cosmo

COIL BOBBIN MATERIALS

ISO 9001 Certified

Property (dry as molded)	ASTM Method	Unfilled nylon 6/6	Glass filled nylon 6/6	Glass filled PBT[a]	Glass filled PET[b]	Glass filled PPS[c]	Liquid crystal polymer	Thermo-setting polyester	Phenolic	Glass filled DAP[d]
Notched izod impact, 73°F, ft-lbs/in.	D-256	1.0/2.1[e]	2.2/2.5[e]	1.3	1.6	1.6	2.4	4.3	.5	.8
Tensile strength, 73°F, psi x 10^3	D-638	12.0/11.2[e]	27/18[e]	19.5	22	22.5	23	6.2	9	12
Elongation, 73°F, %	D-638	60/300+[e]	3/4[e]	1.5	2.3	.9	1.7	-	-	-
Flexural strength, 73°F, psi x 10^3	D-790	-	38	28	32	29.4	31	13	14	19
Compressive strength, psi x 10^3	D-695	4.9	42	18	25	26	18	29.9	40	22
Heat distortion, °F, 264 psi	D-648	194	480	406	435	>500	469	>500	400	400
Heat distortion, °F, 66 psi	D-648	455	500	442	475	>500	543	-	-	-
Thermal expansion, in/in/°C x 10^{-5}	D-696	8.1	2.3	1.4	2.5	2/4[l]	.6	3.5	1.9	1.9
Volume resistivity, ohm-cm	D-257	1015/1013[e]	1015/109[e]	1015	1015	1016	1015	1014	1013	1015
Dielectric constant, 100 Hz	D-150	4/8[e]	4.5/25[e][f]	3.9	3.6[f]	3.9[f]	4.1[f]	6.3	4.1	4.2/3.5[k]
Dielectric strength, v/mil. 1/8" thick.	D-149	385/773[e][h]	530	490	430/1040[g]	450	1110[j]	436	380	450/726[g]
Oxygen index	D-2873	28/31[e]	24	30	33	47	37	-	-	39
Arc resistance, seconds	D-495	60-120	135	123	117	34	137	>180	>180	130
Water absorption, %, 24 hrs.	D-570	1.2	.7	.07	.05	<.05	.02	.19	.1	.25
Flammability rating	UL-94	V2	HB	V0	V0	V0	V0	HB	V0	V0
Specific gravity	D-792	1.14	1.38	1.66	1.67	1.65	1.61	1.98	1.80	1.87
Hot wire ignition, seconds	UL-746	15	9	73	>300	12/300[i]	<30	-	-	-
Comparative tracking index, seconds	-	>599	400-599	250-399	250-399	100-174	175-259	400-599	175-259	>599
Thermoplastic (P), Thermosetting (S)	-	P	P	P	P	P	P	S	S	S

[a] polybutelene terephthalate
[b] polyethylene terephthalate
[c] polyphenylene sulfide
[d] diallyl phthalate
[e] (dry as molded) / (50% relative humidity)
[f] 1kHz
[g] (.125 inch thick molded) / (.032 inch thick molded)
[h] (.125 inch thick molded) / (.048 inch thick molded) @40% RH
[i] (.028" thick molded) / (>.058 inch thick molded)
[j] .058 inch thick molded
[k] 1kHz / 1mHz wet
[l] (axial) / (transverse)

There are many plastic compounds available on the market today. Due to the stringent requirements of coils used in industry, only a small number of these materials are appropriate for the manufacture of coil bobbins. A variety of different molding processes are used to mold bobbins in these materials.

MOLDING PROCESSES

To help understand the material section, we will first explain the basic molding processes that are used to mold the various types of plastic resins. This may help you to relate the materials' physical and thermal properties with the cost of the materials' molding process as another material selection criterion.

Injection Molding

The method that is most widely used today for making bobbins is the injection molding process. The process can be adapted to mold both thermoplastic and thermosetting materials. When using thermosetting materials, relatively cool material is injected into a hot mold and after a short period of time the mold is opened and the parts are ejected. When molding thermoplastic materials, the material is heated in the cylinder, injected and then cooled in the mold prior to removal of the parts.

Transfer Molding

Transfer molding is used with thermosetting material only. The molding material is placed into a chamber in the mold prior to the closing of the mold. An external plunger forces the material from the chamber into the mold through a system of runners. Since this all takes place in a hot mold, the material changes chemically and becomes thermally set. After a prescribed time, the mold is opened

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and the part is removed.

