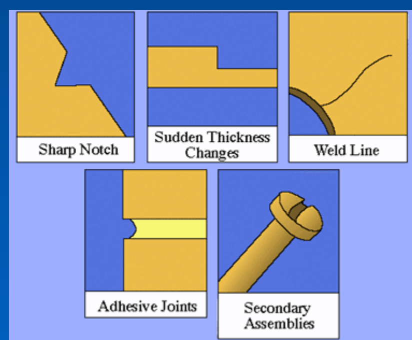
CAL POLY

POMONA

PLASTIC PARTS FAILURE ANALYSIS & PRODUCT LIABILITY PREVENTION



VISHU H. SHAH

CONSULTEK

AUGUST 23, 2006

Topics

- Plastics Part Failures – Overview
- Four Key reasons behind part failures
- Types of Failures
- Analyzing Failures – Steps and Tools
- Case Studies
- Failure Analysis Checklist
- Concurrent Engineering Practices
- Product Liability & Prevention
- Q & A

Why do parts fail?

Plastics

vs.

Metal and other traditional materials

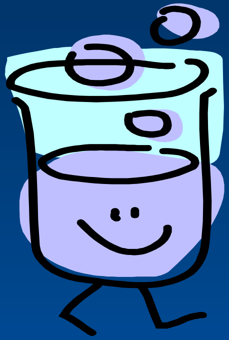
PLASTICS ARE VISCOELASTIC

Metal

Elasticity

Strength

Form-stability



Liquid

Flow characteristics

Depending on time,

Temperature, rate and amount of loading

Viscoelasticity: The tendency of plastics to respond to stress as if they were a combination of elastic solids and viscous fluids.

Viscoelastic behavior of plastics makes them sensitive to strain rate as well as temperature.

Plastics

Plastic is not Metal

- **Designing Metal parts**

  Metals usually display largely unchanged mechanical behavior right up to the vicinity of their recrystallization temperature (> 300°C).

For most applications – Designers can disregard effect of temperature, environment and long term effect of load. Rely on instantaneous stress-strain properties.

- **Designing Plastics Parts**

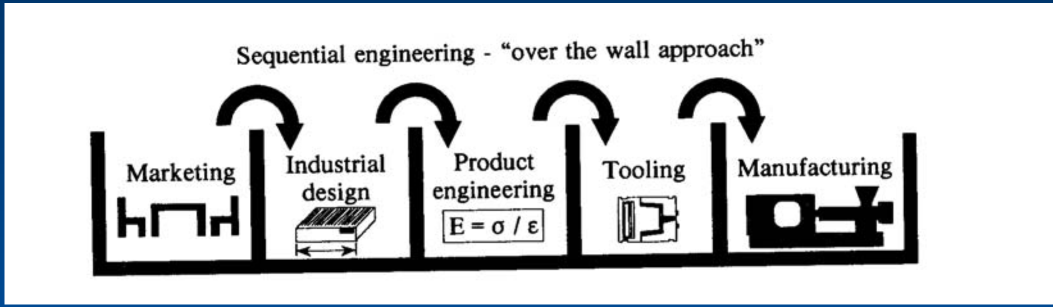
  Properties vary considerably under the influence of temperature, load, environment, and presence of chemicals.

- Synergistic effect – Most often overlooked
- Material Selection Challenge

50	Primary Types
500	Suppliers
50,000	Grades

- Processing Nightmares
  equipment/Tooling/personnel
- End-user education
- Concurrent Engineering

CONCURRENT ENGINEERING TO PREVENT FAILURES



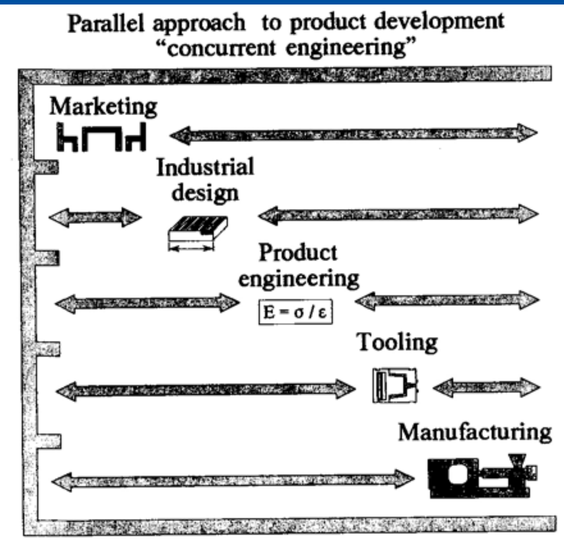
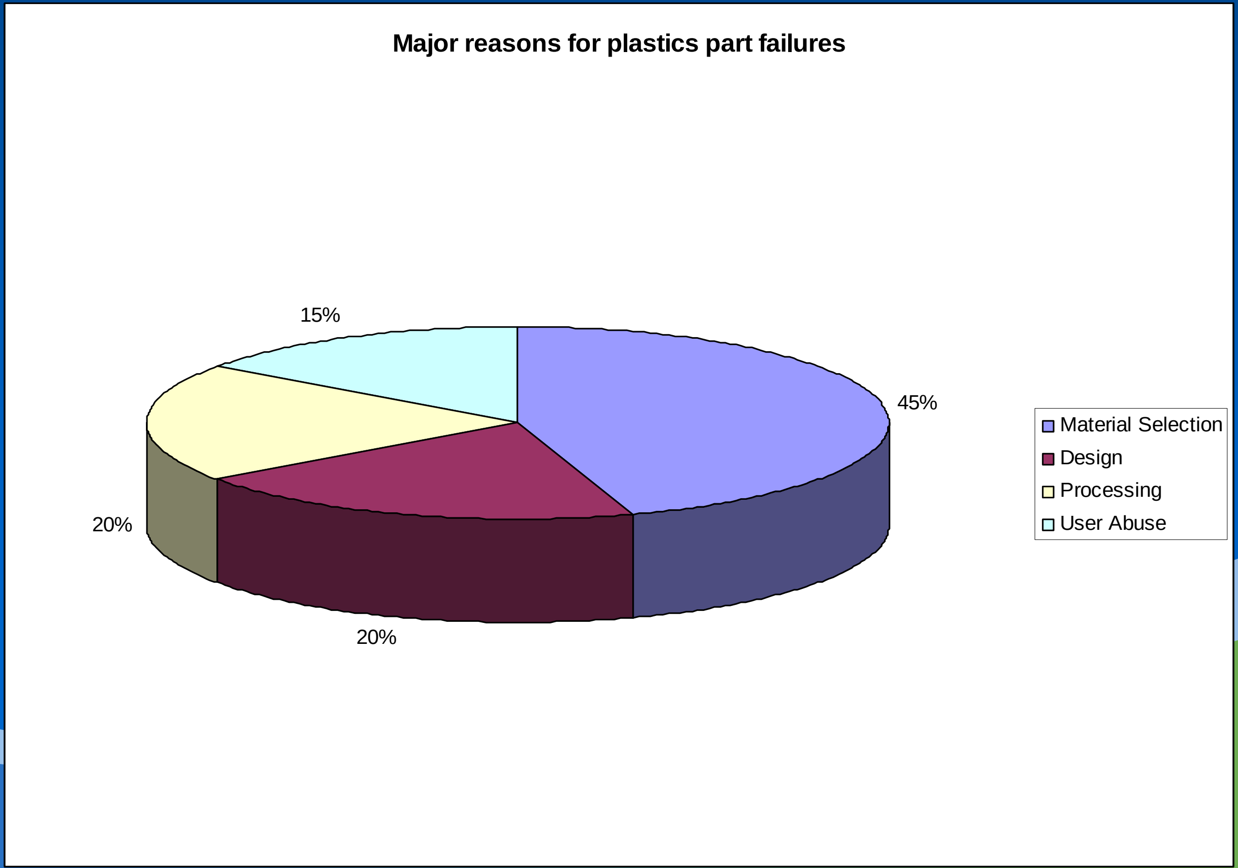


Figure 3.4. "Parallel" or "Concurrent Engineering" approaches to product design reduce development time, improves quality, and minimizes the potential for unanticipated production or performance problems.

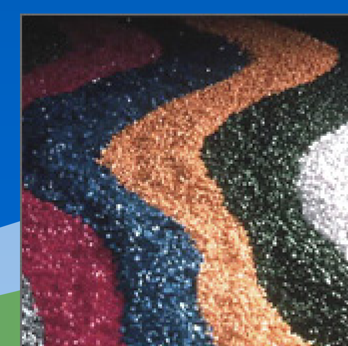
Four Key factors

1. Material Selection
2. Design
3. Process
4. Service Conditions



Material Selection Challenge

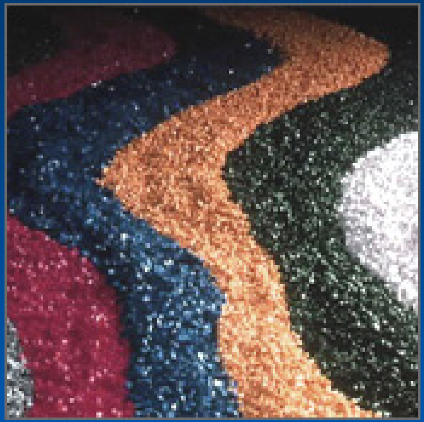
- Large Data base………50 major types – 500 suppliers – 50,000 Grades
- Standardization issues….Tests, test specimen, testing organizations
- Difficulty in comparing data on equal basis
- Lack of multipoint measurement data
- Overzealous sales and marketing efforts
- Limited educational material availability



Material Selection

Material Selection Pitfalls

- Datasheet interpretation
- Synergistic effects
- Economics
- Supplier Recommendations
- Application checklist



Material Supplier Data Sheets

- Material supplier data sheet - purpose
- Origination of data sheets
- Meaning of reported values
- How are the values generated
- Interpretation of the data
- Application of the data for practical use

Typical data sheet

Table 2. Typical Properties of Delrin

		Property[1]	Method ASTM	Method ISO	Unit	Standard Delrin Products[2] — Melt Flow Rates[1] 100	500	900	1700
Mechanical	Strength	Tensile Elongation at Break (5.1 mm/min) −55°C +23°C +70°C +100°C +121°C	D638	R527	%	38 75 230 >250 >250	15 40 220 >250 >250	10 25 180 >250 >250	— 17 — >250 >250
Mechanical	Strength	Tensile Strength (5.1 mm/min) −55°C +23°C +70°C +100°C +121°C	D638	R527	MPa	101 69 48 36 26	101 69 48 36 26	101 69 48 36 26	88 68 40 27 21
Mechanical	Strength	Shear Strength +23°C	D732	—	MPa	66	66	66	58
Mechanical	Strength	Flexural Yield Strength (1.3 mm/min) +23°C	D790	178	MPa	99	97	97	—
Mechanical	Strength	Poisson Ratio	—	—	—	0.35	0.35	0.35	0.35
Mechanical	Stiffness and Creep	Tensile Modulus (5.1 mm/min) +23°C	D638	R527	MPa	2800	3100	3100	3100
Mechanical	Stiffness and Creep	Flexural Modulus (1.3 mm/min) −55°C +23°C +70°C +100°C +121°C	D790	178	MPa	3650 2900 1550 900 600	3900 2950 1600 900 600	4130 2960 1650 950 600	4500 3000 1400 900 700
Mechanical	Stiffness and Creep	Compressive Stress (1.3 mm/min) +23°C at 1% Def. +23°C at 10% Def.	D695	604	MPa	36 124	36 124	34 121	22 106
Mechanical	Stiffness and Creep	Deformation under Load 13.8 MPa at +50°C	D621	—	%	0.5	0.5	0.5	0.9
Mechanical	Stiffness and Creep	Flexural Fatigue Endurance Limit 50% RH, +23°C, 10[6] Cycles	D671	—	MPa	32	31	32	—
Mechanical	Toughness	Tensile-Impact Strength +23°C	D1822 Long	8256 Long	kJ/m²	358	210	147	213
Mechanical	Toughness	Izod Impact (Notched) −40°C +23°C	D256	R180	J/m	96 123	64 80	53 70	53 58
Mechanical	Toughness	Izod Impact (Unnotched) +23°C	D256	R180	J/m	(no break)	(no break)	854	1060

[1] Values listed are only to be used on a comparative basis between melt flow rates. Colorants, additives, and stabilizers used in, or added to, different grades of Delrin may alter some or all of these properties. Contact DuPont for specific data sheets.

[2] Colorants, additives, and stabilizers used in, or added to, different grades of Delrin may alter some or all of these properties. Contact DuPont for specific data sheets.

[3] All of the values reported in this table are based on ASTM methods. ISO methods may produce different test results due to differences in test specimen dimensions and/or test procedures.

[4] 100ST and 500T tensile and elongation values are determined at a strain rate of 5.0 cm/min. Values for other compositions were determined at 0.5 cm/min.

Table 2. Typical Properties of Delrin

	Property[1]	Method ASTM	Method ISO	Unit	Standard Delrin Products[2] — Melt Flow Rates[1] 100	500	900	1700
Thermal	Heat Deflection Temperature[3] 1.8 MPa 0.5 MPa	D648	75	°C	125 169	129 168	130 167	123 171
Thermal	Melting Point (Crystalline)	D2117	3146	°C	175	175	175	175
Thermal	Coefficient of Linear Thermal Expansion −40 to +29°C +29 to +60°C +60 to +104°C +104 to + 149°C	D696	—	10^{-5} m/m°C	10.4 12.2 13.7 14.9	10.4 12.2 13.7 14.9	10.4 12.2 13.7 14.9	— — — —
Thermal	Thermal Conductivity			W/mK	0.4	0.4	0.4	0.33
Electrical	Volume Resistivity at 2% water, +23°C	D257	IEC 93	ohm-cm	10^{15}	10^{15}	10^{15}	10^{14}
Electrical	Dielectric Constant 50% RH, +23°C, 10^6 Hz	D150	IEC 250	—	3.7	3.7	3.7	4.7
Electrical	Dissipation Factor 50% RH, +23°C, 10^6 Hz	D150	IEC 250	—	0.005	0.005	0.005	0.011
Electrical	Dielectric Strength Short Time (2.3 mm)	D149	IEC 243	MV/m	19.7	19.7	19.7	16.0
Electrical	Arc Resistance Flame extinguishes when arcing stops (3.1 mm)	D495	—	sec	220 no tracking	220 no tracking	220 no tracking	120.0 no tracking
Miscellaneous	Water Absorption, +23°C 24 hr Immersion Equilibrium, 50% RH Equilibrium, Immersion	D570	62	%	0.25 0.22 0.90	0.25 0.22 0.90	0.25 0.22 0.90	— — —
Miscellaneous	Rockwell Hardness	D785	2039	—	M94, R120	M94, R120	M94, R120	M91, R122
Miscellaneous	Combustibility[4]	UL94	—	—	94HB	94HB	94HB	94HB
Miscellaneous	Coefficient of Friction (no lubricant)[5] Static Dynamic	D3702	—	— — —	0.20 0.35	0.20 0.35	0.20 0.35	— —
Miscellaneous	Specific Gravity[7]	D792	R1183	—	1.42	1.42	1.42	1.41
Miscellaneous	Melt Flow Rate[8]	D1238	1133	g/10 min	1.0	6.0	11.0	16.0
Miscellaneous	Chemical Resistance[6]	All resins have outstanding resistance to neutral chemicals including a wide variety of solvents.						

[1] Values listed are only to be used on a comparative basis between melt flow rates. Colorants, additives, and stabilizers used in, or added to, different grades of Delrin may alter some or all of these properties. Contact DuPont for specific data sheets.

[2] Colorants, additives, and stabilizers used in, or added to, different grades of Delrin, may alter some or all of these properties. Contact DuPont for specific data sheets.

[3] All of the values reported in this table are based on ASTM methods. ISO methods may produce different test results due to differences in test specimen dimensions and/or test procedures.

[4] The UL 94 test is a laboratory test and does not relate to actual fire hazard.

[5] Thrust washer test results depend upon pressure and velocity. The test conditions for Delrin were 10 fpm (50 mm/s) and 300 psi (2 MPa) rubbing against AISI carbon steel, Rc 20 finished to 16 μm (AA) using a Faville-LeValley rotating disk tester.

Typical Data Sheet

Product Data

RADEL® R
polyphenylsulfone

R-5000, R-5100 NT15, R-5500

RADEL R polyphenylsulfone resins offer exceptional hydrolytic stability, and toughness superior to other commercially-available, high-temperature engineering resins. They offer high deflection temperatures and outstanding resistance to environmental stress cracking. The polymer is inherently flame retardant, and also has excellent thermal stability and good electrical properties.

RADEL R resins are available as an opaque general purpose injection molding grade–R-5100 NT15, a transparent injection molding grade–R-5000, and a transparent extrusion grade–R-5500.

