PROCEEDINGS FROM
TWELFTH ANNUAL STRUCTURAL FOAM CONFERENCE AND PARTS COMPETITION

MAY 7-9, 1984

Proceedings of the S.P.I.
Twelfth Annual Structural Foam Conference

Sponsored by
The Structural Foam Division
The Society of the Plastics Industry, Inc.
355 Lexington Avenue
New York, NY 10017

Proceedings of the S.P.I.
Twelfth Annual Structural Foam Conference

The Society of the Plastics Industry, Inc.
355 Lexington Avenue
New York, NY 10017

1984 STRUCTURAL FOAM CONFERENCE COMMITTEE

POSITION	MEMBER/AFFILIATION
Conference Chairman	John Hoven/Structural Plastic Systems
Conference Vice Chairman	Jack Reilly/Electro-Kinetic Systems
Division Chairman	Jim Eakin/Mobay Chemical
Division Vice Chairman	Ron Jones/Amoco Eng. Plastics
Immediate Past Conf. Chmn.	John Cochrane/Ex-Cell-O Corp.
Parts Chairman	Ed Helwig/K & H Finishing
Parts Vice Chairman	Ken Streit/Tech Plastics
Program Chairman	Rod Roth/Grant & Roth Plastics
Asst. Program Chairman	Joe Bergen/Southeastern-Kusan
Publicity Chairman	Deborah Hauser/Mobay Chemical
Audio/Visual Chairman	Bill Fuller/Fuller-Miree
Asst. Audio/Visual Chairman	Melissa Farrah/General Electric
Activities Chairman	Mike Chapman/Amerdyne West
Session Chairmen	Richard Marchetti/American Hoechst
	Greg Koski/Applied Molding
	Wolfgang Meyer/Battenfeld East
	Ferdinando Beccalli/General Electric
	Les Pierce/Grant & Roth Plastics
	Garry Phillips/Marketing Technologies
	Joe Oates/Northwest Molded Products
	Joe Bergen/Southeastern-Kusan
Members-at-Large	Ed Galli/Industry Media
	Roger Young/Dow

TABLE OF CONTENTS

RESIN MATERIALS FOR STRUCTURAL FOAM MOLDING

Richard C. Von Hor

Ex-Cell-O Corporation

The purpose of this session is to give you an overview of structural foam materials.

Assuming that the majority of you have had limited exposure to the structural foam industry and, in particular, the materials from which it is produced, let's proceed with some basic information, not from a resin suppliers viewpoint, but from a molder/finisher position.

The examples shown in Figure 1 represent a typical thermoplastic resin that was molded without a blowing agent, so it is solid as obtained by an injection molding process, and also a foamed version of the same resin molded via the low pressure structural foam process. The basic difference between the structural foam process and injection molding is that in injection molding the entire mold is filled with plastic (Figure 2), but in the structural foam process the mold is filled eighty to ninety percent with plastic containing a blowing agent. The blowing agent pushes the plastic to the mold extremities and presto we have structural foam (Figure 3).

Now that you know everything that you need to know about structural foam processing, let's continue on to the resins used in the molding process.

Generic Names of Resins

- Styrene
- Polycarbonate
- Modified Polyphenylene Oxide
- Others

Since the purpose of my presentation is to talk about molding resins, I will talk about generic resin types and not specific trade names assigned by the resin manufacturers. Many of the resins are produced by more than one manufacturer and have very similar properties, therefore the information can be presented in general terms. There are a few buzz words that you should be aware of since they are passed around the industry in many conversations:

Thermoplastic

All of you have probably heard the word thermoplastic since the majority of molding resins used in the structural foam industry fall into this category.

Thermoplastic Resins (can be heated repeatedly and reprocessed)

The simplest definition of a thermoplastic resin is one that can be heated repeatedly and reprocessed.

Economics of Thermoplastics

In economic terms, a product molded from a thermoplastic resin can be reground to a pelletized form and reintroduced to the molding process to make another product. The cost is one of machine time consumed, utilities and labor but the resin can usually be reused. The amount of regrind that can be added depends to a large extent on the geometry of the molded product and its end use. Regrind levels of up to 25% are not uncommon but the quality of regrind must be considered. In addition there is some finite number of times that a particular resin can be reprocessed before significant damage is done to its molecular structure and physical properties. Fortunately this does not usually present a problem since a large amount of regrind is not usually produced and when it is a molder will use it at the first opportunity.

Thermoplastic Resins for the Structural Foam Industry

Our industry is well served by many thermoplastic resins that meet a variety of end use needs. Before we continue there is a rhetorical question that I would like you to keep in mind—just what are your end use product requirements?

What Are Your End Use Product Requirements?

The reason for asking this question is basically an economic consideration that should become evident as specific resin types are presented. As in other industries you get what you pay for. If you need a product that has high impact and chemical resistance, good dimensional stability then you will probably specify a polycarbonate or a polyester resin which will cost 50% to 100% more than a styrene resin. On the other hand, if your product doesn't need these requirements don't specify the expensive resin. When specifying materials involve not only your resin supplier but include your molder/finisher.

Thermoplastic Resins for the Structural Foam Industry

Styrene is the least expensive of the SF resins and when matched with the correct product will provide a very adequate, functional and competitive product. There is a place for styrene in the SF industry and when properly molded in the correct tool design you can be assured of a quality product. Styrene is softer than PPO/PPE type resins, has a lower heat distortion temperature but a longer flow length. Properly molded products can be easily painted with the correct solvent and paint selection.

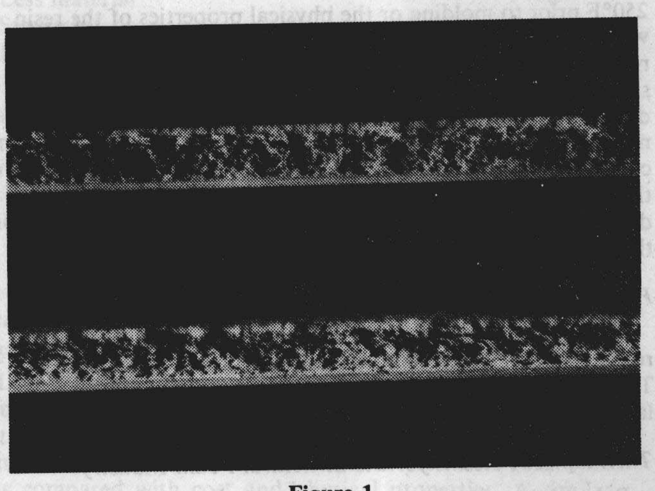

Figure 1

Presented at the Twelfth Annual Structural Foam Conference and Parts Competition, The Society of the Plastics Industry, Inc., May 7-9, 1984, San Francisco, CA.

