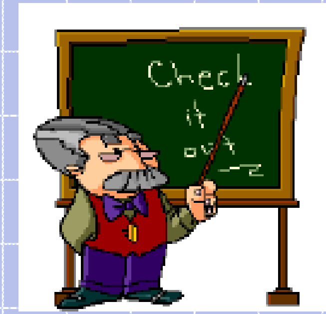
CONSULTEK LLC



Educational Seminars

Multimedia Tour

www.consultekusa.com

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Seminars

PLASTICS A TO Z

Workshop for Injection Molders

Vishu Shah

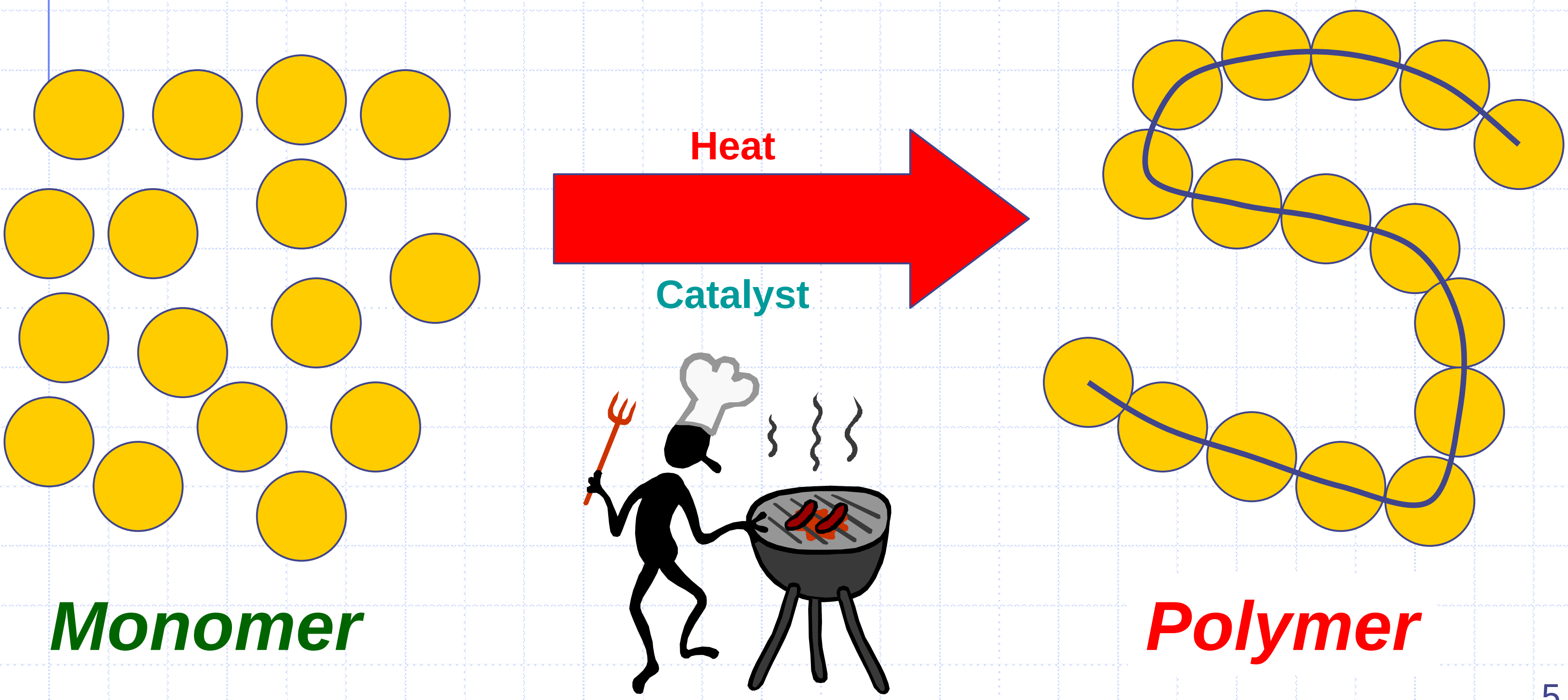
Consultek

Topics

- Plastics Industry Overview, History, Growth, Future
- Polymer Chemistry Basics
- Polymer Structure-Properties-Applications
- Modified Plastics-Alloys-Composites
- Elastomers
- Product Design Basics
- Material Selection Process & Interpreting material data sheets
- Plastics Identification Techniques
- Processing Techniques
- Plastics Tooling
- Decorating and Printing
- Assembling and Secondary Operations
- Part Costing
- Testing and Failure Analysis
- Plastics Industry Standards and Organizations
- Recycling
- Educations and Seminars
- Where to get more information.......

