

# **SYMPOSIUM**

***for***

# **THERMOSETS**



**REGIONAL TECHNICAL CONFERENCE**

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***The Society of Plastics Engineers Inc.***

In cooperation with the Thermoset Division and coordinated  
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***February 20, 21, 22, 1978***

***Sheraton - Oak Brook Motor Hotel  
Oak Brook, Illinois***

"SYMPOSIUM FOR THERMOSETS"

REGIONAL TECHNICAL CONFERENCE OF THE SOCIETY OF PLASTIC ENGINEERS, INC.

Sponsored By The

CHICAGO SECTION

Sheraton-OakBrook Motor Hotel

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**POLYESTER: A THERMOSET/THERMOPLASTIC HYBRID**

**TERRY SHREVE**

**KOPPERS COMPANY  
PITTSBURG, PENN.**

ABSTRACT

THE NEW BREED: THERMOSET OR THERMOPLASTIC?

Within the past decade there has been a great influx of new thermoplastic systems and resins, many of which have attempted to cross over into traditional thermoset markets. Polybutylene terephthate (PBT) even takes advantage of its generic nomenclature in its tradename, "thermoplastic polyester," which connotes a strong tie to thermoset polyesters. The attempt therefore is to liken themselves to thermosets while taking advantage of typical thermoplastic attributes such as ease of handling, and fast, consistent cycling.

On the other side of the coin the thermosets too have made progress and have various new offerings to the molder. One of these systems is Solid Polyester Molding Compound, (SPMC). In a sense, SPMC does the reverse of what PBT does. SPMC combines the inherent thermoset heat, electrical and chemical resistance with the ease of handling, fast cycling and pigmentation that are more "characteristic" of the thermoplastics, all at cost that is significantly less than the thermoplastics.

The choice is obvious. The improved thermoset system gives you the best of both worlds.

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The evolution of plastics into virtually thousands of new, unconventional applications continues and the spectrum of performance requirements has stretched beyond what the traditional thermoplastic and thermoset systems can obtain. Consequently, there has evolved a line of engineering plastics which are oriented towards specific and difficult application requirements. Their growth, specifically in the injection molding market, has been impressive. Their sales represent a significant portion of today's annual dollar volume of plastics consumption. As performance requirements become more strict, this phenomenal growth will continue.

There has been one continuing problem with these new systems — they tend to fall into specialty categories. One resin system seldom covers a wide application area because in designing these systems, compromises naturally occur. If the system is manipulated to yield a certain desirable property (flame retardancy, for example), then another property (mechanical strength, perhaps) might be sacrificed.

From the processor's as well as the end user's point of view, it would be desirable to have one system that could solve a wide variety of problems. Thus, there is a demand for a general purpose engineering plastic. Most likely, this system would have superior heat and electrical resistance, similar to the thermosets, combined with the processibility, specific gravity, low water absorption, and mechanical strengths of the thermoplastics — all at a reasonable price.

Some of the more recently developed engineering thermoplastic systems have a desirable combination of properties. Thermoplastic polyester (PBT), for instance, offers an excellent heat-electrical resistance package. It is

available in a multi-colored and convenient pellet form which yields relatively fast and uniform cycles. PBT could be considered "the most thermoset of the thermoplastics" and approaches the model general purpose engineering plastic.

### **Solid Polyester Molding Compound**

In the thermosets, on the other hand, there has been a recent development of an unsaturated polyester system which also approaches the above criteria. This product is Solid Polyester Molding Compound (SPMC).<sup>\*</sup> Being a thermoset, it retains its inherent heat and electrical resistance while borrowing some of the most outstanding characteristics of the thermoplastics. Some of these characteristics include excellent overall moldability, high impact strengths, and the ability to be pigmented. SPMC represents a fresh new look in thermosets and could be considered "the most thermoplastic of the thermosets." This thermoset-thermoplastic hybrid nature of SPMC makes it an excellent candidate for a general purpose engineering plastic.

The various engineering plastics, in many cases, compete for the same markets. As a result, the relative merits and shortcomings of each have to be weighed carefully before a material can be chosen for a specific application. Table 1 analyzes some of these engineering plastic systems in terms of their most important properties and their relationship to each other.