Compression Molding

Compression molding is another process used only with thermosetting materials. In this case, while the mold is still open, molding material is manually inserted into each separate cavity within the mold and then the mold is closed. The action of closing the mold causes the material to distribute itself throughout each individual cavity. As in transfer molding, the hot mold causes the material to harden. After a prescribed time, the mold is opened and the parts are removed individually, since there is no runner system to hold the parts together.

MOLDING MATERIAL PROPERTIES

Molding materials used to produce today's parts are categorized by their properties:

- Thermal
- Flammability
- Electrical
- Physical

Thermal Properties

Underwriters Laboratories has segmented the range of practically experienced temperatures into a system of classifications. The molding material suppliers have provided materials that serve the needs of these different classifications.

Each temperature class represents the highest service temperature that the material should be able to withstand over its expected life without degrading the properties beyond the limits that UL has specified. This is the foundation for the insulation systems approvals available from UL (Standard 1446).

The officially assigned temperature classifications do not determine the highest temperature to which any specific product can be approved. UL requires that products be individually approved for the temperature class specified.

Flammability Properties

Flammability ratings assigned by UL represent a material's resistance to burning, not its temperature limit or thermal life. There are five ratings of flammability: one based on horizontal burning tests (HB), and four V ratings based on vertical burning tests. Three of these V ratings relate to the flammability performance of portable end-product appliances and devices. The last vertical burning rating applies to parts with extensive surface area such as housings and enclosures.

HB is assigned to those materials whose test bar burns at a maximum burning rate. This is the lowest rating that UL gives to plastic materials in the flammability classification.

V1 is the first of the ratings that specify a test using a vertical orientation to the test bar. The specimen must be extinguished within 25 seconds and any flaming drops may not ignite cotton.

V2 is a variation on V1 in that the same orientation and time limits apply, but the material is fluid enough that as the material starts to burn, flaming drops will drip away and help carry the flame from the burning part. Ignition of cotton by the flaming drops is permitted. Unfilled nylon is rated in this category.

V0 is the class that is commonly thought of when a material with some semblance of self extinguishing property is required. It will extinguish within 5 seconds and any flaming drops will not ignite cotton.

V5 is the class that applies to those materials that not only self extinguish, but also suffer very little part destruction.

Electrical Properties

There are a number of considerations under the subject of electrical properties. Some are true properties of the material and others are the results of tests conducted by UL under certain physical conditions such as thickness, humidity, etc.

Dielectric Strength of the plastic material is probably one of the more important electrical considerations. The dielectric strength of a bobbin is the total voltage required to break through the plastic material causing an electrical failure. The specification for dielectric strength reports the value as voltage per thousandths of an inch (mils) of plastic barrier.

This implies that the voltage to cause dielectric failure varies linearly with the thickness of the plastic barrier. However, voltage per mil is not a constant for a given material. Actually, the voltage varies with the thickness of the material, the temperature, the humidity conditions and the frequency of the current. The molded surfaces of the material provide an initial insulating property that is stronger than the intervening plastic between the two molded surfaces. It will take more voltage per mil to cause an electric failure on something .030 inches thick compared to something .060 inches thick or .125 inches thick.

Ionization, which causes a rapid breakdown of electrical properties, occurs in materials with high moisture content. As the current frequency increases, the dielectric strength decreases causing more problems. The same reduction in dielectric strength occurs when the coil heats up, caused by hot spots in the coil or higher ambient temperature.

Dielectric Constant is another electrical property that should be given consideration. It is a measure of the extent that an insulating material polarizes when placed in an electric field of specified intensity. A low dielectric constant is particularly desirable for communications and electronic circuits employing a wide range of frequencies that rely on a clear transmission of low intensity signals.

Arc Ignition, Arc Resistance, Arc Tracking, and Comparative Tracking are test results that have meaning within the UL approval process. These tests will be discussed later under the subject of the UL Recognized Component (yellow) Card.

Physical Properties

The physical properties of a plastic material tend to be more nebulous and difficult to correlate with the actual performance of the resulting part.

Flexural Modulus is one of the most important physical properties. This is a measure of the stiffness of a plastic material. This stiffness is necessary to keep the wire that is wound onto the bobbin exactly in position. Also, the wire pressure of the winding must not collapse the core of the bobbin and affect the clearances required for the core member going through the coil.