Polymers

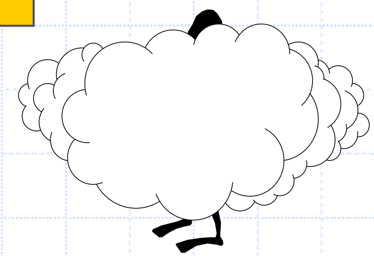
Chemical compounds formed when many small chemical units (***monomers***) combine to form large molecules with a regular repeating structure.



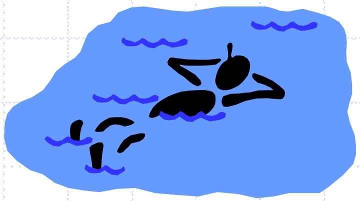
Polymers

Size of the Molecules

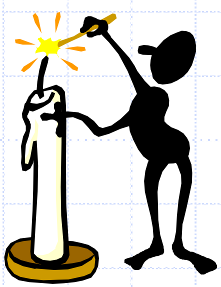
Methane = CH_4 ↓ Gas



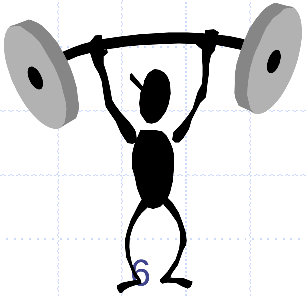
Octane = C_8H_{18} ↓ Liquid



Paraffin Wax = $C_{50}H_{102}$ ↓ Solid



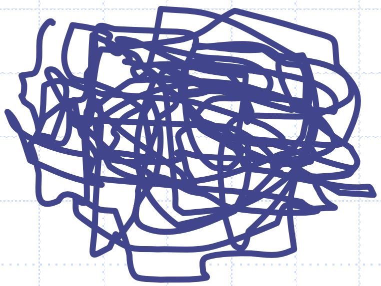
Polyethylene = $C_{2000}H_{4002}$ ↓ Polymer

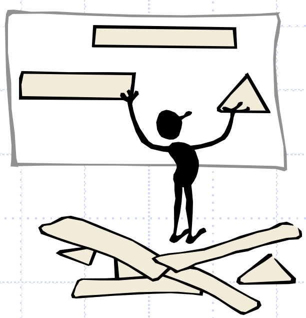


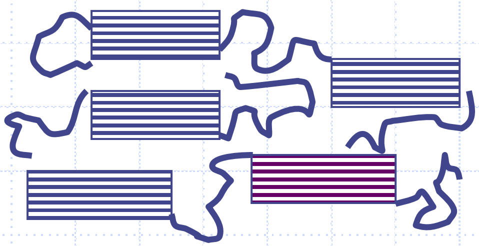
Polymers

Organization of the Molecules

Solid State Structure of *Thermoplastics*







Amorphous

No polymer structure.

Examples: Polystyrene
Polycarbonate
PMMA

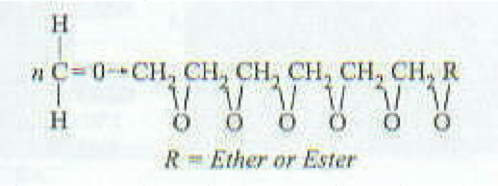
Semi-Crystalline

Contains both crystalline (ordered)and amorphous polymer.

Examples: Polyethylene
Polypropylene
PET
Polyamides (nylon)

ACETAL

Structure

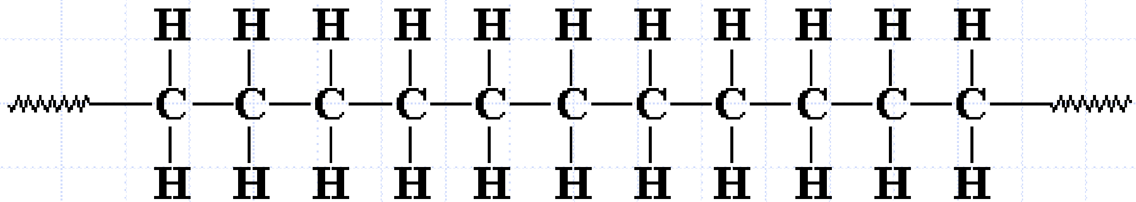


Properties Acetal copolymer provides:

- High tensile strength and stiffness
- Exceptional dynamic fatigue strength and dimensional stability
- High toughness and good resilience
- Minimal moisture absorption
- Low friction and wear properties
- Hard, high gloss surface
- Superior property retention up to 220ºF in air and 180ºF in water
- Excellent resistance to a wide range of chemical, oils, greases and solvents
- Easy to process and fabricate

