TECHNICAL SERVICE REPORT Number 37

Extrusion Blow Molding Geon® Rigid Vinyl Compounds

The technology of converting plastic materials by the blow molding process is generally abundant. However, specific technology related to converting rigid PVC by this process is scarce. The data and suggestions in this report can assist converters in extrusion blow molding of Geon rigid vinyl materials.

INTRODUCTION

Blow molding, although practiced as early as 1881, was not recognized as a potential mass production tool until World War II when light-weight polyethylene containers answered military requirements. Realizing the value of plastic containers and the blow molding process, post-war development efforts to improve resin quality and conversion rates intensified. New equipment was developed offering increased rates as compound technology improved and raw material prices declined. The market grew in all applications except food containers where permeability problems, general disinterest and lack of transparency precluded entrance.

Not until the glass strike of 1965 and the ensuing glass shortage was there any real need for new bottle materials. In recognition of market requirements, Geon developed rigid PVC compounds for glass-clear blow molded containers.

Many hurdles have since been crossed. Geon has met FDA requirements for polyvinyl chloride compounds, has proven PVC an acceptable packaging material, and is operating production facilities to meet the demand for quality products.

As does any material, PVC has limiting factors. Physical properties and bottle color can be adversely affected by improper processing conditions; either under or over-processing of the material. Similarly, too little weight or thin wall in a critical area will reduce impact resistance of bottles. In addition, certain product permeability requirements may demand more protection than PVC can give.

SELECTING MACHINERY

PVC materials are relatively heat and shear sensitive. Food-grade PVC compounds in particular are more sensitive than non-food PVC compounds because of limits in both type and quantity of stabilizer. It is therefore very important that the size (barrel length and diameter) of extrusion equipment be closely matched to the expected size and quantity output of bottles. Also, extrusion rates should be matched with blowing unit rates. It is unreasonable, for example, to expect a 4½" extruder to produce two-ounce bottles with any degree of economy. The first point then is to seek extrusion equipment which will offer the most versatility within a reasonable range of bottle sizes. Equipment manufacturers can help narrow the range of sizes to suit individual needs.

Equipment horsepower rating is the second point of importance. Generally, the manufacturer offers minimal power for a particular piece of equipment with an optional higher power or heavy duty unit available. Choice is dependent on the converter's desire to use different materials for various contacts or stay with a single material of known power requirements. The heavy-duty power unit and gear box should be considered, since equipment versatility will be greater. Then, as new materials are developed, additional power will be available.

Xaloy™ and nitrided steel extruder barrels have been found to be satisfactory in strength and ability to withstand the corrosive characteristics of over-heated PVC melts and are suggested for PVC extrusion blow molding.

Extruder venting is optional for rigid PVC. Most domestic PVC blow molding compounds are produced in the form of pellets and most processors do not use vented extruder barrels. However, a large minority of extrusion blow molders have vents above the blow molding heads / dies and hoppers. These vents or exhaust help to carry away volatiles generated during processing of PVC compounds.

Pressure gauges are generally not offered as standard equipment, partly because they must be cleaned and maintained (grease and silicone types). However, there is value in determining head pressure. Transducers which do not have hang-up problems can be used to measure head pressure. This reduces the chance of exceeding head pressure limitations and the resulting chance of blown heads.

Screw cooling fluid tanks and monitoring systems are often offered with equipment as a total package. Screw tip cooling units are recommended to assist in reducing melt temperature, and variations of screw cooling can affect pressure differences. Increased versatility will justify the cost of this equipment.

The usual temperature controllers operate with full power during heating and with power off until additional heat is called for by the unit. In converting PVC, this type of heating unit can cause hot spots as the melt touches the heating areas during its residence in the extruder. Melt temperature differences of up to 30°F have been recorded. Use of power proportioning heaters (PPH) can minimize this problem.

PPH operates on a percentage power basis; the greater the difference between set temperature and actual temperature, the more power utilized to develop higher heat. Smaller temperature differences require less heat and the heaters operate proportionally. Units of this type can maintain the set temperature ±1°C, offering more uniform conversion melt. For barrel cooling, a time-proportioning unit is available which can be manually set to cool one second, pause one second, cool one second, etc. The value of this type of cooling prevents cold spots along the extruder barrel which can be a cause of non-homogeneous melts and possible gels. Although these units are not a must for processing PVC blow molding compounds, their merits should be discussed with equipment representatives.

Types of blow molding units include wheel, shuttle, horizontal and rising, each offering particular advantages. For purchase of new equipment, complete extrusion blow molding units should be considered. For purchase of blow molding units separately, trim and pinch off devices included in the molding unit have economic advantage. The equipment manufacturer will provide data on clamp pressure needed to produce containers of various sizes as well as to correlate bottle output rates with varying extrusion equipment. A mold chiller unit to insure uniform mold cooling is recommended.

