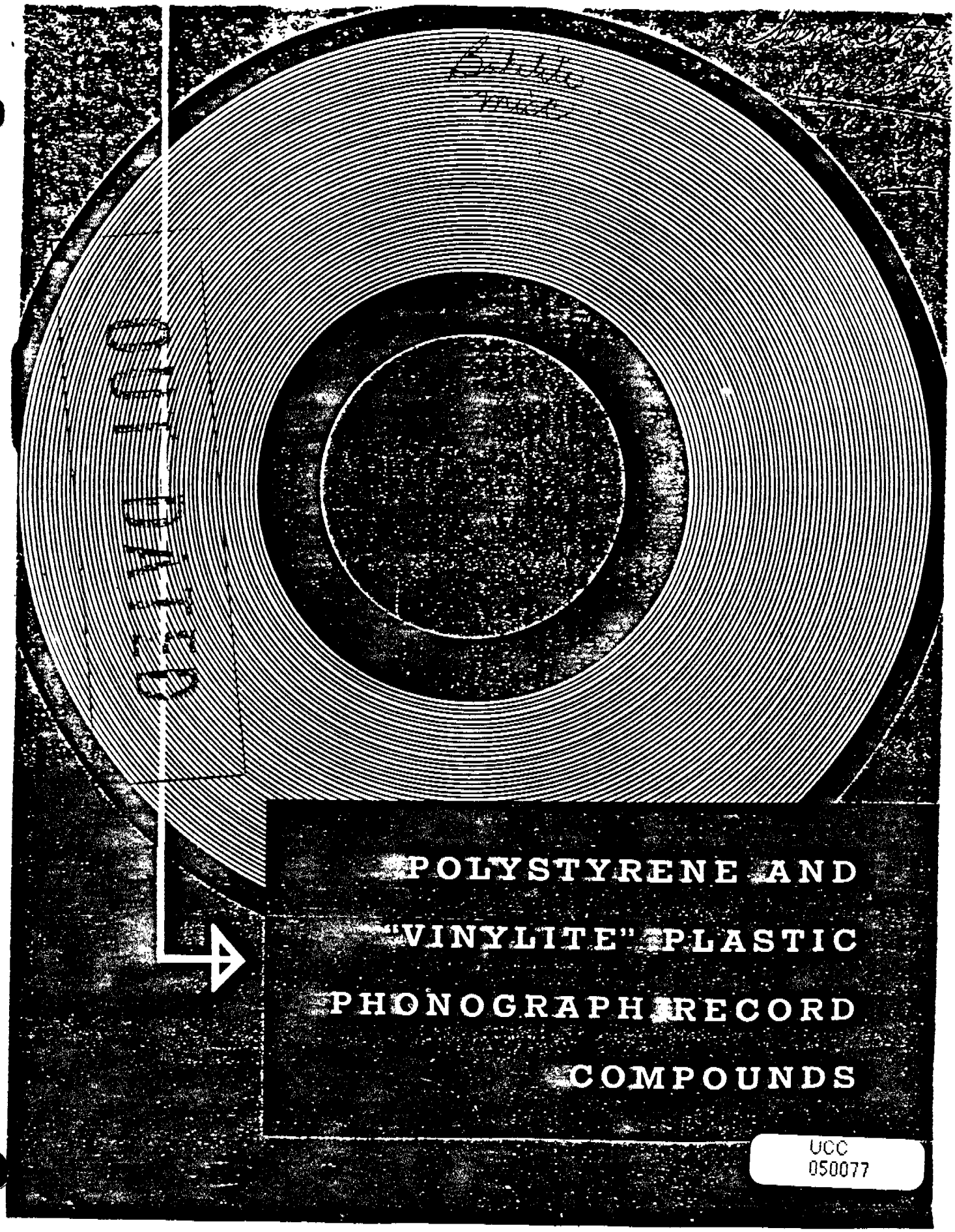

POLYSTYRENE AND
"VINYLITE" PLASTIC
PHONOGRAPH RECORD
COMPOUNDS
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CONTENTS

Introduction	3
VINYLITE Brand Record Compounds	5
Molding Equipment	5
Compounding	7
Molding	9
Polystyrene Record Compounds	13
Molding Equipment	13
Molding Techniques	14
Advantages of Injection Molding	15
Polystyrene Compounds for Compression Molding	16
Compounds Available	17
Equipment Suppliers	18

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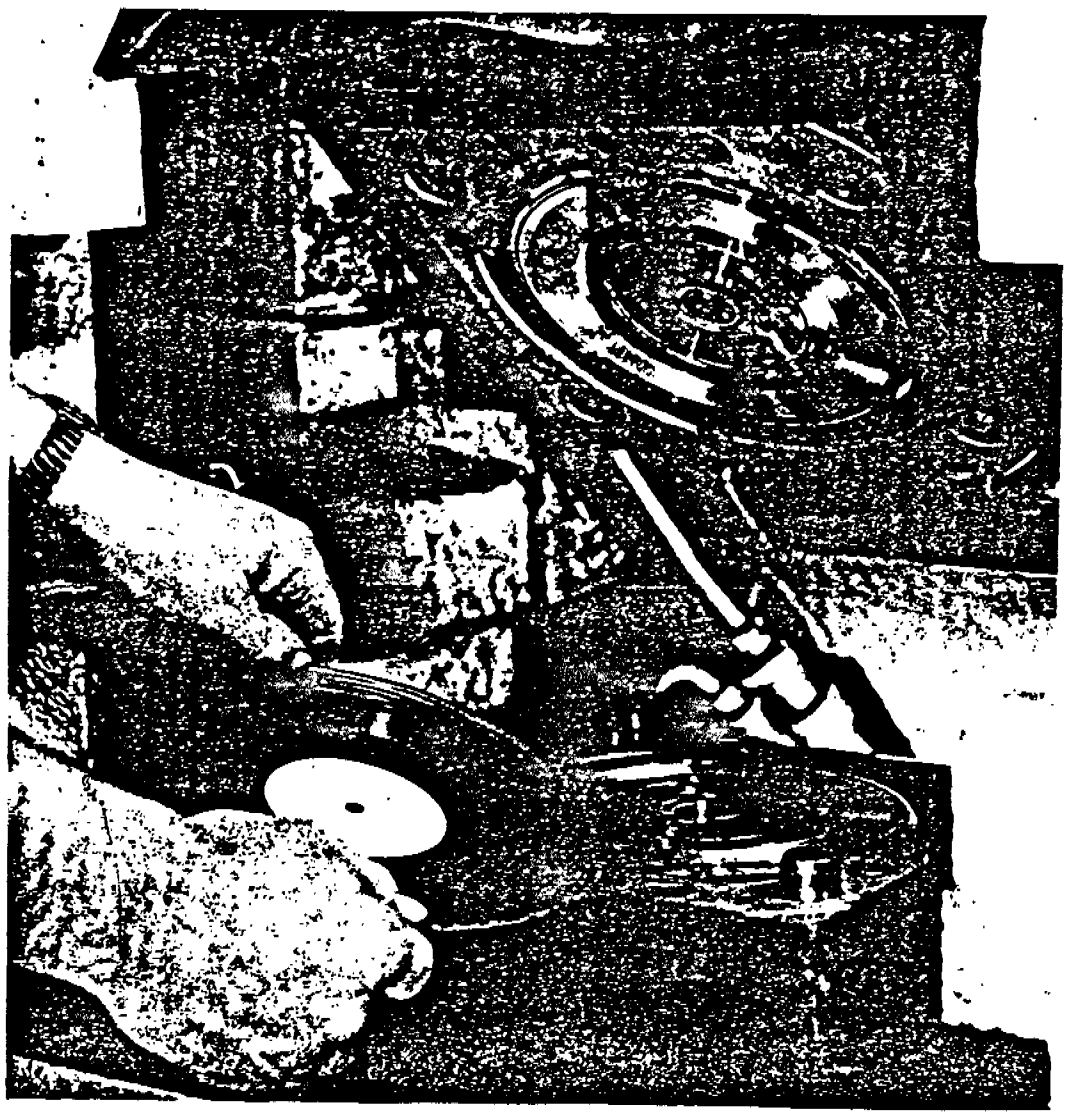
INTRODUCTION