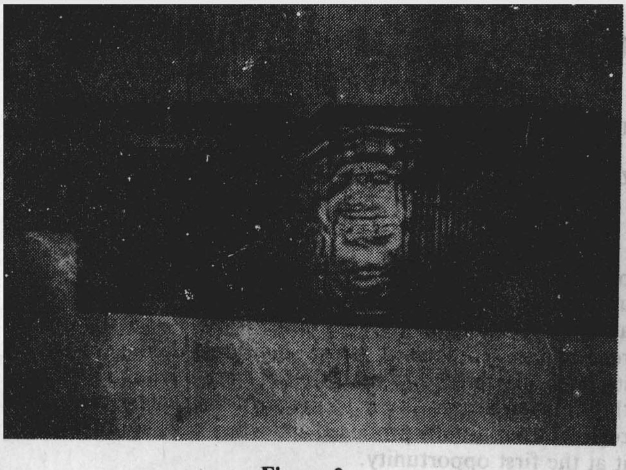

Figure 2

Thermoplastic Resins for the Structural Foam Industry

Modified Polyphenylene Oxides
Modified Polyphenylene Ethers

The modified PPO/PPE resins are probably the most widely used in the SF industry. They fill the gap between the more easily molded styrene and the polycarbonates and polyesters with their superior performance properties. Modified PPO/PPE resins are used throughout the computer and business machine industry as well as in many other applications. They accept a wide variety of paint systems.

Thermoplastic Resins for the Structural Foam Industry

Polycarbonates
Glass filled up to 30%
Mineral filled
Must be dried

Polycarbonate resins, usually a glass filled version of anywhere from 5% to 30% fiberglass or a mineral filled resin, provide structural strength that in some applications allows replacement of sheet metal where metal was used because of its strength. Paints for polycarbonate resins must be carefully selected since polycarbonate resins are sensitive to many of the solvents used commercially. Finishing costs can be higher than PPO/PPE and styrene because of surface porosity associated with the glass fillers. Polycarbonate resins, unlike styrene, PPO and PPE resins must be dried for at least 4 hours at 250°F prior to molding or the physical properties of the resin will be degraded. The hygroscopic nature of polycarbonate resins—their ability to absorb moisture even from the air—is a significant concern for the molder. Not only must the resin be dried before being introduced to the molding machine, but it must be maintained in a dry state until molded. This can be accomplished in a number of ways and a typical one is to pre-dry the polycarbonate off-line in a commercial dehumidifying dryer then transfer the dried resin to a hopper dryer located on the throat of the extruder.

Product Molded in a Polycarbonate Resin

With polycarbonate resins there may be opportunities to replace several sheet metal pieces with one molded product. This has been demonstrated many times from small to very large moldings.

Thermoplastic Resins for the Structural Foam Industry

Polyesters
Polyetherimides

Figure 3

Although used to a lesser extent than the resins previously mentioned, the thermoplastic versions of polyesters and polyetherimides provide some outstanding properties. These resins have superior chemical resistance, high heat distortion, high strength and modulus. Of course you will pay more for these added features. Like the polycarbonate resins, polyesters and polyetherimide resins must be dried for 4 hours at 250° to 300°F.

Thermoplastic Polyester and Polyetherimide Resins

Chemical resistance
High heat distortion
High strength and modulus

Other Resins for the Structural Foam Industry

Blends of Polycarbonate /ABS
RIM (Reaction Injection Molded Urethanes)

At least one resin supplier is making a blend of polycarbonate/ABS which has found primary use in the injection molding industry.

Thermoset Resins—RIM

RIM (Reaction Injection Molded Urethane)
Two Components
Component "A" is an Iscoyanate
Component "B" is a Polyol Resin

RIM (reaction injection molded urethanes) materials, unlike pelletized thermoplastic resins, are composed of two or more liquid streams. These liquid components are processed with special RIM metering and mixing machines that are available from many suppliers. RIM technology is not new, and has been used extensively in the automotive industry. However, application of RIM technology in the SF industry is relatively new, and the number of pounds presently used in the SF industry represents less than 5% of the total pounds of thermoplastic consumed.

Thermoset Resins—RIM

Once processed it is in the final state
Cannot be reprocessed
Requires special RIM machines
Different finishing process

There are advantages and disadvantages to thermoset RIM materials compared with thermoplastic pelletized resins. The chemistry of the RIM materials creates a product that once nolded it is in the final state, and if the product has defect that cannot be repaired, then the product is scrap.

While this should not be considered an over-riding negative t is a consideration that must be understood. Finishing processes will be similar to thermoplastic materials but with the addition of more thorough surface cleaning either through power washing or vapor degreasing.

Thermoset Resins—RIM

Smooth surface
Equivalent physical properties
Fast cycle times
Thin wall possible

Because of their fluid nature, RIM materials can provide a smooth surface to produce a product with physical properties equivalent to some thermoplastic resins. Cycle times could be competitive or faster than with thermoplastic SF products depending on product size and wall thickness.

Although RIM materials do not now represent a significant portion of the SF business, their market penetration and utilization will probably continue to grow.

Now I would like to make a comparison of these significant SF resins that were presented. The comparison is a simple one that of price versus performance properties. Typically styrene resins sell for under one dollar per lb. and all the others sell for greater than one dollar per lb.

SF Resins

PRICE AND PERFORMANCE

Resin Type	Price/LB	Performance Properties
Polyester/Polytherimide Polycarbonate PPO/PPE Styrene	↓ DECREASING	↓ DECREASING

I have purposely grouped all properties and shown them in the table as decreasing in price. The resin suppliers represented at this SPI meeting will be able to provide you with specific numbers for all of the various property measurements and recommended processing conditions.

There are a few more "buzz words" that you will hear about if you have not already.

"FR" Resins

Flame Resistant
Flame Retardant
Ignition Resistant

All of the resins presented fall into a category called "FR Resins"; flame resistant, flame retardant, ignition resistant, call it what you will they are resins that conform to UL-94 burning rating for plastics.