Typical Properties of RADEL R-5000, R-5100 NT15, and R-5500 Resins

Property	ASTM Test Method	Typical Values[(1)] U.S. Customary Units Value	U.S. Customary Units Units	SI Units Value	SI Units Units
Mechanical					
Tensile Strength	D 638	10.1	kpsi	70	MPa
Tensile Modulus	D 638	340	kpsi	2.3	GPa
Tensile Elongation at yield	D 638	7.2	%	7.2	%
Tensile Elongation at break	D 638	60-120	%	60-120	%
Flexural Strength[(2)]	D 790	13.2	kpsi	91	MPa
Flexural Modulus	D 790	350	kpsi	2.4	GPa
Tensile Impact Strength	D 1822	190	ft-lb/in^2	400	kJ/m^2
Izod Impact, Notched	D 256	13	ft-lb/in	690	J/m
Thermal					
Deflection Temperature at 264 psi (1.82 MPa)	D 648	405	°F	207	°C
Flammability Rating[(3)]	UL-94	V-0	0.030 in	V-0	0.75 mm
Coefficient of Thermal Expansion	D 696	31	ppm/°F	56	ppm/°C
Glass Transition Temperature[(4)]		428	°F	220	°C
Electrical					
Dielectric Strength at 0.125 in. (3.2 mm)	D 149	380	V/mil	15	kV/mm
Dielectric Strength at 0.001 in. (0.02 mm)		>5,000	V/mil	>200	kV/mm
Dielectric Constant at 60 Hz	D 150	3.44		3.44	
Volume Resistivity	D 257	9×10^{15}	ohm-cm	9×10^{15}	ohm-cm
Chemical					
Steam Sterilization[(5)] w/ Morpholine, cycles passed without cracking, crazing, or rupture		>1000	cycles	>1000	cycles
Water Absorption at 24 hours	D 570	0.37	%	0.37	%
Water Absorption at Equilibrium	D 570	1.10	%	1.10	%

General and Fabrication		R-5000	R-5100 NT15	R-5500
Specific Gravity	D 792	1.29	1.30	1.29
Refractive Index	D 542	1.672	opaque	1.672
Melt Flow at 689°F (365°C), 5.0 kg, g/10 min	D 1238	17	17	11.5
Mold Shrinkage, %	D 955	0.7	0.7	0.7

(1) Actual properties of individual batches will vary within specification limits. Unless otherwise specified, properties were measured using one-eighth inch (3.2 mm) thick injection molded specimens.

(2) at 5% strain

(3) These flammability ratings are not intended to reflect hazards presented by these or any other materials under actual fire conditions.

(4) Measured by differential scanning calorimetry at a heating rate of 36°F (20°C) per minute.

(5) Steam Autoclave Conditions : Temperature - 270°F 132°C; Time - 30 minutes/cycle; Steam Pressure - 27 psig 0.19 MPa; Stress Level - 1000 psi 7.0 MPa) in flexure; Additive - Morpholine at 50 ppm.

Typical Data Sheet

Product Information

STYRON

General Purpose Polystyrene Resins

685

STYRON 685 high heat resin is designed for medium-to-thick section applications, appliance parts, housewares, foam sheet, and oriented film.

- Izod Impact Strength[1] 0.25
- Melt Flow Rate 2.4
- Vicat Softening Point .... 224°F

Properties
- High heat resistance
- Excellent clarity
- Good moldability
- FDA compliance

Process
- Injection molding
- Extrusion
- Blow molding

Properties[1]	ASTM Method	Compression Molded	Injection Molded
Yield Tensile Strength[2], psi	D 638	6,200	7,900
kgf/cm²		435	555
Ultimate Tensile Strength[2], psi	D 638	6,200	7,900
kgf/cm²		435	555
Yield Elongation, %	D 638	1.5	2.4
Ultimate Elongation, %	D 638	1.5	2.4
Tensile Modulus[3], psi	D 638	470,000	485,000
kgf/cm²		33,000	34,000
Izod Impact Strength,			
ft lbf/in of notch @ 73°F	D 256	0.25	0.45
cm kgf/cm of notch @ 23°C		1.3	2.4
Hardness, Rockwell M	D 785	76	76
Deflection Temperature Annealed,			
°F @ 264 psi	D 648	214	212
°C @ 18.6 kgf/cm²		101	100
Vicat Softening Point, °F	D 1525	224	
°C	(Rate B)	107	
Melt Flow Rate, g/10 min	D 1238 (Cond. G)	2.4	
Specific Gravity	D 792	1.04	

[1]These are typical property values, intended only as guides, and should not be construed as sales specifications.
[1]Measured in ft lbf/in of notch at 73°F on compression molded samples.
[2]Tensile properties obtained at a crosshead speed of 0.2 in/min (0.51 cm/min); gage length of 2.0 in (5.1 cm); span of 4.5 in (11.4 cm).
[3]Tensile modulus obtained at a crosshead speed of 0.05 in/min (0.13 cm/min). Test specimen thickness 1/8 in (0.32 cm).

— Handling Considerations, see reverse side

DOW CHEMICAL U.S.A. • OLEFINS AND STYRENICS, PLASTICS DEPARTMENT • MIDLAND, MI 48674

DOW

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Purpose of a data Sheet

- Compare property values of different plastics materials (Tensile strength of nylon vs. Polystyrene, Impact strength of ABS vs. Polycarbonate)
- Quality control guidelines for material manufacturers
- Purchasing/Material specifications
- Initial screening of various materials

Data Sheets Are <u>NOT</u> Meant to Be Used for

- Engineering design
- Final(ultimate) material selection

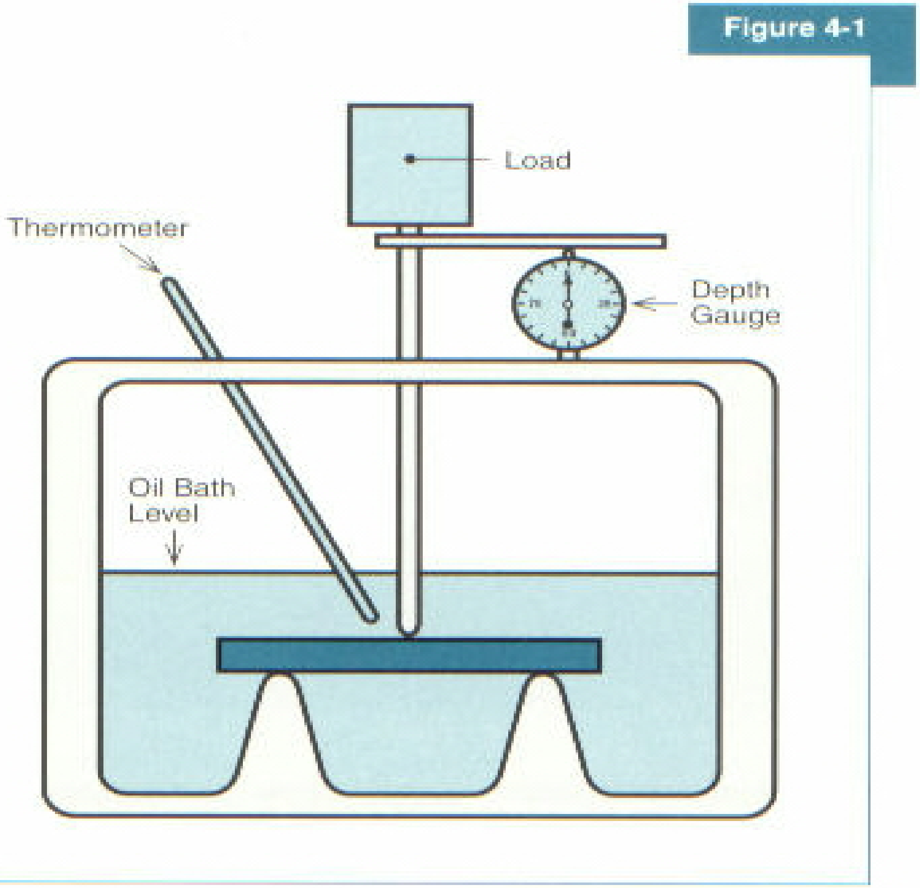
- Why?

- Reported data generally derived from short term tests
- Usually from single point measurement
- Laboratory conditions
- Standard test bars
- Values are generally higher and do not correlate with actual use conditions

HDT vs. CONTINUOUS USE TEMPERATURE(UL TEMPERATURE INDEX)

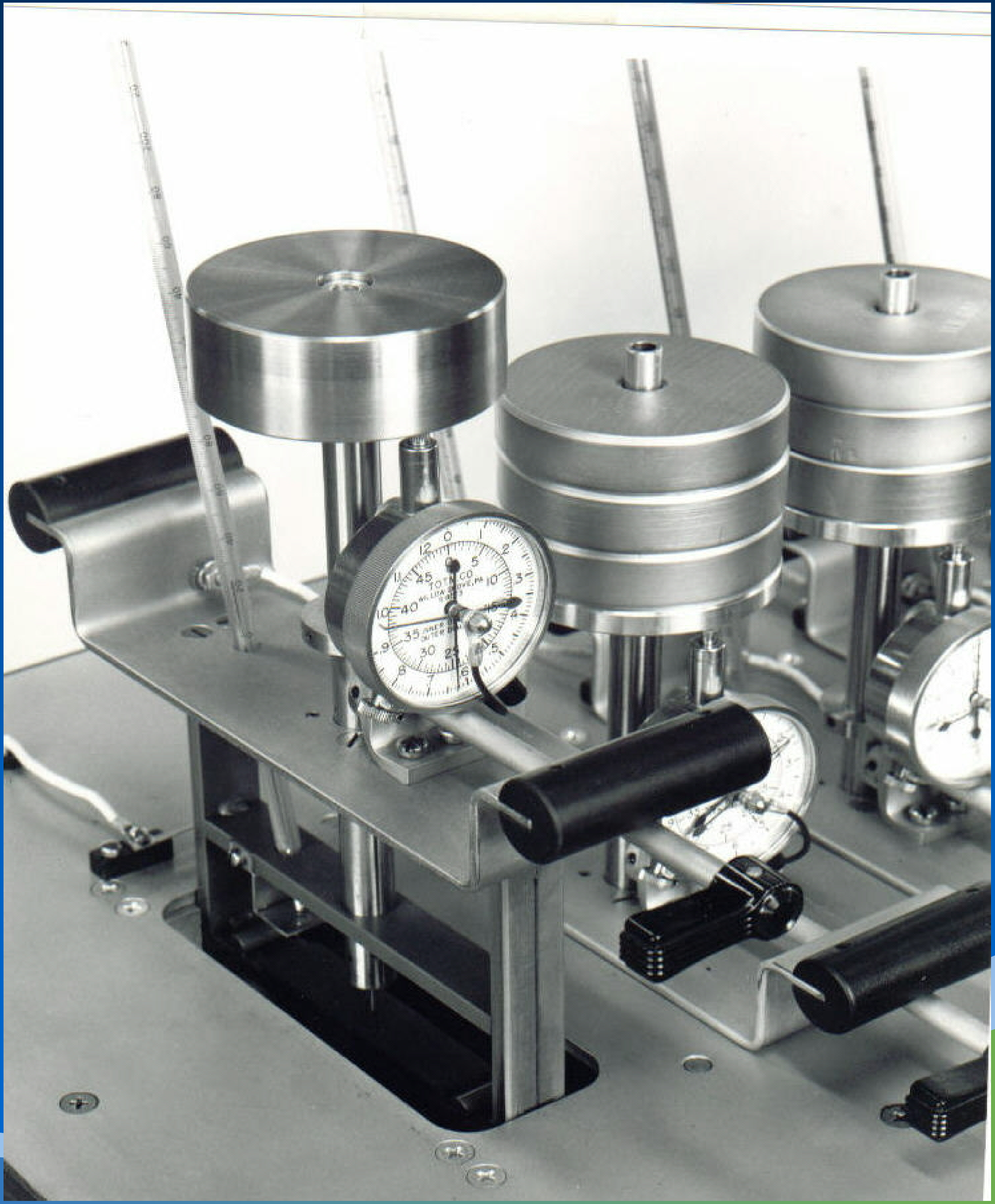
Material	HDT	Continuous Use Temp.
Ryton R-4 (Polyphenylene Sulfide)	>500 °F	338 °F
Ultem 4000 (Polyetherimide)	412 °F	122 °F
Delrin 100AL	325 °F	122 °F

HDT (DTUL) TEST



Test apparatus for deflection temperature under load (DTUL).

HDT Test



Continuous use Temperature

UL's relative Thermal Index based upon historical records

Material °C	Generic Thermal Index
Nylon (type 6, 6/6, 6/10, 11)	65
Polycarbonate	80
Phenolic	150
PTFE	180
RTV Silicone	105
PET Film	105

Failure resulting from Selecting incorrect material from short term thermal test data

Figure 6-8 IPS salad bowls deformed and cracked due to washing in dishwasher

Material Selection Process

- Define requirements
- Narrow down choices…process of elimination…clear vs. opaque
- Rigid, flexible, elastomeric?
- Specific application? Medical?
- Material selection guidelines
- Specific property requirement…

Material Selection Process

- **Identify application requirements**
  Mechanical (Load, Stiffness, Impact etc.)
  Thermal (temperature range, Maximum use temperature, etc)
  Environmental considerations (Weather, UV, Moisture)

- **Identify the chemical environment**
  Define the chemical stress, temperature, contact time, type of chemical

- **Identify special needs**
  Regulatory (UL, FDA, NSF, etc.)
  Outdoor or UV exposure
  Light transmission, Fatigue and creep requirements

- **Define Economics**

- **Define Processing Considerations**
  Type of Process (Injection Molding, Extrusion, Blow Molding, Thermoforming, etc.)
- **Define Assembly requirements**
  Painting/Plating
  Shielding
- **Search history for similar commercial applications**

Identifying Application Requirements

- **Physical Properties**
  Specific Gravity
  Mold Shrinkage
  Rheology

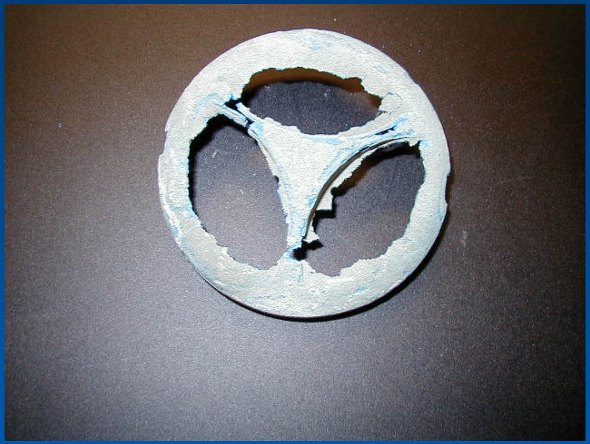
- **Mechanical Properties**
  Tensile Strength
  Tensile Modulus (Stiffness-Resistance to bending)
  Tensile Elongation/Ductility
  Impact strength
  Fatigue Endurance (Resistance to high frequency cyclic loading)
  Creep resistance (Resistance to long-term deformation under load)
- **Thermal Properties**
  Deflection Temperature Under Load (DTUL,HDT)
  Thermal Conductivity
  Thermal expansion coefficient (Problems in Piping systems, Example Expansion Joints)
  Continuous Use Temperature (Relative thermal Index)
- **Regulatory Performance**
  Flammability (UL 94)
  High Voltage Arc Tracking
  FDA

Source: GE Plastics

Identifying Application Requirements *(cont.)*

- **Environmental Considerations**

Exposure to UV, IR, X-Ray
High humidity
Weather Extremes
Pollution: Industrial chemicals
Microorganisms, bacteria, fungus, mold



The combined effect of the factors may be much more severe than any single factor, and the degradation processes are accelerated many times.

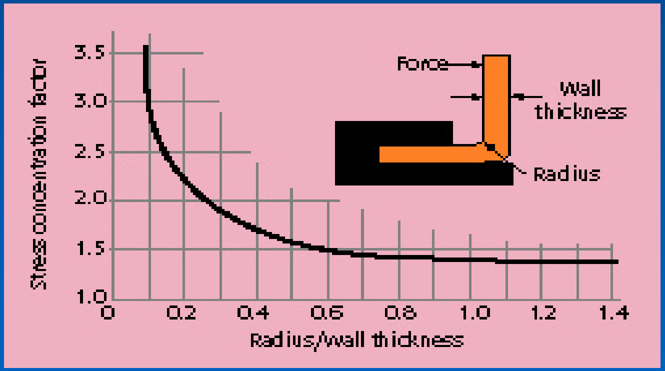
Published test results do not include synergistic effects…always existent in real -life situations.

Identifying Application requirements (Cont.)