From children's records to massive collections of the recordings of popular bands and vocalists, from collector-item Caruso recordings to the modern, long-playing records which can play an entire Beethoven Symphony or Bach Cantata without being turned over, the phonograph record industry manifests its tremendous growth and the popularity of its product. There is an estimated annual $150 million worth of business done in the United States alone. Through the years, the improvement of quality in records has been an important motivating factor for the rapid expansion of the phonograph record industry. Early records were fragile wax rolls which were very soft and of short playing life. The first real improvement in phonograph records was the introduction of the flat, disk-type record made by combining shellac with various fillers. Records became more durable, easier to handle, less expensive, and had longer playing life.

In the past twenty years, UNION CARBIDE has played an active part in the development of plastic records which will surpass the quality of shellac records. UNION CARBIDE has succeeded in the development of two groups of record compounds, VINYLITE Brand plastic compounds and polystyrene compounds, which have proved to be highly successful. Both of these materials compare pricewise and can be molded into phonograph records of equally high tonal quality and wearing ability. The record manufacturer can buy the VINYLITE Brand resin powder, compound it into preforms, and then compression-mold the material into a finished record; or he can buy the preforms, already compounded for molding, from various preform suppliers. Polystyrene record compound is sold in granular form ready for injection molding. The chief difference between VINYLITE vinyl and polystyrene record compounds is that VINYLITE compounds are compression-molded in a manner very similar to shellac molding, whereas polystyrene compounds are injection-molded.

The following pages describe the methods and equipment used to manufacture phonograph records from both VINYLITE Brand resins and polystyrene compounds. It is the task of the fabricator to decide which material will best fit his needs.

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The record shown above has just been removed from the compression press. The label was affixed to the record during molding. The record is finished by trimming the flash.

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RECORD COMPOUNDS

As early as 1933 the value of fabricating plastic records from a vinyl resin base was recognized and proven. The commercial manufacture of records based on VINYLITE Brand resins was due to their superiority over those made from the best available grades of shellac. The high fidelity of reproduction, the intrinsic low noise level, and the resistance to wear of the plastic records were markedly better than shellac records. Furthermore, the inherent strength of the plastic records over a wide range of temperature and humidity changes for the first time enabled manufacturers to label records "unbreakable."

Although these superior qualities were valuable in the production of a better regular groove 78 rpm record, perhaps of greater importance was the fact that vinyl resins made possible the advent of microgroove, long-playing type records. Because of the molding characteristics of vinyl resins, records can now be produced with as many as 300 grooves per inch without a reduction in reproduction quality. Since their introduction, microgroove records have been wholeheartedly accepted in the United States and, more recently, have attracted the attention of consumers throughout the world.

The quality of records made from VINYLITE plastic may be established at will by formulation changes. For best tonal quality and break resistance, an undiluted record compound can be made. With the addition of fillers and/or extenders, both quality and cost can be reduced to a desired level. For regular groove records, highly-filled VINYLITE resin formulations are customarily used, while for microgroove records, unfilled or only slightly-filled VINYLITE resin compounds are considered desirable. This is due to the narrower wall thickness incurred by the increase in the number of grooves per inch. The problems encountered in processing and molding records of VINYLITE plastic are essentially the same for regular groove or microgroove records. However, some differences in techniques and conditions do exist and will be pointed out in the following discussion.

Because of the varied types, makes, designs, and sizes of processing and molding equipment, a specific set of rules for the successful production of records of VINYLITE Brand resin cannot be established. While suggested formulations, processing conditions, molding cycles, etc., will be given in this discussion, the reader must realize that such examples need not necessarily be optimum for his equipment and that some modification may be desirable.

MOLDING EQUIPMENT

Presses

Semi-automatic or fully automatic compression presses are customarily used in the manufacture of records from VINYLITE plastic. These presses, which were standard equipment for shellac records, may be of the tilting head or vertical closing type.

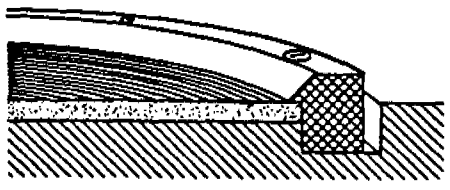


Figure I.

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Molds

Open flash-type molds are used in the molding of records from VINYLITE resin. In the United States two types of tooling are in general use. The first type which is used primarily for 10, 12, and 16-inch moldings is shown in Figure I.

In this instance, the stamper is enclosed in a metal ring of such thickness that when the mold is closed on the landing blocks, a small opening (0.012 - 0.020 inch) will remain for the escape of flash. The second type is termed "coined-edge" tooling and is shown in Figure II.

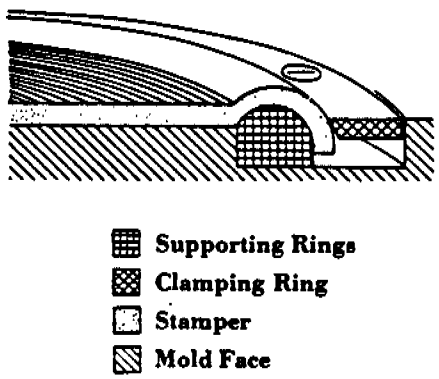


Figure II.

With "coined-edge" tooling, flash leaves the mold between the raised portions of the stampers. Thus, the possibility of material being forced under the stamper is virtually eliminated. In either case, the distance between the stampers when the mold is closed against the landing blocks determines the molded record thickness.

