Structural Foam Molding Guide
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DEFINITION OF STRUCTURAL FOAM

Structural foam molded plastic parts, by definition, have a cellular foamed core surrounded by integral skins forming a total integral structure. Structural foam molded parts have a high strength-to-weight ratio and have 3 to 4 times greater rigidity than solid parts of the same material of equal weight.

The structural foam molding process is similar to conventional injection molding with the exception that a foaming agent is mixed with the polymer melt and injected into the mold in volume less than is required to mold a solid part. Both injection pressure and the expanding gas/polymer mixture fill the mold. The melt in contact with the cool surface of the mold forms an almost solid skin and in the inner core the foaming gas expands to form a cellular structure.

This process has greatly extended the range of product types and sizes that can be considered for molding. Parts weighing up to 150 lbs. are being molded of structural foam.

Almost all thermoplastics can be used for structural foam molding. Their molded parts have the same basic properties as the base resin. Actual physical properties are determined by the density reduction attained, skin thickness, part shape and general design. High density polyethylene, impact polystyrene, polypropylene and engineering resins are among the major thermoplastic materials used for structural foam products. Proper selection of these materials according to their inherent properties, with selective use of additives such as glass fibers, colorants and ultraviolet inhibitors, can meet a wide range of application requirements. These include the ability to withstand rough handling, high temperatures and long term weather exposure.

Structural foam has replaced wood, concrete, solid plastics and metals in a variety of applications. Some benefits realized are lower weight; lower raw material or manufacturing costs; greater part stiffness and stability; elimination of corrosion; greater design flexibility; improved chemical resistance, mechanical properties and cleanability. Its sound-deadening characteristics, low-stress concentration, minimal sink marks and electrical and thermal insulating properties are also advantageous.

Plastic materials in the form of structural foam can truly be called a designer's engineering plastic, regardless of the basic material used. Careful design allows combining many parts and functions into one part, to gain the greatest cost advantage of structural foam. Parts can be painted or wood-grain finished, providing a variety of attractive surface finishes.
STRUCTURAL FOAM PROCESSES

Types of Processes
Presently, 80 percent of all structural foam is molded by low-pressure processes, of which there are two types:

1. Medium velocity injection molding using direct gas and multiple nozzle system – medium fill velocities and 3,000 to 6,000 PSI injection pressure.

2. High velocity injection molding using chemical blowing agents, single nozzles and 5,000 to 14,500 PSI injection pressure.

NOTE: Cavity pressure in both medium and high velocity methods is low, ranging from 150 to 500 PSI.

Other methods which can be considered for special applications are:

1. Urethane foam molding - R.I.M. - Limited to one material.

2. Co-injection - Using two or more melt injectors per machine.

3. High-pressure expansion mold process.

Machine Choices
Several types of machines are available for the low-pressure process:

1. Multiple nozzle, low-pressure injection molding machine, both horizontal and vertical clamp.

2. Single nozzle, low-pressure injection molding machine.

3. High-pressure, single nozzle injection machine using an expandable mold, opened slightly to allow foaming.

4. Converted, standard injection molding machine using a shut-off nozzle, accumulator and CBA (Chemical Blowing Agent).

The bulk of low-pressure work is done using the multiple nozzle machines for maximum part size, and optimum placement of nozzles for uniform fill rates and density distribution.

A wide variety of materials and multiple molds can be run in these low-pressure structural foam machines for widely varied products and designs. Equipment selection will be influenced by the following:

1. Part size and volume required

2. Material (i.e., resin) to be molded

3. Surface finish desired

4. Cost of equipment

5. Suitability for a wide range and variety of parts

6. Your company’s current and long range requirements

Other factors to consider in selecting machinery are:

Machine Specifications
A. Platen size and clamp force
B. Field performance and experience
C. Shot size
D. Plasticating capacity
E. Nozzle types and locations
F. Daylight, clamp stroke and controls offered
G. Machine control features
H. Manufacturers’ ability to service and support equipment
Vendors' Experience
The service support and development assistance offered by the machine manufacturer, both before and after the production phase, will help you properly design and mold large parts. Many parts, large both in weight and physical size, require a large machine platen. A large platen not only permits the molding of large-sized parts but also allows the option of mounting several molds to produce multiple products. Examples would be as follows: (A) four molds installed in a 400-ton press to produce eight parts for a computer housing; (B) four molds to produce ten parts for a door jamb mold.

Platen size selection is determined in conjunction with clamp tonnage required. The projected area of the parts to be produced will determine the clamp tonnage required.

Sizing the Clamp
Several rules-of-thumb are applied for sizing clamping force:

1. Standard injection molding – 2,000-3,000 lbs./sq. inch of projected area.
2. High pressure S.F. molding – 2,000 lbs./sq. inch of projected area.
3. Low-pressure S.F. molding – 150-500 lbs./sq. inch of projected area

An example is a one-piece recreational vehicle top that has an area of approx. 60” x 72” and is molded in polycarbonate in a low-pressure, multiple nozzle machine.

60” x 72” - 4320 sq. in. x 250 PSI = 540 tons required

Part configuration, wall section, polymer viscosity and flow characteristics and nozzle placement will influence the clamping force required. In the case of the vehicle top, because the part was .375” thick, had ribbing that acted as a runner system and the mold had 16 nozzles, the molder could use the lower end of the 150-500 PSI range.

Parts such as shutters or bi-fold doors, with nominal wall cross-section of .200”, no ribs and perhaps edge-gated, would require the use of the higher end of the 150-500 PSI range to estimate clamp tonnage required. Parts with wall thickness of .125” can be molded; however, they cannot be described as structural-foam as little foaming will occur. Usually, single nozzle machines using 12,000-14,000 PSI injection pressure will require a higher range of 500-600 PSI for projected area calculation in figuring clamping force required. Long melt flow paths over 12” usually require higher force and fast fill rates to fill before melt freeze-off, thus higher pressures are required.

Sizing The Shot
Shot size requirements are dictated by the weights of the part or parts to be molded. Structural foam parts produced on converted injection machines are usually limited in size because of their typical small shot capacity and lack of hydraulic flow capacity required for high fill rates. Most of the injection molding machines in the field today are limited in shot size to 5-8 lbs. Unless special manifolding is supplied, only one mold at a time can be used. The intermediate range in shot size (10-20 lbs.) can be provided by single nozzle machines or the multiple nozzle low pressure machines. The large shot size parts (20-150 lbs.) are usually produced on low-pressure, multiple nozzle machines.

It should be noted that machine specifications usually list shot capacity in lbs. of styrene. A 1,500 cu. in. melt accumulator will shoot approximately 50 lbs. of styrene. If polyolefins are to be used, the shot size from this 1,500 cu. in. melt accumulator drops to 41 lbs., due to differences in material specific gravity and
thermal expansion at molding temperature. Plasticating requirements are based on the rate of production required. Molding cycles are determined by the material to be molded and the part thickness. Some guidelines for determining cycles are:

- .150" - .200" 40-30 cycles/hour
- .200" - .250" 30-24 cycles/hour
- .250" - .300" 24-18 cycles/hour
- .300" - .500" 18-12 cycles/hour

These are based on well-designed and properly cooled injection molds, using the proper temperature and flows of cooling water.

**REMEMBER:** The total cycle will be determined by the thickest part section. A 1/4" thick part will cycle at 1/2" rates, if only one boss is 1/2" thick.