Coefficient of Linear Expansion is much greater in plastic materials than metals - up to 5 to 6 times greater, depending on the plastic. Therefore, as the coil is heated, the plastic will expand, causing a change in size.

Moisture Absorption is present to a certain extent in all of the plastic materials with which we work. Some materials absorb enough moisture to have a definite effect on the operation of the molded component. The filled versions of these materials will absorb less moisture, since the glass filler used has zero moisture absorption. The humidity conditions in which the final product will operate must be considered.

Crystallinity of plastic materials is usually not considered by most designers. The plastic materials that Cosmo uses to mold bobbins are generally crystalline. This crystallinity exhibits itself by manifesting in the plastic some of the same properties that are attributed to metals, such as increased flexural modulus and higher dimensional stability.

Depending upon the rate of cooling of the parts while still in the mold, and the temperature at which they are held in the mold, differing amounts of crystallinity are developed. Where it is not economically feasible to get maximally crystalline parts in the mold, some materials can have the crystallinity increased by heat-treating the bobbins at an elevated temperature. This process is referred to as annealing.

Conversely, there are some situations where a high crystallinity is not desired; when a more amorphous structure is needed. If this is the case, the parts should be molded in a cool mold, yielding minimal crystallinity.

UNDERWRITERS LABORATORIES

Underwriters Laboratories and its requirements play a large part in most of the bobbin industry. UL oversees many of the components as well as completed products used in the electric and electronic industry.

All materials approved by UL are documented with a yellow Recognized Component Card and have an entry in the Recognized Component Directory. The card lists the material along with the properties tested under their guidelines. The actual values required for a given application have usually been established by UL. Shown below is an example of a typical UL yellow card.

QMFZ2 **E69578M**
Component—Plastics

E I DUPONT DE NEMOURS & CO INC POLYMER PRODS
DEPT, ENGR POLYMERS DIV POLYESTER RESINS
WILMINGTON DE 19898

Mtl Dsg	Col	Min Thk mm	UL94 Flame Class	RTI	RTI with Imp	RTI w/o Imp	HWI	HAI	HVTR	D495	CTI
Polyethylene terepthalate (PETP), glass reinforced, flame retardant, designated "Rynite", furnished in the form of pellets											
FR-530L	BK, NC	0.35	V0	—	—	—	3	1	—	—	—
❶	All	0.81	V0	150	150	150	2	1	1	—	—
	All	1.57	V0	150	150	150	0	1	1	—	—
	NC, BK	1.57	V0	150	150	150	0	1	1	—	—
	❷	❸	❹		❺		❻	❼	❽	❾	❿

Marking: Company name or trade name and material designation on container, wrapper or molded on finished part.

The items listed on the card are:
❶ Manufacturer's material designation The card only applies to a specific material type made by a specific manufacturer.
❷ Color lists all of the approved colors obtained by the addition of pigment, that do not modify the properties of the material.
❸ Minimum wall thickness applicable to the properties shown.
❹ Flammability classification is the UL classification that indicates whether the material will burn, and if so, the rate of burning.
❺ Relative temperature index (RTI) for electrical and mechanical properties. There are 3 columns of ratings. The first is purely the temperature index for the electrical properties, and the next two columns list the temperature index for mechanical properties with and without impact considered. The material can be used at or below these temperatures without thermal degradation.
❻ Hot wire ignition (HWI) is the number of seconds it takes to ignite the material, when wrapped with a red-hot wire. The longer the number of seconds, the better the material. This represents the material's resistance to the abnormally high temperatures that may result when a conductor carries far in excess of its rated current due to a component failure.
❼ High current arc ignition (HAI) is the number of arc exposures necessary to ignite a material when they are applied to the surface of a material. This rating reflects the ability of a material to withstand arcing on its surface at low voltage/high current levels that might be encountered in the mounting of contacts or the breaking of internal connections.
❽ High voltage arc tracking (HVTR) is the rate at which a tracking

path is produced using a 5,200 volt arc. This is a test used when the part must support current carrying members and is only applied for applications where the available power is in excess of 15 watts.

❾ High voltage, low current Dry Arc Resistance (D495) expressed in seconds, is the number of seconds required for a surface conducting path to develop when subjected to an intermittently occurring arc of high voltage, low current characteristics. This has been historically referred to as the D-495 test.