Undoubtedly the greatest consideration in the design of a record mold should be given to channeling. The following five points are deemed important in mold design:

a. Cooling should be from the center out.
b. Channeling should be of the spiral or concentric ring coring.
c. The cooling rate of both platens should be equal in order to prevent warpage of the molded records. This implies that the total heat transfer surface of the channeling and the distance between the channeling and the mold face must be the same for each platen.
d. Low spots in mold channeling should be avoided since such spaces hold water and prevent uniform heating.
e. As much space as practical, consistent with adequate mechanical strength in the mold, should be devoted to channeling for quick and uniform heating and cooling.

Stampers

Chromium-plated copper or chromium-plated nickel stampers are used for record molding. The copper-backed stampers are normally thicker than the nickel-backed stampers. Stampers will ordinarily withstand several thousand pressings if due care is taken and adequate time is allowed during the chromium-plating. Good chromium-plating will also result in molded records having better groove definition and better tonal quality than can be obtained with poor plating.

Preheating Equipment

In order to minimize the time required to mold a record, preforms are normally preheated on a hot table or in an oven prior to molding. Iron, steel, stainless steel, or chromium are ordinarily chosen as the materials with which the preforms will be placed in contact. Hot tables should be steam-heated and shields provided to minimize draft cooling. If an air oven is used, means should be provided for air circulation within it to ensure a uniform temperature throughout. In either instance, a good insulation is a necessity for maximum efficiency. The size of the preheating equipment will, of course, depend on the production rate and size of the preforms being preheated. Ordinarily, preforms are preheated from 10 to 12 minutes in order to provide adequate heating space for 10 to 12 preforms on a 60-record cycle.

Miscellaneous

Special care should be taken in engineering the installation of the heating and cooling lines to and from the record press. Steam and water lines should be somewhat larger than theoretically necessary so that the pressure of either can be more closely regulated. Valves on the inlet and outlet lines should be of the quick-opening type so that temperature changes can be more easily controlled. Further, a steam trap and by-pass should be provided on the steam outlet line so that maximum efficiency of the steam will be obtained.

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COMPOUNDING

Raw Materials

a. Resin — VINYLITE Brand Resin VYHH-3 is specifically manufactured for the production of phonograph records. This resin is especially suitable since it possesses high strength and resistance to abrasion, and yet has low viscosity characteristics which result in rapid molding.

b. Stabilizers — Because of the excessive thermal treatment to which the resin is subjected both during the preform fabrication and the molding processes, stabilizers are necessary to retard thermal decomposition of the resin.

The most commonly used stablizers are the basic salts of calcium and lead, particularly the stearate salts. Calcium stearate is very effective if a record with some degree of transparency is desired, while fused lead stearate or dibasic lead stearate are very good for opaque records. Hydrated lime has also been found to be quite effective as a stabilizer.

c. Fillers — The main purpose of fillers is to lower cost. Their use will raise the noise level, lower tonal fidelity, and, in high concentrations, degrade strength. The most common filler is calcium carbonate, although the more costly silicates may be used. Care should be exercised in selecting a filler since a large particle-sized filler will foster an objectionable noise level, while a small particle-sized filler cannot be readily dispersed. A filler having an average particle size of 0.1 microns is recommended.

d. Extenders — Low-cost hydrocarbon or resinous-type extenders are sometimes incorporated into record compounds to lower cost and raise plasticity. This addition is made with a

TABLE I

Typical Formulations — Regular and Microgroove Records

	Unfilled, Unextended % by wt.		Filled and Extended % by wt.	
Regular Groove	VYHH-3	97.4	VYHH-3	26.5
	Fused Lead Stearate	1.5	Tribase	1.0
	Carnauba Wax	1.0	Fused Lead Stearate	1.5
	Oil Red Dye	0.1	Filler	60.0
		100.0	Extender	10.0
			Carnauba Wax	1.0
				100.0
Microgroove	VYHH-3	97.5	VYHH-3	57.5
	DS-207	1.5	Tribase	1.0
	Carbon Black	1.0	Fused Lead Stearate	0.5
		100.0	Filler	25.0
			Extender	15.0
			Carbon Black	1.0
				100.0
	or			
	VYHH-3	98.4		
	DS-207	1.5		
	Oil Red Dye	0.1		
		100.0		

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sacrifice in tonal quality and a marked loss in strength. For filled compounds, the addition of extender is not too noticeable, but for unfilled records the effect is quite apparent.

e. Lubricants — In order to improve the molding performance of highly-filled compounds or to improve the release characteristics of some highly extended formulations, lubricants are sometimes added. Carnauba wax or Estawax 211 have proven very satisfactory for this application. However, stearate stabilizers will usually impart enough lubricity to a compound to nullify the necessity of adding additional lubricant.

f. Colorants — Colorants must naturally be evaluated for heat and light stability before being incorporated into the formulation. In addition, such factors as bleeding, cracking, and the effect of the colorant on the heat and light stability of the resin must be taken into consideration.

Typical Formulations

As mentioned previously, the quality level of plastic records molded from VINYLITE Brand resins can be varied at will by formulation changes. Formulating should be made with this consideration in mind as well as the fact that regular-grooved records require a somewhat different formulation than microgroove records. The specific difference is that microgroove formulations generally do not contain wax as a lubricant. Experience has shown that in microgroove formulations, wax will exudate onto the inner grooves of the stampers during molding and deter good mold fill-out. In regular groove formulations, wax will impart better flow characteristics to the compound as well as better wear resistance.

Typical formulations for regular groove and microgroove records are shown in Table I. In both instances, the unfilled, unextended formulation will foster the highest quality.

Equipment and Methods for Preparation of Preforms

The process for fabricating record preforms utilizes conventional equipment in two major steps: (1) fluxing the material into a hot mass preferably in a Banbury-type mixer, and milling fluxed material on a two-roll mill or, if a Banbury is not available, simply fluxing and milling the ingredients on a two-roll differential speed mill; (2) forming the preforms by sheeting-off a two-roll sheeting mill or by extrusion.

The Banbury mixer consists essentially of two sigma-shaped rotors revolving in opposite directions inside a close-fitting jacket. A weighed amount of material, sufficient to fill the working space, is introduced to the blades through a vertical chute equipped with an air-actuated ram. This ram forces the material into the bite of the revolving rotors, where the combination of frictional heat and pressure fluxes the blend in 2 to 5 minutes. After fluxing, the bottom of the jacket is pulled aside by air-activated cylinders and the hot batch is dropped into a convenient cart or conveyor.

The batch sizes involved depend on two factors: (1) the size of the Banbury mixer, and (2) the specific gravity of the compound. In general, the higher the specific gravity, the greater the batch size. Too large a batch results in a prolonged fluxing time and wasted material. Too small a batch inhibits proper fluxing of the material and induces air entrapment. A typical batch weight for an unfilled, unextended compound using a No. 3A Banbury is 140 pounds.