POLYETHYLENE

Structure



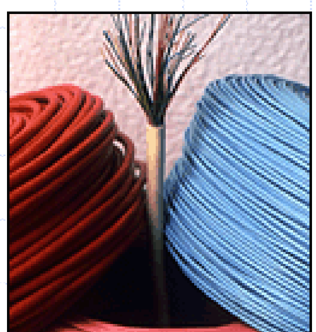
Properties

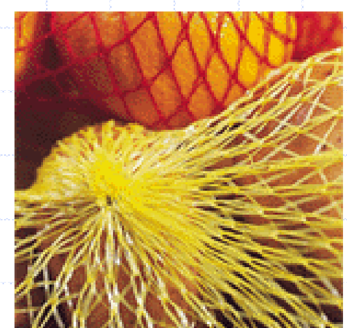
Excellent dielectric properties, moisture resistance, chemical resistance, FDA approved, Poor weathering properties,

difficult to bond, easy to process.

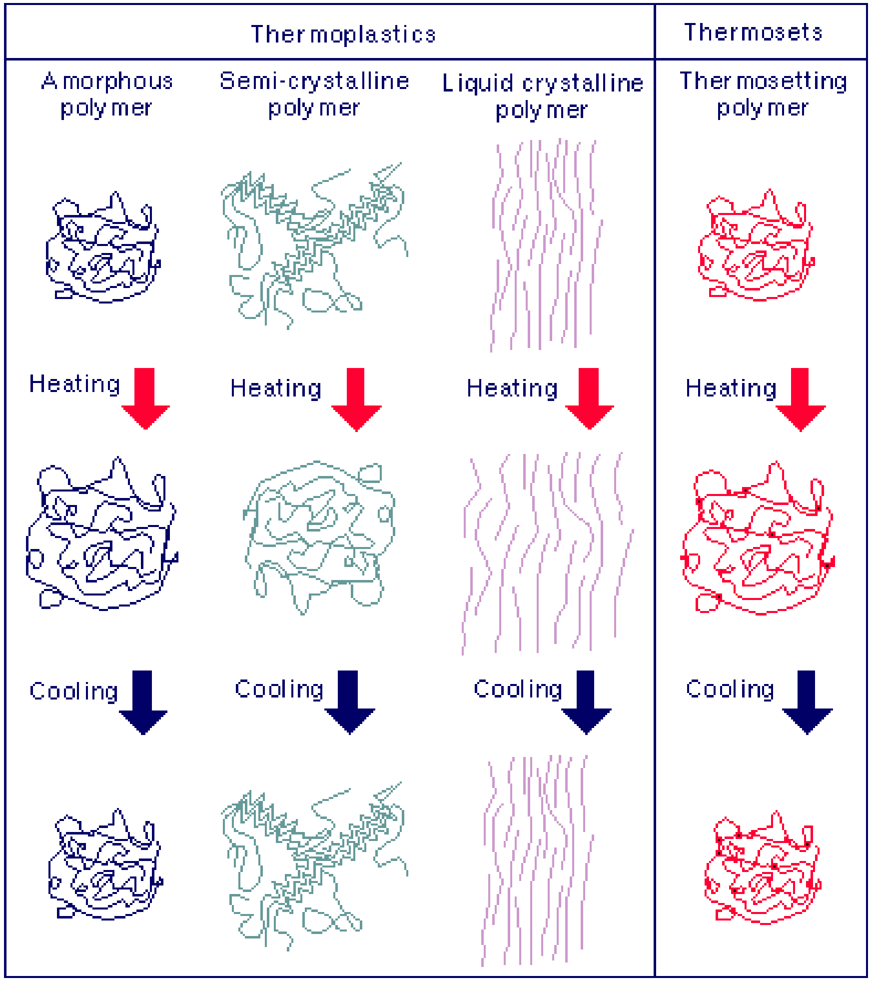
Applications

Containers, toys, Bags, film, agriculture parts, Automotive parts, tubing, bottles, Gas tanks.....
Wire & Cable....



