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THERMOPLASTIC FRONTIER LAWS - GOOD AND BAD GUYS

June, 1964

Prepared by

J. C. Daly

Presented to the Society of Plastics Engineers

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INTERDEPARTMENTAL MEMO

DATE: November 11, 1964

TO: J. E. Long, Dept. 250

SUBJECT: Outline and Speech Given Before Society of Plastics Engineers,
May 18, 1964

Attached you will find a copy of the outline and speech "Thermo-plastic Frontier Laws - Good and Bad Guys". This speech was given before some 30 members of the local section of the Society of Plastics Engineers. You received a rough draft of this written material on May 11. The final draft incorporates your suggestions made to C. Smith and myself in discussions prior to the speech presentation.

The members were most considerate in their question period at the end, asking only two. These were:

1. Q. The temperature parameters given are -65 to 165°F, these are not broad when compared with the automotive industry which has a top of 250°F, do you use other parameters?
 - A. It was stated in the speech that general parameters are -65 to 165°F; certainly when our customer defines others we change our programs to accomodate these.
2. Q. The temperature limits mentioned, -65 to 165°F, seem to reflect some association with the aircraft or missile industry, is this the case?
 - A. In my own mind these limits are associated in general with the military specifications with which we work. Generally, these are troublesome only on the low end in thermoplastic applications and actual end use testing resolves the problem to our customer's satisfaction, since we are aware that standard test specimens do not reflect operating limits of properly designed and molded parts. Any association between these parameters and the industries you have mentioned should not be made in conjunction with my remarks.

JCD:psd
cc: G. L. MacCurdy
J. W. McFarland

J. C. Daly
Materials Engineering
Organization 832-2

Attachment (1)

June 5, 1964

THERMOPLASTIC FRONTIER LAWS - GOOD AND BAD GUYS

I hope the title of this presentation intrigued you a little, and more importantly I hope any sharp shootin' involved is worth your while.

The Bendix Corporation, Kansas City Division, located at 2000 East Bannister Road or 95th and Troost is a prime contractor of The Atomic Energy Commission. It is one of approximately 36 domestic and foreign enterprises of The Bendix Corporation, which long ago sold its patents and good will in the washing machine. The prime contract position of the Kansas City Division is: according to the security approved comment; "Manufacturer of Mechanical and Electrical Components for The Atomic Energy Commission." Since security restrictions are difficult for one to thoroughly grasp, if not in constant contact with them, you will forgive me if I give you only the information which has been approved for public release.

Materials Engineering at Bendix is headed by G. L. MacCurdy. There are approximately forty persons in this group, about three-fourths of them Engineers specializing in the various facets of materials application and specification preparation. The group is roughly divided into three sections as follows:

Metallurgical and Finishes	J. H. Kuehnle
Poly-Chemicals	J. W. McFarland
Potting and Rubber	R. L. Sadler

My assigned responsibility is Thermoplastics. I work in the Poly-Chemicals section, and am ably assisted in this assignment by Messrs. C. Mayberry and R. Melton. The general responsibilities of any engineer in the group is to be cognizant in the assigned areas, to prepare specifications for materials, and to

investigate new materials or fit old materials to our applications.

The activity in a plant such as this is everchanging and challenging, surrounding ones' job with suspense and expectancy. This thought gave birth to the title; for it is imagined that a similar atmosphere might have pervaded the early frontier settlements. We recognize these areas as being on the frontier then, and we in Engineering and Manufacturing at Bendix, like to feel we are on the frontiers of applications now.

In general, I believe we are advanced in several areas of activity at Bendix. Our potting specialists have developed materials and techniques as follows: PAPI foams, shielding, evacuation and filling techniques, hot identor methods of determining state of cure, and improved bonding techniques. All these contribute to parts far superior to normal commercial practice. In the areas of foams based on polyurethanes we have achieved more uniform cell structures and higher temperature foams than are common in industry. In the area of solid polyurethanes, improvements have been achieved by reprocessing commercial materials or assisting the compounders in this area. Some work accomplished in the preceding areas has been published.

Papers co-authored by C. H. Smith and C. A. Peterson:

"Effect of Diisocyanate Structure on Load-Bearing Properties of Flexible Urethane Foams," SPE Journal, April 1962.

"Cast Flexible Urethane Polymers," Modern Plastics, July 1961.

Papers authored by C. H. Smith:

"Rigid Urethane Foam From E-Caprolactone Polyesters," I. and EC Product Research and Development, March 1963.