The rotors and jacket are normally equipped for heating or cooling. However, it is recommended that the temperature be the result of internal friction and pressure rather than from an external source. In this manner, better dispersion and mixing of the compound ingredients can be obtained. The batch temperature of the compound should be in the range of 140 deg. to 150 deg. C. when discharged from the Banbury.

If a Banbury mixer is not available, a two-roll differential-speed mill can be used to flux the ingredients into a homogenous mass, although a comparatively low rate of production will be obtained. It is important in this instance that all ingredients be thoroughly preblended for at least 20 minutes prior to their being charged to the mill because of two reasons:

a) To ensure quick dispersion in the heat-fluxing operation.
b) To prevent danger of the heat adversely affecting the resin prior to the time the heat stabilizers are thoroughly dispersed.

Preblending may be done in conventional ribbon-type blending equipment having good blending action. This equipment should be easy to clean in order to prevent contamination in succeeding batches. In preblending, the usual order of adding ingredients is

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1. Resin
2. Stabilizer
3. Lubricant
4. Filler & Colorants*

(Colorants may be added during the fluxing operation to avoid color cleanup problems in the blender.)

The preblend is fed directly to the mill rolls (generally heated to a temperature of 130 to 145 deg. C.) and worked until thoroughly fluxed and homogenized. It is essential that the condition of the compound and the mill be such as to develop maximum shear stresses between the modifying ingredients and the resin. This can be done best by setting the rolls approximately 0.060 to 0.090 inches apart.

If a Banbury mixer is used for initial fluxing, the batch is fed to the heated two-roll mill immediately after discharge. Small amounts (up to 10 per cent of the batch by weight) of flash trim may be fed back to the Banbury or first mill for refluxing, provided that it is clean.

Attempts have been made to strip a mill sheet of preform thickness from the two-roll mill, which either supplements the Banbury or is the primary mixer, by using the roll setting necessary for the preform thickness of approximately 0.125 inch and over. However, very little work can be done in breaking down the modifying agglomerates in the resin at such wide mill settings. Therefore, we strongly recommend that the mill settings of the compounding mill be adjusted to give a good dispersion, and that a second mill be employed to produce preforms at the proper thickness — this mill is generally smaller than the mixing mill. In addition to the mill roll setting, the temperature of the compound on the mill determines the quality of the dispersion. If the compound is at low temperature, higher shear stresses can be developed and finer dispersion results.

From the two-roll mill, used either as the primary compounding device or as an adjunct to the Banbury mixer, the plastic mass can be fed to a smaller forming mill, as stated above, or it can be fed directly to an extruder having a suitable die opening. When a conventional plastic extruder is used to replace the forming mill, the processed mill sheet from the compounding mill must be granulated to less than a $\frac{5}{16}$ inch particle size prior to extrusion. A die whose width and thickness conforms to the dimensions of the preform should be used.

Approximate extrusion conditions for unfilled formulations such as those given earlier are

Back Cylinder	110 deg. C.
Front Cylinder	140 deg. C.
Head	120 deg. C.
Die	135 deg. C.
Screw	60 deg. C.

From the two-roll forming mill or the extruder, a suitable conveyor belt or takeoff mechanism should be provided to carry the narrow strip of sheet stock as it is produced continuously. This conveyor should be geared to run at a speed equal to the peripheral velocity of the roll from which the sheet is being stripped or the linear velocity of the extruded material. This prevents stretching or distorting of the hot plastic sheet. The material then goes, while still warm, to a suitable blanking device for cutting into the desired preform size. These preforms can then be cooled and stored indefinitely awaiting molding into records.

Temperatures and time factors must be rigidly adhered to once the optimum conditions are set up. When the proper technique has been established, the compounding of these records made from VINYLITE Brand resins is not a particularly difficult task and can be handled without specially-skilled personnel, although some technical supervision is always preferable.

MOLDING

The optimum molding cycle for phonograph records of VINYLITE Brand plastic will depend upon several factors, notably record diameter and thickness, groove shape, and equipment setup. For example, it would be expected that a 10-inch regular groove record would require a longer molding cycle than a 7-inch microgroove record. The magnitude of this difference will depend upon the molding equipment, i.e. stamper thickness, available steam and water pressure. Formulation differences are usually cared for by regulating the pressure exerted on the material rather than by cycle changes. Representative molding cycles which have been successfully used in the United States are shown in Table II.

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TABLE II

Representative Molding Cycles

Record Size	Groove Type	Time in Seconds			
		Preheat	Heat and Pressure	Cooling	Total
7 inch	Microgroove	12	7	16	35
10 inch	Microgroove	12	12	22	46
10 inch	Regular	12	16	20	48
12 inch	Microgoove	12	14	24	50
12 inch	Regular	14	18	30	62

For the molding cycles shown in Table II, the preforms were preheated to a temperature of 120 deg. C. to 125 deg. C. prior to molding. The steam pressure used was 120 lb. per sq. in. to 140 lb. per sq. in., and a peak matrix temperature of 175 deg. C. to 180 deg. C. was usually reached. The temperature of the cooling water was normally 20 deg. C. to 22 deg. C. and the temperature of the records upon removal from the press was approximately 40 deg. C.

In order to avoid clogging of the mold channeling by water, it is the usual practice to allow the water return line to remain open during the first 6 to 9 seconds of the preheat time so that all water is purged from the molds. Although this does not result in maximum heating efficiency during the interval, such a delay is highly recommended. A minimum preheat time of 10 to 12 seconds is necessary since ordinarily press operators cannot unload and load the press within a shorter time.

Minimum pressure required to mold records of VINYLITE plastic can be calculated by the following equation: (P_R = Ram Pressure in lb. per sq. in.)

P_R = Ram Area (sq. in.) X Available Hydraulic Line Pressure (lb. per sq. in.) Area of Record (sq. in.)