- **Chemical Behavior/Chemical resistance**

Resistance of Thermoplastics to various chemicals is dependent on:

- Time (of contact with chemical)
- Temperature
- Stress (Molded-in or External)
- Concentration of the chemical



- **Chemical Exposure may result in:**

- Physical Degradation - Stress cracking, Crazing, Softening, Swelling, Discoloration
- Chemical Attack – Reaction of chemical with polymer and loss of properties

Chemical Exposure

TABLE 7.3 SOME CHOICE MATERIALS

Property	Thermoplastics	Thermosets
Low temperature	TFE	DAP
Low cost	PP, PE, PVC, PS	phenolic
Low gravity	polypropylene methylpentene	phenolic/nylon
Thermal expansion	phenoxy glass	epoxy-glass
Volume resistivity	TFE	DAP
Dielectric strength	PVC	DAP, polyester
Elasticity	EVA, PVC, TPR	silicone
Moisture absorption	chlorotrifluroethylene	alkyd-glass
Steam resistance	polysulfone	DAP
Flame resistance	TFE, PI	melamine
Water immersion	chlorinated polyether	DAP
Stress craze resistance	polypropylene	all
High temperature	TFE, PPS, PI, PAS	silicones
Gasoline resistance	acetal	phenolic
Impact	UHMW PE	epoxy-glass
Cold flow	polysulfone	melamine-glass
Chemical resistance	TFE, FEP, PE, PP	epoxy
Scratch resistance	acrylic	allyl diglycol carbonate
Abrasive wear	polyurethane	phenolic-canvas
Colors	acetate, PS	urea, melamine

Material selection using multi-point data

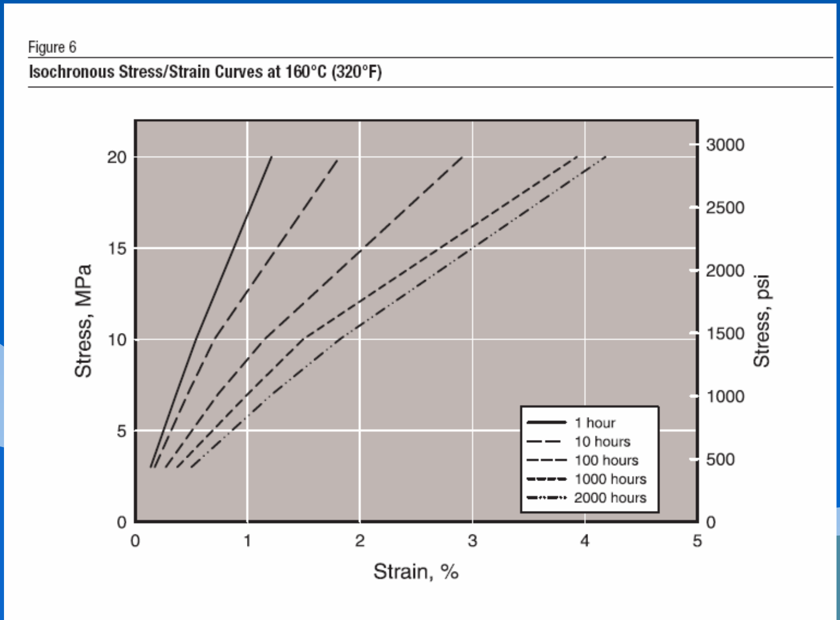
- Data sheets with single point measurement readily available
- Data sheets with multi point data - ask supplier

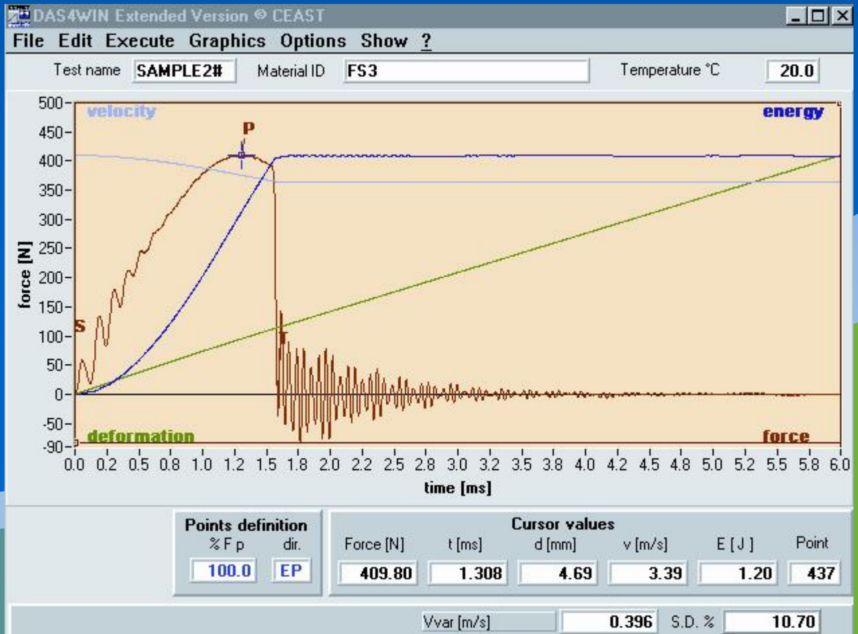
Multi-point data

Isochronous stress-strain curves

Multi point (Load- energy-time) Impact data

Multi point thermal data





New Application Checklist

This checklist includes critical considerations for new part development.
Its use will help provide a more rapid and more accurate recommendation.

Name ______________________ Date ______________________
Customer ______________________ Part ______________________

Project timing ______________________
Driving force ______________________
Current product ______________________
Its performance ______________________

Comments ______________________

***Part Function** — What is the part supposed to do?* ______________________

Appearance

Clear

- ☐ water clear
- ☐ very clear
- ☐ generally clear, maximum haze level: ________
- ☐ transparent color, maximum haze level: ________

Comments: ______________________

Opaque

- ☐ high gloss
- ☐ medium gloss
- ☐ low gloss
  - ☐ from the plastic ☐ from paint ☐ from the mold

Comments: ______________________

Colors desired: ______________________

☐ from the plastic ☐ from paint ☐ from both

Criticality of color match: ________ %

☐ daylight ☐ tungsten light ☐ fluorescent light ☐ all (no metamerism allowed)

Comments: ______________________

***Critical appearance areas** — please attach sketch*

	None	Invisible	Minor	OK
gate blemishes	☐	☐	☐	☐
sink marks	☐	☐	☐	☐
weld lines	☐	☐	☐	☐

Comments: ______________________

***Critical structural areas** — please attach sketch*

Comments: ______________________

Monsanto Plastics
Where the best end products begin.

***Required physical characteristics** — please attach sketch*

	not too important	from plastic	from design	from both
Rigidity	☐	☐	☐	☐
Strength (load bearing)	☐	☐	☐	☐
Heat resistance	☐	☐	☐	☐
Creep resistance	☐	☐	☐	☐
Impact resistance	☐	☐	☐	☐
Chemical resistance	☐	☐	☐	☐
Electrical properties	☐	☐	☐	☐

Details:

applied load/stress	☐ static load	☐ pressure	☐ cyclic
amount	normal ____	min. ____	max. ____
duration	normal ____	min. ____	max. ____
frequency (if cyclic)	normal ____	min. ____	max. ____
operating temperature	normal ____	min. ____	max. ____
operating lifetime	normal ____	min. ____	max. ____

Comments: ____________________

impact resistance

room temp.	acceptable ____	min. ____
low temp., ____ °C/°F	acceptable ____	min. ____

Comments: ____________________

dimensional tolerances

deflection (under stress)	acceptable ____	max. ____
expansion (thermal)	acceptable ____	max. ____
shrinkage (mold)	acceptable ____	max. ____
creep	acceptable ____	max. ____

Comments: ____________________

electrical properties

dielectric constant	acceptable ____	min. ____
dissipation factor	acceptable ____	max. ____
volume resistivity	acceptable ____	min. ____
dielectric strength	acceptable ____	min. ____

Comments: ____________________

chemical resistance (List chemicals, frequency & duration of exposure, part stress/strain level, and type of resistance required.)

____

permanence	not too important	from plastic	from paint, etc.
color stability, indoor	☐	☐	☐
color stability, outdoor	☐	☐	☐
property retention, outdoor	☐	☐	☐

Comments: ____________________

***Required physical characteristics** — continued*

miscellaneous

Rockwell hardness	target ____	min. ____	max. ____

Others: ____________________

Regulatory Approvals Required?

- ☐ Underwriters Laboratory, Inc.
  - ☐ U.L. 94 — rating ________ thickness ________
  - ☐ R.T.I. — electrical ______ °C mechanical ______ °C with impact ______ °C
- ☐ National Sanitation Foundation — type ________________
- ☐ Federal Specifications (Mil. Specs.) — type ________________
- ☐ Canadian Standards Administration — type ________________
- ☐ Food and Drug Association — type ________________
- ☐ U. S. Pharmacopeia — type ________________
- ☐ Automotive Specifications — type ________________
- ☐ Other: — type ________________

Comments: ____

____

____

Process

- ☐ Extrusion
  - ☐ profile extrusion
  - ☐ sheet extrusion — monolayer
  - ☐ sheet extrusion — co-extruded
  - ☐ thermoforming
  - ☐ extrusion/blow molding

  Comments: ____

  ____

  ____

- ☐ Injection Molding

  Comments: ____

  ____

  ____

- ☐ Secondary Operations
  - ☐ decorating
    - ☐ painting
    - ☐ plating
    - ☐ hot stamping
    - ☐ laminating
  - ☐ assembly
    - ☐ gluing
    - ☐ sonic welding
    - ☐ vibrational welding
    - ☐ mechanical assembly

  Comments (What is attached to what, difference in types of plastic, etc.?)

  ____

  ____

Customer Part Testing Requirements

____

____

____

____

Final Comments

____

____

____

____

____

____

Why Reinvent the Wheel?

Search history for similar commercial applications

Material Selection

Previous Applications

Before addressing a detailed material selection process, it is often worthwhile to determine if a similar part has been made before, and if so, from which material it was made. If such an application exists, it may be advisable to conduct further investigation into the specifics of the particular application to see whether newer or more appropriate materials can now be used.

Since it is impossible to list all applications – some grades are used for a multitude of parts in many industries – a relatively limited number has been listed.

This Application Matrix provides an overview of some typical applications in some of the numerous market segments served by GE Plastics.

For further information on a particular grade, please contact your local GE Plastics' representative.

Table 1-6. Application Matrix.

Products		Automotive Interior
CYCOLAC ABS Resin	• ease of molding • surface quality • thermal stability • impact resistance • wide range of colors	Instrument clusters and panels; glove box lids; pillar trim, vents, speaker grilles; door liners, pock ets; seat covers and knobs; ash trays; steering column covers; c soles, cladding
CYCOLOY PC/ABS Resin	• ease of molding • very good flow • low temperature impact • very good indoor UV stability • flame resistance	Dashboard components and car ers, center consoles; glove boxe pillar trim, vents, grilles; air nozz parcel shelves
ENDURAN PBT Resin	• chemical and stain resistance • dimensional stability • low water absorption • very good processibility • noise attenuation	
GELOY ASA Resin	• excellent weatherability • heat resistance • impact resistance • aesthetics, colorability	Dashboard and door skins
GESAN SAN Resin	• clarity • chemical resistance • very good flow • thermal stability	Instrument lenses
LEXAN PC Resin	• transparency • high impact • dimensional stability • temperature resistance • flame resistance	Seat belts; boot panels; speaker grilles; dashboard components, instrument panels and clusters, center consoles; heater covers; instrumentation lenses
NORYL Modified PPO Resin	• electrical properties • dimensional stability • hydrolysis resistance • temperature resistance • low water absorption • flame resistance	Dashboards and components, instrument clusters, center con soles; glove boxes, vents, grilles ashtrays; panel trim; airducts, a nozzles; steering wheel parts; p cel shelves; roof liners; seats; s belts, armrests, headrests; hand winders
NORYL GTX PPE/PA Resin	• on-line paintability • low temperature impact • temperature resistance • chemical resistance • low mold shrinkage	Dashboard components, center consoles; parcel shelf speaker covers; headrest frames; demis rails; heater covers; air nozzles vents, grilles; seat-parts; switch
SUPEC PPS Resin	• chemical resistance • inherent flame resistance • heat resistance • high strength • very good electrical properties	
ULTEM PEI Resin	• chemical resistance • temperature resistance • dimensional stability • inherent flame resistance	
VALOX PBT Resin	• very good electrical properties • chemical resistance • temperature resistance • flame resistance • fast molding	Dashboard components, conne tors instrument clusters; windo cranks, door handles; pillar trim
XENOY PC/PBT Resin	• high impact resistance • chemical resistance • dimensional stability • UV stability	Structural components for dash boards and instrument clusters door liners and cladding; boot p els; roof liners; seat component sunroof components; door hand

Material Selection

Table 1-6. (Continued)

Products	Appliances	Office Automation	Communication Equipment
CYCOLAC ABS Resin	Bathroom and kitchen appliances; vacuum cleaners, refrigerator door liners and panels, fans; covers, fronts and panels for washing machines; food preparation: mixers, processors, fruit presses; dental showers; lawn mower housings	Components and housings for business machines: computers, copying machines, printers, paper trays, cassettes, calculators; keyboard caps and housings	Telephones: cordless handsets; cassettes; terminals
CYCOLOY PC/ABS Resin	Coffee makers, hairdryers, irons, mixers; shower backplates; control panels; computer housings: terminals, towers, desktops, laptops, notebooks, palmtops; printer housings and components; copier parts	Structural components and housings for business machines: computers, printers, copiers, fax machines	Telephones: portable phones, car phones; telephone racks; modems; fax machine components; franking machines; battery chargers
ENDURAN PBT Resin	Speaker housings; oven handles, iron handles, shaver handles		
GELOY ASA Resin			Outdoor, telecom
GESAN SAN Resin	Small appliances: blender jars, mincer jars, water pitchers, fans	Inkjet cassette housings, clear covers	Inkjet cassette housing, clear covers
LEXAN PC Resin	Chainsaw housings; iron handles, heated combs, hairdryers; food mixers and processors; sewing machines; air filters; mini vacuum cleaners; oven doors; components for dishwasher and laundry washing machines	Structural components for business machines: chassis, frames, covers; paper trays, brackets and supports, card cages, copier internals, disk drives, terminals; barcode scanners; smart cards; cassettes, cartridges	Exchange equipment; switchboards; telephone modems and housings; smart cards
NORYL Modified PPO Resin	Washing machines, dryers, dishwasher components; vacuum cleaners, hairdryers, mixers, coffee makers	Business machine chassis, frames and housings; components for computers, printers, copiers; keyboard parts	Telephone components
NORYL GTX PPE/PA Resin	Laundry washer and dryer doors, top loader frames, powder coatable panels; electrical engine frames; diffusors, gears, impellers		
SUPEC PPS Resin			
ULTEM PEI Resin	Hot combs, styling brushes, internal hairdryer parts; microwave oven parts; food preparation appliances; iron reservoirs	Disk drive cartridges, cooling fans; copier gears; sleeve bearings	Molded circuit boards, molded interconnect devices; telephone components
VALOX PBT Resin	Various housings such as chainsaw – grinder – powertool housings; vacuum cleaners, irons, coffeemakers, oven grilles, mixers, deep fat fryers, toasters; handles and knobs; motor components	Components for business machines: fans, fan housings, frames, keys and keyboards, switches, connectors	Components for telephones
XENOY PC/PBT Resin	Grinder and powertool housings, lawn mower decks, snowblowers, weed trimmers		Wire and cable; fiber optic tubing

Material Selection using Web

- Matweb www.matweb.com

MatWeb, Your Source for Materials Information

- Ides www.ides.com

The Plastics Industry at Your Fingertips!

- Plaspec www.plaspec.com

Failure resulting from improper material selection

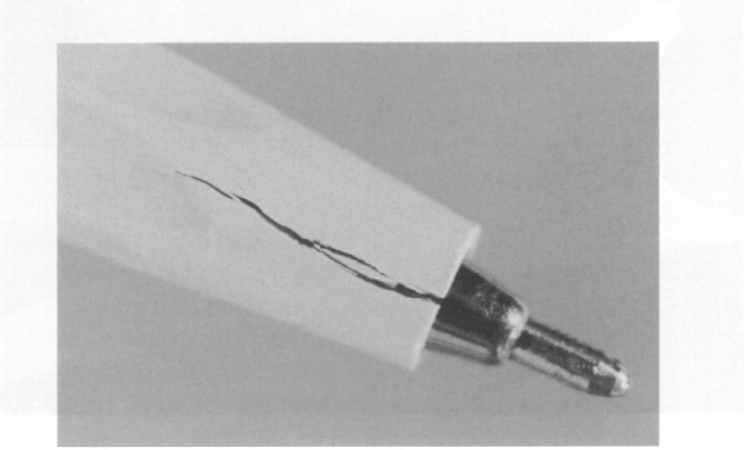


Figure 4-35 Impact polystyrene ballpoint pen barrel that cracked first or second time pen was used

Designing Plastics Parts

- With exception of few basic rules in designing plastic parts, the design criteria changes from material to material & application to application
- Challenge: Economics, functionality, manufacturability and aesthetics
- Compromise & trade offs lead to failures
- Systematic approach to developing new product

Design

Most Common Mistakes in Design of Plastics

- Non-uniform wall thickness
- Sharp corners, lack of radius
- Draft angle considerations
- Thread design
- Lack of Creep considerations
- Lack of Environmental considerations
- Direct conversion from other materials

Wall Thickness

Basic Rules

- Nominal Wall thickness - 0.250 or less
- Transition must be less than +/- 25% nominal wall thickness, gradual transition is the best
- Draft greater than 1 degree preferred
- Draft for textured parts +/- 1 degree for every 0.001 inch of textured depth

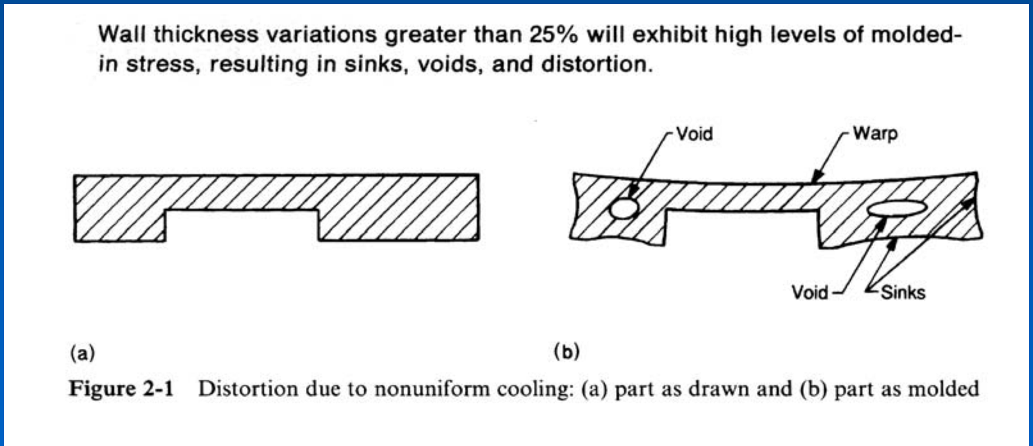
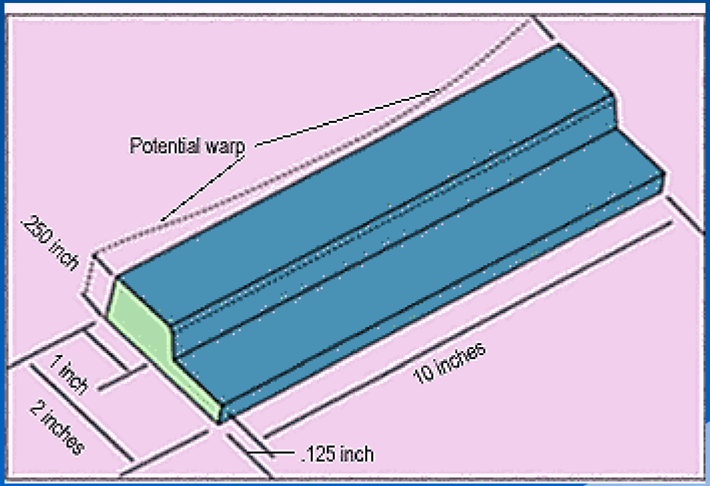


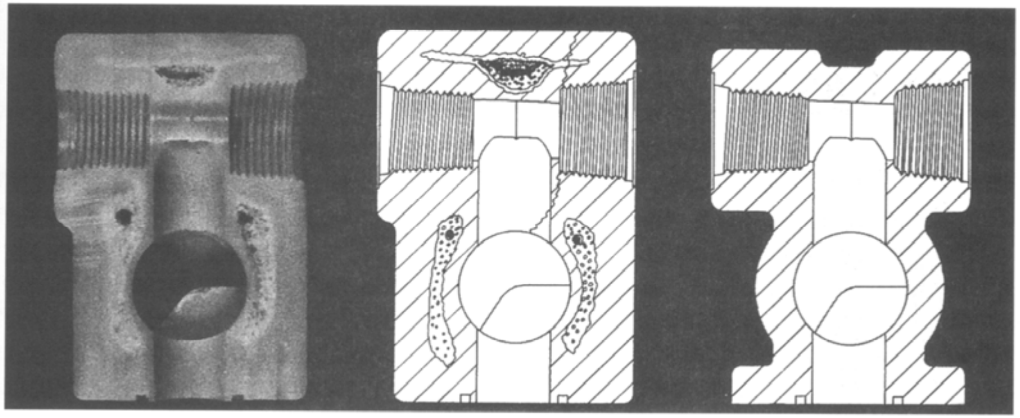
Figure 2-1 Distortion due to nonuniform cooling: (a) part as drawn and (b) part as molded



Higher the shrinkage, Greater the warp

How does wall thicknesses variations affect material flow in the mold?