❿ Comparative tracking index (CTI) is the voltage at which tracking is produced on a wet surface. Usually this test only runs to 500 volts before it is discontinued.

INSULATION SYSTEMS

Insulation systems have been developed for specific combinations of materials used in the manufacture of finished components. These materials have been tested by the manufacturers and include everything that goes into a making a wound coil, including the plastic materials, wire, varnishes, and tape.

Meeting UL requirements for electrical equipment can be very expensive, both in time and money. Usually, thermal aging tests are required to determine the feasibility of the materials that are going to be used. This can take anywhere from 12 to 18 months or more and costs thousands of dollars in related expenses. (UL Standard 1446)

These Insulation Systems give approval for operation using specific material combinations at a maximum temperature. This temperature limit assures that the unit or the materials will not have lost more than an acceptable level of their electrical and mechanical properties. Insulation systems simplify the approval process by reducing the scope of the testing to an audit of the unit's safety features without retesting the materials. This means substantial savings in the time and expense that would otherwise be expended in securing UL approval.

In the case of interlayer windings, the use of insulation systems and higher temperature bobbin materials, plus the use of specialized terminations, can minimize the cost of the finished coil.

Temperature Classifications

UL will assign a temperature limit of 65°C on almost any unknown insulating material. The following chart shows the higher temperature classifications that are assigned by UL.

Class	Temp	Typical materials
A	105°C	unfilled nylon 6/6
B	130°C	filled nylon 6/6, PET, PBT
F	155°C	PET and, with some insulation system approvals, PBT
H	180°C	PPS and, with some insulation system approvals, PET
N	200°C	LCP and, with some insulation system approvals, PPS, PET
R	220°C	
S	240°C	
C	>240°C	

Most of the commercially available thermoplastics stop at about the Class N level. The only materials to reach higher are the ceramics and some exotic materials. In our recent experience, our customers have successfully used Cosmo bobbins molded with LCP at the higher temperature ratings.

Caution must be exercised in applying these insulation system approvals to real world designs. These insulation system approvals and the temperature limits involved only refer to the degradation properties of the materials and specifically to any potentially harmful interrelationships. This does not mean that your product will be approved by UL to function and be safe at the temperature that the insulation system specifies. The safety audit includes tests designed to determine if your total package will operate at the temperature level implied by the insulation system approval.

A major case in point is the potential disparity between the temperature classification of the bobbin material and that of the entire insulation system. The material temperature classification is determined by UL when the bobbin material is under low physical load. However, final insulation systems approval is determined under the actual load conditions experienced by the complete component. There have been specific instances where the actual load was higher than expected, and required a bobbin material with a higher distortion point. It pays to evaluate all of your temperature requirements to avoid this trap.

MOLDING MATERIALS

There are over 100 different materials that could be used in molding bobbins. However, the majority of bobbin requirements can be satisfied using one of 10 specific materials.

By specializing in these industry-standard materials, it is possible to eliminate the high cost of changing materials and tools every time a different job is run. However, this does not mean that bobbins cannot be made in a wider variety of materials. In actuality, Cosmo does make bobbins out of many other materials, where the requirement is for a very specialized application requiring properties that are not handled by our standard materials.

Thermoplastic vs. Thermosetting

All molding materials can be classified as either thermoplastic or thermosetting. This basic difference is characterized by the material's reaction to the initial and subsequent applications of heat.

Thermoplastic materials soften and can be formed into a desired shape upon the initial application of heat. If you desire to reuse the material, the material can be ground, reheated to the softening point and reused.

Thermosetting materials react chemically upon the application of heat. This reaction is not reversible. When the part is cooled and subsequently reheated, the material will not soften. The result is that if the part is not correct, the material cannot be salvaged.

Thermoplastic materials require the injection molding process. Thermosetting materials can be molded using a thermosetting injection process, transfer molding or compression molding.

When a part molded in a thermoplastic material is removed from the mold, it generally is a clean part, free of flash. Parts molded of thermosetting materials normally exhibit varying amounts of flash that must be removed in a secondary operation. They can be deflashed by various methods depending upon the volume, the kind of material and the amount of flash.

Most of these materials can be purchased from any number of chemical companies under a variety of trade names. Throughout this design manual, we will use the generic names of the materials by which they are known chemically, rather than by the trade name of the materials under which they are marketed.