Styrene and polycarbonate parts can usually be molded on shorter cycles than parts using polyolefins. Examples in commercial production are: shutters and bi-fold doors (.200") in impact styrene - 30 cycles/hour; furniture frames (.250") in polypropylene - 24 cycles/hour; pallets (.375") in HDPE - 15 cycles/hour. It follows that the shot size, times the cycles per hour, will determine the plasticizing capacity required. For instance, a molder running two 35 lbs. pallets at a time for a four-minute cycle would need 2 x 35 x 15 = 1,050 lbs./hour. It should be noted that most machine specifications rate extruder capacity in lbs./hour of styrene. A design change in the extruder screw can be made if an equivalent output is required in polyethylene or polycarbonate. Consideration should also be given to match the size of the extruder to the clamp and platen sizes. Generally speaking, for low-pressure structural foam molding, they are matched as below:

<table>
<thead>
<tr>
<th>Clamp (tons)</th>
<th>Shot Size</th>
<th>Extruder</th>
<th>Plasticizing lbs./hr.</th>
</tr>
</thead>
<tbody>
<tr>
<td>150-200</td>
<td>20-40 lbs.</td>
<td>2 1/2&quot; - 3 1/2&quot;</td>
<td>300-400</td>
</tr>
<tr>
<td>300-400</td>
<td>40-65 lbs.</td>
<td>4 1/2&quot;</td>
<td>600-800</td>
</tr>
<tr>
<td>500-750</td>
<td>100-150 lbs.</td>
<td>6&quot;</td>
<td>1200-1800</td>
</tr>
<tr>
<td>1000-2500</td>
<td>150-300 lbs.</td>
<td>2&quot;-6&quot;</td>
<td>2400-3600</td>
</tr>
</tbody>
</table>
REMEMBER: Size your machine to your job; don't try and make one machine fit all of your possible combinations. Proper sizing pays off in better parts at the lowest possible cost.

**Machine Configuration**

Many early, custom-built machines used available vertical compression clamps and standard extruders. However, when standard machines were designed and built, the horizontal clamp soon became dominant, as is the case for standard injection molding machines.

<table>
<thead>
<tr>
<th>Vertical</th>
<th>Horizontal</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. *No crane required for mold setup.</td>
<td>1. Required less overhead clearance.</td>
</tr>
<tr>
<td>2. Better for insert molding.</td>
<td>2. Easy to automate.</td>
</tr>
<tr>
<td>3. Less floor space, but required a pit or high ceiling.</td>
<td>3. Better melt temp. control because of shorter melt system.</td>
</tr>
<tr>
<td>*This is a disadvantage if heavy molds must be mounted.</td>
<td>4. Lower installation costs.</td>
</tr>
<tr>
<td></td>
<td>5. Lower maint. costs.</td>
</tr>
<tr>
<td></td>
<td>6. Safer machine oper. and OSHA compliance.</td>
</tr>
</tbody>
</table>

In general, unless insert molding is required, over 90 percent of the purchasers of structural foam equipment today choose horizontal clamp machines.
Sizing the Clamp Space
Specifications for stroke and daylight should be taken into account as with standard injection molding machines. Because large, heavy parts may also require deep draw molds, be sure the part can be removed from the press.

In the example below, the 60" stroke is adequate, the daylight is inadequate because the mold shut height is greater than 30".

The amount over 30" must be deducted from the available stroke or added to the daylight required. One requirement not usually listed in machinery specifications is mold weight-carrying capacity. With the large molded parts under consideration by the automotive companies, which usually demand heavy tooling, tie bar deflection should be considered.

NOTE: Be sure of your machine specifications and requirements. Don't buy more than you need; however, get it right - major changes on your new machine are both time-consuming and expensive.

An example.......................a large tote-bin
44"W X 48"L X 29"D Mold thickness or shut height - 39"

[Closed and open position diagrams]
MACHINE OPTIONS AND CONTROLS

The following standard options are available and should be considered when you select a machine. Each option has a particular use and can often be useful in molding better parts at greater speed. A careful review of your needs and discussions with manufacturers will be well worth the time and effort.

Standard Options List
1. Extra nozzles and controls
2. Larger extruder and H.P./D.C. drive
3. Oversize melt injection cylinder
4. Hydraulic ejector plate
5. Fixed guards in ejection area
6. Catrac for hydraulic, water and electrical hoses
7. Segmented horizon melt manifold
8. Solid state timers
9. Digital set temperature monitor
10. Central temperature monitor
11. Digital melt pressure indicators
12. Trabon auto lube system
13. Larger stroke, daylight and tie bars
14. Dual melt manifolds
15. Larger zone barrel cooling
16. Hydraulic core pull system
17. Sequential injection
18. Microprocessor Control

Sequential Injection Control
Uniloy Milacron has developed a multi-nozzle sequential injection control that provides the molder with accurate and repeatable filling of each mold cavity regardless of dissimilar mold filling requirements. One of the great benefits of a multi-nozzle low pressure SF machine is the capability to fill more than one cavity or mold at a time. Grouping of molds on a single platen increases molding productivity many fold by producing multiple and dissimilar parts per cycle on the same machine.

Generally standard machine controls for multi-nozzle injection consist of one injection accumulator servicing a common manifold system with multiple nozzles. The accumulator recovers its shot charge during the cooling cycle and injects this total charge through all nozzles simultaneously. Balancing the shot size between each cavity is controlled by individual throttling valves at each nozzle and material can thus be distributed between mold cavities of different shot size requirements. It is not uncommon to run 4 or 6 molds on one multi-nozzle platen and service these molds with one injection accumulator. The shot size variation between these molds can range from 1 lb. to 20 lbs.

The sequential injection control now offers multi-mold shot to shot repeatability which was only possible on multi-accumulator machines or single mold setups. Each mold cavity is filled individually with its own set of nozzles on a sequential basis. Sequential mold cavity filling can reduce reject rates, reduce part weight, improve surface finish, increase machine molding capacity and generally improve part repeatability.

Process Control Features
1. Independent extruder and dual injection pressure control for improved machine control and part quality.

2. Electronic shot size control for improved shot-to-shot consistency.

Separate shot size control for each mold cavity reduces part reject rates caused by fluctuation in shot size when filling multi-molds simultaneously. At times, production scheduling necessitates setting up multiple molds with extremely diverse flow conditions. If these molds are filled simultaneously they may from time to time flash or come up short thus increasing the part reject rate. The sequential injection control isolates each mold cavity during injection and delivers a precise quantity of plastic to each cavity every cycle. This in turn improves shot size accuracy and reduces rejected parts caused by overfilling and underfilling.

Part weight is also reduced and optimized by sequential injection. Simultaneous injection can cause easy to fill cavities to be overpacked while the machine tries to fill out a hard to fill cavity. This is eliminated with sequential filling of each cavity because the correct shot size is delivered to each cavity, no more and no less.

Part surface conditions tend to be a function of injection rate. Each part has its own optimum injection rate which produces the best surface with L.P.S.F. With simultaneous injection of multiple parts, all parts are filled at the same rate and a trade off in surface finish acknowledged. When mold cavity is filling sequentially, each shot can have a different injection speed, thus optimizing surface quality. Note that the standard sequential injection control provides only one speed control, but independent speed control for each shot sequence can be provided as an option.

Sequential filling of each mold cavity can more than double the machine’s molding capacity. A 400 ton low pressure SF machine has molded more than 800 tons of multi-part cavity pressure. This is accomplished by filling one part at a time and providing a slight cooling dwell time between each shot. This cooling dwell time was in the range of 2-10 seconds and allows enough time for the skin of the previous part to set up and reduce cavity pressure by 80% or more. Once cavity pressure is sufficiently reduced, the next shot takes place. When two or more parts are filled in this manner clamp molding capacity is boosted over 100%.

Part repeatability is improved from cycle to cycle by sequential injections, individual control of shot size and injection rate for each mold cavity. Repeatability of part weight can considerably reduce costs over life of the part. Surface finish and part mechanical properties become more repeatable and in turn make the molded product more saleable.

The sequential injection system features a linear positioner and a completely electronic control package. The standard limit switch shot size control is replaced by a very reliable linear positioning L.V.D.T (linear voltage differential transducer). Plastic accumulation is measured by the L.V.D.T and is transmitted to a digital readout. This digital readout converts a linear voltage to the actual volume of shot size in cubic inches of displacement. The operator can continuously monitor the shot size during the accumulator filling cycle.

Systems with as many as twelve (12) independent shots have been built and larger systems are possible. An individual set point is provided to allow accurate adjustment of shot size for each shot sequence along with an adjustment for final cushion (plunger deceleration). Each shot setting is displayed on a common digital readout. All shot size adjustments are displayed in actual volumetric quantities calibrated in cubic inches. Changes in shot size can be made to less than one cubic inch (approx. 1/2 oz.). The L.V.D.T is an extremely reliable means of measuring linear position. Unlike linear potentiometers, it has no moving contact points and is not subject to deterioration caused by weak or contaminated contacts.