UL-94 Ratings

V-0/5V Most stringent
V-2
V-1
H-B Least stringent

Ul ratings are available from the resin suppliers for their products in foamed and solid moldings. Ratings on the "yellow card" which give the specifics such as the resin code and the thickness for which the rating was given.

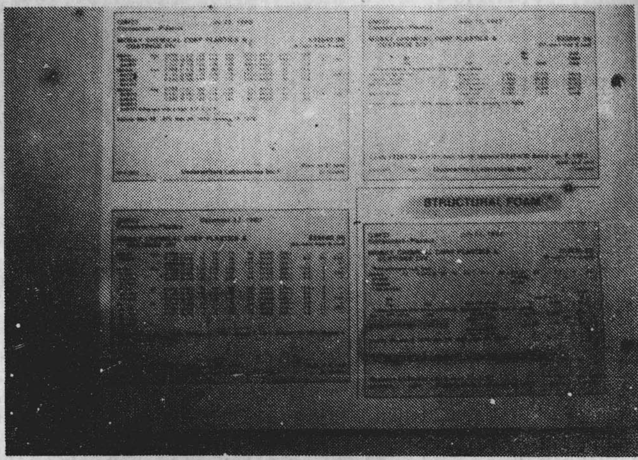

Figure 4

UL Yellow Card

The UL yellow card shown in Figure 4 is typical of other plastics that have received UL approval. Significant identification on the card includes the manufacturer, material designation, whether solid or foam, the nominal thickness and the UL94 flammability classification. The yellow card is available from the resin supplier.

Thickness of the foamed product brings us to the next "buzz word", "Thin Wall SF".

Thin Wall SF

Approximately 0.157 to 0.170 inches

The thin wall SF is somewhere around 0.157 to 0.170 inches thickness as compared with "normal" SF at a nominal wall thickness of 0.250 inches. Molded SF products have been around for several years that have had some thin wall concepts built into existing 0.250 inch wall. The driving force for thin wall SF is basically economic. Thin wall provides an opportunity to take lbs. of plastic out of a product while maintaining some of the desirable SF features such as:

Thin Wall

Less material
Strength from foam core
No sinks

By designing a product for maximizing the thin wall concept, material savings can be realized while retaining some of the benefits of a SF product such as strength from the foamed core and the absence of sinks around ribs and bosses usually associated with injection molded products. Of course there are trade offs with thin wall.

Thin Wall

Flow problems
Less density reduction

Some resins designed to flow in 0.250 inch wall thickness do not flow as well with thinner wall sections. An interesting comparison can be made from earlier tables where resin type was compared with cost and physical properties. A similar comparison can be made with the same resins and their ease of flow.

Resin Type vs. Flow

Resin	*Flow*
Styrene	INCREASING DIFFICULTY ↓
PPO/PPE	
Polycarbonate	

Styrene with its inherently good flow properties still flows reasonably well in thin wall sections. Going down the list, the flow of PPO/PPE becomes more difficult and when you get to glass filled polycarbonates still more difficulty is encountered. In 1983 some resin suppliers intoduced new PPO and polycarbonate resins designed for the thin wall concept. Density reduction obtained by the use of various blowing agents becomes less effective in thin wall products. In thin wall a maximum reduction of only 3% may be possible compared with 10 to 15% in thicker sections on typical commercial products obtained with a low pressure SF molding process. However, there are advantages of a foamed product in terms of structural benefits and a sink free surface even in thin wall products.

Composites for EMI/RFI

EMI: Electromagnetic interference
RMI: Radio frequency interference

You can hardly pick up a trade magazine today without finding at least one article related to the FCC rulings pertaining to EMI (electromagnetic interference), and RFI (radio frequency interference). Of course the concern is for EMI/RFI emitters such as computers and other electronic equipment. When housed in plastic containers instead of sheet metal, often some type of shielding may be required to the plastic to prevent excessive EMI/RFI leakage. I am going to just hit the highlights of EMI/RFI shielding materials since other sections of this SPI Conference will provide details on materials and methods.

Shielding for EMI/RFI

Add-On Methods

- Conductive foils and tapes
- Conductive paints
- Arc sprayed zinc
- Vacuum metalizing
- Platings (ion, electrolytic, electroless)

There are two basic EMI/RFI shielding approaches. First is the add-on method where the plastic housing is partially or completely covered by some conductive material. The add-on methods are the most widely practiced and includes; conductive foils and tapes that are applied to the molded product, conductive paints that are sprayed onto the plastic product @2 mils, arc sprayed zinc which is sprayed on @ 2 to 5 mils, vacuum metalizing and plating methods that can totally encapsulate the molded plastic with a thin, 0.03 to 0.05 mils, metal film. That is all that I will say about these add-on shielding methods. The second basic method of shielding is to have a plastic that is conductive so that it would not require any of the previously mentioned add-on techniques.

Conductive Plastics

- Composites
- Inherently conductive

Conductive plastics fall into two categories; composites which are plastics to which conductive materials have been added and get dispersed throughout the plastic, and the other category is plastics that are inherently conductive, that is, their ability to conduct EMI/RFI is built into the molecular structure of the polymer. We will dispose of inherently conductive plastics by saying that few are commercially available in terms of being economically justified for use in the typical structural foam product line.

Composites

- Nylon
- Polycarbonates
- PBT
- Polycarbonate/ABS Alloy

Composite Fillers

- Aluminum flakes
- Powders (carbon, graphite)
- Metallized glass fibers
- Graphite fibers

Composites are available that are filled with aluminum flakes, carbon and graphite powders, metallized glass fibers, and graphite fibers, however they are expensive $3 to $4 or more per pound and usually cause some loss of polymer properties. In addition, the very nature of structural foam with its cellular core detracts somewhat from the need to have the fillers in intimate contact with each other to provide electrical continuity. While composites and inherently conductive polymers may be economically feasible in the future, the various add-on methods for EMI/RFI of structural foam products will dominate in the near future.

In summary, there are many resins that will provide a wide range of physical properties for your end product.

Resin Selection

- Know what properties you need
- Work with resin suppliers
- Work with your mold maker
- Work with your molder

The more knowledge and ideas you can exchange with your resin supplier and your molder, and possibly with your mold maker, the better chance you will have for a successful, cost effective program.

BIOGRAPHY

Richard C. Von Hor is a graduate of the University of New Hampshire with a B.S. in Chemical Engineering. He attended several coatings courses offered by professional societies and educational institutions.