THERMOPLASTIC MATERIALS

Unfilled Nylon 6/6

Unfilled nylon 6/6 has an outstanding balance of properties combining strength, moderate stiffness, high service temperature and a high level of toughness. It is resistant to impact, has a low coefficient of friction and resists fuels, lubricants and most chemicals. In addition, it is comparatively easily molded, filling thin sections due to the low mold viscosity when molten. It is a crystalline polymer that sets up rapidly. This combination of easy fill and fast set up allows generally fast molding cycles.

Unfilled nylon 6/6 absorbs moisture and comes to equilibrium at a moisture content of 2.5%, at 50% relative humidity. This moisture acts as a plasticizer for the nylon, somewhat lowering its strength and stiffness, but increasing its toughness and elongation. Where parts have been fully annealed, normal dimensional growth will be .006 inches per inch of length with the application of moisture at 50% relative humidity. Of course, if the part is subsequently dehydrated, the process is reversed, stiffness increases and dimensions decrease as the moisture content decreases.

Today, nylon 6/6, both unfilled and glass filled, accounts for approximately 50% of bobbin production. The combination of high temperature properties, toughness, abrasion resistance, and chemical resistance, along with its electrical properties is adequate for most power frequencies and voltages.

Glass Filled Nylon 6/6

The glass filled nylon normally used in bobbins is the same nylon 6/6 used in the unfilled variety, but with the addition of 30-35% glass, depending upon each manufacturer's specific formula. Because glass fibers do not absorb any moisture, the moisture absorption of glass filled nylon parts is reduced proportionally.

The addition of the glass to the nylon increases the heat distortion point and raises the stiffness considerably. Glass fibers retain a memory of their original orientation even after realignment within the part during molding. After molding, these fibers begin to return to their original shape. Therefore, there is more warpage in glass filled nylon parts. However, by varying the molding process, mold design and temperature control, the warpage of the glass filled nylon can be minimized.

By adding glass to the nylon, the material carries a UL heat distortion rating of 120° C. While unfilled nylon has a flammability rating of V2, meaning it has restricted burning with dripping allowed, glass filled nylon is only classified as HB. The glass fibers act as a mat and will not allow the flaming material to drip away. Therefore, the nylon continues burning until the entire product is consumed.

Thermoplastic Polyester

There are several materials that are classified as thermoplastic polyesters:

- PBT - polybutylene teraphthalate
- PET - polyethylene teraphthalate

These materials have a 30% glass fiber content.

PBT, as formulated for the manufacture of bobbins, is a flame retardant material with a UL rating of V0. It has a temperature index of 130° C, and an insulation system approval of Class F, 155° C. It has good volume resistivity, low moisture absorption, and is quite stiff.

PET has generally the same properties and flammability rating, except that PET, being a more stable material with a slightly higher melt temperature, has a temperature index of 140° C and has been able to get an insulation systems approval for Class H, 180° C and Class N, 200° C.

Insulation system approval temperatures only reflect resistance to degradation of material, and have nothing to do with heat distortion properties.

PBT is a little easier to mold because the material only has to be dried to .02% moisture before it is molded, while PET has to be dried to .01% moisture. It is extremely critical that this lower moisture content be adhered to since excess moisture can degrade the physical properties during the molding process.

Polyphenylene Sulfide

Polyphenylene sulfide (PPS) with its high temperature index, is currently the most affordable of the high temperature thermoplastic materials available for molding larger bobbins. Its high crystallinity results in a glass like material that actually sounds like glass when dropped on a hard surface.

PPS has a 40% glass fiber content. It carries a UL flammability rating of V0, a temperature index of 200° C, and it has a Class H, 180° C insulation system approval.

The high melting point of this material resists the transfer of heat when soldering terminals. This makes PPS a good choice when high temperature soldering is required. Its high heat distortion point makes it a very good choice for highly loaded coils, where the plastic will be used as a direct support for current carrying metal parts.

This material is exceedingly stiff and it has a very high resistance to loading, and correspondingly a very low amount of creep. PPS is also chemically inert. Consequently, it will fulfill the requirements of most high demand applications. The material is a little more expensive, but when you need its superior properties the benefits far outweigh the extra cost.