Liquid Crystal Polymers (LCP)



Consequences of Molecular Structure

➨ **High Flow-Fills Thin, Complicated Parts Easily**

◆ Rapid Set-up - Fast Cycle Time

◆ Excellent Dimensional Stability

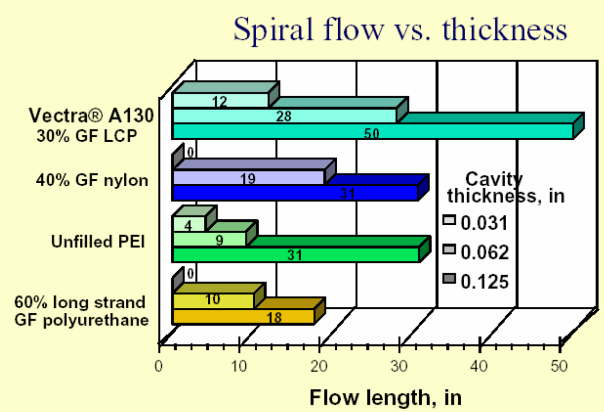
◆ High Strength/Stiffness

◆ Chemical Stability

◆ Excellent Barrier Properties

High Flow of LCPs

NPE2000



LCPs fill thin parts easily

ELASTOMERS

- Thermoplastic or Thermoset
- Thermoplastic Elastomer (TPEs) combine processing advantage of thermoplastics with properties of cross linked rubber.
- Use standard processing equipment, decorated, reground, reprocessed

Styrenic based	Kraton, Monprene
Olefinic based	Catalloy, Affinity
Thermoplastic Urethane(TPUs)	Pellethanes, Elastollan, Texin
Polyester based	Hytrel
Polyamid based	Pebex
TPVs (PP/EPDM)	Santoprene
Melt Processable Rubber	Alcryn
Synthetic Rubbers	NBR, EPDM, SBR

PRODUCT DESIGN BASICS

Wall Thickness considerations

Why is uniform wall thickness important?

- **Sink marks, Warpage, Voids, Molded-in Stress, Long cooling time, Even material flow**

What causes non-uniform wall thickness?

- **Corners……………….Add radii**
- **Transition areas…………..taper over distance**
- **General Ignorance……….Get educated**

Basic Rules

- **Nominal Wall thickness - 0.250 or less**
- **Transition must be less than + / - 25% nominal wall thickness, gradual transition is the best**

POOR DESIGN

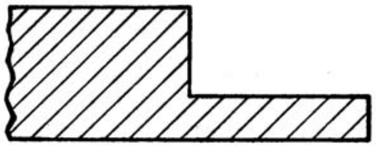


FIG. A

BETTER DESIGN

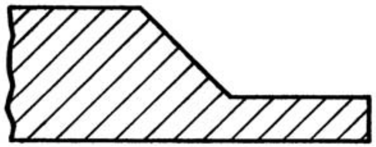


FIG. B

The first cardinal rule of designing parts for injection molding is to maintain a uniform wall thickness.

It is not always possible to maintain a uniform wall thickness. When faced with this problem, the junction between the thick and thin walls should be gradually blended together.

Parts with variations of more than 25% will begin to demonstrate problems due to warpage, sink marks and high levels of molded-in stress.

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...next slide

IDENTIFICATION ANALYSIS

Why Identify?

- Competitive product identification
- Failure analysis
- Verification at later date
- Separation of Plastics by type for recycling/reprocessing
- Identify stored and unmarked materials, foils etc.
- Development of new materials
- Discover forgeries and imitations
- Validate material specification

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File Edit Document View Window Help

PLASTICS IDENTIFICATION CHART

PLASTIC MATERIALS

PRESS A SOLDERING IRON OR A HOT ROD (500 F) AGAINST THE SAMPLE

- SOFTENS → **THERMOPLASTICS**
  - DROP A SMALL SAMPLE IN WATER
    - FLOATS → PP,PE
    - SINKS → ALL OTHERS
      - BURN A SMALL CORNER OF THE SAMPLE
        - NO FLAMES: PTFE, CTFE, PVF, FEP → DRIPS (YES / NO)
        - CONTINUES TO BURN: ABS, ACRYLICS, ACETALS, CELLULOSE ACETATE, CELLULOSE ACETATE BUTYRATE, CELLULOSE PROPIONATE, CELLULOSE NITRATE, POLYSTYRENE, POLYURETHANE, POLYESTER → DRIPS (YES / NO)
        - SELF-EXTINGUISHING: NYLON, POLYCARBONATE, PPO, POLYSULFONE, PVC → DRIPS (YES / NO)
- **THERMOSETS**
  - BURN A SMALL CORNER OF THE SAMPLE
    - SELF-EXTINGUISHING
    - CONTINUES TO BURN

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	....

Thermosets

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

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 – sinks

MATERIAL / OBSERVATIONS	FEP	CTFE	PTFE	PVF
DRIPS	YES	YES	NO	NO
COLOR OF FLAME	....	....	....	....
ODOR	BURNT HAIR	ACETIC ACID	BURNT HAIR	ACIDIC
SPEED OF BURNING SLOW ≤ 3 INCHES FAST > 3 PER MIN.	....	....	....	....
OTHER CHARACTERISTICS	....	....	....	....