Mr. Von Hor joined Ex-Cell-O Corporation's Plastic Components Division in Athens, TN in January, 1981 as Director of Finishing. He was appointed Technical Director in July, 1982 with responsibility for all processing, materials, new product development and research and development.

Prior to joining Ex-Cell-O he was a Senior Research Engineer and Project Leader in Applications Research at PPG's Coatings and Resins R&D Center in Allison Park, PA for approximately three years.

Mr. Von Hor worked for E.I. DuPont as an Engineer in their Pigments Department at Chestnut Run location in Wilmington, DE, and held various technical positions at Davidson Rubber Company's plants in New Hampshire with laboratory and manufacturing responsibilities.

He is a member of SPE and an active member in the AFP division of SME.

STRUCTURAL FOAM PROCESS HISTORY AND RECENT DEVELOPMENT

Ronald Jay Anderson

West and Associates

During the 1930's, the first concept of structural foam took shape. The function of this new process, involving urethane chemistry technology, allowed material to be processed in a less dense form. Thereby reducing weight and still providing a structurally sound part. These first applications were for aircraft where weight and structural soundness are critical.

The process evolved slowly until Union Carbide developed the process and started to sell process liscenses after an unsuccessful attempt to sell structural foam molded product. The idea of obtaining structural soundness and gaining a weight reduction, as the original 1930's concept did, illustrated great promise to many industries.

Like most new ideas, the process was not without its limitations. Process controls, material, tooling, equipment, training and other related technology lagged behind demand and need of industry.

Many failures were recorded in early processing. Sometimes, just getting a full part was a success. Along with the successful results additional requirements were established. The addition of a blowing agent to a resin produced structurally sound parts. However, some physical properties and surface finish were sacrificed.

Several processes were born to improve structural foam production. Each process gives alternatives that aid the decision making process required for the successful application of structural foam projects.

The following presentation gives basic process information for low pressure and high pressure structural foam production.

The information can be useful to the end user community in as much as it explains that there are many processes provided by many capable manufacturers.

The body of the presentation will give a description of the earlier processes and improvements made on these processes.

LOW PRESSURE PROCESS

The term "pressure" in low pressure refers to the resistance to flow of the injected material into the cavity of the mold which forms the part. Typical internal cavity pressures for conventional injection molding can reach several thousands of pounds per square inch.

In low pressure molding the internal cavity pressure is in the range of 250 to 500 PSI. This is so, because the shot volume is less than the cavity volume of the mold. Consequently there is less resistance to material during the molding process.

Here are some different methods to mold parts in the low pressure process multi-nozzle process.

One of the considerations of structural foam is to take the advantage of the low pressure process. As mentioned, the internal cavity pressure is lower. Therefore, clamp tonnage required for making large parts is lower. In calculating clamp tonnage a simple formula is used. 2 to 5 tons of clamping force per square inch of projected surface area is required. Therefore if a particular part of parts equaled 1000 square inches in projected surface area one could use 125 to 250 tons of clamp force for a structural foam part. Or, in the case of an injection molded solid wall part, one would have to use a 3000 to 5000 tons of clamp force.

A problem that may be encountered is one of material flow. Some material flow may be shorter that the size or length of the part itself. A solution to this problem might be solved with the use of multi-nozzle low pressure molding process.

MULTI-NOZZLE LOW PRESSURE MOLDING

Multi-nozzle presses position injection nozzles in matrix location on the stationary platen of the press. In cases where part size goes beyond the capability of the material flow, injection points (gate) are positioned in correlation to the predetermined matrix of the multi-nozzle press to aid material flow problems. In the case of multiple molds, the mold is positioned on the platen in correlation with the predetermined matrix of nozzle locations on the multi-nozzle press.

As well, multi-nozzle presses typically have large shot capacities. Therefore, along with the larger physical size, one would not have to be concerned with weight, as most multi-nozzle systems have accumulators that range from 20 to over 100 pounds.

The multi-nozzle low pressure equipment uses the following process.

The material and chemical blowing agent is introduced at the rear of the extruder. In the case of using liquid nitrogen as a blowing agent, it is introduced in the center of a two-story extruder screw. The melt is mixed into a homogeneous form. The melt is held under heat and pressure (about 500 F and 3,000 P.S.I.) and the blowing agent is in micro-structure form. The melt is extruded into an accumulator/accumulators, still under heat and pressure. The pressurized melt is injected into an unpressurized mold cavity. Since the cavity is unpressurized, the blowing agent starts to come out of solution and the melt expands. This activity forces the melt to conform to the cavity contours. As mentioned previously, the shot volume is less than the cavity volume, the part is less dense than a solid part.

Here are some advantages and disadvantages to the multi-nozzle low pressure process.

Advantages:
1. Large part sizes can be molded
2. Multiple mold processing can be used
3. Large part weights can be obtained

Disadvantages:
1. Poor surface quality
2. Longer cycle times
3. Internal cell network is irregular

REACTION INJECTION LOW PRESSURE MOLDING

As mentioned previously in multi-nozzle low pressure molding, one may take the advantages of low cavity pressure molding. This can be done with reaction injection molding. To begin, here is an explanation of the process. Reaction injection molding utilizes liquid material, polyol and isocyanate. The

Presented at the Twelfth Annual Structural Foam Conference and Parts Competition, The Society of the Plastics Industry, Inc., May 7–9, 1984, San Francisco, CA.

two components are held in separate containers under pressure (2500 to 3000 p.s.i.) Metering pumps measure the amount of each material that is transported through injection tubes to a mixing head. The mixing head, as defined, mixes the material together while being forced into the mold. When the mixed material components are in the mold an exothermic reaction occurs and the material expands to conform to the cavity walls. The result of the reaction creates very little cavity pressure. The following table shows a comparison of clamp requirements for a part that has one thousand square inches of projected surface area.

Process	Clamp pressure required
Solid wall injection	4,000 tons
Multi-nozzle low pressure	250 tons
Reaction injection low pressure	175 tons

One could assume that less costly molds could be utilized for reaction injection molding. In fact, aluminum and cast tools are ideal for reaction injection molding.

Since the cavity pressure is low the opportunity to make large parts is available. The rheology of the material allows for tremendous flow lengths. Making parts that are 18 feet in length have been successfully produced in the building products industry.

Two types of basic materials are available for processing—flexible and rigid urethane. They produce a myriad of parts.