Wall thickness related failures



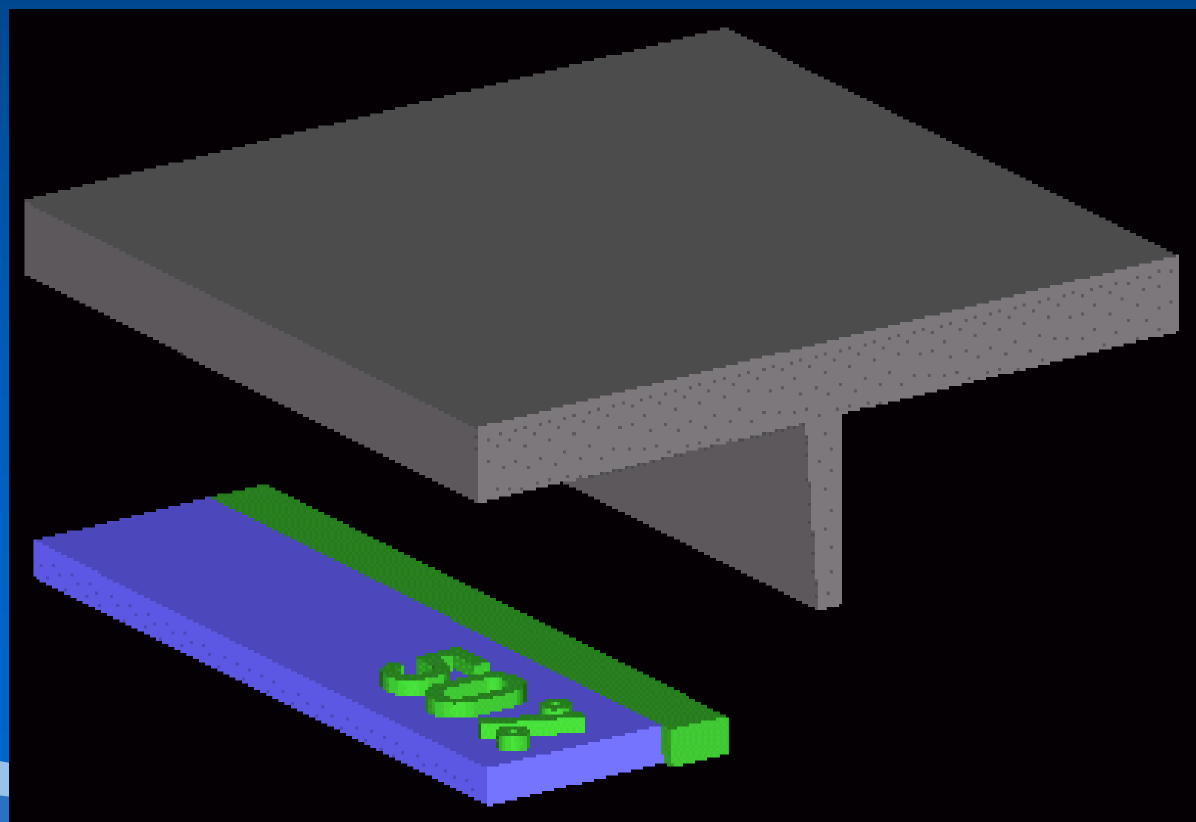
A B C

Figure 4-13 A. Acetal valve body design problem—photograph of interior ([1] Fig. 1, reproduced with permission). B. Diagram showing voids in acetal valve of Fig. 4-13A ([1] Fig. 2, reproduced with permission). C. Diagram showing improved design of acetal valve ([1] Fig. 3, reproduced with permission)

THE DIVINE 66% RULE

The thickness of ribs should never exceed 66% of the nominal wall thickness.

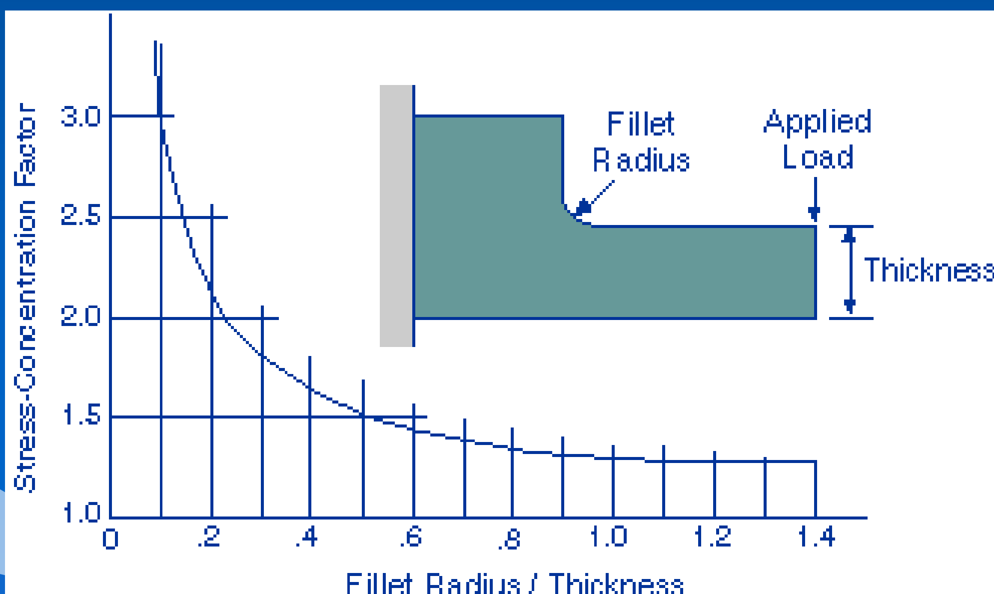
If your ribs never exceed 50-66% of nominal wall thickness you will never have a problem with sink.

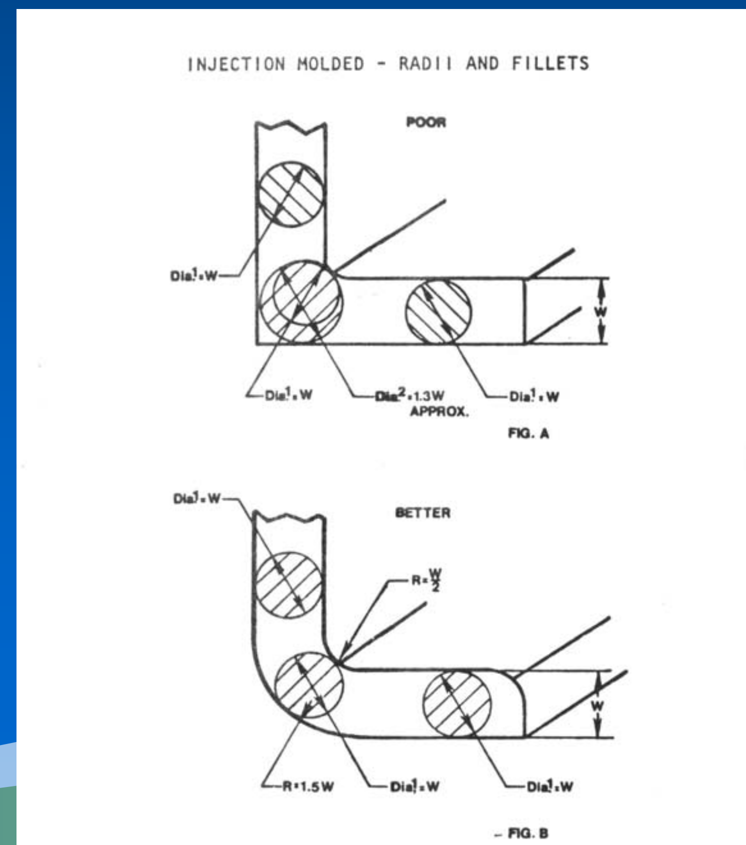


Radii

Rules.......

- Avoid sharp corners at all costs
- Radii for inside corners........50% nominal wall thickness R1 = W/2
- Radii for outside corners.....150% nominal wall thickness R2 = 1.5 W or R2 = R1 + W

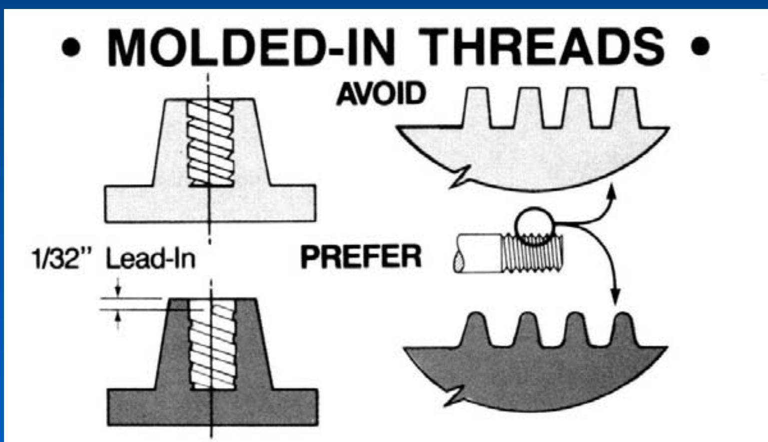


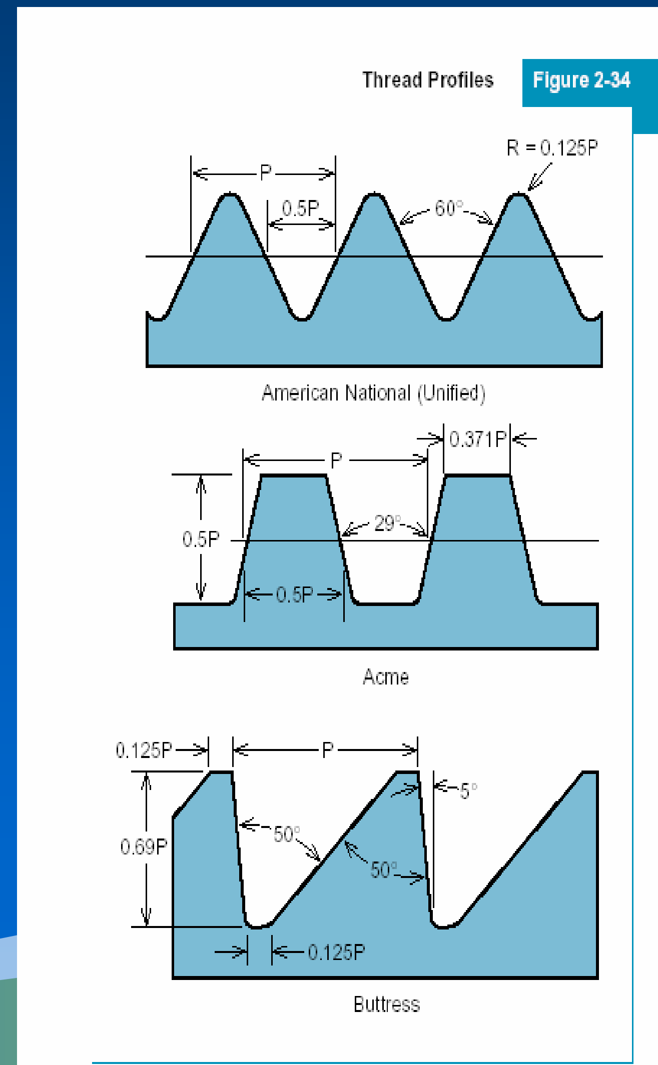


Radii

Threads

- Threads must have radii……no flat or "V" notched at root and crest
- Pitch should be less than 1/32 in.
- Lead depth must be greater than 1/32 in.

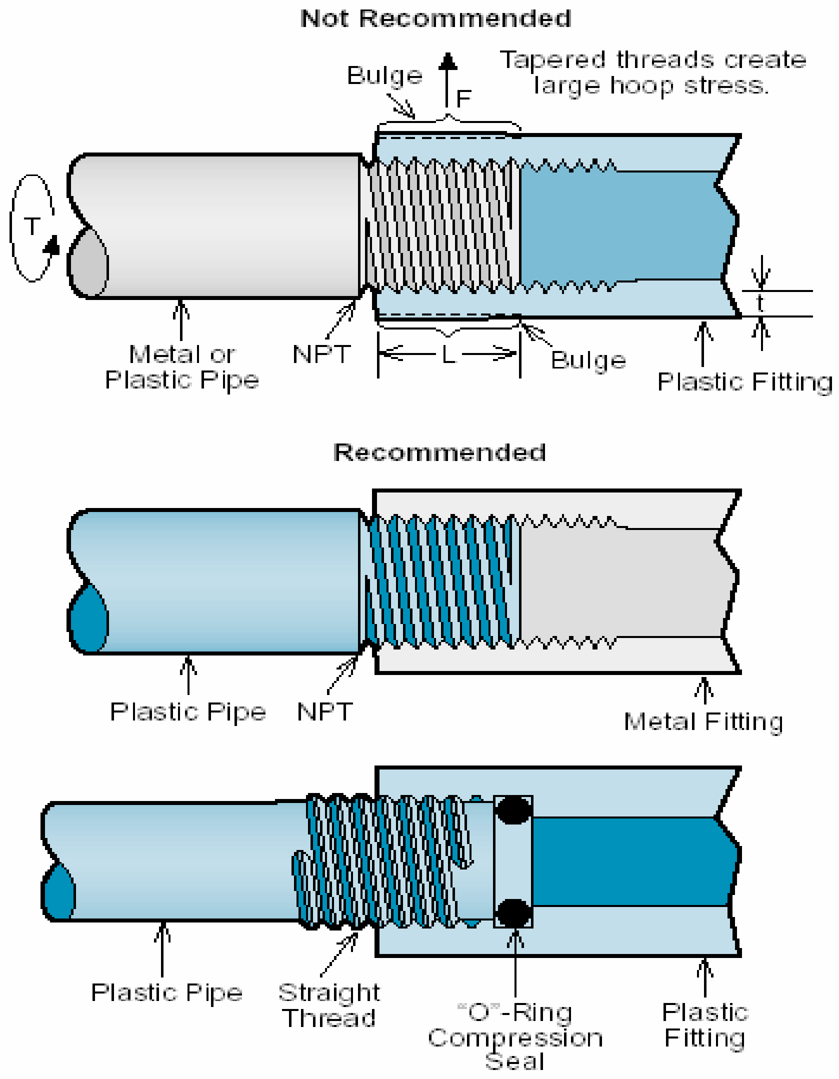




Common thread profiles used in plastic parts.

Threads

Figure 2-36 **Pipe Threads**

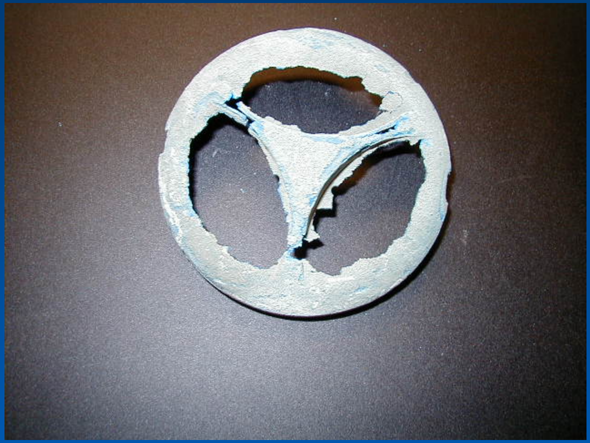


Standard NPT tapered pipe threads can cause excessive hoop stresses in the plastic fitting.