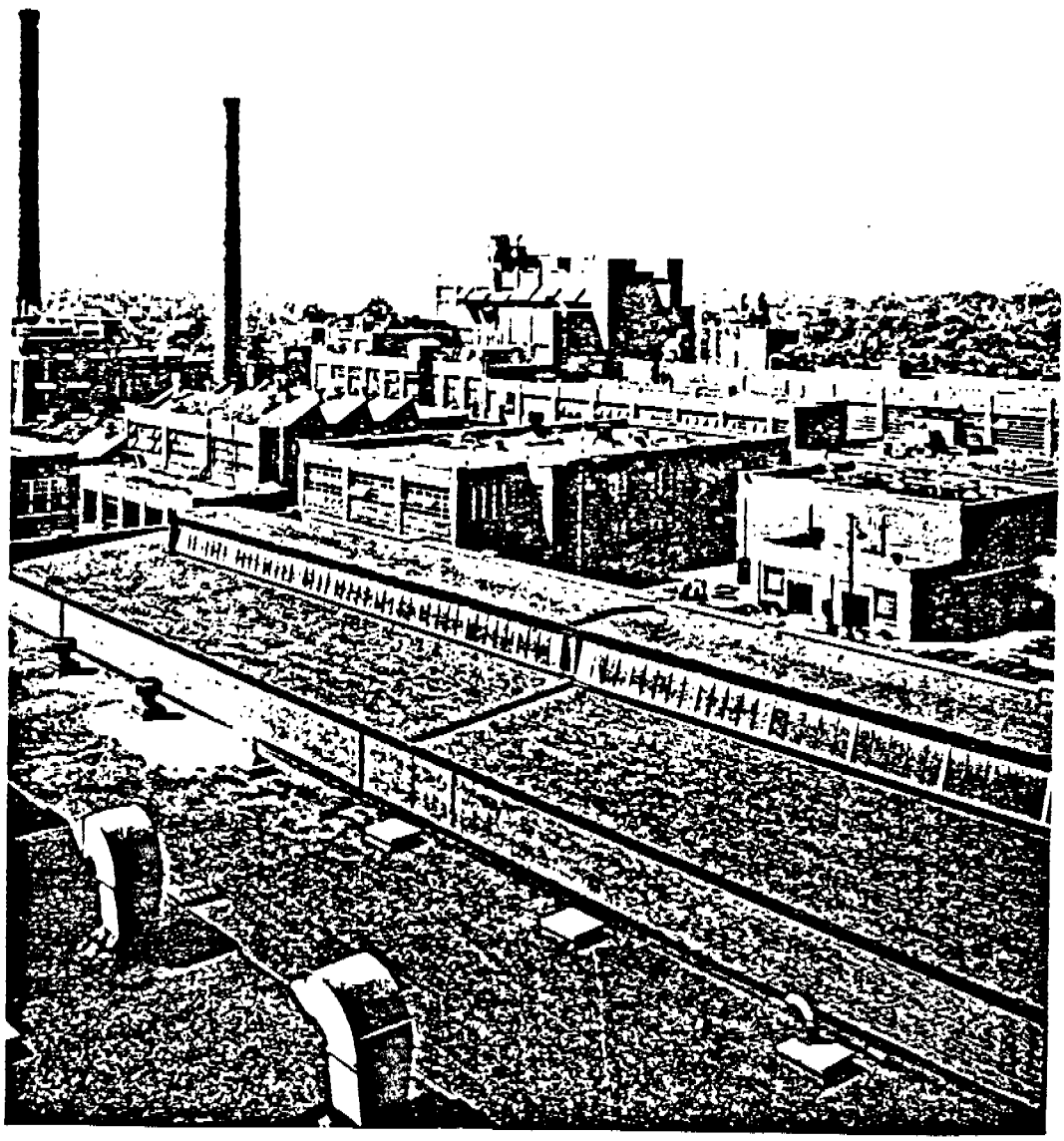
Although this equation is very helpful in establishing a suitable molding pressure, a somewhat higher pressure than calculated will usually be found to be optimum. This is especially true for highly filled compounds. Ordinarily the record molder will find that increasing ram pressure will be more economical than changing cycle constants when molding difficulties are encountered. The pressures usually employed when molding records made from VINYLITE Brand resins are in the range of 1,200 to 2,000 lb. per sq. in. exerted on the matrix.

In general, the closing of the mold may be fairly rapid until such time as the material begins to flow. Further, closing and flowing should be slow. A nominal time interval of 4 seconds should be sufficient time for the total ram travel.

Several incidental techniques which will aid the molder in minimizing production rejects are as follows:

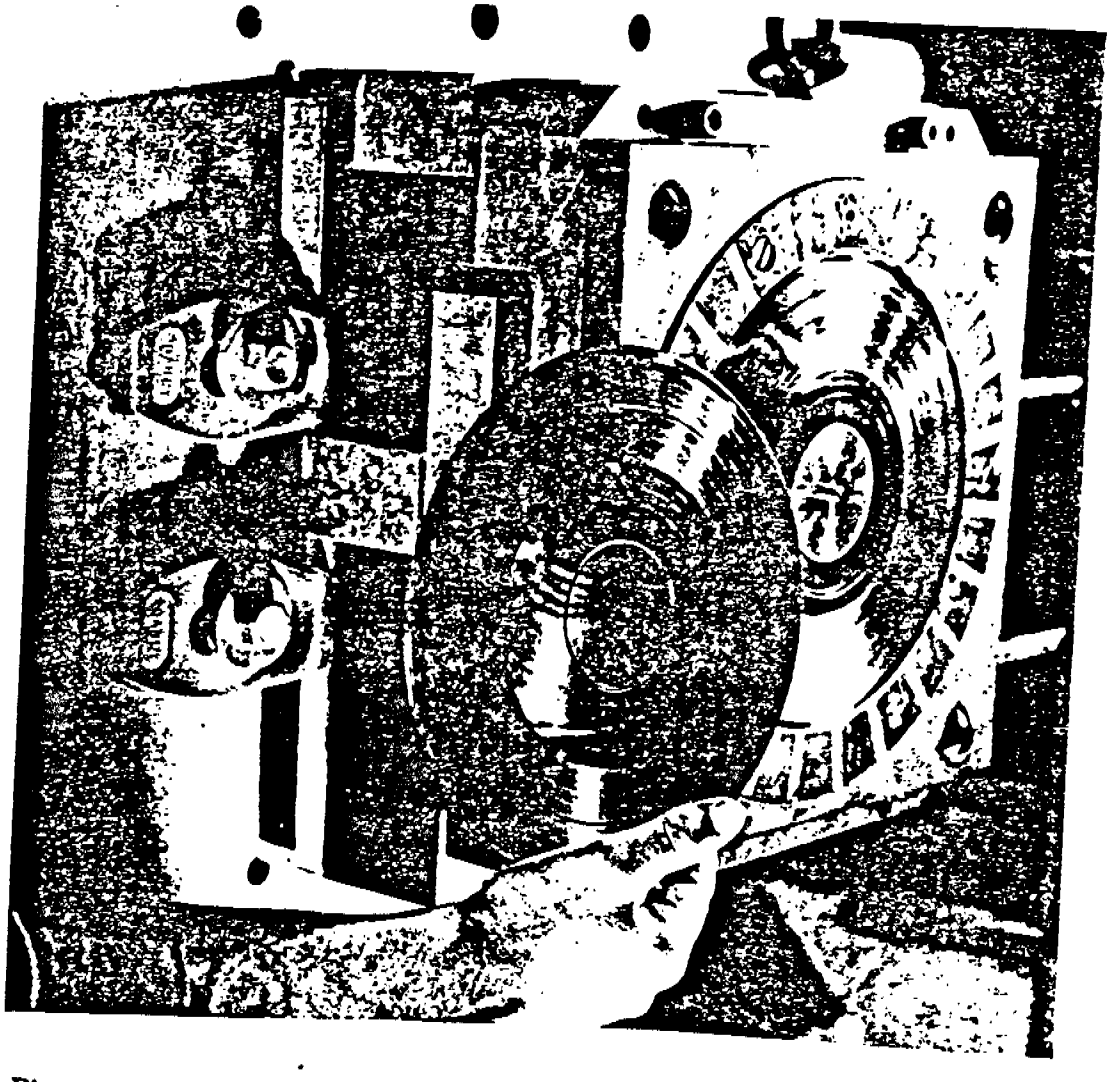
1. Elimination of all sources of contamination in the processing and pressing areas minimizes rejects due to foreign matter.
2. A periodic turning over of preforms during preheating ensures equal heating and guards against unfilled groove areas.
3. The insertion of flat preforms rather than rolled or folded preforms into the record press tends to diminish blister rejects.
4. A relatively thick preform usually results in better mold fill-out than a thin preform, although the latter requires less time to preheat.
5. Flash-trimming immediately after removal of the record from the press prevents post-mold warping.
6. Rejects due to broken labels can often be prevented by heating the labels and, thus, drying them prior to molding.