In either case smooth swirl free items can be produced. As well, thickness does not restrict design or expectations. Parts measuring from 1/4" to 1" in thickness can be produced sink free. Density reduction of .4 to .6 with respect to solid parts, can be achieved with uniform cellular structure.

Here are some advantages and disadvantages of the low pressure reaction injection molding process.

Advantages:
—ability to process large parts
—ability to produce smooth swirl free parts
—ability to control density thru processing

Disadvantages:
—uses a liquid system
—material used cannot be reprocessed

CONVENTIONAL LOW PRESSURE MOLDING

This process infers that this method is widely used. It is. The process is very simple and starts with a conventional injection molding machine. Chemical blowing agents can be introduced in the following manner.

1. Tumble mixed
2. Metered by a mixing blender
3. Metered at the feed throat (in instances of liquid blowing agents)

The extruder with its mixing action, along with heat to plasticate the material, causes decomposition of the blowing agent. This reaction creates a gas which goes into solution with the transformed resin and is held under pressure with the aid of a shut-off nozzle. When the material is injected into the cavity of the mold, the gas comes out of solution and the material is forced against the contours of the mold.

Design considerations are restricted to the flow lengths of material. Some occasions make it necessary to push the limits of the material due to the part design.

Examples are:

1. To fill a part—packing the mold and increasing the resin stock temperature.
2. To reduce swirl—increase injection speed, increase mold temperatures

These alterations to the process produce a more dense part, can cause sink, and creates more molded in stress which could result in warp.

Here are some advantages and disadvantages to the conventional low pressure injection process.

Advantages:
1. More equipment available
2. Production start-up is simplified
3. Improved surface condition

Disadvantages:
1. Part size restricted to material flow length criteria
2. Higher densities—heavier parts
3. Multiple mold setup not available
4. Sink and warp is less controllable

CO-INJECTION LOW PRESSURE PROCESSING

This process was designed so that the consideration of injection molding and structural foam molding could be combined. The function is to obtain an injection quality surface with the weight savings of structural foam. This will allow the opportunity of eliminating the labor intensive operation of post mold finishing.

This type of processing requires a specific type of equipment. The equipment must have two extruders. One extruder mixes an injection grade of resin. The other mixes a compatible structural foam resin. The injection grade resin is released first. Next, but almost simultaneously the structural foam grade resin follows. The injection grade resin is forced against the walls of the cavity. The structural foam resin forms the cellular core.

This process disallows the economics of cast and aluminum molds, as steel molds are strongly recommended. Molds manufactured for this process should be textured or grained. If an untextured or ungrained highly polished mold is required.

Here are some advantages and disadvantages of this co-injection low pressure process.

Advantages:
1. High quality smooth surface
2. Structural foam weight savings

Disadvantages:
1. Light tolerance processing parameters
2. Increased mold cost
3. Limited capability resources

HIGH PRESSURE STRUCTURAL FOAM MOLDING

As in "low pressure" molding, the pressure is created by the restriction of material flow into the mold. When the high pressure structural foam process is utilized the shot volume equals the cavity volume. This is the same analogy used with injection molding. In fact, the equipment used for high pressure structural foam molding can also be used for injection molding. The purpose of this process is to obtain injection quality surface where required. And, gain the advantage of localized structural foam.

This technique of localized structural foam follows the same process procedure as low pressure molding. Resin and blowing agent is plasticated and mixed in the extruder. The melt is injected, through a common nozzle into an unpressurized mold. After a brief period of time (seconds) the clamp pressure is reduced and the moving platen is allowed to move back a fractional amount. Simultaneously, the mold is allowed to expand the same distance as the platen. Keep in consideration that the mold can expand in a localized area or the whole surface side of the mold could move. When the mold expansion occurs the foamed resin forms a cellular core inside the injection quality surfaces. The density reduction will be proportional to the area allowed to expand.

Since the process is injected through a single point the part design size is restricted to material flow parameters. Steel molds are required for this process due to the high clamp requirements. Remember, the clamp requirement for an injection part that has 1000 square inches of projected surface requires 2500 to 4000 tons of clamping force.

The mold is more difficult to build due to additional mechanical actions required for expansion. Consequently, the mold cost will be higher than other structural foam processes.

Here are advantages and disadvantages of the high pressure structure 1 foam process.

Advantages:

1. Injection quality surface
2. Uniform cell structure
3. Localized density control

Disadvantages:

1. Tool cost
2. Limited capability resource

The previously mentioned processes still left undesirable results. Structural foam parts, in most cases still needed post mold surface treatment (sanding and painting) before the products were acceptable for cosmetic critical applications. The cost to mold large parts and finish large parts with a three step paint process was beginning to get cost prohibitive.

Several improvements were made in the equipment. New material was configured. Design concepts were changed and processes were altered.

The R.I.M. process equipment continues to improve. As opposed to thermoplastic processing problems with swirl and sink, the R.I.M. process surface finish is virtually swirl free and sink free. The improvements comes with the ability to inject fillers with material. This leaves alternatives of modifying materials to increase the flexural modulus of the material as opposed to simply making the mass thicker. Common filler includes chopped glass, mica and talc. The surface still remains swirl free and without sink.

The mutli-nozzle low pressure process improved with the addition of "webbed foam." This process improves the surface quality of large parts. The process mechanics are the same as before. The difference is in area of tooling. When the melt is introduced to the cavity of the mold, air is pulsated into the cavity. This tends to pressurize the mold. The melt is forced against the mold and large random voids replace the cellular core. Early testing results indicate that thicker mass section are not required. As a matter of fact favorable results, relative to strength, have been achieved with wall sections of 3/16". The surface quality has been excellent. The only surface preparation required for a commercially acceptable part would be a single coat of paint. In many cases the molded surface quality is acceptable.

The conventional equipment low pressure molding has developed with "gas counter pressure" and "thin wall foam."

Gas counter pressure is not really a new process. The process has had a great deal more success in Europe than in the U.S.

The process involved the same mechanics as in other conventional low pressure molding. But, the mold is sealed allowing no vents and is pressurized to approximately 500 to 1000 PSI. In as much as the melt in the extruder is under heat (about 500 F) and pressure (2000 to 3000 PSI), pressurizing the mold would reduce the amount gas coming out of solution by 16% to 50%. Assuming that time required for gas coming out of solution is approximately 0.75 seconds the pressure does not have to be applied continuously during this molding cycle.