Only one injection accumulator is required to store the total shot size. The PLC adds up all
(12) shots and allows the accumulator to fill with only the precise amount needed for each shot. After all shots are complete the accumulator completely bottoms out at the end of the last shot in order to completely purge old material and refill with new plastic. All twelve shot size adjustments are independent of each other and readjustments as small as one cubic inch can be made to any sequence at any time.

An external time is provided between each shot in order to allow dwell time before the next shot can begin. These timers can be adjusted from 0 sec. to 15 sec. but in most cases are actually set between 2 and 6 sec. The purpose of these dwell timers is to anticipate cavity pressure decay before injecting the next charge of material. In this way, the machine can mold multi-parts whose total projected cavity pressure exceeds the machine clamp capacity by as much as 100%, i.e. Shot #1 required 100% of clamp capacity, say 400 tons, now 5 sec. after Shot #1 is completed, its cavity pressure has decayed to 100 tons, at this time we can start Shot #2 which required 300 tons, etc.

A time totalizer calibrated to one tenth of a second is provided for each shot. The standard sequential control has one injection speed setting adjustment for all four shots, but optional equipment can be installed to provide a separate injection speed adjustment for each shot sequence.

Each shot time is monitored by an independent timer and if any shot sequence takes longer than anticipated, the total injection cycle is discontinued, all nozzles close and an alarm light indicates which sequence went into a fault condition. This feature helps to prevent overshooting a cavity in the event that a previous part or sprue was not removed from the mold. This also prevents overfilling one mold in a multimold setup.

A separate hydraulic module consisting of a directional valve, manifold and nozzle actuation quick disconnects is provided for each shot sequence. As many as six nozzles per mold can be operated by each hydraulic module during each shot. The hydraulic quick disconnects are identified for each shot sequence to aid the set up personnel. A selector switch is provided to allow the machine to be switched back to standard simultaneous injection if required. During this mode of operation, all hydraulic directional valves energize together allowing all nozzles to open and close simultaneously. More than six (6) nozzle functions per hydraulic manifold are available optionally upon request.

The sequential injection control is available in 2, 3, 4, 6, or 12 shot form. Greater numbers of shot sequences are possible and can be quoted upon request.

Gas Systems for Foam
Process controls and configurations: there has been much written about the advantages and disadvantages of using chemical blowing agents (CBA's). In selecting machinery, it should be noted that most medium-high injection pressure, single nozzle S.F. Injection Molding machines use chemical blowing agents for foaming, whereas the low-pressure, multiple nozzle machines are designed to use either CBA's or nitrogen gas. For large volume production, the lower cost and ease of processing with nitrogen should be taken into account.

Nitrogen vs. Chemical Blowing Agent
Although low-pressure, multiple nozzle equipment will perform with any blowing agent, because of low cost, nitrogen is used almost exclusively. Those who favor nitrogen over CBA's derive support for their position from the following statements:
Neatness Counts
CBA's decompose. That's how they generate gas. But they also generate other things gaseous and solid byproducts which can degrade resins, corrode equipment and molds, interfere with regrind and even discomfort workers. (Some new CBA's are somewhat cleaner; they can be recognized by their higher prices). Nitrogen is 100% inert and 100% gas: no corrosion, no plate-out, no discoloration.

Freedom Of Choice
There is no universal CBA – or even a multinational one. Temperature is critical; the engineering thermoplastics, for instance, need higher operating temperatures than HDPE, so a CBA with a higher temperature of decomposition is required. There's also the matter of byproduct incompatibility again. Nitrogen works with any resin.

Gas Economy
Nitrogen adds less than .1 of a cent/lb. to the molding material cost, whereas a CBA can add as much as .5 to 3 cents/lb. If your equipment processes 1-3 million lbs. of material per year, the difference in foaming cost is a significant factor. Consider also the cost of handling. The simple system that delivers nitrogen to the extruder barrel is no more costly than that which stores, meters and mixes CBA's. And you need store only one item - nitrogen - with no shelf life problems.

Simplicity
Structural foam is a two-phase material, sensitive to many outside forces. Many times a slight change in blowing agent concentration can restore equilibrium. With nitrogen, the gas valve does it. Humid day? Turn the valve. New resin batch? Turn the valve. Want to change density? Turn the valve. No downtime, no complex calculations.

No Product Difference
Having reviewed these substantial differences, it is important to indicate what remains the same: the product. Whether the blowing agent is chemical or nitrogen, once the gas is in the melt and the melt is in the mold, the results are the same. Density, cell structure, and finish don't indicate what method provided the blowing agent (ignoring, for the moment, the possibilities of resin degradation with CBA's).

General Comments and Auxiliary Equipment
The molding of engineering resins requires that machines be equipped with instrumentation to carefully control the polymer throughout its entire flow path. Flow paths, junctions, accumulators, etc., must be designed and temperature-controlled to prevent possible degradation of heat sensitive materials. The first and second generation S.F. molding machines with rheostats for temperature controls and a single air spring tank for injection pressure are no longer considered adequate. Newer equipment is available with control and instrumentation to equal that on the most sophisticated injection molding machines.

Other General Considerations Are:
1. Does the machine meet O.S.H.A. requirements in regard to safety and noise levels?

2. Energy requirements - is the machine designed to use minimum energy?

3. Is the machine standard or a special? This is a consideration for low-cost maintenance.

4. Is the machine supplier financially stable? Will the company be in business in years to come? Live up to warranty?

5. Spare parts and service available?

6. Resale value?

Other questions often asked are "what equipment, besides a press, is needed?" and "how much does it cost to operate a structural foam molding department?".
In Addition To The S.F. Molding Machine, The Following Equipment Should Be Available:

1. Plastics molding material handling equipment. This can be a simple hopper loader supplying material to the machine from gay loards or bags to a sophisticated automated material handling system with silos, hopper car unloaders, distribution system and color and regrind blending equipment.

2. A grinder and a saw to granulate scrap molded parts.

3. Air compressor.

4. Nitrogen compressor/receiver tanks

5. Water chiller to cool the molds or mold temperature control unit.

6. Hoist to install molds.

7. Work bench and parts conveyors.

8. Material handling equipment, i.e., lift truck or plastic bulk handling systems.

9. Finishing and/or assembly equipment.
**MOLDING COSTS**

To determine the cost of operating a structural foam molding department, a pro forma operating statement may be used, as shown:

Machine hourly costs for a single 400 ton machine

Please note that in the interest of being conservative, four operators are listed although many jobs can be run with one operator, who completes finishing and assembly operations during the cooling portion of the cycle. The expenses listed for other items are composite averages obtained from several similar operations.

**REMEMBER:** Only you can determine your costs. Use this pro forma guideline and put in your own figures. There are many ways to compute hourly machine costs. This one is presented to serve as a guide only, as costs for space, utilities and labor will vary depending on location. Also remember, we are talking about molding costs, not product costs. Other factors depending on your parts and your requirements for finishing, quality control, tolerances and assembly operations will affect the final cost.

---

### TYPICAL PRO FORMA MOLDING COSTS

<table>
<thead>
<tr>
<th>Equipment List</th>
<th></th>
</tr>
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<tbody>
<tr>
<td>1 - 400 ton machine</td>
<td>$</td>
</tr>
<tr>
<td>For Installation</td>
<td></td>
</tr>
<tr>
<td>1 - Nitrogen compressor</td>
<td>$</td>
</tr>
<tr>
<td>1 - Air compressor</td>
<td>$</td>
</tr>
<tr>
<td>1 - Scrap grinder</td>
<td>$</td>
</tr>
<tr>
<td>1 - Set/hand tools</td>
<td>$</td>
</tr>
<tr>
<td>1 - Water chiller (50 ton)</td>
<td>$</td>
</tr>
<tr>
<td>1 - Set/minimum spare parts</td>
<td>$</td>
</tr>
<tr>
<td>1 - Fork lift and material handling equipment</td>
<td>$</td>
</tr>
<tr>
<td>1 - Overhead crane with hoist (20 - 30 ton)</td>
<td>$</td>
</tr>
<tr>
<td>1 - Resin material handling system</td>
<td>$</td>
</tr>
</tbody>
</table>

Total Equipment cost                                  $           
Depreciation 10 Yr. St. Line 10% Salvage Value       $           

**Available Machine Hours**

120 hrs./wk. x 50 wks. = 6,000 hrs./yr. x 85% efficiency = 5,100 hrs./yr./machine

**Manufacturing Area Required**

$ __________ sq. ft./yr.; 10,000 sq. ft.; $ __________ mo.; $ __________ yr.
Utilities
$ __________ yr.