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Many of the resins and plastics sold by Union Carbide International Company are made at the Bound Brook, New Jersey (U.S.A.) plant shown above.

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Pictured above is a polystyrene record being removed from the injection press. Labels are then added to finish the record. Note the vents evenly spaced around the stamper clamping ring.

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RECORD COMPOUNDS

Because of its low cost, low specific gravity, good mechanical strength, excellent chemical stability and molding characteristics, polystyrene has found wide use in the sound record industry. Development work quickly showed that to obtain records of the desired commercial quality, a special line of modified polystyrene compounds was necessary. Records molded from the normal grades of polystyrene, both by injection and compression techniques, were of entirely unsatisfactory sound and wear characteristics although they possessed good appearance. A series of new polystyrene compounds has been developed by UNION CARBIDE from which non-breakable type sound records — both the microgroove and standard groove (78 rpm) — of high fidelity and excellent sound quality may be injection- or compression-molded. The injection molding process has many inherent advantages, particularly the economies that may be effected in most phases of sound record production and the high reproducibility of the quality of records produced by this process. Today, the injection molding of records is considered to be a commercial operation and is being adopted by the record industry.

MOLDING EQUIPMENT

Presses

Basically, the equipment required for record manufacture consists of a 6-ounce or larger injection machine, a mold and matrices. The development of the injection molding process has indicated modifications of regular injection equipment, and it is now possible to buy injection machines designed specifically for the manufacture of phonograph records. In most instances the machines have been so designed that they can also be used for the general line of injection molding. This is a very important factor because it allows the molder a much wider diversity of products with an investment of only one machine.

Molds

The type of molds used for the injection molding of polystyrene are, in general, the same as those used for compression molding of VINYLITE plastic compound. Please refer to page 5, Figure 1 for details.

Matrix

It is very important that the matrix, from which the stamper is made, be cut to certain specifications to ensure a top-quality molded record. Pitch and groove angles are the two most important considerations in cutting a matrix. It is recommended that microgroove matrices be cut with a pitch of approximately 185 to 225 lines per inch. However, records of good sound and wear quality may be obtained with groove cut up to 250 lines or slightly more per inch. Very often, these matrices are themselves defective and, unless very carefully prepared, may contain such small land areas that distortion readily develops in the records pressed from them. In some instances, the land area may break down completely, causing the needle to break through into the next groove.

For optimum wear results, regular groove (78 rpm) matrices are usually cut with pitches of 90 to 100 lines per inch when the conventional "V" shaped groove is used. However, using a special radial groove, equivalent wear results have been obtained with pitches up to 135 lines per inch. Extensive evaluation of records molded from matrices cut with grooves having various angles has shown that in order to obtain the optimum quality from injection-molded polystyrene sound records, the groove angles should be between 80 degrees and 85 degrees. This angle range applies

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to either regular (78 rpm) or microgroove (33⅓ rpm and 45 rpm) records. Experience with records molded in the field has shown that, in many instances, the groove angles have been opened up to overcome unfavorable forming properties of commercially available materials. Records of good quality may be produced with grooves having angles of 85 deg. to 90 deg.; but in the majority of cases where grooves have angles larger than this, the records are of inferior quality.

Stamper

Relatively thin (0.010 in. to 0.035 in.) music or speech stampers are attached to each half of the cavity by outside and center clamping rings. Proper handling of these stampers requires better-than-average care, since the sound grooves in the records are raised surfaces on the stampers and any scratch, toolmark or damage to the stamper will be reproduced in the record. These imperfections will inevitably be reflected in the sound characteristics of the record when the record is played. Scratches on the molded record itself made after molding, though they may mar the appearance of the record, are not as serious from a reproduction viewpoint as a scratch on the stamper. Such scratches on the record are usually confined to the surface of the record and do not penetrate into the music grooves.

Care must also be exercised in replacing stampers in the mold in order to guard against the introduction of contaminating materials (metal chips, plastic particles, etc.) between the stamper and the mold. Since the majority of commercial stampers are either thin nickel, chromium-plated, or nickel-plated copper stampers, the shape of any contaminating material trapped between the stamper and the metal base will be transmitted to the music side of the stamper shortly after it is placed in service. This, of course, results in a reproduction of this surface in the molded record. While stamper handling care may appear to be a critical proposition, proper handling techniques can be easily acquired with experience, as is attested by the appearance of the many millions of polystyrene records already produced by injection molding.

In injection molding work, stampers can be used to produce 30,000 or more records. Consequently, the cost of a stamper in injection molding becomes almost a negligible item in the final cost of the record. When a change in the selection on a record is required, the particular stamper is removed and replaced with a stamper containing another selection. Since the replacement of one or more stampers in a multiple cavity mold necessitates suspension of production of all records in that mold until the change has been completed, the mold should be designed to permit easy and rapid changing of the stampers as a means of minimizing "down" time.

MOLDING TECHNIQUES

Preheating

It is not generally necessary to preheat polystyrene injection molding compounds prior to molding. However, it is possible that on prolonged storage these materials may pick up moisture which may cause mica specks or blisters on the finished piece. If difficulties of this type are encountered, it is recommended that the material be preheated in an oven at 80 deg. C., for about one hour. If the material is known to have become wet on storage, then this preheating time should be extended.