SPMC's difference is its physical form. It is a convenient and free-flowing dry pellet containing up to 20% glass.

---

<sup>\*</sup>SPMC (Solid Polyester Molding Compound) is the trademark of Koppers Co., Inc., Pittsburgh, Penn.

**Table 1 — Price/Performance Characteristics  
of SPMC Compared to Other Selected Materials**

Materials*	Pre-Molding Properties				Post-Molding Properties					
	Cost	Material Handling	General Moldability	Shrinkage Control	Mechanical Strength	Electrical Resistance	Heat Resistance	H <sub>2</sub> O Absorption	Specific Gravity	Pigmentation
Phenolic, heat resistant	++	+	-	-	-	+	++	+	0	=
Polyester, SPMC	+	+	0	+	+	++	++	+	-	+
Polyester, granular alkyd	+	+	-	-	=	++	+	+	-	+
Polyester, BMC	+	=	=	++	++	++	++	=	-	-
Melamine PPO,	+	+	-	=	-	++	+	-	0	=
modified-glass filled	-	+	0	0	+	-	-	++	++	+
Nylon, 6-6 type glass filled	-	+	+	0	+	-	0	-	+	+
Polycarbonate, glass filled	=	+	0	0	++	-	-	++	+	++
PBT, glass filled	-	+	+	0	+	+	0	++	0	+

++ excellent + very good 0 average - below average = poor

\*All systems are UL 94 V-0 rated grades.

Other better known polyester systems for the automatic molding markets (alkyds and BMC) have limitations.

Alkyds are characterized by their high mold shrinkage. They usually do not contain glass fiber and, thus, they are very low impact systems. Even in cases where glass is introduced into the alkyd, its processing characteristics limit glass loading capacity and tend to degrade glass fiber bundles. As a result, the notched Izod impact strength does not exceed 1 ft-lb/in. in these glass filled systems.

On the other hand, BMC systems boast very high impact strengths, but are difficult to handle and mold. The utilization of "stuffer" systems has been, at best, partially successful. These systems also significantly limit the molder's machine versatility and

flexibility, have shelf life limitations, and cause excessive flashing because the material is relatively ductile.

The extrusion processing technique used to produce SPMC, however, permits the addition and wetting of glass fibers with minimal fiber bundle degradation. The resulting pellets can be easily fed to an in-line screw injection molding machine to mold parts with impact strengths approaching 2 ft-lb/in.

SPMC was developed for use in automatic molding systems such as injection, transfer, and compression molding. It contains no asbestos and is currently available in various colors, flow grades, and shrinkage factors.

### **Premolding, Molding, and Finishing**

*Convenient handling.* Free-flowing and uniform in size, SPMC can be con-

veyed with conventional vacuum equipment into the hopper and then into most molding machines without mechanical feed assists.

*No special storage.* SPMC compound can be stored for a minimum of six months in enclosed areas at temperatures below 80°F.

*Faster cycle times.* Because SPMC cures two to three times faster than other thermosets, cycle times can be reduced up to 50% over most phenolics.

*Reduced machine maintenance.* Low injection pressure reduces wear on screws and runners.

*Excellent stability.* All grades of SPMC have excellent stability in the barrel and in cold manifold or runnerless molds without sacrificing cycle times.

*No objectionable by-products.* This 100% reactive system produces no by-products (such as water or ammonia), minimizes out-gassing, eliminates the need for breathing or oversize vents, and is non-corrosive to copper

alloys.

*Reduces scrap losses in secondary operations.* High impact strength, three to five times phenolic, minimizes damaged parts in further processing steps.

*Resists dimensional changes.* SPMC is a true thermoset, and remains dimensionally stable under conditions of heat, moisture, or loading. It holds clearances in assemblies with moving parts and will not contaminate them. **Staked or crimped inserts stay tight, because of good creep resistance.**

*Thermal expansion* is similar to that of most metals and reduces stresses between metal inserts and the plastic caused by thermal cycling.

*Paintability.* SPMC can be painted by the usual methods and with customarily used coatings.

## Performance of Molded Parts

*Electrical resistance* is excellent with non-tracking at high humidity and temperatures. SPMC is listed by Underwriters Laboratory under file number 65432.

*Resists deterioration* at high temperatures. SPMC has a minimum heat deflection of greater than 450°F, and all grades show better than 130°C, or higher, in continuous use.