Liquid Crystal Polymer

Liquid crystal polymer provides a level of properties previously unavailable. It has the potential to be used in place of some ceramics in very demanding end use applications. This material has an exceptionally strong molecular structure with extremely high tensile strength and stiffness. Instead of having a crystal structure, this material has a linear, rigid, rod-like structure that aligns to a very high degree during flow, making for an ordered structure in the molten state.

This material can be readily injection molded and, inasmuch as the material is extremely liquid in the molten state, it can be molded into extremely thin sections. Like most of the other materials, added glass further enhances the heat-distortion point and stiffness.

Liquid crystal Polymer has a UL flammability rating of V0. It has a very high dielectric strength - in some instances twice as high as most other materials - allowing for very thin walls. Moisture absorption is very low, as is the coefficient of thermal expansion. These combined properties make for a material that is dimensionally very stable, and allow for the design of very close tolerance, and extremely small parts.

THERMOSETTING MATERIALS

Diallyl Phthalate

Diallyl phthalate (DAP) can easily be recognized by its characteristic green color and the green dust generated by the required deflashing operation. The material contains a high concentration of glass, and by nature is generally considered brittle.

It is dimensionally very stable and has good electrical properties. When immersed for soldering operations, the material will not soften. This allows a longer dwell time in most soldering operations. However, DAP requires a thermoset method of molding that is a slower and more expensive process. This fact, combined with the high cost of the material, and the waste of material in the runner system, results in higher part prices.

Phenolic Resin

Phenolic materials in general, both filled and unfilled, have an advantage over other thermosetting materials in that they are only about 1/3rd the cost of high temperature thermoplastic materials. However, the low price of phenolic material is offset by the fact that it is much more expensive to mold, and does require a deflashing step that adds additional cost. Phenolic parts are generally brittle and require more care in handling.

Thermosetting Polyester

The kinds of thermosetting polyesters that are in general use in our industry are called bulk molding compounds. This material is furnished in a very heavy putty-like consistency and requires special methods of feeding the material to the molding machine.

The material flows exceedingly freely and results in heavily flashed parts that require extensive finishing to deflash. Like the rest of the thermosetting materials, thermosetting polyester is dimensionally very stable, but also brittle in thin sections. Therefore, parts made from this material must have a minimum wall thickness of 1/16th inch.

Thermosetting polyester is primarily used for molding the large coil forms required for the high output lighting ballast transformers used in street lighting.

MATERIAL SELECTION CRITERIA

The preceding discussion has provided a basic framework for specific criteria to be considered in the coil bobbin designer's choice of materials. These selection criteria encompass a wide range of physical, manufacturing, and cost considerations. Many are interrelated and often cannot be optimized. Bobbin material selection is always a compromise. The following suggests some of the questions that must be answered in selecting a material for a bobbin. These considerations are listed here without regard for priority, because the priority of any specific item depends upon the use of the component.

The basic criteria include:

- Temperature limitations
- Termination and Soldering Method
- Flammability
- Electrical Requirements
- Physical Properties
- Dimensional Tolerances
- Insulation Systems
- Material Costs
- Molding Method Costs
- Finish Requirements
- The World Marketplace.

Temperature

The specific temperature that will actually be experienced by the coil in operation must be considered. Will there be heavy physical loading on this coil that at the elevated temperature could possibly cause the unit to collapse due to the winding pressure? Will the limiting heat distortion point of the material or materials under consideration be exceeded by the heat buildup due to the operation of the coil and perhaps the buildup of heat due to any enclosure around the coil?

Termination And Soldering Method

Will the part be hand soldered with leads, or will terminations inserted into the plastic part be used to electrically connect the coil? If terminals are used, what method of soldering is going to be used: automatic dip soldering, wave soldering or hand soldering? What will be the effect of the transfer of the heat of soldering into the plastic part? Will it distort the part? Will it loosen the terminals?

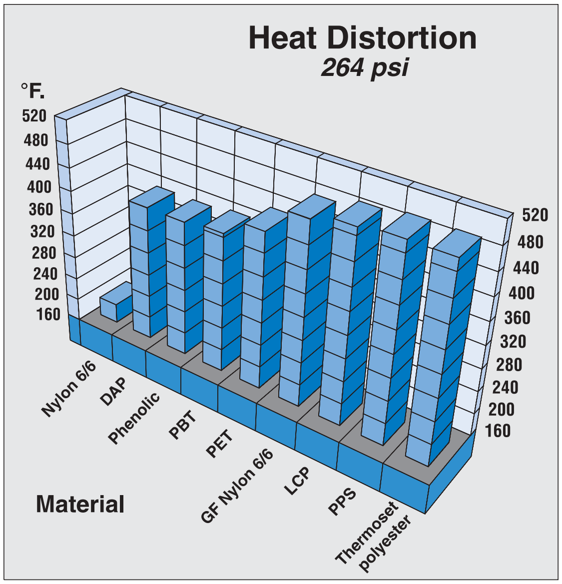
Flammability

Will UL require that a V0 material be used?