A hot melt granulator (grinder) is necessary to grind PVC materials in the event of failure of the molding unit. If the PVC extrudate is not separated and is allowed to accumulate in a lump, degradation can occur, and it will be difficult to separate the accumulation for regrinding.

Equipment check list for extrusion blow molding of PVC containers:

Extruder Sizes (in.)	1½	2½	3	3½
Horsepower	15-20	24-40	30-60	75-100
Approx. Output (lbs./hr.)	30-70	75-125	100-220	200-300
Bottle Size (oz.)	Up to 6	4 to 16	over 16	over 24

Barrel Material - Nitrided steel or Xaloy™
Venting - Optional
Pressure Transducers - Yes, in head section.
Non-contacting piezoelectric units measuring melt pressure from strain transmitted through metal recommended.
Temperature Controllers - power proportioning for heating
time proportioning for cooling
Screw Cooling - Yes
Blow Molding Unit - Type Optional
Recommend purchase of complete system
Mold Chiller - Yes
Hot Melt Granulator - Yes

SCREW DESIGN

Screw dimensions differ for varying materials. A general purpose screw is not efficient for all materials. In most cases, equipment manufacturers have evaluated various raw materials and can suggest proper screw tooling for a specific material.

For those who are not purchasing new equipment or screws and want to run Geon compounds on present equipment, the following specifications are recommended:

	Two Stage Screw	Single Stage Metering Screw
Extruder:	60MM(2.36")	60MM(2.36")
Barrel:	24:1	20:1
	5 turns @ 0.426"	3 turns @ 0.280"
	3 turns compression	14 turns compression
	6 turns @ 0.125"	3 turns @ 0.150"
	1½ turns decompression	
	2 turns @ 0.581"	
	3 turns compression	
	3½ turns @ 0.220"	

All of the above screws have torpedo tips allowing for minimum inventory at the tip end. This is important. Stagnant material will degrade and eventually spread to the prime melt flow, producing streaks and discoloration of the parison. All screws should be bored for tip cooling. Operating conditions for the various screws are available from Geon upon request.

Each screw is balanced with the extruder, head and molding unit. Each component of the total system complements the other, and none can operate successfully without balance with the other three. Changes in any single component may affect the remaining system members necessitating further changes in the system. For example, a system balanced for 24 ounce bottle production will require changes and adjustment to produce 32 ounce containers.

TOOLING SUGGESTIONS

Cold-rolled steel tooling has caused irregular flow of the melt and excessive frictional build-up in the head and die, causing poor bottle appearance.

Use a good quality tool similar to A.I.S.I. Type 02 or 400 series stainless steel from the extruder barrel forward. A two-mil chrome-plating on all tooling helps deliver a high quality parison to the molding unit with minimal problems.

Aesthetics required in transparent blown materials increase the need to minimize spider lines. Fewer spider legs result in fewer lines in the finished container from this source. Two legged spiders are preferable and can be lined up with the bottle seam so that spider lines will not be apparent.

Die land length will vary according to size of equipment, screw design, rate and the type of container required. Start with a die land to die opening ratio of 10:1. A 10:1 ratio should provide back pressure to re-knit spider lines and polish the parison to a high quality.

For assistance in mold design tolerances, a shrinkage of from 0.005 to 0.00693 inches per inch is a guideline for rigid Geon PVC molding compound.

For mold construction, either stainless steel or machined aircraft aluminum with copper beryllium inserts can be used. They have the cooling capacity and durability for sustained quality bottle production. In addition, a chiller unit is recommended to maintain constant mold temperature.

Mold cooling channels to the neck and body sections of the bottle should be separate and capable of individual control because of the differences in wall thickness. A single cooling channel requires more mold dwell time than separate or dual channels operating at colder temperatures in the neck cooling area.

OPERATIONAL GUIDES

ABS or Polyethylene have been used as startup / shutdown materials because of their heat stability. Use of these materials is not objectionable, although there is no substitute for starting up with completely clean equipment. Polyethylene or ABS is quite useful for short runs or when tooling changes require extended extruder downtime. PVC left in a heated extruder for a long time will degrade and necessitate full shutdown and clean up.

The following temperature profile is recommended for extrusion startup using rigid Geon blow molding compounds 87390, 87444, 87453 and 87445.

Feed Zone	310°F
Zone 2	320°F
Zone 3	330°F
Zone 4	340°F
Head	340-350°F
Die	380-390°F
Mold Temperature	55-65°F

Make adjustments after the parison reaches equilibrium temperature. A stock temperature between 380 and 400°F should produce bottles of high quality. Melt temperatures above 405°F are not recommended because it could cause poor stability of the regrind.

Trim materials and bottle rejects should be granulated using a 3/8" screen. Blend with virgin material at about 30-50%. Do not blend regrinds of different compounds. If regrind materials are not immediately blended and reprocessed, store in polyethylene-lined containers. This minimizes moisture pickup and will keep the regrind clean. Do not blend too much fine regrind with virgin material. Fine particles require abnormal shearing to break them down and blend them into the melt. They can cause gels in the bottle wall if not fully dispersed.