Identifying Application Requirements *(cont.)*

- **Environmental Considerations**

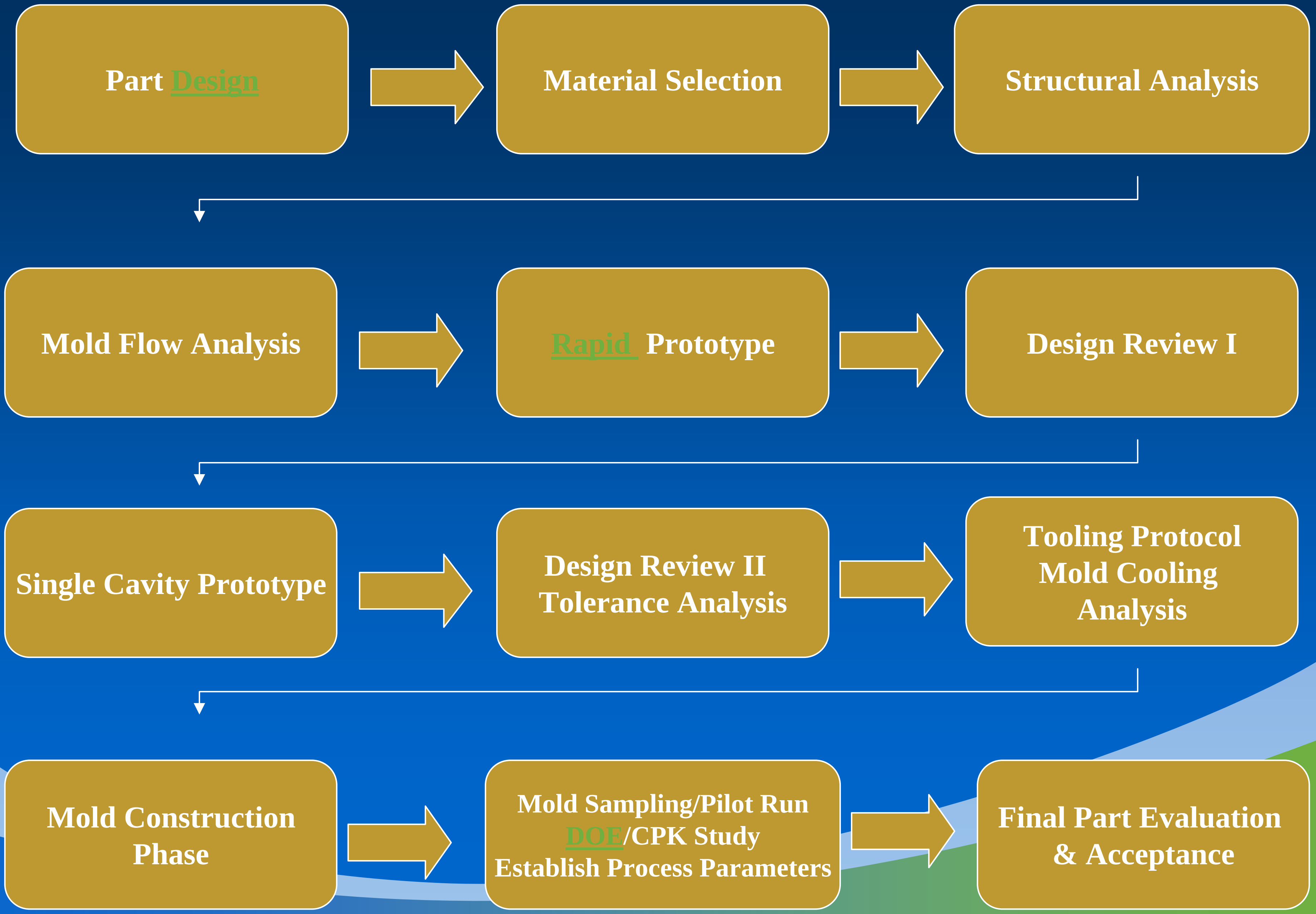
  Exposure to UV, IR, X-Ray
  High humidity
  Weather Extremes
  Pollution: Industrial chemicals
  Microorganisms, bacteria, fungus, mold



The combined effect of the factors may be much more severe than any single factor, and the degradation processes are accelerated many times.

Published test results do not include synergistic effects…always existent in real -life situations.

Steps for Robust Part Design Process



Process

Most Common Process Induced Failures

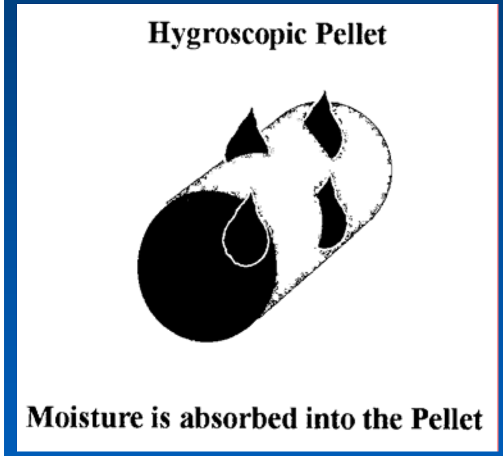
- **Drying of material**
- **Cold or overheated material**
- **Under or Over Packing**
- **Improper additive/regrind mixing and utilization**

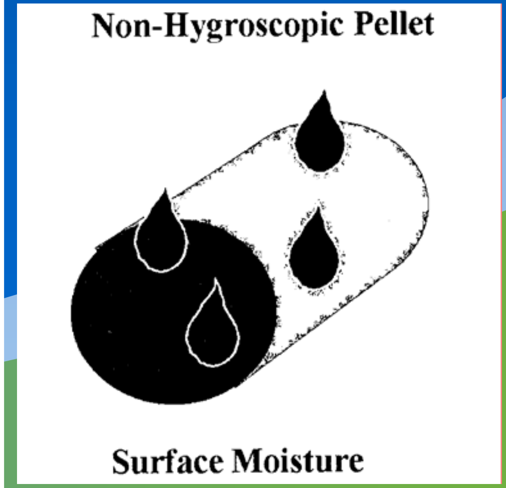
Materials Drying

Why do we need to dry Plastics Materials?

All Plastics, when exposed to atmosphere, will pick up moisture to a certain degree depending upon the humidity and type of the polymer.

Hygroscopic	Non Hygroscopic
Polymers with high affinity for moisture	Polymers with very little or no affinity for moisture
Moisture is absorbed into the pellet over time until equilibrium is reached	No absorption of moisture into the pellet. May pick up surface moisture.
Nylon, ABS	Polystyrene
Polycarbonate	Polyethylene
Polyester	PVC, Polypropylene
Polyurethane	Acetal
Desiccant Dryer	Hot Air Dryer





Is Your Material Dry?

Dry air vs. Dry Material

Checks the efficiency of the dryer

Checks Material dryness

Temperature

What is important….Barrel temperature or Melt temperature?

Optimum MELT TEMPERATURE is the key to successful molding

Factors affecting melt temperature

- Barrel temperature settings
- Screw speed
- Screw back pressure
- Residence time
- Cycle time

Too Cold?

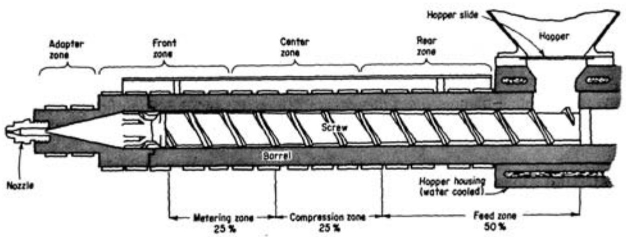
Too Hot?

Cold or Overheated material

EX: PVC

Non-Return Valve

Screw & Barrel



24-2 A typical in-line, reciprocating screw in cross section showing the three primary barrel zones. (*Reprinted by permission of Modern Plastics.*)

Nozzle

Use as short a nozzle as possible

Nozzle bore diameter as large as possible

Use proper tips

Additives and Regrind

- Loss of properties
- Additives depletion (Antioxidant, Stabilizer)
- Fines
- Inadvertent mixing
- Missing additives

Table 2.3 · Effect of Remolding on the Properties of Fiberglass Reinforced Celcon® Acetal

Property	1st Molding	3rd Molding	5th Molding
Tensile yield strength, MPa			
Value	110	92.5	85.6
percent retention	—	81.7	75.6
Tensile modulus, MPa			
Value	8,280	7,660	6,970
percent retention	—	92.6	84.2
Flexural modulus, MPa			
Value	7,250	6,830	6,350
percent retention	—	94.1	87.6

PROCESS RELATED FAILURE

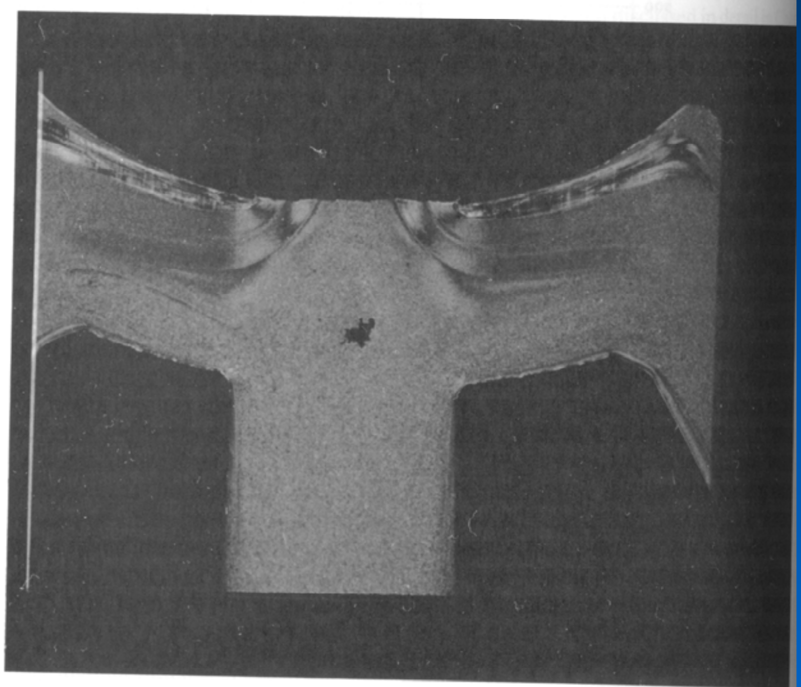
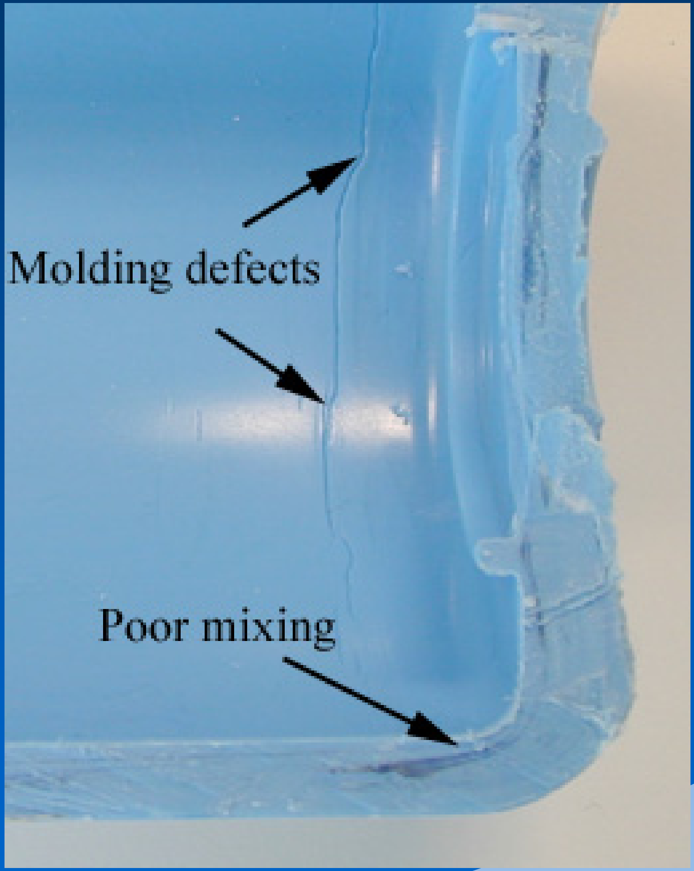


Figure 15-4. Shrinkage voids created by insufficient time and pressure to freeze the gates during injection molding process. (Courtesy BASF Corporation.)



Service Conditions

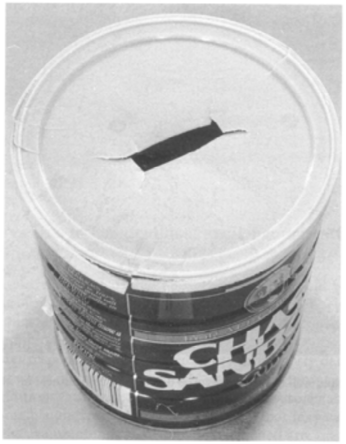


Figure 6-16 PE coffee can cover used beyond its intended service; a rectangular hole was cut in the center, leading to cracks at the corners ([1] Fig. 3, reproduced with permission)

Failures due to:

- "Reasonable" misuse…….Examples

  Trash Container, Ladder, Exposure to solvents, Compacts disks in cars

- Use of product beyond its intended lifetime

- Unstable/Unintentional/Unanticipated service condition

  - **Thermal, Chemical, Environmental, Physical, Biological, Mechanical**
  - **Examples of unintentional service…..coffee can lid, cash drawer, one time short service..bags, cups**
  - **Examples of unexpected service……underground animals**

- Service conditions beyond reasonable misuse

- Simultaneous application of two stresses operating synergistically

Service condition related failures

Failure resulting from ignoring installation instructions

Types Of Failures

Mechanical

Thermal

Chemical

Environmental

Mechanical Failures

Mechanical Failures arise from the applied external forces.

- **Brittle Failure**

- **Ductile Failure**

- **Fatigue failure**

- **Creep & Stress relaxation**

Brittle & Ductile failures

Brittle Failure

Brittle failures are characterized by a sudden and complete catastrophic failure in which rapid crack propagation is observed without appreciable plastic deformation. Brittle failures, once initiated require no further energy for the crack to propagate.

Ductile failure

Ductile failures are characterized by gradual tearing of the surfaces when applied forces exceed the yield strength of the material. For the crack resulting from the ductile mode of failure, additional energy must be provided to propagate the crack by some type of external loading. Ductile failure is slow and non catastrophic in nature and the failed specimen generally shows gross plastic deformation in terms of stress whitening, jagged and torn surfaces, necking (reduction in cross sectional area) and some elongation.

IMPACT PROPERTIES

- Impact properties relates to the toughness of the material
- Toughness>>>>Ability of material to absorb applied energy
- Impact Resistance>>>Resistance to breakage under shock loading
- Impact Energy>>>Crack initiation at surface + crack propagation

BRITTLE (NO YIELDING) VS. DUCTILE FAILURE (definite yielding with cracking)

Notch sensitive plastics (PS, PMMA) are more prone to brittle failure

Ductile - Brittle Transition Temperature

44 Fundamental Materials Variables

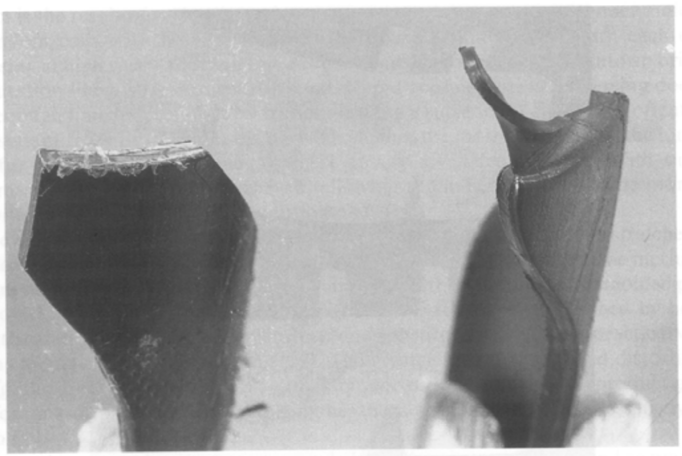


Figure 2-21 Brittle fracture of poorly fused polyethylene garden hose vs. ductile failure of well fused polyethylene ([24] Fig. 3, reproduced with permission)

Creep & Stress Relaxation

- Creep is a non-reversible deformation of material under load over time. Stress relaxation is gradual decrease in stress with time under a constant deformation.

- Creep failure (Creep rupture) occurs when polymer chains can no longer hold the applied load and stress reaches levels high enough for microcracks to form. In case of stress relaxation, at a constant deformation the movement of the polymer chain reduces the force necessary for a given deformation.

Thermal Failures

High & Low Temperatures (Temperature Extremes)

Thermal Expansion & Contraction

Thermal degradation

Misinterpretation of published data

(HDT vs. Continuous use temp.)