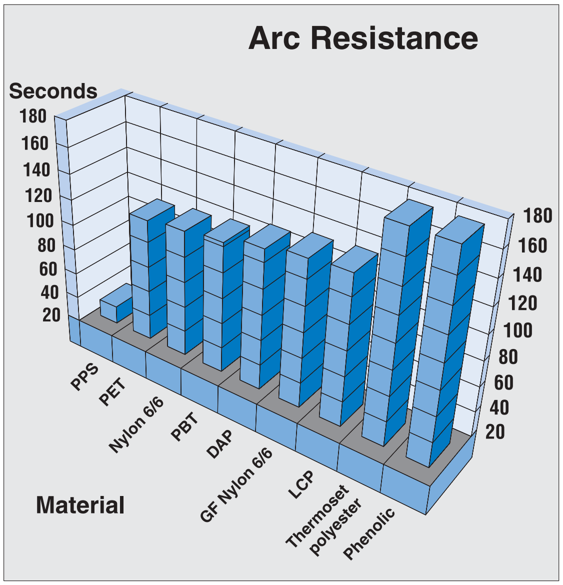
Electrical

What voltages will be encountered? What are the dielectric strengths in volts per mil? What about volume resistivity?

When molding bobbins, the molder must always be concerned with the problem of releasing the parts from the mold. Good mold design



should provide for proper part release. However, when a molder with inexperience in the use of bobbins runs into a problem of poor release, a mold release agent may be used. This can have

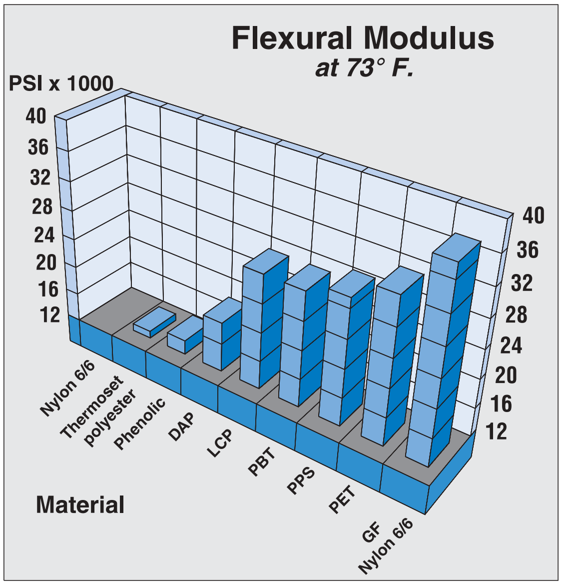


far reaching effects on the electrical properties of the bobbin. Arc tracking resistance and dielectric strength can be affected.

One specific mold release, silicone, has a rather nasty propensity to migrate. It can be deposited anywhere on the surface and at that point the silicone acts like a spider, it starts to crawl, and it never stops, no matter how thin the film. It will crawl into any other part in your unit, and if you have any place where you have contacts making or breaking, it will crawl over the contact surface and act like an insulator. As a general rule, mold release agents should not be used on bobbins.

Physical
Care must be taken so that when large wire sizes are going to be used, the wall thicknesses are sufficient to prevent flange flaring or the collapse of the ID of the bobbin. Therefore, the flexural strength of the material should be considered.