*Hard surface* resists wear and will not contaminate moving electrical parts.

*High impact strength* adapts SPMC compound for many uses where other thermosets and many thermoplastics are not suitable.

In conclusion, SPMC represents a new direction for unsaturated polyester resins. The system will undoubtedly carve out its niche in the existing molding markets. With its good price/performance package, it should soon be recognized as one of the most versatile and dynamic engineering plastics available. ●

**Table 2—SPMC After-Molded Properties**

Property	Typical Values
Specific gravity	1.8-2.0
Mold shrinkage, mil/in.	1-6
Tensile strength, 10 <sup>3</sup> psi	5-8
Flexural strength, 10 <sup>3</sup> psi	10-12
Flexural modulus, 10 <sup>3</sup> psi	1.3-2.0
Izod Impact strength, ft-lb/in. notched	1.0-2.5
Deflection temperature, 264 psi, °F	450-500+
Maximum continuous use temp, (Est.), °F	266-356
U.L. 94 Flammability Rating	HB-VO
Water absorption, 24 hr., %	0.1-0.3
Dielectric strength, S.T., v/mil	350-600
Arc resistance, sec.	185-195
Tracking index, IEC, volts	600+

## A THERMOSETTING STRUCTURAL FOAM

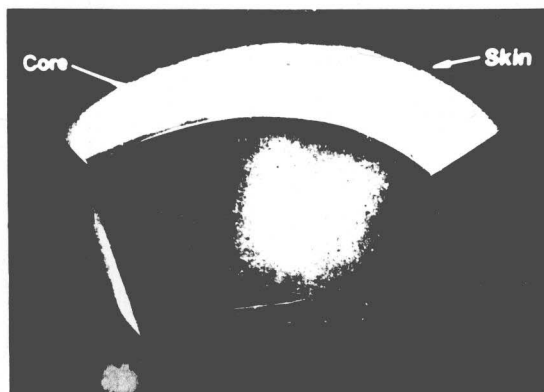
J. L. Eakin, Mobay Chemical Corp., Pittsburg, Pa.

In checking through the literature, the term "Structural Foam" dates back to before 1930, but it only began to be widely used during the 60's when it was used as a suffix to categorize thermoplastics that achieved a lower density by the addition of various gasses. These products became so successful that soon structural foam was synonymous with thermoplastic structural foam. During the 60's one thermoplastic after another entered the structural foam market. It was not until late in 1968 that a completely different type of structural foam was introduced (Polyurethane Structural Foam). This time it was a thermoset rather than thermoplastic and was developed by a directly opposite approach. Low and medium density rigid foams had been used for a number of years. By increasing the density, slightly altering the chemistry and controlling the reaction, it was found that a self skinning structural foam could be produced. Urethanes were well known in a wide area of applications including elastomers, fibers, coatings, adhesives and flexible and rigid foams. But this was the first time that the structural characteristics of this polymer were important.

In the last ten years Polyurethane Structural Foam has improved greatly. Technological advances in physical properties, process techniques and equipment have made it possible for this material to become an effective competitor with traditional foamed thermoplastic materials and has opened new markets that until now could not be satisfied with plastic materials. Today we will discuss this unique product and how to use it so that you can take full advantage of its outstanding problem solving properties as you develop new products or improve old ones.

First, let's look at Polyurethane Structural Foam in terms of its physical and chemical characteristics.