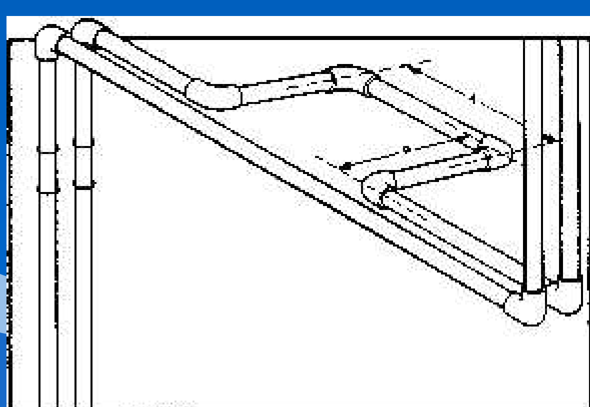


Figure 6-8 IPS salad bowls deformed and cracked due to washing in dishwasher

Chemical Failures

Chemical reactions – Chemical attack

Environmental Stress Cracking – Chemical reaction in presence of stress

Hydrolysis

Chemical compatibility factors*

- Exposure Time
- Temperature
- Chemical Concentration
- Molded-in Stresses
- External Stresses

Degradation from prolonged contact with Gasoline

* Synergistic Effects

Environmental Failures

UV radiation – Indoor/Outdoor

Ozone

Oxidation

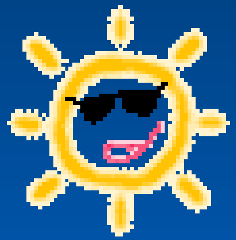
Weather-Temperature extremes

Acid rain

Humidity and moisture

Pollution

Biological



Analyzing Failures

Failure Analysis Steps & Tools

- 1. Visual examination.
- 2. Identification analysis.
- 3. Stress analysis.
- 4. Heat reversion Technique
- 5. Microstructural analysis (Microtoming).
- 6. Mechanical testing.
- 7. Thermal analysis
- 8. Non Destructive Testing (NDT) techniques
- 9. Fractography
- 10. Simulation testing

Visual Examination

- Magnifying Glass & Good Lighting
- Handling evidence
- Cavity Numbers, compare with good parts
- Gate size and location, Sharp corners, Voids
- Visual defects, burn marks, contamination
- User Abuse, Gouge marks, Cuts
- Sectioning parts
- Surface….Smooth, Jagged, Shiny?
- UV effect

Identification Analysis

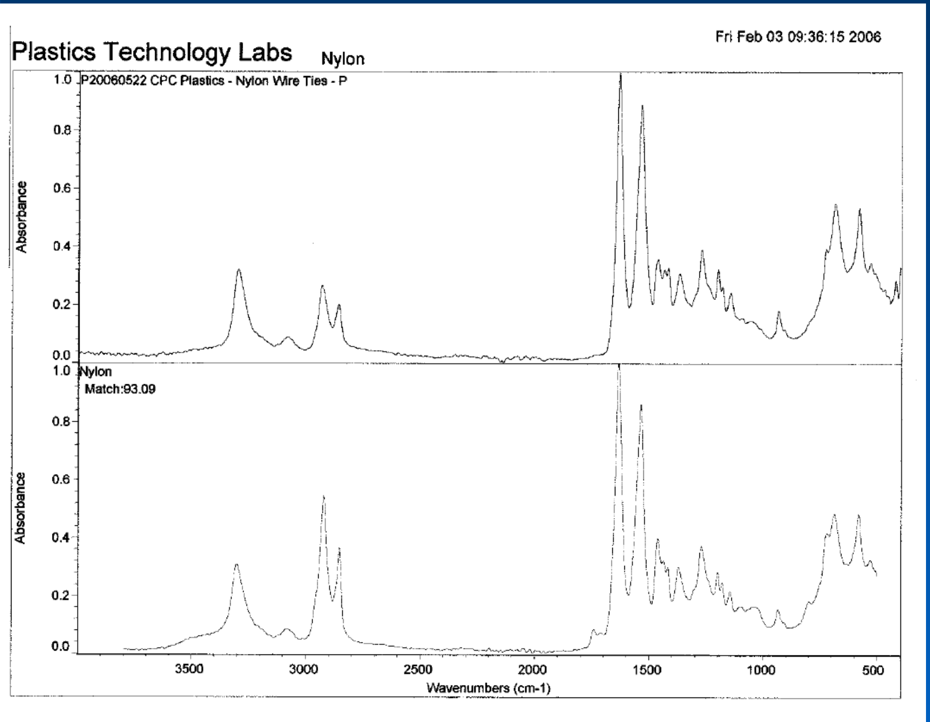
One of the most Common Reasons for product failure is simply the use of wrong material

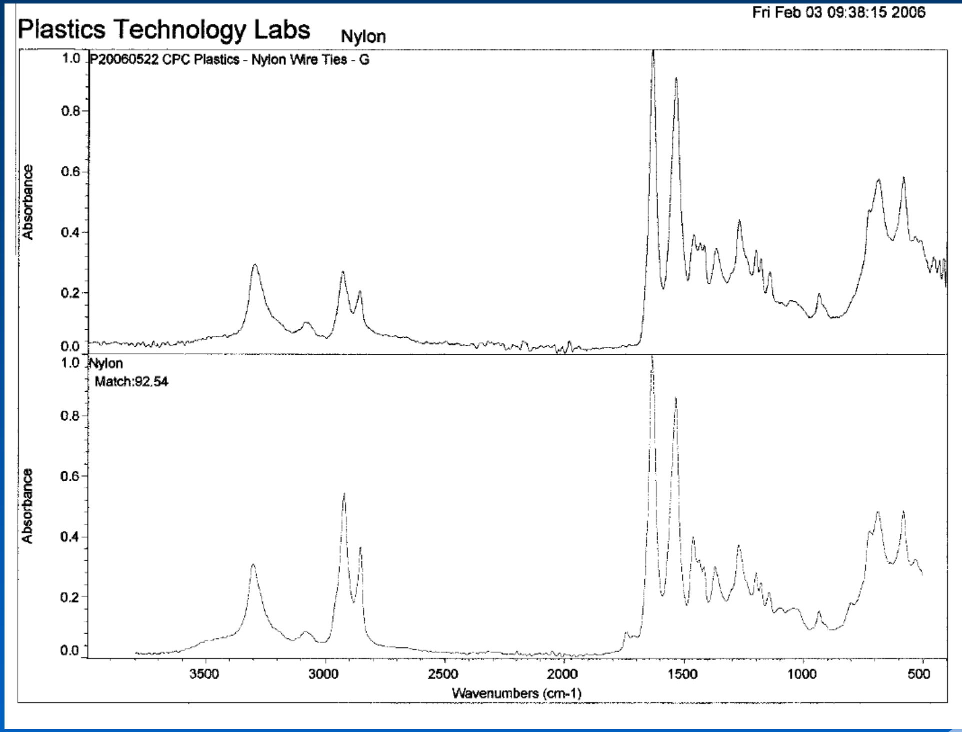
Reasons	Techniques
Material Type	FTIR
Grade	Melt Index, DSC
Regrind	Melt Index
Material degradation	Melt index, Viscosity tests
Missing ingredients	Deformulation, LC, GCMS, PYMS, NMR
Unwanted substances	SEM-EDX

Four Most Common Techniques

- FTIR
- DSC
- Ash Content (Burn-off test) or TGA
- Viscosity tests

FTIR


Plastics Technology Labs
Nylon
Fri Feb 03 09:36:15 2006
P20060522 CPC Plastics - Nylon Wire Ties - P
Nylon
Match:93.09
Absorbance
Wavenumbers (cm-1)


Plastics Technology Labs
Nylon
Fri Feb 03 09:38:15 2006
P20060522 CPC Plastics - Nylon Wire Ties - G
Nylon
Match:92.54
Absorbance
Wavenumbers (cm-1)


Thermo

DSC

Plastics Technology Labs was requested to perform Differential Scanning Calorimetry Analysis (DSC) on two samples.

The results of the DSC testing are as follows:

Sample Name	Peak Tm (°C)	ΔHm (J/g)	Nylon Type by Tm
Nylon Wire Ties - P	**266**	**75.7**	**6/6**
Nylon Wire Ties - G	**265**	**74.0**	**6/6**

The Tm is the temperature at which a crystalline polymer melts.

ΔHm is the amount of energy a sample absorbs while melting.

Copies of the scans used to determine these results are attached.

If you have any questions, please feel free to call.

Viscosity

	Brookfield Viscosity (cP)		Relative Viscosity
P	64.6		43.1
	64.6		43.1
	64.6		43.1
	64.6		43.1
	64.6		43.1
		Average	**43.1**
G	71.0		47.4
	71.0		47.4
	71.6		47.8
	71.0		47.4
	71.6		47.8
		Average	**47.6**

P = Poor (Bad Lot)

G = Good Lot

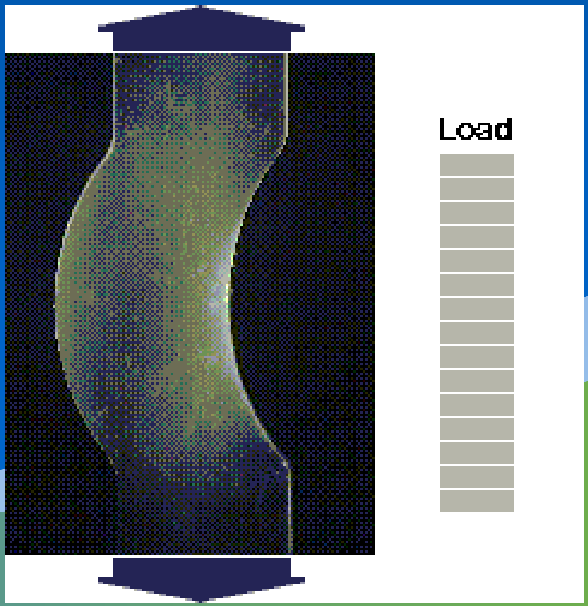
Standard RV = 47 to 51

Pyrolysis

Stress Analysis

- Photoelastic Method
- Brittle Coatings Method
- Strain gage Method
- Chemical (Solvent Stress Analysis)

Photoelastic Pattern



How to quantify the results…..

- **Qualitative**…….Visual, Best guess, interpretation variations
- **Quantitative**….reliable, measurable values, ASTM D 4093
- Manual measurement techniques
- **Equipment** : Polariscope or Polarimeter with compensator and Calibrated wedge

Instruments for Photoelastic Analysis (DIY)

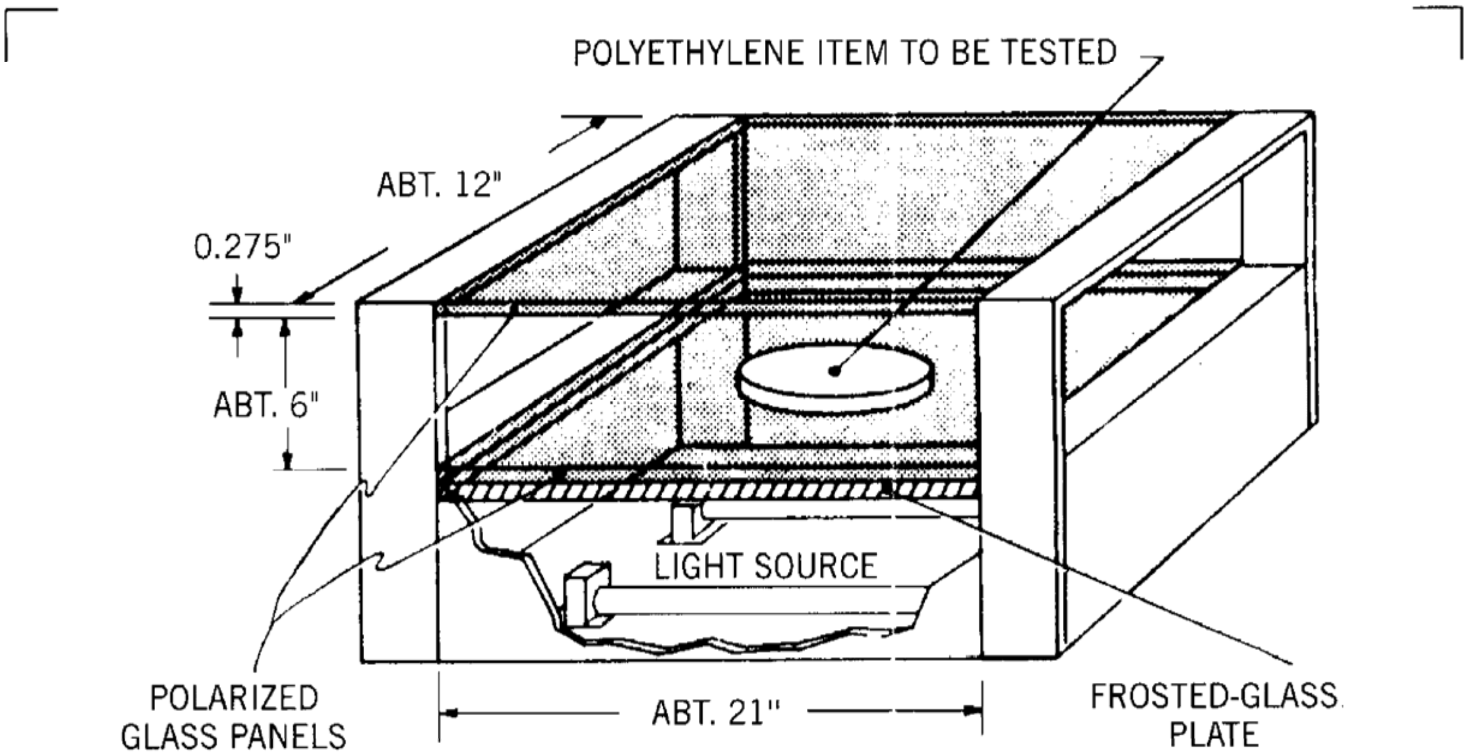
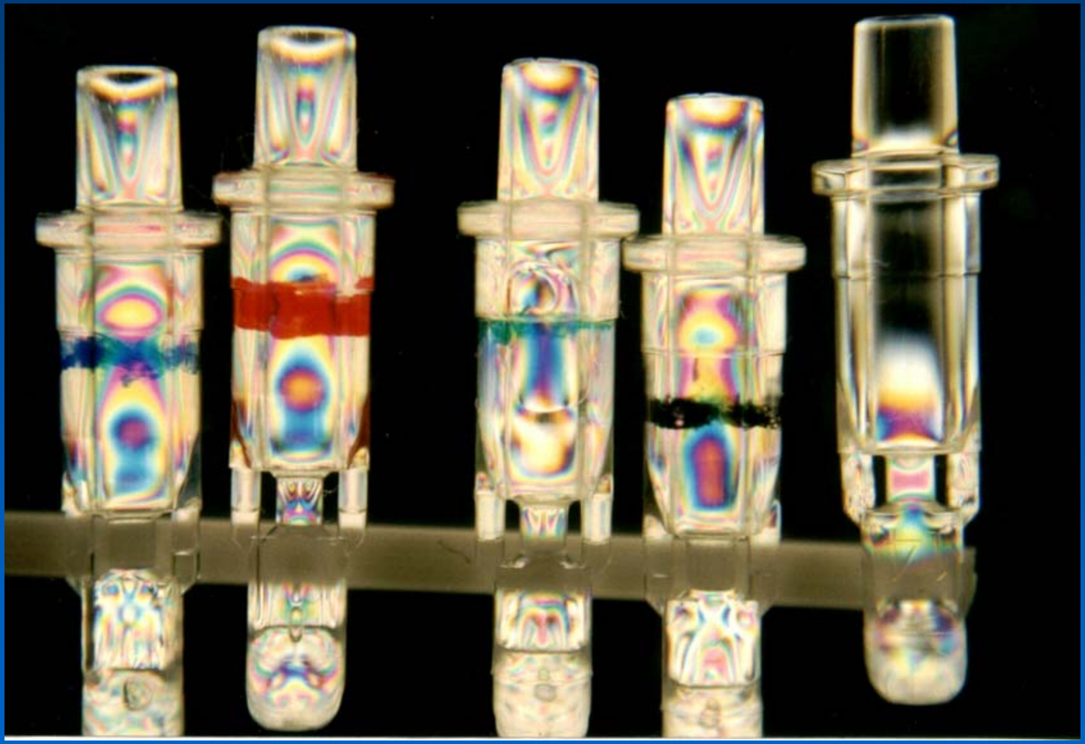


Figure 6-7. Light box for stress-optical sensitivity examination.

Annealing to reduce Molded-in Stresses



Brittle-Coating Method

- Brittle-coating method is a useful technique for measuring localized stress in the part. Brittle coatings are specially prepared lacquers that are usually applied by spraying on actual part.
- Small cracks appear on the surface of the part as a result of external loading.
- The brittle-coating technique is not suitable for detailed quantitative analysis like photoelasticity.
- Helps pinpoint the location of stress in the part

Strain Gauge Method

In order to measure residual stress with these standard sensors, the locked-in stress must be relieved in some fashion (with the sensor present) so that the sensor can register the change in strain caused by removal of the stress. This was usually done destructively in the past -- by cutting and sectioning the part, by removal of successive surface layers, or by trepanning and coring.

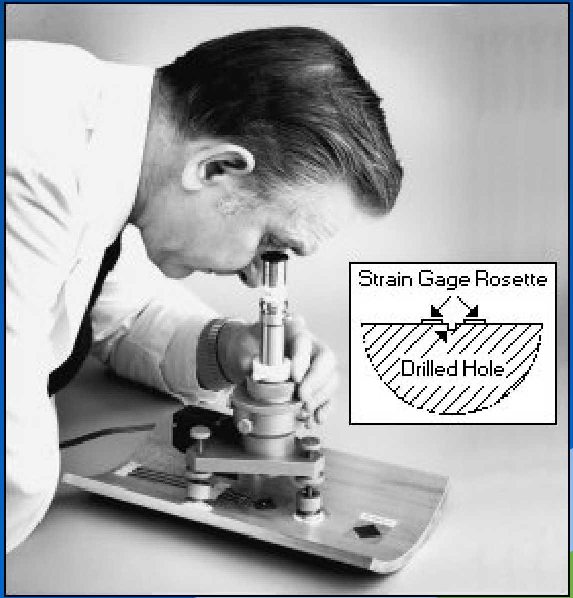
With strain sensors judiciously placed before dissecting the part, the sensors respond to the deformation produced by relaxation of the stress with material removal. The initial residual stress can then be inferred from the measured strains by elasticity considerations.

Strain Gauge Method

ASTM E 837

The Hole-Drilling Method

- The most widely used modern technique for measuring residual stress is the hole-drilling strain gage method of stress relaxation, illustrated on the right.