Personnel Requirements
Based on 3 shifts, fringes, FICA, workman’s comp., computed as 25% of base salary.

<table>
<thead>
<tr>
<th></th>
<th>Salary Each</th>
<th>Salary Total</th>
<th>Salary + 25%</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 - Foreman</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4 - Machine Operators</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 - Maintenance Man</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 - Misc. Labor</td>
<td></td>
<td></td>
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Manufacturing Expenses

<table>
<thead>
<tr>
<th>Item</th>
<th>Annual</th>
</tr>
</thead>
<tbody>
<tr>
<td>Depreciation</td>
<td>$ _____</td>
</tr>
<tr>
<td>Maintenance</td>
<td>$ _____</td>
</tr>
<tr>
<td>Shop Supplies</td>
<td>$ _____</td>
</tr>
<tr>
<td>Freight/Postage</td>
<td>$ _____</td>
</tr>
<tr>
<td>Building Rental</td>
<td>$ _____</td>
</tr>
<tr>
<td>Utilities</td>
<td>$ _____</td>
</tr>
<tr>
<td>Labor &amp; Fringes</td>
<td>$ _____</td>
</tr>
<tr>
<td>Insurance</td>
<td>$ _____</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>$ _____</td>
</tr>
</tbody>
</table>

Cost Per Available Machine Hours
Total Manufacturing Expense ÷ 5100 hours = $ ____ /hr.
STRUCTURAL FOAM PART DESIGN

Some Basic Considerations Are:
1. Foamed structural plastic parts make sense for the same reasons as solid plastic parts - only on a larger scale.
2. The part size possible is only limited by your machine size and your imagination.
3. Performance properties of foamed plastics are basically the same as the base resin except the mechanical strengths. Remember gas does not have physical strength.
4. The low-pressure process can produce large parts with a cellular core, integral skins and a high degree of stiffness compared to a solid plastic part of the same weight.
5. The process provides low-stress, tough cellular parts with a minimum sink effect.
6. The designer should be familiar with basic S.F. processing terms in order to fully understand his options and limitations.
7. The typical swirl pattern on the surface will normally require painting or other finishing if appearance is important.

Approaching Basic Structural Foam Design:
1. First figure how you may combine separate parts and functions into one part. This is an important area to realize savings.
2. Don't mimic requirements of your replaced material. Proper application will allow the designer to avoid many limitations of the old concept.
3. Don't design parts in S.F. on a one-to-one replacement basis.
4. When making cost comparisons, the place to look for savings is in the production costs, not in the tooling.
5. Material selection for structural foam is almost the same as for straight solid plastic parts.
6. Remember that the design can be structural in nature without using an engineering type resin. In other words, commodity resins can be used for structural parts.
7. Almost all plastic materials, with the exception of vinyl, can be considered for your applications.
8. Use ribs to strengthen the part instead of an overall thicker part. Wall thickness and cooling cycles are linear. The thicker the part, the longer the molding cycle.
9. Use generous radii and fillets to provide section thickness transitions.
10. Use bosses adjacent to ribs for both fastening and support where possible.
11. Watch grilles or louvers in your parts; filling can be a problem. Gating in the direction of flow and connecting rib across the back will help the fill.
12. Remember that if the base resin can be solvent bonded, sonic welded, or sonic inserted, then so can the structural foamed part.
13. Core your self-tapping screw holes to provide the outer skin for more holding power.

REMEMBER: When you design your part that structural foam is sound deadening; has insulation value; won't rot, rust, or corrode. It is stable and relatively stress-free so it will stay flat if molded that way. It can be nailed, sawed, stapled, screwed, glued, and sonic welded.
Considering all its features and attributes, it is apparent that structural foam is an attractive, workable, economical process. Think — how can S.F. parts serve your needs?

### PHYSICAL PROPERTIES OF THERMOPLASTIC STRUCTURAL FOAM

**(at.250 Wall With 20% Density Reduction)**

<table>
<thead>
<tr>
<th>Property</th>
<th>Unit</th>
<th>Method of Testing</th>
<th>High Density Polyethylene</th>
<th>Polypropylene</th>
<th>High Impact Polystyrene</th>
<th>High Impact Polystyrene w/FR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Specific Gravity</td>
<td>lbs./ft³</td>
<td>ASTM-D-792</td>
<td>.60</td>
<td>.67</td>
<td>.70</td>
<td>.85</td>
</tr>
<tr>
<td>Deflection Temperature</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Under Load</td>
<td>F@66psi</td>
<td>ASTM-D-792</td>
<td>129.6</td>
<td>167.00</td>
<td>189.00</td>
<td>194.00</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coefficient of Thermal Expansion</td>
<td>in./in./F x 10⁻³</td>
<td>ASTM-D-696</td>
<td>12.0</td>
<td>5.20</td>
<td>9.00</td>
<td>4.50</td>
</tr>
<tr>
<td>Tensile Strength</td>
<td>psi</td>
<td>ASTM-D-638</td>
<td>1,310.0</td>
<td>1,900.0</td>
<td>1,800.0</td>
<td>2,300.0</td>
</tr>
<tr>
<td>Tensile Modulus</td>
<td>psi</td>
<td>ASTM-D-638</td>
<td>79,000.0</td>
<td>141,160.0</td>
<td>245,000.0</td>
<td></td>
</tr>
<tr>
<td>Flexural Modulus</td>
<td>psi</td>
<td>ASTM-D-790</td>
<td>120,000.0</td>
<td>80,000.0</td>
<td>200,321.0</td>
<td>276,000.0</td>
</tr>
<tr>
<td>Compressive Strength (10 Deformation)</td>
<td>psi</td>
<td>ASTM-D-695</td>
<td>1,840.0</td>
<td>2,800.00</td>
<td>3,447.00</td>
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</tr>
<tr>
<td>Comustibility Rating</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>UL Standard 94</td>
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</tr>
<tr>
<td></td>
<td>HB</td>
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<tr>
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<td>HB</td>
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<td></td>
</tr>
<tr>
<td></td>
<td>V-0</td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*This rating is not intended to reflect hazards presented by this or any other material under actual fire conditions.

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### PHYSICAL PROPERTIES OF THERMOPLASTIC STRUCTURAL FOAM ENGINEERED RESINS

**(at.250 Wall With 20% Density Reduction)**

<table>
<thead>
<tr>
<th>Property</th>
<th>Unit</th>
<th>ABS</th>
<th>Modified Polyphenylene</th>
<th>Polycarbonate</th>
<th>Thermoplastic Polyester</th>
</tr>
</thead>
<tbody>
<tr>
<td>Specific Gravity</td>
<td>lbs./ft³</td>
<td>.86</td>
<td>.85</td>
<td>.90</td>
<td>1.2</td>
</tr>
<tr>
<td>Deflection Temperature</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Under Load</td>
<td>F@66psi</td>
<td>187.00</td>
<td>205.00</td>
<td>280.00</td>
<td>405.0</td>
</tr>
<tr>
<td></td>
<td>F@264psi</td>
<td>172.00</td>
<td>189.00</td>
<td>280.00</td>
<td>340.0</td>
</tr>
<tr>
<td>Coefficient of Thermal Expansion</td>
<td>in./in./F x 10⁻³</td>
<td>4.90</td>
<td>3.80</td>
<td>2.00</td>
<td>4.5</td>
</tr>
<tr>
<td>Tensile Strength</td>
<td>psi</td>
<td>3,000.0</td>
<td>3,400.0</td>
<td>6,100.0</td>
<td>9,910.0</td>
</tr>
<tr>
<td>Tensile Modulus</td>
<td>psi</td>
<td>2,500,000.0</td>
<td>235,000.0</td>
<td>300,000.0</td>
<td>1,028,000.0</td>
</tr>
<tr>
<td>Flexural Modulus</td>
<td>psi</td>
<td>2,800,000.0</td>
<td>261,000.0</td>
<td>357,000.0</td>
<td>1,000,000.0</td>
</tr>
<tr>
<td>Compressive Strength (10 deformation)</td>
<td>psi</td>
<td>4,400.00</td>
<td>5,200.00</td>
<td>5,200.00</td>
<td>11,300.0</td>
</tr>
<tr>
<td>Comustibility Rating</td>
<td></td>
<td>V-0</td>
<td>V-05V</td>
<td>V-0Q5V</td>
<td>V-0</td>
</tr>
</tbody>
</table>

*This rating is not intended to reflect hazards presented by this or any other material under actual fire conditions.