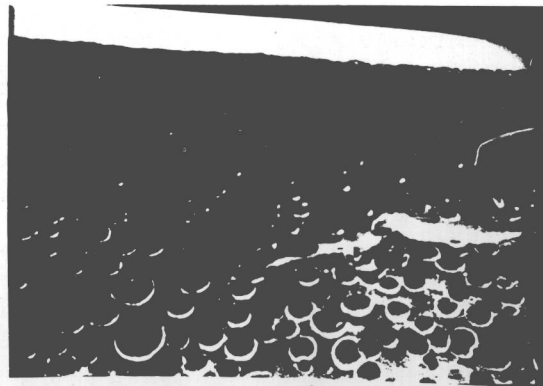
FIG. 1





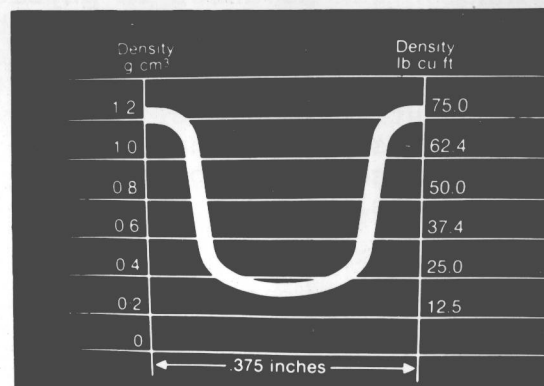
The structure of Polyurethane Structural Foam is sandwich-like, being comprised of solid outer skins, and a low-density core.

FIG. 2



A highly magnified view (Fig. 2) of the Polyurethane Structural Foam surface shows the transition from solid outer skin, to the foamed core. The thickness of the skin is controlled by mold temperature, shot weight, and formulation, while surface quality is controlled by the mold's finish

FIG. 3

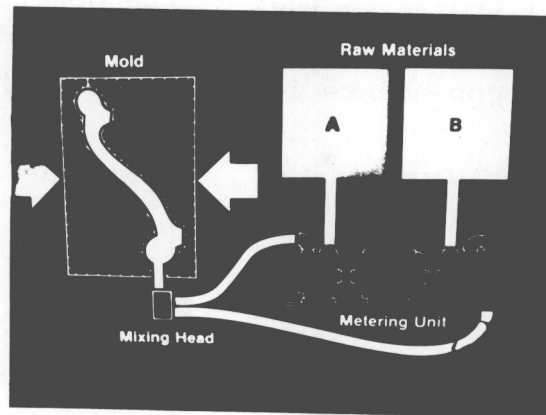


The graph in Fig. 3 shows the density gradient of a typical molded part. Note the solid skin and the gradual transition of a low-density core. The overall density of a part can be varied to meet specific end-use requirements. However, in most current applications, a specific gravity between .5 and .6 is specified.

The process by which this product is made is Reaction Injection Molding - more commonly called RIM. With this process, the basic urethane chemistry remains unchanged. Two reactive liquid components, an isocyanate and a polyol, are accurately metered by a synchronized, high pressure pumping system under controlled temperature and pressure conditions. Mixing is accomplished by high pressure impingement in an automatic self cleaning mixhead attached to the mold.

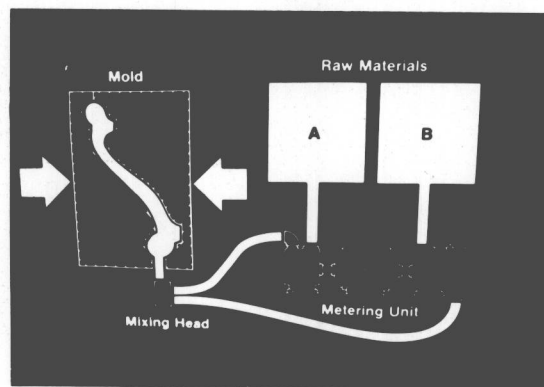
The reaction mixture flows (at atmospheric pressure) into the lowest point of the mold, filling the cavity between 40 and 60%. (Fig. 4.)

FIG. 4



At this point, the exotherm generated by the reaction vaporizes a blowing agent and causes the mixture to expand and fill the remaining portion of the mold cavity. (Fig. 5.) The polymer then solidifies. The part can be demolded as soon as enough of the exothermic heat has been removed by the mold to lower the part temperature below its heat distortion point.

FIG. 5



It should be noted at this point that a major advantage of the RIM process is that one pumping system can service up to 12 molds or clamping units while producing parts varying in weights from two to 40 pounds. Thus one RIM installation provides high production of different size parts at a surprisingly low capital investment.

Among the advantages of Polyurethane Structural Foam is the ability to vary the overall molded density between specific gravities of 0.4 and 0.6, as compared to thermoplastic foams with specific gravities of between 0.8 and 0.9. Densities within each Polyurethane Structural Foam part, regardless of size, is very consistent.

In foamed plastics many properties are density and thickness dependent. This fact plays a larger role in Polyurethane Structural Foams than in the thermoplastic structural foams because of the wider range of densities that can be obtained. Densities between 25 and 45 pcf (sp.gr. .4 and .7) are being used.