Chemical Method

- Most plastics, when exposed to certain chemicals while under stress, show stress cracking. Molded parts can be stress analyzed to determine the level of molded-in or residual stress using these techniques.
- **ABS Acetic acid immersion test**
  ASTM D 1939
- **PVC Acetone immersion test**
  ASTM D 2152
- **Polycarbonate Solvent Stress Analysis**
  GE Plastics test method T-77

Polycarbonate Solvent stress Analysis – Critical Stress

- Critical Stress level is defined as the stress level at which a given solvent will craze a polycarbonate part when exposed for a specified time period.

Critical stress level…..Methanol………………..3400 psi

Critical stress level…..Ethyl acetate……………500 psi

- Solutions ranging from 0 to 50% by volume of ethyl acetate in Methanol are used for this test using 3 minute immersion test.

Polycarbonate Solvent Stress Analysis Typical Results

- Typical test results

PLASTICS TECHNOLOGY LABORATORIES, INC.

Testing	:	Solvent Stress Analysis
Test Method	:	GE Plastics Test Method (T-77)
Project #	:	P20010083 **Purchase Order # : 102**
Customer	:	Consultek
Attention	:	Vishu Shah
Analyst	:	T. Keith
Date	:	November 28, 2000
Material	:	Polycarbonate Connector Tubes
Test Conditions	:	23°C / 50%RH
Sample Preparation	:	Not Required
Sample Type	:	As Received
Test Duration	:	3 Minutes
Solvent	:	Methanol / Ethyl Acetate (MeOH / EtOAc)

Critical Stress (MeOH / EtOAc)	Clear New as Molded	Clear Old as Molded	Clear New Annealed	Clear Old Annealed
	Stress Cracking Present			
1200 psi (71:29)	No	No	No	No
1100 psi (69:31)	No	No	No	No
1000 psi (67:33)	Yes	Yes	No	No
800 psi (63:37)	Yes	Yes	No	No
570 psi (50:50)	Yes	Yes	No	No
Samples have a stress level of	**< 1100 psi.**	**< 1100 psi.**	**< 570 psi.**	**< 570 psi.**

12 samples of Opaque Finished Parts showed a stress level of <u>< 800 psi</u>. There were two instances of the parts breaking at a stress level of 570 psi. This accounts for the rating of < 800 psi.

Following the test specification above, the following was performed.

A set of three specimens from each test group was immersed in each solution for a period of three minutes. The samples were then removed and placed in deionized water at room temperature for rinsing. The samples were then visually analyzed for stress cracking.

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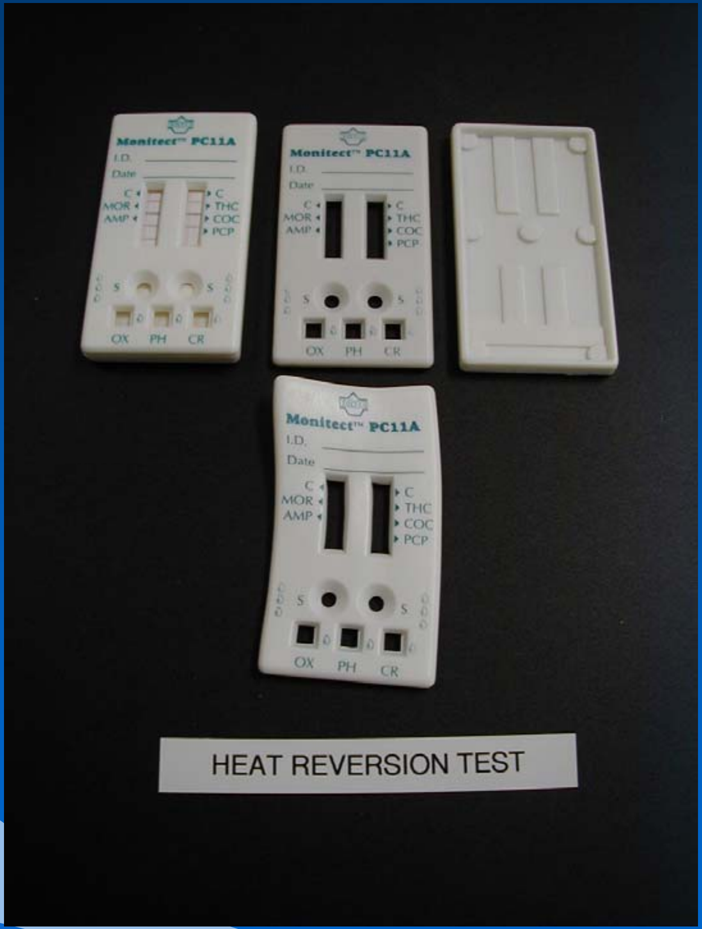
http://www.ptli.com

Heat Reversion Technique



All plastics manufacturing processes introduce some degree of stress in the finished product. By reversing the process, by reheating the molded or extruded product, the presence of stress can be determined.

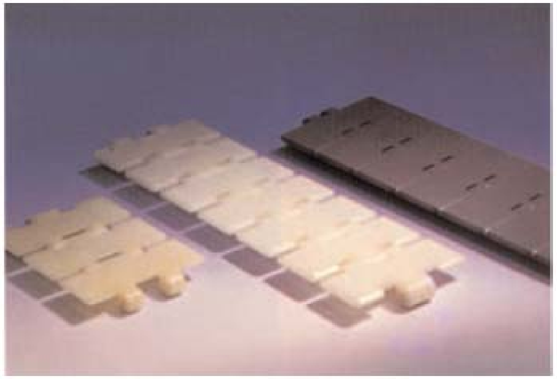
The degree and severity of warpage, blistering, wall separation, fish-scaling, and distortion in the gate area of the molded parts indicate stress level.

Note: No quantitative measurements possible

Microstructural Analysis

Microtoming is a technique of slicing an ultra thin section from a molded plastic part for microscopic examination.

- Under packed parts……voids
- Contamination
- Color dispersion
- Filler dispersion such as glass fibers
- Degree of bonding
- Molded-in stresses using polarizer



A Parts

B Void and inhomogeneous melt

Mechanical Testing

- Tensile, Impact, compression etc using actual defective parts
- Compare with “Good” parts

- Grind-up defective parts and mold test bars for physical testing

Thermal Analysis

- DSC

Melting point, Glass transition temperature, Crystallinity

Level of anti-oxidant in polymer

- TGA

Quantitative determination of additives

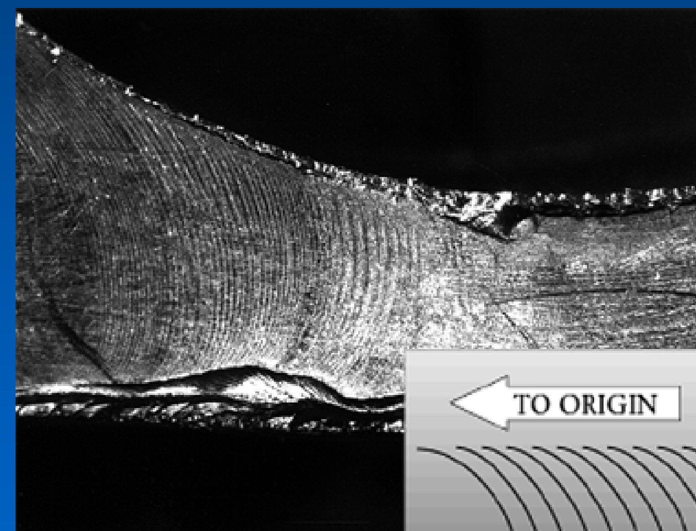
- TMA

Thermal expansion, Chemical blowing agent

Fractography

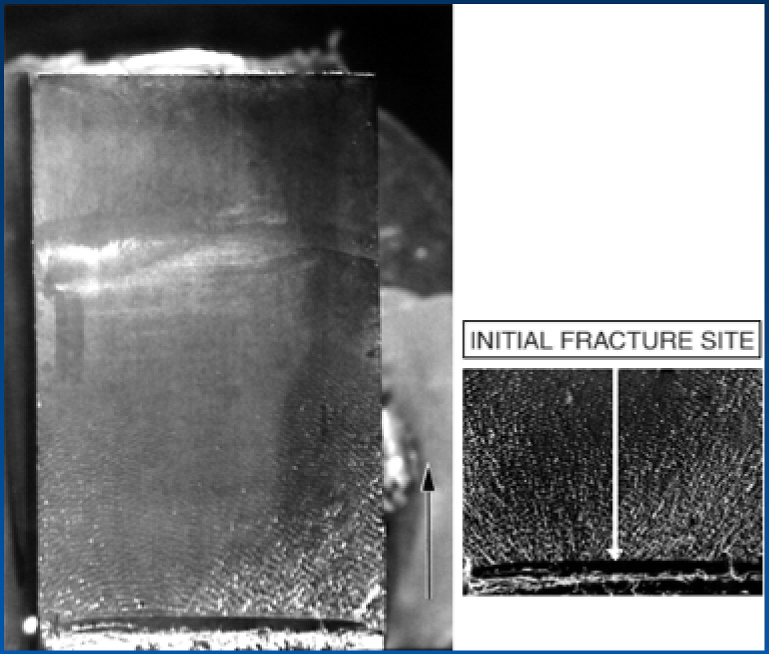
Electron Microscopy - SEM

Branching
Look for cracks on the failed part. The cracks that end before they reach the edge of the part are AWAY from the origin. These cracks typically exhibit branching.



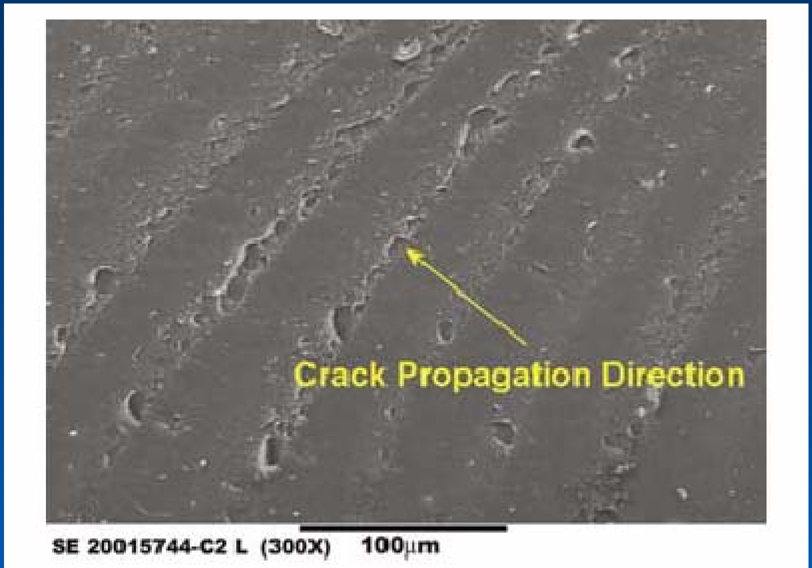
River marks
River marks may be visible on the fracture edge. A magnifying lens may be used to locate these markings. The pattern shown in the inset illustrates the river markings 'pointing' toward the fracture origin.

Source: Eastman



Wallner Lines
These wavelike bands radiate from the fracture origin.

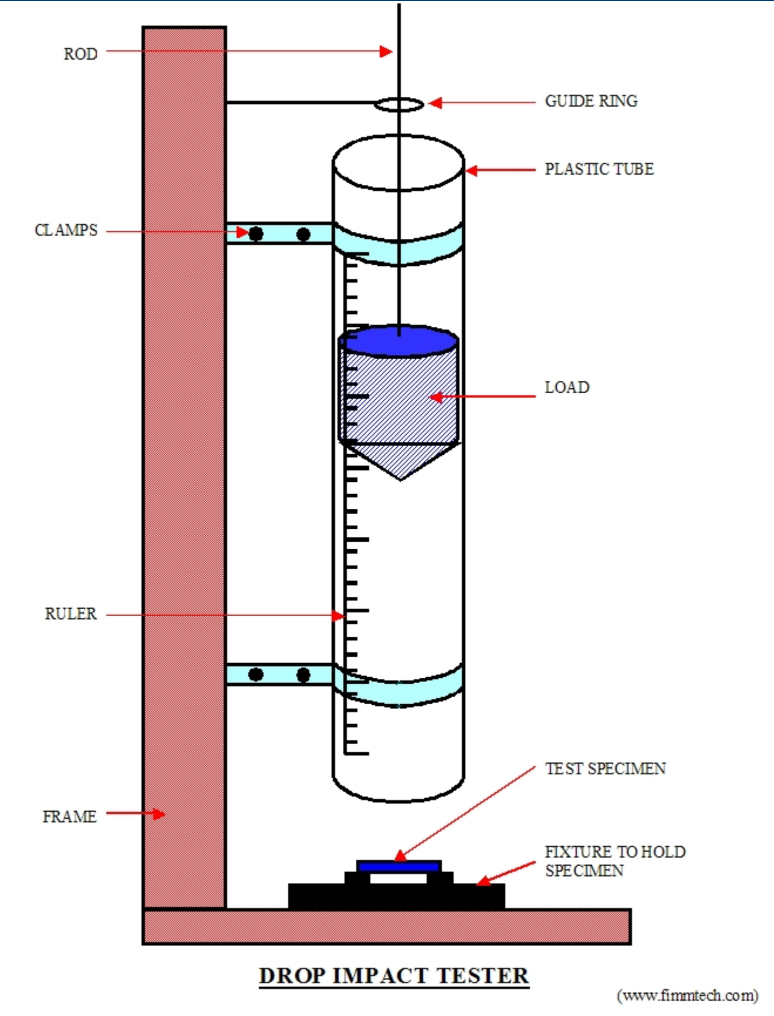
Source: Eastman



Fatigue striations emanating from fracture origin of polycarbonate latch handle

Simulation Testing

Exposing parts similar to the one that has failed to chemicals and other environment to learn about probable cause for failure.



Case Studies

The Case

Company ABC approached Polymer Solutions Incorporated (PSI) for us to determine if any differences existed between two different polyacetal samples, labeled as Sample A and Sample B

The Approach

In order to arrive at this conclusion, PSI used several analytical techniques to compare and contrast the two samples:

Melt Rheology

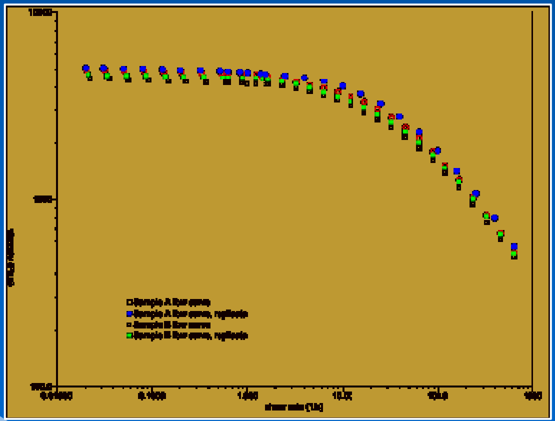
Nuclear magnetic resonance (NMR) spectroscopy

Fourier transform infrared (FTIR) spectrometry

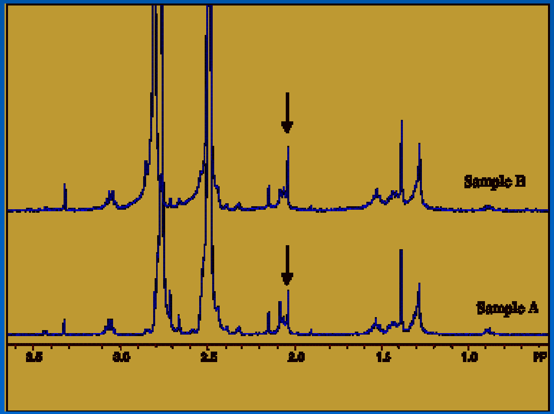
Extraction and additive analysis

Capillary gas chromatography (GC)

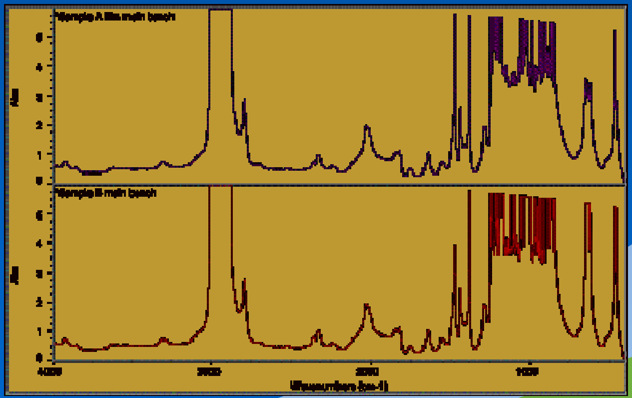
Melt Rheology



NMR



FTIR



Conclusion

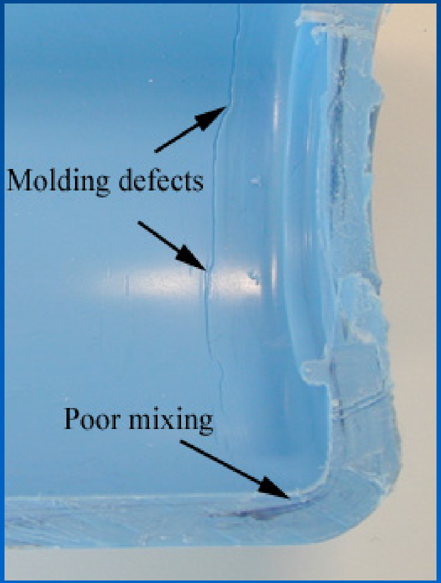
From the data sets it was concluded that Sample A and Sample B are indistinguishable