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Material properties given above are typical and vary from supplier to supplier. It is recommended that an end user contact his supplier and/or molder to obtain specific properties for use in a given application.
MOLDING STRUCTURAL FOAM

Mold Setup Procedure

1. Prior to the installation of any mold, lay out the setup on a platen outline drawing. This will eliminate many installation problems, such as:
   A. Placing a mold nozzle opening in a location where no matching opening exists in the stationary platen, such as opposite the center rib on a 500-ton machine.
   B. Not having the correct number of manifold extension blocks available.
   C. Locating a mold in a position where no knockout holes exist in the moving platen, such as the area taken up by the jack ram.
   D. Covering all mold mounting keyways with a single large mold, making it necessary to clamp the mold by other means, such as through unused feed nozzle locations.
   E. Interference between molds because of conflicting clamps, water lines, core cylinders, etc.

2. When only one mold is to be installed on a machine, locate the mold in the center of the platen. If this is not possible, a standoff must be installed on the other side of the mold on the platen to keep platens parallel. The standoff must be the same length as the shut height of the mold.

3. Before lifting molds into the press, inspect the feed nozzle seats. Mold seat dimensions must match those on the nozzle for proper sealing.

4. Install molds in the machine without the nozzles attached. Before lifting molds into the press, use layout from step #1 to mark mold outline on the stationary platen.

5. Lift mold into position on the stationary platen and clamp lightly. Use vertical and horizontal locating keys on mold to locate mold relative to feed nozzles. These keys should be installed on stationary face of mold so they align with vertical and horizontal locating slots in stationary platen.

6. When installing molds beside each other (horizontally), place bolts between them before clamping the machine shut. When installing molds above one another, install the lower mold first so that the hoist chain will not become caught between halves of upper mold.

7. Adjust slow open and slow close flow controls for desired slow speed.

8. After molds are installed, manually close machine (at slow speed) to within a few inches of the mold and check alignment of knockout holes in molds and moving platen. Close platen until it touches the mold.

9. Clamp molds tightly to platens and remove chains and hoist. Remove any mold straps before opening machine. When all molds are clamped to platens, set feed position cam on power positioner.

10. Place knockout rods in proper holes in the moving platen.

11. Adjust machine ejection plate and maximum open positioner so that press opens enough to allow part removal. Excessive platen travel adds to overall cycle time.

12. Set "slow close" so that platen slows before mold halves make contact. Set "slow open" at point where platen slows before knockout rods touch ejector plate.
13. Adjust slow open and slow close flow controls for desired slow speed.

14. Connect all core pull wiring and piping, if needed.

15. Connect all cooling lines. Cooling liquid should enter at lowest point in molds and drain from the highest point, to insure that mold is completely filled with cooling fluid before it begins to drain.

16. When installing nozzles, use new "rulon" insulating nozzle tips. Use a small amount of high temperature lubricant between rulon insulator and steel nozzle tip to hold the insulator in place during nozzle installation. Use new "vented" metal o-rings between nozzle and heater blocks on manifold. Install all nozzles in proper locations.

17. Inspect nozzle seating in the mold. This is easily done by looking into the mold on the stationary platen. A correctly seated nozzle will show no gaps between the rulon insulator and mold seat. Inspect nozzle seating before each startup.

18. Install clamps that hold nozzle blocks to platen. A torque of 10 ft. lbs. per bolt should be sufficient to seal nozzle properly. Heat nozzles to operating temperature before torquing bolts down.

19. Tighten four manifold tie rod nuts in each nozzle stack to proper torque value.

20. Plug nozzles and heater blocks into proper receptacles on machine.

21. Connect hydraulic hoses to proper open and close manifold.

22. Set proper heat profile on the extruder and machine for type of material to be used.

Machine Startup Procedures

1. Set desired heat profile on temperature controllers. Some suggested settings for various polymers are listed on Table 1 that follows.

2. Turn 480 volt and 240 volt disconnect switches to "on" position.

3. Turn main power key switch to "on" position.

4. Depress melt control pushbutton, observe amperage readings on melt system zones. Low readings indicate open or shorted heaters, which should be replaced before proceeding.

5. Allow approximately one hour for melt system to reach operating temperature.

6. Turn on those nozzle controllers being used.

7. Turn on water to extruder feed throat and hydraulic system heat exchanger.
### TABLE 1 - SUGGESTED TEMPERATURES FOR VARIOUS RESINS (4-1/2" EXTRUDER)

<table>
<thead>
<tr>
<th>Material</th>
<th>Rear 1</th>
<th>Zone 2</th>
<th>Zone 3</th>
<th>Zone 4</th>
<th>Zone 5</th>
<th>Mach Melt Sys-A</th>
<th>Feed Nozzles-B</th>
</tr>
</thead>
<tbody>
<tr>
<td>High Density Polyethylene</td>
<td>370</td>
<td>440</td>
<td>460</td>
<td>500</td>
<td>500</td>
<td>500</td>
<td>500-525</td>
</tr>
<tr>
<td>(8 MI)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>High Density Polyethylene</td>
<td>370</td>
<td>440</td>
<td>450</td>
<td>450</td>
<td>450</td>
<td>450</td>
<td>450-470</td>
</tr>
<tr>
<td>(12 MI)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Polypropylene</td>
<td>380</td>
<td>430</td>
<td>460</td>
<td>470</td>
<td>470</td>
<td>470</td>
<td>470-490</td>
</tr>
<tr>
<td>Polycarbonate</td>
<td>530</td>
<td>535</td>
<td>535</td>
<td>550</td>
<td>550</td>
<td>550</td>
<td>550-570</td>
</tr>
<tr>
<td>Modified PPO</td>
<td>430</td>
<td>450</td>
<td>505</td>
<td>520</td>
<td>525</td>
<td>525</td>
<td>525</td>
</tr>
<tr>
<td>ABS</td>
<td>430</td>
<td>450</td>
<td>505</td>
<td>520</td>
<td>525</td>
<td>525</td>
<td>525</td>
</tr>
</tbody>
</table>

**Notes:**

A - Machine melt system includes: melt relief valve, fill pipe, accumulator front and rear, manifold tube, manifold and manifold extensions - normally all set the same.

B - Range of temperatures may be used to help fill sections of the mold that are hard to fill.

8. Inspect nozzle seating in the mold. This is easily done by looking into the stationary mold half. A correctly seated nozzle will show no gaps between nozzle insulator and mold seat.

9. Calibrate melt pressure indicators as outlined in electrical section.

10. Depress cycle control pushbutton.

11. Depress clamp hydraulic start and injection hydraulic start pushbuttons.

12. Check melt relief valve operation by turning selector switch to "close", and then return to "open" position.

13. Set the extruder speed at zero RPM. Check the extruder ammeter for zero reading. Depress D.C. start pushbutton.

14. Open the hopper feed gate.

15. Set extruder screw at the required speed. (Make sure the dump valve is open.) Extruder speed is determined by shot size and cycle time.
16. **WARNING** - Do not let head pressure exceed 3,500 PSI. If pressure gets too high, shut down extruder and determine cause.

17. When plastic flows freely from dump valve, open feed nozzles and close dump valve, watching extruder head pressure gauge. If pressure reaches 3,500 PSI, open dump valve and investigate cause. Safety gates must be closed for nozzles to open.