Dimensional Requirements
What are the dimensional tolerance requirements related to part function? Is this a coil that has to be in a specific environment where a coil size change of a few thousands of an inch will make



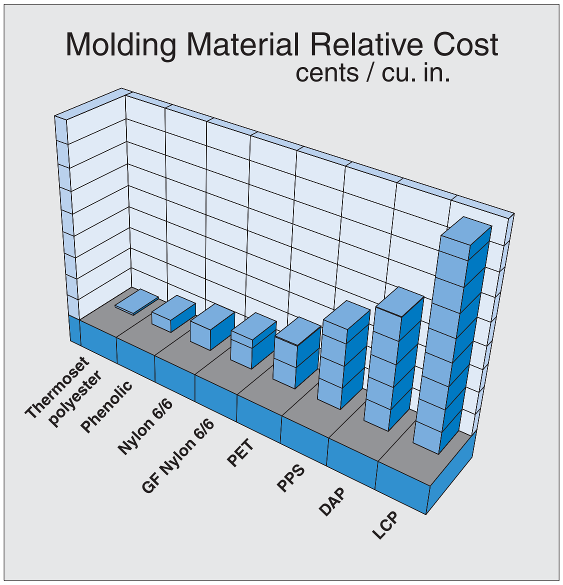
a significant difference or will it be used in such a way that the overall envelope size is insignificant? Will this component contain moving parts connected to the bobbin involving the making and breaking of contacts, where close tolerances are imperative, or will this part be used only to generate a magnetic flux. The use of the part can determine the dimensional tolerances required, and dictate the choice of materials. Alternately, the use of automation in the assembly of the component may be the driving factor in requiring a close tolerance material with good dimensional stability over time.

Insulation Systems
If your product contains a wound coil, and has to be submitted to UL, the use of an insulation system will reduce the cost and the time required for UL testing.

Material Cost
The material cost should be rather low in the list of priorities. Specifically, material cost must be considered per cubic inch because of the wide variety of specific gravities involved. Also, most bobbins, by the very nature of their configuration, have a rather low material content per unit. One should remember that the cost reductions resulting from the improved properties of higher cost materials usually outweighs the higher cost of the material itself.

Molding Method Cost
The selection of a specific molding material can influence the molding cost by requiring a molding method that may be higher in cost. Some materials are compatible only with more expensive tooling.

Thermoset materials, because of the need to transfer heat from the mold, require a longer mold residence time than thermoplastic materials. In addition, the need for manual introduction of the molding material into the mold in compression and transfer molding further slows the cycle. The end result is that the molding cost per unit of thermosetting materials is typically higher than for thermoplastic materials. It is possible, in some cases, to trade a



higher material cost for a lower molding cost with roughly the same properties by switching to one of the new sophisticated thermoplastic materials.

Mold wear, the second source of variation in molding method cost, is typically caused either by chemical corrosion or physical abrasion. Normally, unfilled materials have very little effect on the mold because their abrasion level is very low. Also, very few materials are chemically active enough to cause corrosion. For those few materials that do cause corrosion to the mold surfaces, a more corrosion resistant steel or a corrosion resistant coating can be used.

The addition of glass to the resin to increase the heat distortion point and flexural modulus increases the abrasiveness of the melt. This tends to wear the mold after a period of time. The main antidote for this problem is the use of high hardness steels in the manufacture of the molds. Also, the alloying of 5% chrome into these steels provides corrosion resistance and increases the wear resistance of the cavity. The air hardening method of heat treating that is employed with these steels reduces the amount of distortion that can be caused by the heat treating process. This reduced distortion enables the construction of more accurate molds.

When using thermosetting materials, the wear rate is significantly higher due to the high abrasiveness of the material and the higher corrosiveness of the gases given off during the chemical reaction that takes place in the mold. Fully chrome-plated molds are necessary, however, their maintenance costs are higher.

Finish Requirements

Winding coils is a very delicate process, especially when using some of the very fine wires that are available. When thermoplastic bobbins are removed from the molding machine, they are usually considered to be a finished part and do not require any further processing to assure smooth bobbins. However, when using ultra fine wires, the finish may not be adequate. In these cases the bobbins can be roto-tumbled using an abrasive media that will hone the surface of the bobbins to a smoother finish, eliminating any possibilities of points of drag that can cause wire snagging and stop the coil winding operation.

The World Marketplace

Will the product be used in the world marketplace? Will it meet foreign regulatory requirements. VDE is the German counterpart to our Underwriters Labs. VDE stands for the Verband Deutscher Elektrotechniker. In Europe, VDE has such stringent requirements that generally, if parts meet VDE requirements for temperature classification, flammability, insulation approval and safety requirements, it is reasonably assured that they will meet the most stringent world requirements. The reason for the higher level of requirements of VDE is the fact that typical European household voltage is 240 volts versus the U.S. standard of 120 volts.

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