Stock Temperatures

The most desirable range of stock temperatures to be used is 210 deg. C. to 250 deg. C. These figures represent the actual stock temperatures which are measured by purging the machine on the desired overall molding cycle and quickly immersing the needle of an immersion pyrometer in the purged material. It is important that these tests be carried out on cycle, otherwise the results will be misleading. The indicated cylinder temperature required to produce these stock temperatures will vary with the size of the machine, the size of the molded piece and the length of the cycle. Thus, the cylinder settings are best determined by trial and error — experience has shown that the desired stock temperatures are generally obtained by using cylinder settings of 260 deg. C.

Injection Pressures

The exact injection pressure required to produce filled-out records will be affected by a number of factors: the temperature of the plastic, the resistance to flow in the mold, and the type of record being molded. However, it must be remembered that to ensure a positive pressure being exerted upon the record as it cools, the two halves

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of the die must be opened approximately 4 to 5 mils by the material as it fills the cavity. This positive pressure will ensure the maintenance of good groove characteristics during the cooling cycle, provided that the other conditions are satisfactory. The proper separation of the molds can be accomplished by adjusting the injection and clamping pressures. The injection pressures should be greater than the clamping pressure to the degree where the mold faces will be forced apart by about 0.004 to 0.005 inches. To obtain the desired separation of mold faces, it is suggested that a record first be molded with the injection pressure sufficient that no separation of the mold faces takes place. Then, by measuring the thickness of the finished record, it is a very simple procedure to either decrease the clamping pressure or increase the injection pressure until the thickness of the finished record is increased by 0.004 to 0.005 inches. Some of the older machines are not equipped with clamping pressure regulators; consequently, only the injection pressure can be regulated. In general, the injection pressure for molding a 10-inch diameter record in a single cavity mold using a 12-ounce machine should be on the order of 15,000 to 16,000 lb. per sq. in.

Cycle Length

The length of the cycle will depend upon a number of factors, particularly the efficiency of the die cooling system. The injection dwell must be long enough to ensure that the material has set up sufficiently for the grooves to maintain their shape. If the injection dwell is too short, shrinkage may result and the grooves will not have the optimum characteristics. For experimental work, a recommended starting cycle for molding a 10-inch L.P. record is to injection-dwell 24 seconds and to clamp-dwell or cure 4 to 15 seconds. Further changes in the cycles may be made depending upon the record flatness and the groove definition.

Mold Temperatures

Experience has shown that records of good quality may be injection-molded from polystyrene record compounds using constant temperature dies as opposed to cycled dies. However, to obtain grooves of the optimum shape, water must be circulated through the die to maintain a die temperature of 78 deg. C. to 80 deg. C. The amount of water circulating through the die is an extremely important factor and determines, to a large extent, the length of the overall molding cycle. Heated water, cycling at 50 gallons per minute, is suggested.

Record Thickness

The length of the overall molding cycle is controlled to some extent by the thickness of the finished record. Hence, the thickness should be measured carefully when setting up the molding operation or after changing matrices. A change in the thickness of the record will often cause either a dished or warped record to be produced. If the records are considerably thinner than those which were molded previously, a dish may occur, due to overcooling in the piece. If the records are thicker, warping may result due to insufficient cooling. Therefore, it is recommended that before any other conditions are altered on the press, the length of the clamping dwell or cure be increased or decreased, as the case may be, to rectify this condition. If this move fails to rectify the condition, then other factors must be considered and temperatures and cycles should be checked. Standard record thicknesses accepted by the sound record manufacturing trade are 0.07-inch to 0.090-inch for 10-inch records and 0.075-inch to 0.100-inch for 12-inch records. Children's records are more common in 6-inch and 7-inch diameters than in large sizes, and their thickness is usually 0.060-inch. A 10-inch record weighs approximately 100 grams (3.5 ounces). A 45 rpm 7-inch record weighs about 28 grams (1 ounce).

Elimination of Nozzle Drip

Because of nozzle drip, streaking in the records is visible in some instances. Although this will not affect the sound and wear characteristics, it is undesirable from a visual aspect. These streaks usually may be eliminated by the use of a mixing nozzle, such as is used for the dispersion of colorants in polystyrene when the dry coloring technique is used. Because of the design of these nozzles, the nozzle drip is minimized. The pineapple type or the breaker-plate type nozzle is suggested.

ADVANTAGES OF INJECTION MOLDING

The main advantage of injection molding phonograph records from polystyrene is the uniformity

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of quality of the molded record. Once the proper operating conditions have been established, the high quality is easily maintained throughout the production run. Instead of the varying quality of each record associated with other methods, uniform quality of every record is realized.

Another important advantage of the injection method is the rate of production; this method is more than twice as fast as compression molding. Also, it has been found that the stamper life is about 20 times longer. There is no scrap resulting from this process; one hundred pounds of polystyrene produces one hundred pounds of phonograph records. Other advantages are that the record produced is light in weight and is non-breakable under normal handling.

As mentioned previously, the injection machine is not confined strictly to record manufacture but can also be used for general injection molding. General experience has shown that the use of injection molding techniques for the production of sound records makes for an extremely economical operation. For instance, 6-inch records may be produced at a rate of 8 records per minute in a 4-cavity mold using a 12-ounce press. Using a 2-cavity mold, approximately 4.5 ten-inch L.P. (33⅓ rpm) records may be produced per minute. In a single cavity mold, 12-inch L.P. records may be produced at a rate of 2 records per minute. When the fully automatic injection molding process is used, it is possible to produce 7-inch 45 rpm records or 7-inch regular groove records at a rate of 3 records per minute in a single cavity mold using a 6-ounce machine. In the larger injection machines (20 ounce), a 10-inch record may be molded at the rate of 2½ to 3 per minute while the corresponding rate of 12-inch L.P. records is 2½ records per minute. The above figures are given to demonstrate the production rates to be expected when records are injection-molded from polystyrene sound record compounds. They may often be exceeded in practice.

After 100 plays, tests have shown that records molded from approved polystyrene microgroove compounds should not show any significant change in quality as determined by aural listening tests on high-fidelity equipment.

Records molded from approved regular groove polystyrene compounds show a slight increase in background noise on high-fidelity equipment after 100 plays. On home-type equipment the increase in background noise is negligible.

POLYSTYRENE COMPOUNDS FOR COMPRESSION MOLDING

Since a number of record manufacturers are presently set up to compression-mold, UNION CARBIDE'S development laboratory is evaluating, experimentally, polystyrene compounds formulated specifically for compression record molding. The compound is extruded and then cut into preform biscuits. The biscuits are preheated just prior to being molded.

Work is now in progress to eliminate the necessity of using preforms for compression molding records. Several ingenious methods of transferring granular compound into a hot, air-free mass of uniformly plasticized material are being evaluated. In this operation, all flash and trim are merely reground and reused.