The density dependence is obvious as illustrated in the following chart.

PROPERTY VS SPECIFIC GRAVITY -

BAYDUR® 722 System

	.4	.5	.6
Specific Gravity			
Flexural Strength (psi)	3,200	4,600	6,000
Flexural Modulus (psi)	100,000	130,000	160,000
Compressive Strength (psi)	800	1,800	2,800
Tensile Strength (psi)	1,600	2,500	3,400
Heat Deflection Temp @ 66 psi (°F)	180	192	205
Charpy Impact, Unnotched (ft-lb/in. <sup>2</sup> )	4.0	5.6	7.2
Skin Hardness, Shore D	70	75	80

The effect of wall thickness is due to the density distribution over the cross section. In thin wall sections, the ratio of solid skin to the lower density foam core is much higher. The result is that at the same overall density, the thinner part will have a higher value for flexural modulus but the compressive strength will be lower. Generally all properties improve with thickness as shown below:

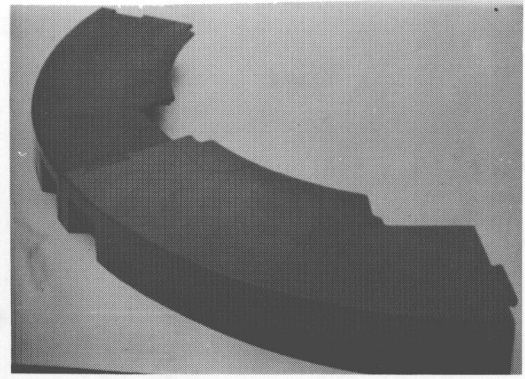
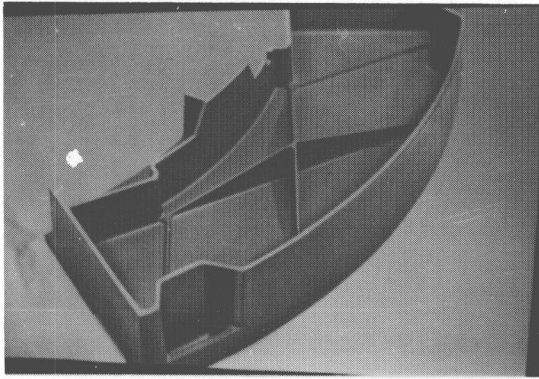
PROPERTY VS THICKNESS

BAYDUR® 722 System

	1/4	3/8	1/2
Sample Thickness (in.)			
Specific Gravity	.6	.6	.6
Flexural Strength (psi)	5,200	5,600	6,000
Flexural Modulus (psi)	200,000	180,000	160,000
Compressive Strength (psi)	2,000	2,400	2,800
Tensile Strength (psi)	3,000	3,200	3,400
Heat Deflection Temp. @ 66 psi (°F)	183	194	205
Charpy Impact, Unnotched (ft-lb/in. <sup>2</sup> )	6.5	7.0	7.2

Part stiffness can be effectively controlled by increasing wall thickness. To achieve maximum stiffness, without increasing part weight, the thickest wall at the lowest reasonable density should be used. However, thin walls offer the shortest demolding times. Thus, there must be a compromise between part design and processing cycle. Production experience indicates that the most practical wall thickness is from 3/8 to 1/2 inch.

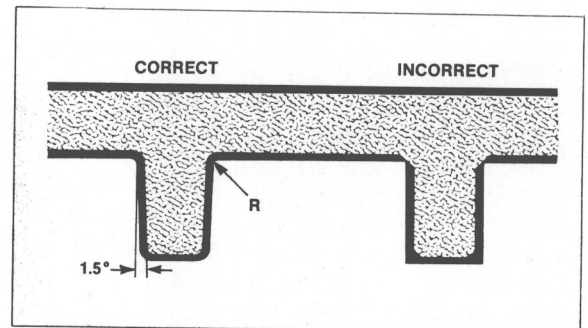
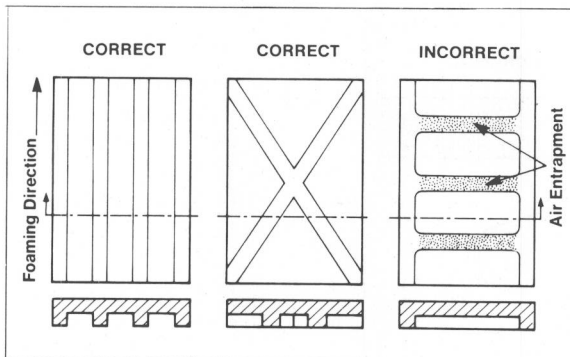
Another way to increase the rigidity of the part without increasing its weight and cost is with the use of ribs. When molding with Polyurethane Structural Foam no sink marks occur, and ribs such as these do not telegraph through to the opposite face as shown in the following pictures.