18. When plastic flows freely from all feed nozzles, close nozzles and watch extruder head pressure gauge. If pressure reaches 3,500 PSI, open dump valve and investigate cause.

19. Adjust extruder back pressure for desired head pressure. A nominal head melt pressure reading of 2,000 PSI is a good pressure setting for most polymers. However, this pressure can be increased or decreased depending on polymer and molding conditions.

**NOTE:** Lower pressures will increase extruder output.

20. After the injection plunger has started to move and the gas port pressure reading has stabilized, note this reading.

21. Open the foaming gas shut-off valve.

22. Set the foaming gas pressure a minimum of 100-200 PSI higher than the pressure noted in Step #20.

23. The gas port pressure indicator and the foaming gas pressure gauge should now read approximately the same.

24. Set injection pressure to desired injection pressure. This pressure setting is infinitely variable between 100 and 3,000 PSI, and may be different for each mold setup. Start low (approx. 1,000 PSI) and increase from shot to shot until an optimum molded part is achieved. Melt injection pressure will be 2 times hydraulic setting, i.e. 3,000 PSI on hydraulic gauge equals 6,000 PSI shooting pressure.

25. Let accumulator fill, then open nozzles just before accumulator reaches the shot size. Empty accumulator through feed nozzle then close feed nozzles again. Repeat this purging procedure (3-4 times) times until "foam" is visible in stock.

26. After last purging shot, clean plastic out of mold cavity and check rear half of mold for plastic particles.

27. Select "semi-auto" mode of operation and with the press at maximum open, depress cycle start pushbutton.

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Model SF-400 Structural Foam Machine

**HYDRAULIC PRESSURE vs. CLAMP FORCE**

![Graph](image.png)
28. When the press is closed, set high pressure clamp to necessary tonnage. This can be calculated using 300 PSI as an average cavity pressure. For example: a part with a projected surface area of 1,000 sq. in. would require:

1,000 sq. in. x 300 lb./sq. in. – 300,000 lb. of clamping force

Converting to tons:

300,000 lb. - 2,000 lb./ton = 150 tons of clamp

If this part is to be molded in a 400 ton machine, Graph 1 can be used to determine the required hydraulic pressure necessary to develop 150 tons of clamp, which is approximately 1,100 PSI. Proper setup of high pressure clamp is essential for two reasons:

A. Insufficient clamp can lead to flashed molds.

B. Excessive clamp can damage small molds or close off mold venting, leading to mold fill problems.

29. From estimates of part weight or volume, determine the proper shot size setting. This can be calculated from the specific volume of resins listed in Table 2, and the fact that 1 in. of melt accumulator stroke equals about 39 cu. inches.

30. Once the correct shot size has been calculated, set the shot size on the machine less than this value. This is particularly important when starting up multiple mold or multiple cavity molds to prevent flashing or overpacking.

31. Gradually increase shot size until one mold or cavity is full. Then begin throttling down those nozzles and increasing shot size until all molds are full.

32. After all molds or cavities are making parts which meet specifications of weight, density, surface finish, etc., fill out a machine setup sheet to aid quality control. A sample sheet follows.

<table>
<thead>
<tr>
<th>Resin</th>
<th>Specific Volume (Cu. In./lb.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>15% Glass ABS</td>
<td>27</td>
</tr>
<tr>
<td>Modified PPO</td>
<td>29</td>
</tr>
<tr>
<td>High Impact Polystyrene</td>
<td>30</td>
</tr>
<tr>
<td>Polypropylene</td>
<td>37</td>
</tr>
<tr>
<td>High Density Polyethylene</td>
<td>37</td>
</tr>
</tbody>
</table>

NOTE: Above values measured at processing temperatures and pressures.
Machine Setup Sheet

<table>
<thead>
<tr>
<th>Machine Number</th>
<th>Customer</th>
<th>Date</th>
</tr>
</thead>
</table>

Heat Profile (°F)

<table>
<thead>
<tr>
<th>Rear 1</th>
<th>Zone 5</th>
<th>Accum Front</th>
<th>Manifold Ext.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zone 2</td>
<td>Gate</td>
<td>Accum Rear</td>
<td>Nozzles</td>
</tr>
<tr>
<td>Zone 3</td>
<td>Relief Valve</td>
<td>Manifold Tube</td>
<td>Stock</td>
</tr>
<tr>
<td>Zone 4</td>
<td>Fill Pipe</td>
<td>Manifold</td>
<td>Mold Surface</td>
</tr>
</tbody>
</table>

Timers

<table>
<thead>
<tr>
<th>Shot Override ____ Sec.</th>
<th>Cool _____ Min.</th>
<th>Press Open _____ Sec.</th>
<th>Overall Cycle Time ____ Min. ____ Sec.</th>
<th>Shot Time ____ Sec.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Injection Pressure Delay ____ Sec.</td>
<td>Hour Meter Startup ____ Hrs.</td>
<td>Cycle Counter ____ Startup ____ Shutdown</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Extruder Drive

| AMPS ______ RPM ______ Material ______________________ |

Shot Size Cu. In. _______ Pounds ____________

Injection Hydraulics

<table>
<thead>
<tr>
<th>Hyd. Inj. Press Low Range ____ PSI X 2 = _____ PSI</th>
<th>PSI Melt Injection Pressure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hyd. Inj. Press High Range ____ PSI X 2 = _____ PSI</td>
<td>PSI Melt Injection Pressure</td>
</tr>
<tr>
<td>Inj. Cyl. Hyd. Back Pressure ____ PSI</td>
<td>Head Press Dynisco ____ PSI</td>
</tr>
<tr>
<td>Gas Port Press Dynisco ____ PSI</td>
<td>Foaming Gas Press ____ PSI</td>
</tr>
<tr>
<td>High Press Clamp ____ PSI</td>
<td>Traverse Press ____ PSI</td>
</tr>
</tbody>
</table>

Part Description

<table>
<thead>
<tr>
<th></th>
<th></th>
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<tbody>
<tr>
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</tr>
</tbody>
</table>

24
MOLDS FOR STRUCTURAL FOAM

Molds for structural foam molding are constructed similarly to those used for conventional injection molding. The considerations of mold material, gating, cooling, ejection and other items are comparable for both processes.

Materials
The primary consideration is what type of material should be used to construct a particular mold. The majority of S.F. molds are built from forged aluminum plate; generally the 6061-T651 grade. This type of aluminum has good machinability, dimensional accuracy, excellent cooling, weldability and ready availability. The 6061 grade is available in the heat-treated T-651 condition in thicknesses up to 6". Beyond this, the metal is only available in its as-forged state known as 6061F because the heat treat method used for aluminum penetrates to a maximum depth of 3" per side. The 6061F aluminum, however, is a heat-treatable alloy and after rough machining, the block could be sent for heat treating, provided there are facilities available. One caution - the 6061F alloy when machined and heat-treated tends to be much more expensive than the 6061-T651 plates described earlier.

Other materials used for structural foam molds are steel, cast aluminum, beryllium copper, and kirksite. Extremely high production runs, such as a million parts and up, might dictate the use of steel due to its desirable long life. The use of steel naturally creates problems in (1) handling due to increased weight; (2) machining due to toughness of the material; and (3) cooling time. Costs are normally 15 to 30 percent higher than aluminum.

Cast aluminum and kirksite are used primarily for molds with non-critical dimensions and extremely low production requirements. Problems with cast tooling are the inability to hold tight tolerances (normal tolerances for cast tooling are +.005" for the first inch and +.001 for each additional inch), porosity and uncontrollable shrinkage of the metal when cast. Also, cast metal is generally softer than the machined plates and can, therefore, be damaged more easily than heat-treated alloys. The main advantages of casting are low tooling cost and high reproducibility of pattern detail. Cast tooling was the cornerstone on which structural foam was built, but it is slowly being phased out as part size and production requirements increase.

Beryllium copper has been used to a small extent in the production of molds for the furniture industry. The reason for this is that cast BeCu has the highest degree of pattern reproducibility of any metal. The price of BeCu, however, has skyrocketed and, therefore, it is rarely used today.