The result is that the parts should have a surface that has injection surface quality. In fact, favorable results have been witnessed even in the case of multi-cavity molds.

Thin wall structural foam has required different considerations for material as opposed to process. Typical thickness can be 4 mm (.160). The problem with dèveloping this process has been getting a U.L. approved material at this wall thickness. This has been accomplished. What one can expect from a design concept is a skin thickness .030 to .060 and the cellular core taking up the balance. A density reduction of 10% can be expected. Most likely steel molds are the best consideration. However, aluminum tools and cast kirtsite tools have had good results. If the molds are textured or grained, a one coat paint system will ample for a finish. The reduction in weight and a less labor intensive finishing system will allow a closer look at thin wall foam as opposed to injection molding.

Counter pressure, webbed foam, R.I.M. and this wall foam have been developed as the results of processes that needed additional technology. Proving that the demands of the industry are accepted by the processors, material supplies, and equipment manufacturers as challenges to be satisfactorily resolved.

BIOGRAPHY

Ronald Jay Anderson was graduated from Lawrence Institute of Technology, Southfield, Michigan in 1975 with a B.S. in Industrial Management. His previous experience includes process engineer at Beaver Precision Products; tool designer/process engineer at Modern American Corp.; tool designer at Abex Corp.; consulting product engineer, Jaw-Bar Plastics; marketing analyst, Whitaker Steel; sales engineer, Uniloy-Springfield; plant manager, I.T.T.-United Plastics; director of sales, Southeastern-Kusan, Inc. Since October 1983 Mr. Anderson has been manufacturers representative for West and Associates.

DECORATIVE FINISHING OF STRUCTURAL FOAM

Randolph K. Fick

E/M Lubricants Inc.

In many cases, structural foam requires the application of a decorative finish to the exterior of a molded part to satisfy OEM requirements. The processes for decorative finishing are many and in some cases quite complex. This paper is intended to educate and inform about most parts of the decorative finishing industry.

Before detailing the specifics of decorative finishing, the reasons for selecting structural foam as the polymeric materials of choice for many applications should be examined.

Structural foam offers many of the same cost advantages to molding large plastic parts that injection molding has offered to smaller parts. The most obvious advantage of foamed plastic is its ability to produce very large parts with a high degree of rigidity. The rigidity is the result of the greater wall thickness required with structural foam. Another significant advantage is that the molding process itself is low stress and limited sink allowing for design flexibilities unobtainable in other forms of manufacture. Structural foam parts, because of their ability to be molded into large parts, allow for part and component consolidation as well as function consolidation resulting in an overall reduction in unit cost.

The basic plastic advantages should also be noted. These advantages included weight savings, corrosion resistance, electrical, thermal acoustic insulation, flexibility of resin selection for maximum cost effectiveness vs. polymer preperties and, of course, the substantial design freedom allowed by using plastics.

There are a number of processes for producing structural foam parts, low-pressure molding, high-pressure molding, counter pressure, and co-injection to name a few. The low pressure process most often is the process that requires decorative finishing when parts are to be used in an environment where cosmetic surface appearance is important. The advantages of low pressure structural foam molding include low density (0.6–0.9 g/cc), lower mold costs, very large parts are possible by the use of multiple accumulators, normal thermal shrinkage is dramatically reduced, and it is possible to use the already installed capacity of conventional molding equipment with some modification to produce structural foam parts. Some limitations of the low pressure molding process are a lower quality surface finish caused by gas splay, long cycle times, and irregular cellular innercore structure. Decorative finishing on structural foam parts is a well defined, easy to understand process. A basic question is why do the structural foam parts need decorative finishing. When structural foam is selected by an OEM for cosmetic application the following reasons for decorative finishing are considered: (1) low quality raw part surface caused by gas splay, (2) the decorative paints are UV stable (photochemically non-reactive) and can offer a surface more durable, cleanable, and asthetically pleasing with better color control than plastics that are pre-colored, (3) a single part can be finished in multiple colors, (4) decorative paint application can be used to ensure matching of components made from different materials or by different processes and (5) some configurations have varied wall thicknesses, sinks, weld/knit lines, parting lines and other mold defects that due to a variety of factors (including part design requirements) must be removed or repaired for an acceptable final finish. In many cases the high performance paints used for decorative coatings are tougher, more durable, and more solvent resistant than the plastic to which they are being applied.

On all foam parts, the following items must be examined before the decorative finishing process can begin.

a. the generic polymer type to be finished,
b. the typical amount of swirl, splay or "elephant hide" present on the part surfaces,
c. out-gassing time requirements before finishing,
d. a mutually agreed upon accurate and effectively incoming raw parts inspection procedure, and
e. storage constraints relative to packaging type.

After the finisher makes the appropriate assessment of the part relative to the aforementioned key items, a specific process must be described. In many cases, the OEM has very complete specifications that dictate virtually all the key items relative to decorative paint application upon the molded structural foam part. The OEM typically could dictate the painting process, manufacturer of the paint, paint type, application conditions, paint cure time, solvent types, application equipment (spray guns, needles, nozzles, tips), and many other items too numerous to mention. Additionally many OEM's require paint batch approval by their internal paint laboratories before paint is released for use by the finisher.

There are three basic types of paint processes applied to structural foam parts. One is the spray application of a color only coat of paint. This is used in some cases as a mist coat or fog coat of paint to make some thin wall or high pressure foam parts more cosmetically acceptable and is frequently applied to injection molded parts for color match and UV stability. Single coat painting also is used for internal structure parts in some cases where a high degree of cosmetic finish is not required. A second type of general system is to select a paint where texture finish is required that allows for the initial application of a base color coat of paint followed by the texture paint application. These systems have to be very carefully selected for good adhesion characteristics to the specific plastic substrate upon which they are applied. A third basic paint process is the application of a primer coat (either for promoting adhesion or filling in deep swirl patterns) application of a color coat over the surface of the primer and finally the application of texture paint. This three phase painting system of primer, color and texture coat is the most common system for structural foam decorative finishing and generally is considered to be the safest, most effective process known. The key point is that before any point system process is selected, the OEM and finishing contractor must work closely together to clearly understand the finishing parameters relative to the paint system chosen. This allows for the most cost effective process to be selected.

Once the specific paint process is selected the finisher begins designing a part processing system that will produce a part of high quality for the OEM.

Presented at the Twelfth Annual Structural Foam Conference and Parts Competition, The Society of the Plastics Industry, Inc., May 7–9, 1984, San Francisco, CA.