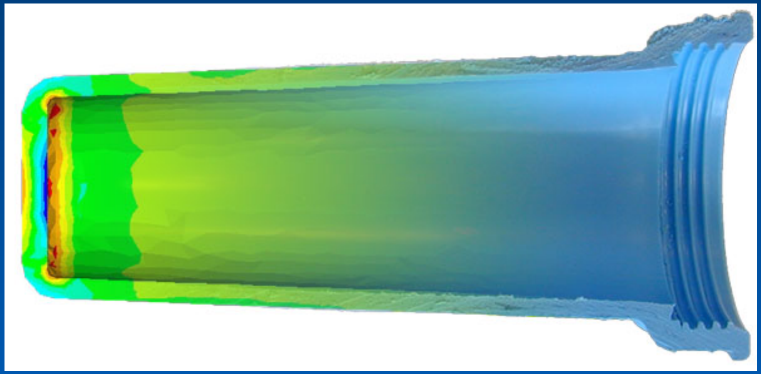
Source: Polymer solutions

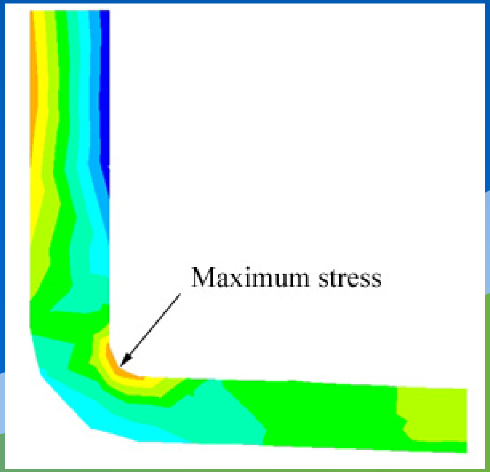
Case Studies

Water Filter Housing

The failure appears as a circumferential crack that completely separated the bottom cap from the housing. This failure caused extensive water damage in the property where it was installed



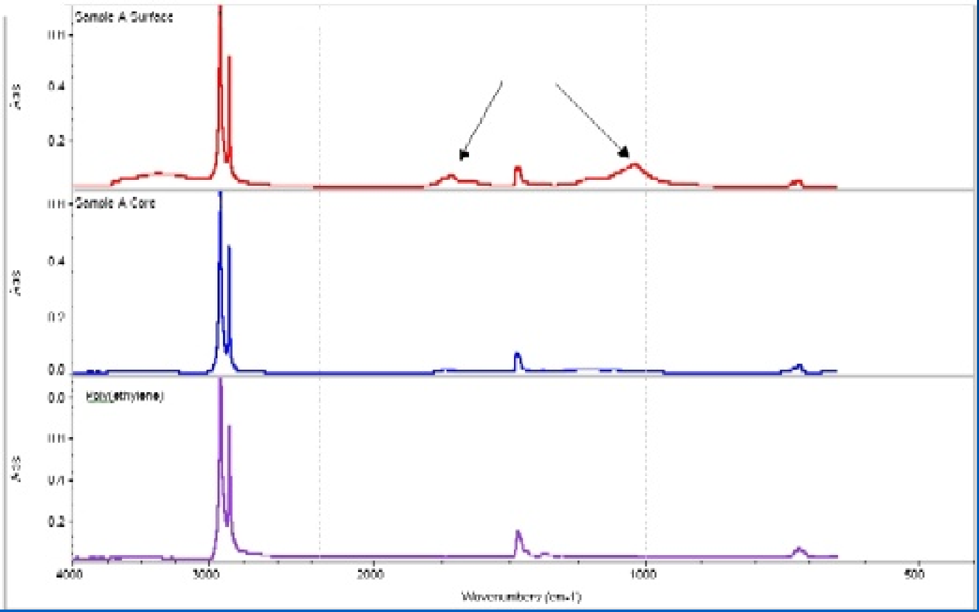




Source: Madison Group

Case Studies

Outdoors Degradation of High Density Polyethylene



MFR Test

This large difference between specified and tested MFR is due to the molecules breaking because of material degradation.

The formation of carbonyls and byproducts associated with oxidation. The FTIR performed at the surface of the part shows stronger absorption bands compared to the FTIR at the core. Therefore, the level of oxidation at the surface is much higher than the oxidation at the core of the part.

Source: Madison Group

Failure Analysis Checklist

Material	What material is it? What Grade? Color Number? Lot Number? Any regrind? How Much?
Design	Fail in same place? Knit Line location? Part to print comparison? Sharp corners? Uniform wall thickness?
Application History	Did it ever work? When did it happen? How many parts? Chemical exposure?
Secondary Ops.	How is it joined? Failure mode? Performance? Procedure details?
Environment	Appearance differences? Weathering effects? Chemical Exposure? Compatibility checked?
End-Use	In-Use? In-storage? Accidental? Abuse? Source: GE Plastics

Identifying Plastics Materials

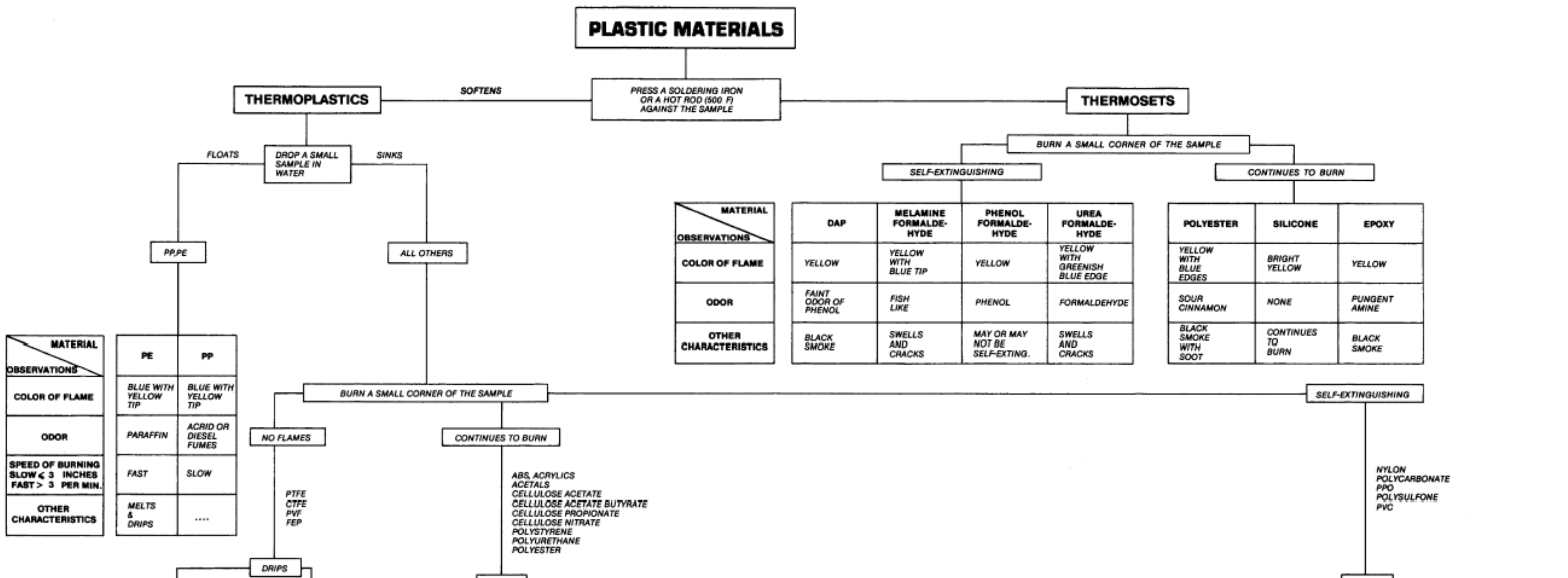
- Simple methods
- Advance methods

SIMPLE METHODS OF IDENTIFICATION

- Useful for identifying basic polymer and differentiating between the different types of polymers within the same family.
- Requires no special equipment or in-depth knowledge of analytical chemistry
- Simple step by step identification procedure using flow chart


Simple methods
Thermoplastic
Thermoset
Visual
Visual
Sp. gravity or Float test
Burn test
Burn test
Solubility test
Copper wire test
Pyrolysis
Melting point test
Solvent extraction
Solubility test
Pyrolysis
Solvent extraction

PLASTICS IDENTIFICATION CHART



Thermosets — Self-extinguishing

MATERIAL / OBSERVATIONS	DAP	MELAMINE FORMALDE-HYDE	PHENOL FORMALDE-HYDE	UREA FORMALDE-HYDE
COLOR OF FLAME	YELLOW	YELLOW WITH BLUE TIP	YELLOW	YELLOW WITH GREENISH BLUE EDGE
ODOR	FAINT ODOR OF PHENOL	FISH LIKE	PHENOL	FORMALDEHYDE
OTHER CHARACTERISTICS	BLACK SMOKE	SWELLS AND CRACKS	MAY OR MAY NOT BE SELF-EXTING.	SWELLS AND CRACKS

Thermosets — Continues to burn

MATERIAL / OBSERVATIONS	POLYESTER	SILICONE	EPOXY
COLOR OF FLAME	YELLOW WITH BLUE EDGES	BRIGHT YELLOW	YELLOW
ODOR	SOUR CINNAMON	NONE	PUNGENT AMINE
OTHER CHARACTERISTICS	BLACK SMOKE WITH SOOT	CONTINUES TO BURN	BLACK SMOKE

Thermoplastics — Floats (PP, PE)

MATERIAL / OBSERVATIONS	PE	PP
COLOR OF FLAME	BLUE WITH YELLOW TIP	BLUE WITH YELLOW TIP
ODOR	PARAFFIN	ACRID OR DIESEL FUMES
SPEED OF BURNING SLOW < 3 INCHES FAST > 3 PER MIN.	FAST	SLOW
OTHER CHARACTERISTICS	MELTS & DRIPS	....

No flames — Drips: Yes / No

MATERIAL / OBSERVATIONS	FEP	CTFE	PTFE	PVF
COLOR OF FLAME	....	....	....	....
ODOR	BURNT HAIR	ACETIC ACID	BURNT HAIR	ACIDIC
SPEED OF BURNING SLOW < 3 INCHES FAST > 3 PER MIN.	....	....	....	....
OTHER CHARACTERISTICS	....	....	....	....

Continues to burn — Drips: Yes

MATERIAL / OBSERVATIONS	ABS	ACETAL	ACRYLICS	CELLULOSE ACETATE	CELLULOSE ACETATE BUTYRATE	CELLULOSE PROPIONATE	POLY-STYRENE	POLYESTER
COLOR OF FLAME	BLUE WITH YELLOW EDGES	BLUE	BLUE WITH YELLOW TIP	YELLOW WITH SPARKS	YELLOW WITH BLUE TIP	YELLOW	YELLOW	YELLOW WITH BLUE EDGES
ODOR	ACRID	FORMALDE-HYDE	FRUITY/ FLORAL	VINEGAR	RANCID BUTTER	BURNT SUGAR	ILLUMINATING GAS OR MARIGOLD	BURNING RUBBER
SPEED OF BURNING	SLOW	SLOW	FAST	SLOW	SLOW	FAST	FAST	FAST
OTHER CHARACTERISTICS	BLACK SMOKE WITH SOOT	NO SMOKE	FROTHS AND CRACKLES	BLACK SMOKE WITH SOOT	SOME SMOKE WITH SOOT	SOME BLACK SMOKE	DENSE SMOKE WITH SOOT	BLACK SMOKE WITH SOOT

Continues to burn — Drips: No

MATERIAL / OBSERVATIONS	CELLULOSE NITRATE	POLY-URETHANE
COLOR OF FLAME	PALE YELLOW	YELLOW
ODOR	CAMPHOR	FAINT APPLE
SPEED OF BURNING	FAST	FAST
OTHER CHARACTERISTICS	SAMPLE BURNS COMPLETELY	SLIGHT BLACK SMOKE

Self-extinguishing — Drips: Yes

MATERIAL / OBSERVATIONS	NYLON	POLY-SULFONE	POLY-CARBONATE
COLOR OF FLAME	BLUE WITH YELLOW TIP	ORANGE	ORANGE OR YELLOW
ODOR	BURNT WOOL OR HAIR	ODOR OF SULFUR	PHENOL
SPEED OF BURNING	SLOW	FAST	SLOW
OTHER CHARACTERISTICS	FROTHS	BLACK SMOKE WITH SOOT	BLACK SMOKE WITH SOOT

Self-extinguishing — Drips: No

MATERIAL / OBSERVATIONS	PPO	PPS	PVC
COLOR OF FLAME	YELLOWISH ORANGE	YELLOW-ORANGE	YELLOW WITH GREEN EDGES
ODOR	PHENOL	FAINT ROTTEN EGGS	HYDRO-CHLORIC ACID
SPEED OF BURNING	SLOW	SLOW	SLOW
OTHER CHARACTERISTICS	DIFFICULT TO IGNITE SMOKE	METALLIC SOUND WHEN DROPPED	WHITE SMOKE

ishu Shah, Consultek, LLC., 1102 Seneca Pl., Diamond Bar, CA 91765 Phone: (909) 860-3040 Fax: (909) 860-6267 E-Mail: consultek@cosmoslink.net

BURN TEST OBSERVATIONS

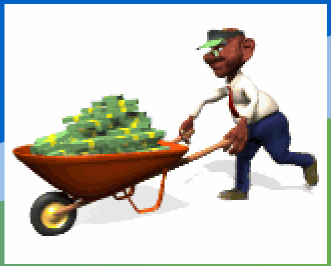
- Does the material burn?
- Color of flame
- Odor
- Does the material drip while burning?
- Nature of smoke and color of smoke
- The presence of soot in the air
- Self-extinguishes or continues to burn
- Speed of burning – fast or slow

Product Liability

The manufacturer may be held liable if:

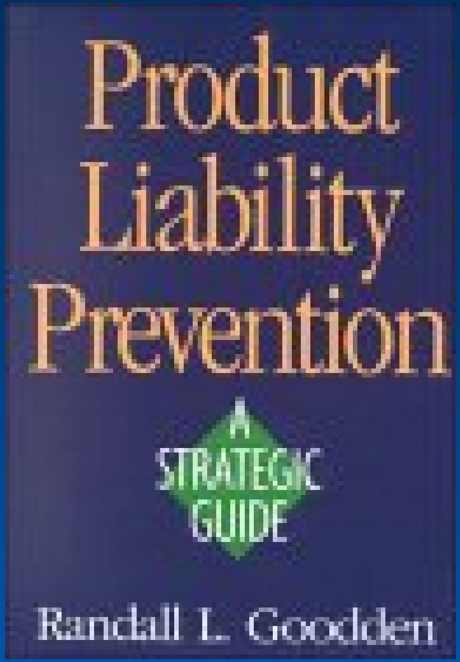
- 1. The product is defective in design and is not suitable for its intended use.
- 2. The product is manufactured defective and proper testing and inspection was not carried out.
- 3. The product lacks adequate labeling and warnings.
- 4. The product is unsafely packaged.
- 5. The proper records of product sale, distribution, and manufacturer are not kept up-to-date.
- 6. The proper records of failure and customer complaints are not maintained

- **INSTRUCTIONS, WARNING LABELS, AND TRAINING**
- **TESTING AND RECORDKEEPING**



Key Points

- Product design
- Reliability Testing
- Document Control
- Warning Labels
- Record Retention
- Recall Procedures
- Liability Incidents and Investigation
- Litigation Teaching


Product
Liability
Prevention
A
STRATEGIC
GUIDE
Randall L. Goodden

Contents

Local Failure Analysis Laboratories

- KARS' ADVANCED MATERIALS, INC.
  7271-CD Garden Grove Blvd.Garden Grove, CA 92841
  (714) 892-8987 Fax: (714) 894-0225 *kars@karslab.com*

Seal Laboratories Inc.
250 N. Nash Street, El Segundo CA 90245 PH: 310-322-2011
www.seallabs.com

CRT Laboratories, Inc.
1680 N. Main Street, Orange, CA 92867 PH: 800-597-LABS
www.crtlabs.com

OCM Test Laboratories, Inc.
3883 East Eagle Drive
Anaheim, CA 92807

Phone Number: 714-630-3003 Ext. 222
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PLASTICS: THEORY AND PRACTICE	**WINTER**
PLASTICS PART DESIGN FOR INJECTION MOLDING/ TOOLING FOR INJECTION MOLDING	**Spring**
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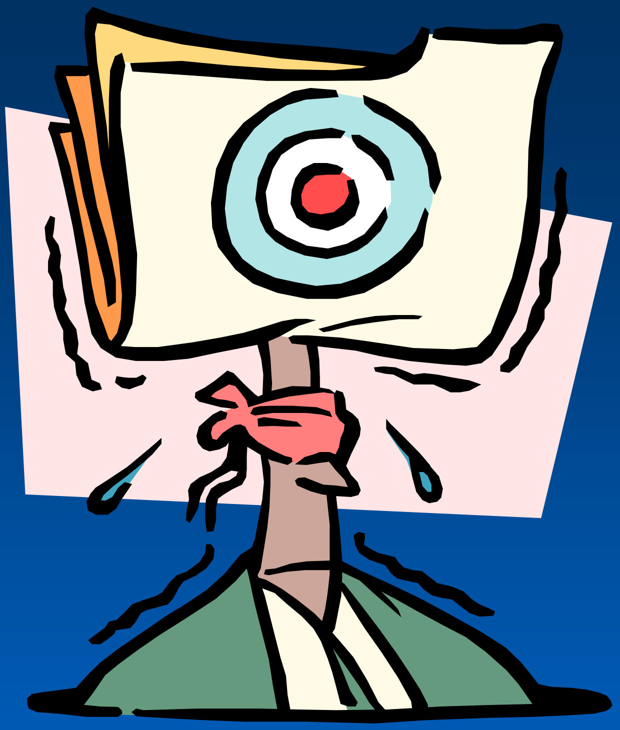

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