Gating
The nozzle arrangement on most structural foam machines provides for a multitude of locations. Therefore, the common practice for placing nozzle seats in a tool is to gate directly on the part in an area that is not visible in the final assembly. Standard nozzle seats are 2-1/2" from platen to tip (however varying lengths are available). Depending on part geometry, nozzles up to 36" platen to tip dimension have been used.

It is beneficial to gate directly over or into a rib in the part. The method increases the flow length of the material as the rib acts as a natural runner. If it is impractical to gate directly onto the part, tab or fan gates are used. The tab gate is usually a half round approximately 1/2" deep x 1" wide with a 1/4" deep by 1" wide entry into the part. The fan gate is similar to the tab gate except that the width of the entry may vary depending on the part configuration.

This arrangement minimizes if not eliminates the need for a trimming operation to remove
the gates. A rule of thumb is to install one standard 5/8" nozzle per 2-1/2 lbs. of part weight. High flow 7/8" orifice nozzles are available for one nozzle per 5 lbs. of part weight.

Venting
Venting a mold is important; the location and quantity of vents will determine if a part fills easily and completely or not. The quicker entrapped air is evacuated the longer the possible flow length of the material and the better the part finish. Nozzle and gate locations, fill rates and melt paths will determine where and how many vents will be required.

The venting of an S.F. mold is similar to injection molding practice except that the vents are generally .003"/.005" deep for the olefins and .005"/.008" for the styrenic-based materials. Vents are generally 3/4" wide and are placed along the parting lines at proper intervals. Ejection pins act as natural vents as they generally have a .005" clearance. Where there are deep ribs which might trap air, it is desirable to place an ejector pin in that location.

Cooling
Cooling line placement is also important to the production of a quality tool. Though it is true that foamed material will only give up heat at a given rate, it is desirable not to have any hot spots which could cause the part to post-blown after removal. If the skin strength is not sufficient to withstand internal gas pressure, an expanding bubble will form on the part surface which could ruin the appearance or hamper assembly. Therefore, good cooling is a must.

Cooling lines which are drilled into machined metals are generally 9/16" in diameter, 3" apart. For best results, the lines should be looped and broken into a number of small circuits to afford the fastest cooling rate. Baffle blades and water cascades (bubblers) are used in tight places where deep cores or core pins are involved. These allow for a continuous flow of water where lines cannot be cross drilled to create a circuit.

In the case of cast tooling, 1 1/2" O.D. stainless steel tubing is used and it is generally cast in place. Chilled water is used for cooling the styrenics and olefins, and mold temperature control is used for the engineering type resins.
Ejection
Parts ejection is very similar to conventional injection molding tools. The standard types of ejection utilize pins, bars, or plates which can be activated by normal operation of the molding machine or by hydraulic cylinders, chains or pull rods; the latter two being least desirable. All ejector housings, pins and bushings are made from steel plates. For the majority of foam molds, four 1-1/4" diameter guide pins and four 1" diameter return pins are sufficient for normal ejection. It is extremely important for the moldmaker to know what type of machine the tool will be used with, as the knockout arrangement differs with each machine. In order to run the press on an automatic cycle, it is essential that ejection be sufficient to strip the part entirely from the core, letting it fall freely to the part removal area below.

Core Pulls and Slides
It is desirable to mold as many features as possible into the finished part. In some cases this may involve little more than a core pin to create a hole for some sort of attachment or assembly. However, in the case of items which are contrary to the normal parting line, a slide or some other mechanism is needed. It may be simply a core pin attached to a cylinder to create a hole in a wall, or it could require moving an entire wall of the mold. Whatever the case, care should be taken to provide for safe trouble-free operation of every core pull. These slides can be activated by hydraulic or air cylinders, cams, angle pins, or springs.

In all cases, each moving piece which is installed in a tool should have some means of positive lock or limit switch to position the slide in its proper molding condition and to prevent damage to the mold or operator. The sliding pieces and the surfaces they ride should be constructed of dissimilar metals - usually steel and bronze. There should be some means for lubrication of these slides.

Although slides or core pulls are essential and justifiable in some cases, it is better to avoid them because the cost of the mold is directly increased by their quantity and complexity. Also, the more slides and the more complex they are, the greater the possibility of mechanical failure and damage. Electrical safety interlocks are a must for all slide action.

It is essential to find a tooling source capable of producing your molds with the quality you desire. Price does not equate directly with quality; a number of items dictate price. These items are the work load of the tool shop, the type of machine tools in the shop and the expertise of its moldmakers.

Test molding by the vendor prior to shipment of your mold is well worth considering. The savings in time and money will make it worthwhile.

Flow Length
One of the great advantages of multi-nozzle structural foam is the ability to locate nozzles in hard to fill areas. Don’t pack materials to reach these areas, install a nozzle for low pressure structural foam molding. The L/T (length/thickness) flow ration should not exceed 50/1, i.e., .250 thick section has a maximum flow length of 12". The 50/1 flow ratio will yield approximately 300 PSI cavity pressure. A ratio of 100/1 is possible but cavity pressure may exceed 600 PSI, and cold flow and weak weld lines may result.
MOLDING AND TROUBLE SHOOTING GUIDE

Start Up Procedures
NOTE: All electrical and hydraulic controls must be set at their anticipated operating levels. These may be readjusted after the first few cycles obtain optimum results.

The extruder screw must not be operated until all heat zones are up to set temperatures.

1. Turn all control cabinet main power handles to the -on- position. Make sure that all extruder and melt system temperature controllers have breakers -on-. All feed nozzle controllers being used should have switches -on-.

2. Start machine exhaust fan, if provided.

3. Turn the main power key switch to the -on- position, depress the master cycle control (power -on-) pushbutton and then the melt control pushbutton, in that order. The master cycle control pushbutton arms all control circuits and the melt control pushbutton turns on all heat. Check all ammeters for low or high readings which will indicate open or shorted heater bands.

NOTE: In the event of power failure or if the machine stops, these pushbuttons must again be depressed before the melt system is activated.

4. Allow approximately one hour for the system to come up to temperature and melt through the plastic inside pump valve.

5. After approximately one hour, turn -on- water to extruder heat exchanger and feed throat control cabinet heat exchanger.

6. Inspect nozzle seating in the mold. This is easily done by looking into the mold on the stationary platen. A correctly seated nozzle will show no gaps between the rolon insulator and mold seat. Inspect nozzle seating before each startup.

7. Calibrate dynisco pressure indicators as outlined in electrical section of manual.

8. Check dump valve and melt relief valve operation by turning selector to -close- and then return the selector switch to the -open- position.

9. Start the hydraulic motor by depressing hydraulic start pushbutton.

10. Allow 15-20 sec. for hydraulic pressure to build up, then check the operation of the feed nozzles by switching selector from -close- to -open- return switch to the -close- position.

11. Set the extruder speed at zero RPM. Check the extruder tachometer and ammeter for zero readings. Depress D.C. start pushbutton.

12. Open the hopper feed gate.

13. Set extruder screw at the required speed. (Make sure the dump valve is open.) Extruder speed is determined by shot size and cycle time.

14. WARNING: Do not let pressure gauge at extruder head go over 3,500 PSI. If pressure gets too high, shut down the extruder and determine cause.
15. When plastic flows freely from dump valve, open feed nozzles and close dump valve. Watch extruder head pressure gauge. If pressure reaches 3,500 PSI open dump valve and investigate cause. Safety gates must be closed for nozzles to open.

16. When plastic flows freely from all feed nozzles, close nozzles and watch extruder head pressure gauge. If pressure reaches 3,500 PSI open dump valve and investigate cause.

17. When the injection plunger starts to move, read the gas port pressure indicator.

18. Open the foaming gas shutoff valve on the gas panel. Set the foaming gas pressure 100-200 PSI higher than gas port pressure read in Step 17 above. Foaming gas pressure is increased by turning the foaming gas regulator clockwise.

19. With the needle valve open, the foaming gas pressure and the gas port pressure should be approximately the same (+ 100 PSI).

20. Let accumulator fill, then open feed nozzles just before accumulator cam reaches the shot size. Empty accumulator through feed nozzle, then close feed nozzles again. Repeat this purging procedure (3-4 times) until “foam” is visible in stock.