MACHINERY SUPPLIERS

We suggest that interested companies write any of the following manufacturers for the latest information on complete phonograph record injection molding equipment:

A. Massler & Wilson Company
Central Ave.
Clark Township, N.J., U.S.A.

B. Improved Paper Machinery Corp.
Plastic Molding Machinery Div.
Nashua, N.H., U.S.A.

C. The Watson-Stillman Company
Roselle, N.J., U.S.A.

D. Reed-Prentice Corporation
Worcester, Mass., U.S.A.

For information on suppliers of stampers and molds only for use in machines presently being used for general injection molding, please write directly to:

Plastics Department
Union Carbide International Company
A Division of Union Carbide and Carbon Corp.
30 East 42nd Street, New York 17, N.Y., U.S.A.

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050092

COMPOUNDS AVAILABLE

Four compounds are now available for regular groove (78 rpm) records: BMS-45 Yellow, BMS-46 Red, BMSQ-161 Blue, BMS-90 Black, and BMSQ-109 Green. Five microgroove compounds are available for either 33⅓ or 45 rpm records. The two black compounds offered, BMS-66 and BMS-87, are essentially of the same quality. BMS-87 was designed to give less needle wear when records molded from this material are played with very soft metal needles. With standard osmium or sapphire needles, according to tests little or no significant needle wear is experienced after 100 plays with either of these two compounds or with the colored microgroove compounds, BMSQ-98 Red, BMSQ-99 Blue, and BMSQ-112 Yellow.

The compression-type compounds are development products and are presently available only in the black formulations for both standard and microgroove molding.

The data in this publication define the quality ordinarily to be expected of these resins as measured by UNION CARBIDE'S test methods in use at the date of issue.

Values of certain resin properties are subject to intermittent rather than continuous verification. If complete verification of all values, certain values, or of properties not given is necessary because of usually critical requirements, the problem should be discussed with a UNION CARBIDE Technical Representative.

Because of the infinite variety in the nature or quality of ingredients used with this resin and the conditions under which they are processed, UNION CARBIDE is unable to guarantee like or optimum values for all properties and performance data.

Data and suggestions made in this publication are not to be construed as recommendations to use any product in violation of existing patents covering any material or its use.

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050093

EQUIPMENT SOURCES FOR MANUFACTURING PHONOGRAPH RECORDS FROM PREFORMS OF "VINYLITE" BRAND PLASTIC

EQUIPMENT	SUPPLIERS
Preheating Oven	Industrial Equipment Co., 43 Clinton Street, Newark, N.J., U.S.A.
Molding Press	Industrial Equipment Co., 43 Clinton Street, Newark, N.J., U.S.A. French Oil Machinery Co., 90 West Street, New York, N.Y., U.S.A. Lake Erie Engineering Corporation, 500 Woodward Avenue, Buffalo, N.Y., U.S.A. F. J. Stokes Machine Co., 5930 Tabor Road, Olney, P.O. Philadelphia, Pa., U.S.A. The Watson-Stillman Co., 109 Aldene Road, Roselle, N.J., U.S.A. The Baldwin Locomotive Works, Standard Steels Works Division, 940 Simpson Street, Burnham, Pa., U.S.A.

EQUIPMENT SOURCES FOR MANUFACTURING RECORD PREFORMS FROM "VINYLITE" BRAND RESIN

EQUIPMENT	SUPPLIERS
Blender	The J. H. Day Co., 480 Lexington Avenue, New York, N.Y., U.S.A. Read Machinery Division, The Standard Stoker Co., Inc., 350 Madison Avenue, New York, N.Y., U.S.A. Mercer-Robinson Co., Inc., 30 Church Street, New York, N.Y., U.S.A. Sprout-Waldron & Co., Inc., 50 Church Street, New York, N.Y., U.S.A.
Banbury Mixer	The Biggs Boiler Works Co., Ken Street and B & O R.R., Akron, Ohio, U.S.A. Farrel-Birmingham Co., Inc., Chrysler Building, New York, N.Y., U.S.A.
Two-Roll Mill	Farrel-Birmingham Co., Inc., Chrysler Building, New York, N.Y., U.S.A. Wm. R. Thropp & Sons Co., East State and Esquire Streets, Trenton, N.J., U.S.A. Adamson United Company, 50 Church Street, New York, N.Y., U.S.A.
Extruder	Modern Plastic Machinery Corporation, 15 Union Street, Lodi, N.J., U.S.A. National Erie Corporation, Mullen and Allen Streets, Erie, Pa., U.S.A. National Rubber Machine Co., 47 West Exchange Street, Akron, Ohio, U.S.A. John Royle & Sons, 10 Essex Street, Paterson, N.J., U.S.A. Standard Machines Co., Mystic, Conn., U.S.A. Hartig Engine & Machine Co., 498 Hillside Avenue, Hillside, N.J., U.S.A.

Suggested sources of supply for the following items as mentioned in the formulas in Table I are:

DS-207	National Lead Company, 111 Broadway, New York, N.Y., U.S.A.
Tribase	National Lead Company, 111 Broadway, New York, N.Y., U.S.A.
Estawax 211	Lovell Chemical Co., 36 Pleasant Street, Watertown, Mass., U.S.A.
Fillers	A fine particle size precipitated Calcium Carbonate is suggested for microgroove records.

The appearance of the name of a manufacturer on this list does not necessarily constitute an endorsement of his products by Union Carbide International Company, nor is this list to be considered as complete.

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050094

OTHER UNION CARBIDE INTERNATIONAL COMPANY
Plastics and Resins of wide interest and application

Although this booklet discusses VINYLITE Brand Resins and polystyrene materials for phonograph records, Union Carbide International Company also markets a wide variety of other plastic materials that are available for extrusion and molding purposes. Information pertaining to these materials is available upon request.

RIGID SHEETS

VINYLITE Rigid Sheets can be blow molded, vacuum molded, or swaged to give thin but tough articles such as three dimensional signs and doll faces.

PLASTISOLS

Plastisols based on VINYLITE Resins, which are paste-like dispersions of a resin in a plasticizer, can be dipped molded or slush molded to give elastomeric articles with very complex shapes and very thin inserts such as are beyond the tolerances of standard molding equipment and mold design.

POLYETHYLENE

Polyethylene is an outstanding plastic that can be molded into squeezable, chemically-resistant bottles, bottle closures, and many other articles; and can be extruded into thin film for packaging purposes or into chemically-resistant tubing or moisture-resistant electrical cable insulation.

POLYSTYRENE

Styrene Plastics are well known for their ease of molding, their low mold shrinkage, their clarity, their brilliant colors, their light-weight and many other desirable properties. Styrene Plastics find wide use in industrial articles and in toys, kitchen and picnic items, attractive wall tile, and many other applications.

PHENOLIC PLASTICS

Phenolic resins and plastics are important thermosetting materials, and they are widely used in electrical applications, in radio and television cabinets, washing machine agitators, and many industrial-type applications.

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