"An Epoxy Resin with Improved Electrical Properties," Modern Plastics, July 1963.

Papers Authored by L. C. Jackson:

"Preparing Plastic Surfaces for Adhesive Bonding," Adhesives Age Magazine, February 1961.

"Bonding Plastics Onto Metal," Adhesives Age Magazine, January 1962.

"Management: Teach Your Engineers to Design Better With Adhesives," Society for Automotive Engineers Magazine, October 1961.

"In-Company 'School' Provides Adhesive Training For Engineers," Adhesives Age Magazine, May 1962.

"Studies Into A Room Temperature Curing Adhesive With Intermediate (300°F) Strength," Adhesives Age Magazine, September 1963.

In all areas where a material is developed or improved by Bendix for our application, a diligent search is made for someone in the commercial field to take over and supply the required material for production. Such development and improvement as we are forced to do at our location, is only undertaken because commercial incentive is lacking or the technique needs to be developed beyond current commercial practice.

In other cases, especially thermoplastics, it is only a matter of selecting a material to do the job and then refining the techniques of processing to force the material to present the best already built into a polymer. Selection of a material from the many thermoplastics appears to be overwhelming at first glance, but a systematic approach using design parameters usually simplifies the problem. Data sheets are utilized to obtain a general tabulation of the commonly reported mechanical and electrical properties of materials which might accomplish our design functions. The properties for one chemical class of material or perhaps

several classes of materials are analyzed as they generally fit the design parameters. Some are found to be unacceptable on the basis of physical stability at our general temperature operating limits -65°F to 165°F . Others have dimensional stability problems and are eliminated on this basis. When the preliminary analysis is completed we have between three and four materials that might accomplish our objectives. A program of final evaluation is then outlined to complete the selection. Upon approval from other engineering personnel and our customer, the program of evaluation with strict attention to design parameters is completed. This generally results in the selection of one material for the job, and often provides a back-up material.

We now come to a few generalities about those Good and Bad Guys. We have found several bad actors among the polymers. The three worst offenders on our current list are all there because of dimensional problems. ABS materials seem to us to be very poor at holding even normal .002 inch/inch tolerances. These materials have, in our investigations, shown a tendency to change injection molding characteristics from lot to lot. They have not been abandoned, but certainly at the moment are sidelined.

Another bad actor at the moment is the polyacetal resin. I might hasten to remark at this time that tolerances inside normal commercial standards of .002 inch/inch are being attempted. We in engineering are not certain, at this point, whether the material is causing our trouble or the measuring techniques are at fault. The material is not following the general trends one might expect of it after reading the published data.

Yet a third material which has always given us some concern is polyamide. The tendency of this material to shift when exposed and withdrawn from high humidity environment has been a continuing problem for us. In many instances, this undesirable characteristic of polyamide can be corralled by suitable stabilization prior to assembly in a known environment. However, in perhaps more cases the problem is unresolved.

Two materials which have split personalities and border somewhere between good and bad are the polycarbonates and polyvinylchlorides. The first plastic suffered severely from inadequate publicity on its weak points at the time of introduction. The severe machine stress which can be worked into a prototype machined part contributed to several disastrous failures at the time this material was introduced. The stress problem was compounded by the ease of attack of amines on a machine stressed part. Some failures were so bad the resultant encapsulated part appeared to have molding pellets where the solid part formerly occupied space. Both the machine stress, and subsequent damage from solvents in mold releases; or from amine curing agents in epoxy encapsulating compounds have been largely overcome. Unfortunately, a number of "wanted" posters remain in many engineers' minds and still label this material, polycarbonate, a bad guy.

Polyvinylchloride is a good material for many applications when unplasticized. The material is rarely used in our electrical units in this state. Tubing made from the base resin was heavily plasticized and some, low quality materials used extensively to permit testing to MIL-I-7444 requirements caused severe coating or surface contamination problems by migration of the plasticizer. The

plasticizer also had the habit of migrating to wire identification tape markings resulting in smudging or complete removal. The material has lately been improved but other materials have now largely replaced it in our applications.