21. After last purging shot, clean plastic out of mold cavity, check rear half of mold for plastic particles.

**Shutdown Procedures**

1. Close foaming gas shutoff valve on gas panel.

2. Purge machine as follows:
   A. Switch to manual operation.
   B. Open press and cover mold.
   C. Fill melt accumulator to 4" mark.
   D. Open feed nozzles, let accumulator empty and close nozzles. Repeat until clean purging material flows from nozzles.
   E. Reduce screw speed to approximately 20 RPM.
   F. Close nozzles and open melt manifold bleed valves.
   G. Open nozzles when clean purging material flows from bleeders.

3. Turn hydraulic motor off.

4. Close the hopper feed gate.

5. Open dump valve.

6. Turn extruder speed to zero RPM when the flow of material from the dump valve slows. Turn D.C. drive off.

7. Turn 240 volt main switch off.

8. Turn main power key off.

9. Turn 480 volt main switch off.
TROUBLE-SHOOTING GUIDE

Condition: Molds Are Flashing

Causes:  
1. Projected surface area of parts too great  
2. Low clamp pressure  
3. Molds too cold or too hot  
4. Melt temperature too high  
5. Foaming gas pressure too high  
6. Overshot size  
7. Injection pressure too high or too low  
8. Molds not same shut height  
9. Insufficient mold venting  
10. Nozzle malfunction - not opening or restricted  
11. Nozzle, feeder extension or manifold heat control problem  
12. Improper nozzle throttling adjustment

Condition: Molds Short Parts

Causes:  
1. Injection pressure too low  
2. Molds too cold  
3. Insufficient shot size  
4. Improper nozzle throttling adjustment  
5. Foaming gas pressure too low  
6. Melt temperature too low  
7. Insufficient mold venting  
8. Shot aborted due to shot override or nozzle opening malfunction  
9. Loss of injection oil supply

Condition: Post-Expansion

Causes:  
1. Flow path in mold too long  
2. Molds too hot  
3. Cooling time too short  
4. Oversize shot  
5. Foaming gas pressure too high  
6. Water cooling failure  
7. Hot spot in mold  
8. Large internal voids  
9. Thick section in part  
10. Melt system not purged
Condition: Sink Marks

Causes:
1. Injection speed too slow
2. Undersize shot
3. Foaming gas pressure too low
4. Flow path in mold too long

Condition: Parts Stick In Cavity

Causes:
1. Mold is too hot
2. Material leaking back around nozzle tip
3. Shot size too small or too large
4. Undercuts in cavity or backdraft
5. Improper part design

Condition: Parts Stick In Core

Causes:
1. Cooling time too long
2. Mold is too cold
3. Insufficient knockout pins

Condition: Nozzles Do Not Open Or Close

Causes:
1. Hydraulic motor not on
2. Nozzle hydraulic pressure too low
3. Nozzle hydraulic accumulator failure
4. Nozzle temperature too low
5. Nozzle thermocouple failure
6. Safety gate interlock open
7. Hydraulic hose disconnected
8. Quick disconnect failure
9. Nozzle block or feeder extension block temperature too low
10. Nozzle rod/rod bushing tolerances too tight
11. Nozzle improperly assembled
### Condition: Part Weight Varies

**Causes:**

1. Nozzle not opening or restricted
2. Temperature control problem in nozzles, feeder extensions or melt manifold
3. Inconsistent mix of regrind or additives with virgin material
4. Injection pressure changing from shot to shot
5. Loss of injection oil supply
6. Foaming gas pressure fluctuating

### Condition: Poor Surface Finish

**Causes:**

1. Foaming gas pressure too high
2. Insufficient mold venting
3. Mold temperature too low
4. Mold surface temperature too low
5. Injection pressure too high or too low
6. Water leaking into cavity, mold sweating
7. Material not properly dried
8. Flow path in mold too long
9. Incompatible resin additives
10. Resin or additives attacking mold surface
11. Contaminated material or foaming gas

### Condition: Large Voids

**Causes:**

1. Foaming gas pressure too high
2. Flow path in mold too long
3. Part thickness changes
4. Injection pressure too high or too low
5. Stock temperature too high or too low
6. Contaminated foaming gas
7. Material melt strength too low
8. Shot size too small
9. Material not dried properly
10. Improper nozzle adjustment
11. Insufficient mold venting
Condition: Mechanical Failure After Molding

Causes:
1. Foaming gas pressure too high
2. Injection speed too fast - thin skins
3. Stock temperature too high
4. Inconsistent mix of regrind or additives with virgin resin
5. Part density too low
6. Improper part design
7. Material not dried properly

Condition: Part Warps

Causes:
1. Mold too hot
2. Cooling time too short
3. Part twists on ejection
4. Part thickness changes

Condition: Weak Weld Lines

Causes:
1. Melt temperature too low
2. Insufficient mold venting
3. Foaming gas pressure too low
4. Flow path in mold too long
5. Injection speed too low

Condition: No Or Little Foam In Part

Causes:
1. Foaming gas pressure too low or fluctuating
2. Material melt strength too low
3. Shot size too large
4. Flow path in mold too long
5. Material not dried properly
6. Injection speed too low
7. Mold not properly vented
8. Extruder gas port pressure fluctuating
### Condition: Contaminated Material On Surface

**Causes:**

1. Stock temperature too high  
2. Contaminated foaming gas or material  
3. Hot spots in machine  
4. Melt manifold bleeders not operating  
5. Excessive use of anti-seizing compound

### Condition: Delamination Of Skins

**Causes:**

1. Contaminated foaming gas or material  
2. Incompatible resin additives  
3. Mold too cold  
4. Injection speed too fast  
5. Excessive use of anti-seizing compound  
6. Dissimilar materials in system  
7. System not fully purged

### Condition: Slow Injection

**Causes:**

1. Stock temperature too low  
2. Foaming gas pressure too low  
3. Cold spots in machine  
4. Molds too cold  
5. Shot size too large  
6. Loss of injection oil supply  
7. Improper nitrogen/oil pressure settings  
8. Nozzle malfunction or restriction
UNILOY-SPRINGFIELD™
STRUCTURAL FOAM MOLDING SYSTEMS

BENEFITS

- We can provide turn key structural foam molding systems including part design, mold and machine.

- Examples of some turn key system:
  - Large shipping containers up to 60" X 40" X 30" weighing 120 lbs.
  - Wire and cable spools
  - Storm doors
  - House shutters molded 6 per cycle
  - Toys
  - Modular institutional and office cabinets and furniture
  - Pallets

- Complete range of machine sizes:
  - 150 ton clamp – 57" X 57" platens
  - 400 ton clamp – 86" X 89" platens
  - 750 ton clamp – 80" X 130" platens
  - 750 ton wp clamp – 86" X 167" platens
  - 1000 ton wp clamp – 104" X 167" platens
  - Shot sizes range from 50 lbs.
    - up to 300 lbs.
  - Extruder rates up to 5000 lbs./hr.

- Machines feature integral design including clamp, extruder, injection unit and control cabinet. Preassembled, piped, wired and tested.

- Multiple nozzles offer the following advantages:
  - Larger, more complex parts
  - Accommodate multiple molds
  - Reduced flow paths to improve quality and weight reduction
  - More uniform cell structure
  - Stronger knit lines
  - Reduces cavity pressure
  - Improves surface finish
  - Versatile nozzle pattern on 6" X 6" centers

- Modular melt manifold system
  - Quick set up and tear down
  - Permits service for each nozzle
  - Smooth flow for Engineering resins
  - Fast color and material changes
  - Reduced pressure drop for faster injection speeds

- Heavy duty long stroke clamping unit

- Xaloy lined injection cylinder and extruder barrel for long life

- 2 Stage 30/1 extruder designed for N2 and CBA's

- Intermittent extruder operation reduces material consumption and cycle time

- 2 Stage injection control with independent extruder back pressure

- Optional hydraulic knock out

- Sequential injection
  - Improves multi-mold shot-to-shot repeatability
  - Each mold cavity is filled individually and sequentially
  - Reduces reject rates
  - Optimizes part weight
  - Increases machine molding capacity