In designing ribs, cross sections of the ribs must be sufficient to obtain the desired loading resistance, however, excessively thick cross sections will increase demold times. Thus the width of the rib base should be no thicker than the wall to which it is attached. Ribs should be located in the direction of foam rise or provisions for the prevention of air entrapment caused by the expanding foam must be incorporated in the mold as shown in Fig. 6. Draft on the ribs should be at least  $1.5^\circ$ . All fillets should have a minimum radius of  $1/8"$ . As Fig. 7 shows a sharp internal corner has poor heat conduction in the mold, which results in reduced skin formation, and a decrease in mechanical properties

FIG. 6

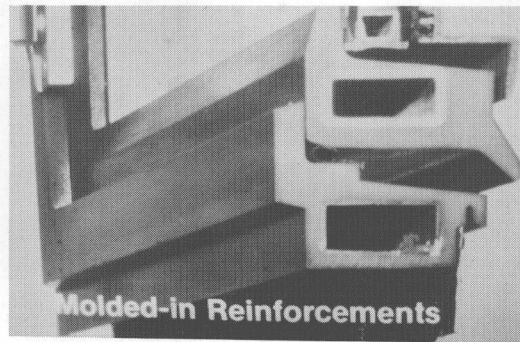
FIG. 7



Another means of reinforcement is the in-place molding of tubular inserts within the part. The cost comparison of stiffening by increasing thickness or the addition of ribs, vs stiffening with inserts, should always be the overriding consideration for choosing one technique over the other. The ability to mold inserts has another advantage. As was previously stated, when a part contains large areas with thick cross sections, the demold time can be adversely affected and possibly make a part uneconomical to produce. If the design does not allow for the elimination of these thick sections, as in the window profile in Fig. 8, a reduction of cross section can be accomplished by the addition of an insert. This reduces material costs as well as cycle times.



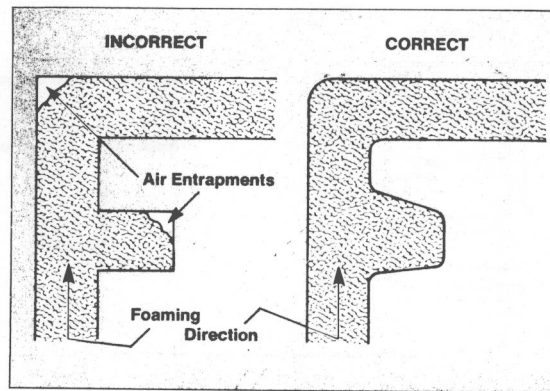
FIG. 8



To successfully use Polyurethane Structural Foam maximum advantage should be taken of this material's versatile properties. However, good design practice implies that the following design fundamentals be adhered to.

Rounded corners, rather than sharp edges, should always be used if possible. To insure a good skin formation, inside corners should have a minimum radius of  $1/8$ ". In addition, rounding of corners will have the least chance to entrap air during foaming and give the easiest release.

FIG. 9



All parts should be designed with a minimum draft of  $1.5^\circ$ . A draft less than this makes demolding the part difficult. For some enclosures, it is often sufficient to only have draft on the male portion of the mold surface, since the part will shrink away from the cavity wall. Normally this no draft condition should only be used for parts with heights less than 8 inches.

Slots should be oriented in the direction of flow to prevent air entrapment and to facilitate the removal of flash cores, should not shut off against the opposite wall, but should be seated approximately  $1/8$ " into the wall. (Fig. 10) If any flash develops it will then stand perpendicular to the part surface and can be easily removed.