Clean up head and die tooling using brass tools only. Nicks and other tooling damage can be avoided by developing and maintaining a sound clean-up procedure designed around individual operations.

Following are potential problems and suggested solutions:

Problem	Probable Cause	Correction
I. BOTTTLE SURFACE		
A. Orange Peel	Material tool cold	Increase stock temperature to 385-400°F.
B. Sink Marks	Mold entrapped air Material tool cold	Vent mold to release air. Increase stock temperature to 385-400°F.
C. Die Lines	Die heat non-uniform Insufficient back pressure Burr or scratches in die Hang up / contamination	Check heater band location and heat uniformity. See swirls below. Smooth Burr. Fill in scratches. Clean up entire set.
D. Swirls	Insufficient back pressure	Increase extruder RPM. Reduce die temperature. Add oil or air to cool screw. Increase die land length. Reduce heating zones in rear of extruder.
II. BOTTLE COLOR (CLEAR TRANSPARENT COMPOUNDS)		
A. Amber or Green	Stock temperature too high Screw too shallow Blunt nosed screw Regrind ratio too high	Reduce stock temperature to 385-400°F. Increase extruder RPM to reduce dwell time. Adjust oil or air cool on screw. Need deeper flighted screw. Need torpedo tipped screw. Use between 25-35% regrind.
B. Blue or Purple	Stock temperature too low	Increase stock temperature to 385-400°F. Reduce RPM for longer dwell. Increase RPM for higher shear
III. BOTTLE WALL		
A. Surging	Screw surging Material too cold Extruder drive	Increase extruder RPM. May need different screw. Increase stock temperature to 385-400°F. May not be able to correct.
B. Thin Section	Mold off-center Parison off center	Center mold. Center parison.
C. Blow-Out	Molds misaligned Material too cold Parison off-center	Align molds. Increase stock temperature to 385-400°F. Center parison.
IV. OTHER		
A. Dark Specks	Contamination Hang-up Burning	Inspect system. Use clean regrind material. Clean system watching for dead areas - streamline or smooth dead areas. Clean system - reduce temperature in degraded areas.
B. Excessive Gels	Too many fines in regrind. Screw too deep	Screen-out fines in regrind. May need shallower screw. Increase of die temperature at same time can help.
C. Bubbles	Material left uncovered and picked up moisture. Regrind left uncovered	Keep PE liners tied when not using material. Dry the material. Vented extruder may help. Keep regrind in tied PE lined containers. Dry material before extrusion.
	Air entrapment not venting back through hopper	Slow extruder to allow air to escape through hopper. Increase temperature on barrel of extruder.

BOTTLE DESIGN AND TESTING

PVC bottles offer versatility of design, weight savings, shatter resistance and other advantages. The advantages of PVC are, in part, a function of bottle design.

PVC gives more freedom of design than some of the more common non-plastic container materials. However, avoid sharp corners and angles, allowing for as great a radius as aesthetically acceptable for enhanced impact strength. Drop impact testing of prototype bottles will indicate areas of weakness; increased radius may reduce failures.

Weight savings can be realized in nearly every size PVC container. Half-gallon bottles weigh 2 1/2 pounds in glass, 3 1/2 ounces in PVC.

Bottles using rigid Geon compounds are shatter-resistant. Properly molded bottles made from Geon vinyl offer out-standing impact resistance. They do not produce sharp splinters on the production line or in the home. Design of contoured, shock-absorbing bottles with strength-building radii is imperative to a successful package.

Bottles can be impact-tested by either manual drop from a given height and reported in terms of number and type of failures and passes, or by using mechanical methods such as the Bruceton Staircase method. Usually, manual drops suffice to determine values for the bottle purchaser.

Several points are important to bottle drop testing:

1. Use a firm smooth surface for the impact base; machined metal works well.
2. Use room-temperature water for filling containers; containers should be at room temperature at time of testing.
3. Do not overfill containers; allow headspace typical of product filled containers.
4. Wipe water off the impact base as failure occurs. This is done to remove any cushioning of bottle impact.

SUMMARY

Geon PVC compounds are being used more and more in varying applications throughout the packaging industry. The recommendations in this report will assist in successful conversion of Geon material into high-quality containers. The prime points are:

1. PVC compounds develop optimum bottle properties, impact and chemical resistance when they are highly fused (melted) during processing. Use the proper processing conditions with melt temperatures between 380-405°F.
2. Select and balance equipment for specific bottle size ranges as recommended by machinery manufacturers.
3. Use good-quality tooling designed for PVC conversion.
4. Follow operational suggestions to solve on-line problems.
5. Test bottles manually if desired, but develop uniformity in method.
6. Refer to Technical Service Report #17 for a listing of PVC blow molding compounds suitable for packaging.

PLEASE CONTACT YOUR GEON VINYL DIVISION REPRESENTATIVE IF YOU HAVE ANY QUESTIONS OR DESIRE MORE INFORMATION.

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