The first stage of the painting process is substrate surface preparation. Most structural foam parts arrive in the finishing shop in a raw, as-molded state. The proper initial procedure after incoming inspection is to wash the part with a simple water/detergent solution of a mixture of 90% water and 10% methyl ethyl ketone to remove all traces of potential surface contaminants such as mold releases and some potential internal polymer sublimation products such as fire retardants that can affect the adhesion performance of the decorative paint. Flat surfaces on the part are then sanded using hand held machine sanding devices called orbitals and jitterbugs. This sanding removes the very deep swirl or elephant hide to a point where paint will cover the surface completely. Some areas are unreachable with machine sanders and manual hand sanding is performed in these areas. In some cases areas on the part must be filled with an appropriate putty for patching, filing and repair of large raw part defects such as sprue or gate marks in cosmetic areas. Sanding machines typically are produced by companies such as Thor, Sioux and Black and Decker. Sandpaper is commonly acquired from 3M, Carbarundum and Acme Abrasives. After the part surface is ready to accept paint, the next process phase is generally part masking. Many parts in the business machine area have key areas that must be free of paint and/or shielding coatings. Many techniques exist for masking. The most common (but also most labor intensive) is the application of masking tape to the surface to be free of coating. Tape can be pre-cut to fit the proper areas or simply unrolled and applied depending on the OEM requirement. Novel part masking technology that requires the use of formed silicone rubber, EPDM, and urethanes of varying durometers is gaining in popularity for larger scale production runs involving structural foam parts. A mold using hardwoods, plaster of Paris or any other suitable material is prepared, the specific maskmaking material is poured, cast, compressed and cured, the plug or mask is trimmed and installed on the part to keep key areas free of paint or other coatings. The technique allows for less labor intensive, more accurate, and more reproducible masking to be performed if required. Electroform or conforming matrix masks produced using a plating process have also been used with limited success for masking plastic parts. Costs to the OEM or customer for the preparation of the more sophisticated mask types are most commonly a part of an upfront or amortized charge as tooling similar to mold making for a structural foam part.

Parts are painted in a processing facility in one of two ways—batch or continuous conveyor processing. In a batch process parts are processed in groups through the use of a small number of paint booths, storage racks, and batch ovens. This process is suitable for small quantities of parts. A typical scenario would be the finishing of 100 parts by batch. The parts would be primed, racked for solvent flash, color coated, racked for solvent flash, texture coated, racked and batch oven cured to properly develop the paint properties and to allow for the parts to be quickly packaged. In a batch booth parts are generally placed on a hanger overhead or a swivel table device. Both systems allow for multiple spraygun passes at a variety of angles for proper paint coverage. Conveyor systems generally are of the overhead type although in some operations pallet conveyor systems commonly have multiple paint booths and paint curing ovens. The placement of the spray booths and ovens along the paint line is important as the most effective conveyor systems allow for final inspection and packaging at the end of the line. The scenario for conveyor processing would be to design suitable hangers or fixtures for proper part coating, schedule a volume of parts that would allow for timely processing, load surface pretreated parts onto the line with the line as fully loaded as possible, parts continuously move through the first booth (primer coat applied), then air time or short oven time for solvent flash, parts to booth two for color coat application, again air solvent flash or short oven time follows, then the final booth is where the texture is applied to match the OEM specifications. The parts now have high levels of proper residence time in a combination of paint curing ovens and constantly moving air dry to allow for immediate after paint operations to occur. Several points are keys to paint line operation. The following list details the key items:

(1) Line hanger design and fixture change-over efficiency.
(2) Oven efficiencies and type. Ovens must be designed to adequately process a variety of paint types.
(3) Paint booths must be of a type that meet the State and local EPA requirements and can be filtered air or water wash booths.
(4) Line length and oven design must meet basic OEM requirements and allow for part handling after part is removed from the line.
(5) Operator training programs must be on-going to allow for the application of a variety of different paints and texture types.
(6) Efficient novel masking technology must be used where required.

Some typical equipment manufacturers for batch and conveyor systems are as follows:

(1) Batch Process Ovens
 a. Dispatch
 b. Therma-Tron-X
 c. Precision Quincy
 d. Bayco
(2) Overhead Conveyors
 a. Bridgeveyor
 b. Richard-Wilcox
 c. Litton
(3) Pallet Conveyors
 a. Rapidstan
 b. Logan
(4) Paint Booth Manufacturers
 a. JBI
 b. Binks
 c. DeVilbiss

Currently most companies involved in applying cosmetic or decorative paint finishes to structural foam parts use a variety of hand held spray guns. The spray guns are high precision devices designed to operate effectively and reproducibly for many years. Companies involved in spray gun and spray equipment manufacture include Binks, DeVilbiss, Graco, Ransburg, Nordson and many others. Many different spray guns and devices are produced for paint application. These include air assisted, spray air assisted, airless, electrostatic and other types of paint application devices.

Professional finishing contractors are responding to zero defects production through substantial improvement of quality control organizations and techniques. High quality finishing organizations generally use the following eleven quality items for decorative part processing:

(1) Incoming raw part inspection is done using mutually agreed upon AQL levels for molded part quality.
(2) The finisher should maintain an acceptable raw part and an acceptable finished part library to use as a training aid and quality guideline or production aid for inspection and operations personnel.
(3) The finishers at times develop a quality/inspection system jointly with the customer whether OEM or molder.
(4) OEM approved and updated paint color and texture standards are maintained by the quality organization and supplied to the trained inspectors for comparison in a 100% final part inspection plan.

(5) Random adhesion testing is done very selectively as the proper procedure is a destructive test; however, this testing should be done at least once on each lot of parts early in the process.
(6) Gloss testing, if necessary, should be performed using a Gardner 60° Glossmeter. Some OEM's require this test.
(7) A part retain procedure should be used taking at random a part from the last run to have for example or later technical paint testing.
(8) OEM/Molder agreed upon outbound AQL system to guarantee acceptance by the OEM when received.
(9) A formal quality control manual and plan should be developed and followed by the finisher.
(10) A job ticket or work order that describes all operations and paint technical data should accompany the lot of parts from start to finish.
(11) A formal zero defects awareness program should be a functional part of the entire manufacturing/quality assurance process.