Another material lately to make its appearance on our scene is polyvinylalcohol. We are using the material, if you will, out of context. It may be unfair then, to say it is either a good or bad guy, since as the saying goes, "we have howdied but we ain't shook." Our application at the moment is associated with a sea marker with which you are probably familiar in life vests. We would like to utilize the water soluble material, PVA, as a binder to formulate a part to specific dimensions. The tolerance on this dimension is 2.21 plus zero minus .04 inch, which look reasonable. The only unfortunate part is an almost total lack of information on how the material responds to ambient air carried moisture and how to compression mold PVA while retaining the solubility. We're still looking at this one with a jaundiced eye.

Let us now get into a case history of a couple of materials which are generally good guys applied in design environments and manufacturing situations which are questionable. About six years ago, Bendix was asked to develop an electronic cable which would have good temperature capability, resistance to moisture, and extremely good electrical characteristics combined with flexibility. The temperature limitations given in the initial design note were: -65°F to at least 250°F with 300°F preferred. The electrical characteristics were: to withstand a test voltage of 15,000 volts direct current for 15 seconds and exhibit no more than 10 micro-amperes leakage. The preliminary work in this case had narrowed the field to film. We based our search on the fluorocarbon and polyester families primarily, because the polyolefins were eliminated on the basis of temperature extremes and most

other items on the basis of electrical characteristics of flexibility.

Polyethylene terephlate film and polychlorotrifluoroethylene film were the major products contending for the application. In the design of the part, thickness tolerances were very tight. They were so close, in fact, that if the polyethylene terephlate film, as manufactured, were placed in the assembly, the unit would automatically be outside the maximum tolerance of the assembly because the film thickness tolerances were too wide. The assembly exceeded print tolerances without the glue line of adhesive needed to cement all the materials together. This turned out to be a bad guy in our plot because it forced the assembly to be fabricated from selected stock and forced us to write a specification which attempted to cope with all these contingencies. Another problem associated with the use of polyethylene terephlate was its inability, at that time, to heat-seal and form an acceptable bond even with the treatment of benzoyl alcohol. It was therefore, necessary to select an adhesive to complete the fabrication. A number of commercially available materials were tried but were eliminated because of various problems of adhesive thickness and commercial back-size treatments which inhibited permanent adhesion. It is interesting to note that now commercial tapes are available which recognize this problem. It was finally decided to develop a dry adhesive which would allow positioning of the copper layers by using a hot iron to heat tack, and then compression molding to heat seal the layers together. It was determined that two polyester materials were available which would be compatible with the film. One of these was selected because of superior functioning in cold bend test. It was then necessary to obtain a source for the film coated with polyester material. The only source interested was then producing tape similar to the one desired

for their own use. Their tape used for a mechanical product would not make an electrical cable of the high quality required. It was therefore, necessary to work with the source and include pictorial inspection levels in our standard to achieve our objective.

It developed that the polychlorotrifluoroethylene copolymer material also could be used in this application and have some advantages over the polyester film. It was discovered, however, that commercial film tolerances for the thickness needed for our assembly contributed to manufacturing problems. It was, again, necessary to obtain a special source for this material.

One of our better materials has been linear polyethylene for use in structural parts. We have successfully machined the material to hold a tolerance of $\pm .010$ inch over 10.000 inches. This requires some extensive treatment throughout the manufacturing stage, but controls have been established and are producing parts.

In conclusion, we must reaffirm our belief that synthetic thermoplastic polymers are here to stay, but the road to high quality successful application is still not a smooth one. There are, we believe, basic weaknesses in polymer applications because of what we choose to call weak polymer application engineering. This may be corrected in time by the correlation of data and may be one of the problems normally associated with a new rapidly expanding field.

An area of confusion, also, exists in the avalanche of trade names. It appears at times that plastics will go the way of other fields wherein a material will have to have at least ten components, five of which may be the same, just to make it important. These materials then tend not to contribute to a reliable product but to a trade name flaunted pretty package.

A word might be offered on specifications and certifications. It seems that another confusion factor has been injected by publishing extensive data on properties without a follow-up of the control testing procedures for these materials. The inadequacy is a lack of reasonable test frequency both batchwise and in the number of tests.

It does appear sometimes that extreme competition in sales hurts the progress of the field as a whole by confused methods of data reporting. It is also somewhat dismaying to find pages and pages of good data only to be confronted by a legal exception clause at the end. Of course, it is understood that resin manufacturers cannot be accountable for subsequent processing of their materials. However, what really causes concern is the playing down or total omission of areas of data showing material short-comings. Lack of data or little data on a specific area always makes one think twice about that particular parameter. To our thinking the cautious will not suffer from this, but it cannot help but contribute to some problems among the exhuberent.

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