Packaging a well molded, high quality decoratively finished part is generally done to OEM specifications although there are times when the finisher and OEM together develop a procedure for part packaging after painting. There are many items that must be considered in the total packaging scheme; size of the pallet, number of parts per container, wrap type (polybag, microfoam, paper), carton design, carton storage and a host of others. Common sense must prevail to protect the part and its finish while designing packaging for cost effective shipments. There is no panacea system for packaging, but specific packaging criteria must be established as early as possible in the process of part design. In most areas packaging supplies are produced locally and can be purchased economically in reasonable quantities.

There are basically four types of distinctly different paint systems used to decoratively finish structural foam. These systems are two part urethanes, waterborne systems, epoxies, and polyester paints. Each system is distinctive and would require effectively separate paper on each. The two part urethane is by far the most popular and is generally thought to be the toughest, most durable, environmentally stable, solvent resistant coating that can be applied. Manufacturers of paint for structural foam include Reliance, Lilly, Sherwin Williams, Red Spot, Eastern Chemlac, Armitage and several others.

The attached Technical Data Sheets about paint systems are not intended to be all inclusive or representative of all available technology with decorative coatings for structural foam resins. This product data however is representative of many materials in common usage in many finishing facilities today.

An inexpensive alternative to decorative painting is Vapor Polishing. This is a relatively new finishing technique for low pressure structural foam. Finishing costs have been reduced by up to 50% by the use of this process. Cost for decorative painting averages between $1.25 to $2.50 per square foot and if a vapor polish finish is acceptable to the OEM, savings are obvious. This process offers a real alternative to painting of low visibility parts such as bases, lower housings and other visible surfaces where a high gloss surface finish is desirable. The vapor polishing procedure involves immersing a structural foam part in solvent vapors for 5 to 10 seconds. These vapors dissolve and reflow the exposed surface resulting in a gloss finish replacing the normal dull swirled surface. Methylene Chloride is typically used for vapor polishing modified polyphenylene oxide (Noryl), polyphenylene ether (Prevex), polycarbonate (Merlon, Lexan) and polystyrene (Fyrid, Styron). Usually a part that has molded-in texture is used for this process, but the texture size must be reasonably large as fine texture is not compatible with this process due to surface polymer flow being substantial.

Structural foam resins have been examined for physical properties after exposure to the methylene chloride vapor polishing process. Impact strength, flexural modulus, tensile strength, taber abrasion and elongation all have been examined and the resins have been found to retain properties within acceptable limits. The solvents used for vapor polishing must be carefully selected. The wrong solvent can cause destruction of the polymer. The correct solvent can aid in the production of a cosmetically pleasing finished part.

In an attempt to consolidate as many operations as possible without having to involve a host of subcontractors, professional finishing companies now offer a lot of services to the OEM and/or molder. These services can include plastic part machining operations, inserting, silkscreening, mechanical and electronic assembly, metal finishing, and finally a wide variety of EMI/RFI shielding techniques to satisfy OEM and FCC/VDE/CSA requirements. The desire of the finisher is to receive a raw/well molded plastic part and through the use of proper techniques in a total finishing process, supply the OEM with a part completely ready for final assembly.

This paper has been offered only to inform about many of the basic and fundamental products, processes, and equipment used to turn a well-molded structural foam part into a strong, cost efficient, aesthetically pleasing, long lasting package that will compliment the use and appeal of the functioning OEM device.

It is important to note that the plastics finishing industry is rapidly maturing. There is a definitive move away from small localized finishing operations to larger scale national organizations that can offer sincere professional technical support and problem solving abilities. Quality systems must be properly installed, paints and processes must be used in a specific, technically correct manner, OEM specifications must be followed and all operations personnel adequately trained to provide quality finishing.

Finally, before the decision is made to paint or not to paint, the following items should be carefully examined.

(1) Sunlight or fluorescent light can fade or darken unpainted plastic colors and, in some cases, impair physical properties.
(2) Matching an in-mold texture with a painted texture is virtually impossible. A painted texture usually has a warmer, more sturdy look and is often used to ensure matching of components made from different materials or by different processes.
(3) Many paint formulations can offer environmental resistance unobtainable in the conventional resin systems.
(4) Knit lines or flow lines in some parts may be impossible to eliminate. These surface defects can be adequately lowered with textured paint application.
(5) Part design limitations, such as those applying to draft angles may not permit in-mold texturing and thus require the application of textured paint.

Painting has its place in this industry.

BIBLIOGRAPHY

1. *Machine Design*, "Better Surface Finishes for Structural Foam Plastics." July 7, 1983; Donald R. Dreger, Staff Editor.

2. "Vapor Polishing of Structural Foam Parts." Stewart R. Levy, Technical Marketing Specialist, Structural Foam Resins, specialty Plastics Division-Plastics Group, General Electric Company.

3. "Selecting Materials for Optimum Wall Structural Foam." Nelissa Farah, General Electric Company.

FORM 40 2M

LILLY INDUSTRIAL COATINGS, INC.

686 SOUTH CALIFORNIA STREET • INDIANAPOLIS, INDIANA 46225

TECHNICAL DATA SHEET

CUSTOMER: COMPUTER MANUFACTURERS DATE: February 16, 1981

MATERIAL NUMBER & NAME: White Low Cure Waterbase Enamel

F. O. NO. ____ PRODUCTION NO. ____ SALESMAN: ____

VISCOSITY: ____ SECONDS ____ CUP @ ____ °F.

OR: 95 - 100 KU @ 80 °F.

SPECIFIC GRAVITY: 1.24 WT/GAL: 10.33

NON-VOLATILE: 50 ± 2 % (WT) 36 ± 2 % (VOL)

GLOSS: ____ TYPE METER: ____

TYPE OF VEHICLE: Acrylic

SUGGESTED USE: Decorative Coat - Business Machines

SURFACE: Plastics or steel

PREPARATION: Steel: Iron Phosphate

METHOD OF APPLICATION: Spray (see application instructions)

REDUCTION (SPECIFY REDUCER): 10-1 with tap water, basecoat*

REDUCED VISC: Basecoat 30 - 35 SECS. Zahn 3 CUPS @ 80 °F.

CATALYST REQUIREMENT: ____

BAKING SCHEDULE: 30 min. @ 140°F

AIR DRY SCHEDULE: Overnight (18-24 hours)

QUALITY OF: ____

GLOSS OF: ____

COLOR OF: ____

ADDITIONAL INFORMATION: *Full body, texture.

DO NOT FREEZE!!!!!!!