MATERIAL / OBSERVATIONS	ABS	ACETAL	ACRYLICS	CELLULOSE ACETATE	CELLULOSE ACETATE BUTYRATE	CELLULOSE PROPIONATE	POLY-STYRENE	POLYESTER	CELLULOSE NITRATE	POLY-URETHANE
DRIPS	YES	YES	YES	YES	YES	YES	YES	YES	NO	NO
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	PALE YELLOW	YELLOW
ODOR	ACRID	FORMALDE-HYDE	FRUITY/ FLORAL	VINEGAR	RANCID BUTTER	BURNT SUGAR	ILLUMINATING GAS OR MARIGOLD	BURNING RUBBER	CAMPHOR	FAINT APPLE
SPEED OF BURNING	SLOW	SLOW	FAST	SLOW	SLOW	FAST	FAST	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	SAMPLE BURNS COMPLETELY	SLIGHT BLACK SMOKE

MATERIAL / OBSERVATIONS	NYLON	POLY-SULFONE	POLY-CARBONATE	PPO	PPS	PVC
DRIPS	YES	YES	YES	NO	NO	NO
COLOR OF FLAME	BLUE WITH YELLOW TIP	ORANGE	ORANGE OR YELLOW	YELLOWISH ORANGE	YELLOW-ORANGE	YELLOW WITH GREEN EDGES
ODOR	BURNT WOOL OR HAIR	ODOR OF SULFUR	PHENOL	PHENOL	FAINT ROTTEN EGGS	HYDRO-CHLORIC ACID
SPEED OF BURNING	SLOW	FAST	SLOW	SLOW	SLOW	SLOW
OTHER CHARACTERISTICS	FROTHS	BLACK SMOKE WITH SOOT	BLACK SMOKE WITH SOOT	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

ID Chart
122% 1 of 1 15.43 x 9 in

Injection Molding

Machine Types

Toggle...........Small machines, Fast, High maintenance,
Hydraulic........Large machines, Slow, more expensive
Electric...........Up to 500 Tons, Accurate, excellent repeatability, 50 to 70 percent less electricity consumption, low maintenance

Injection Unit

Clamping Unit

Machine Specifications.....Tonnage/Shot size Tons/Oz

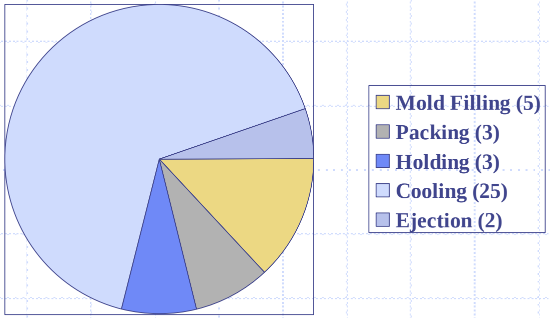
Injection Molding Cycle:

Mold Close – Inject – Hold – Cooling – Open – Eject

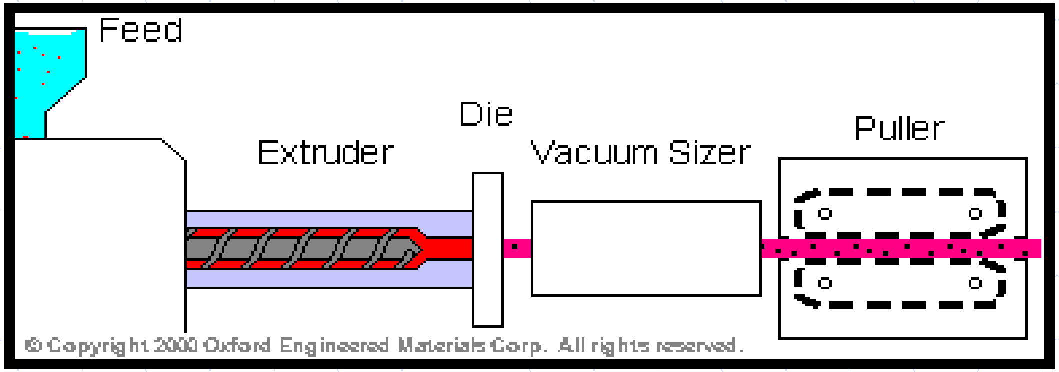
Multi-Material Molding(Coinjection)

Reaction Injection Molding(RIM)

Liquid Injection Molding(LIM)



EXTRUSION


Feed
Die
Extruder
Vacuum Sizer
Puller
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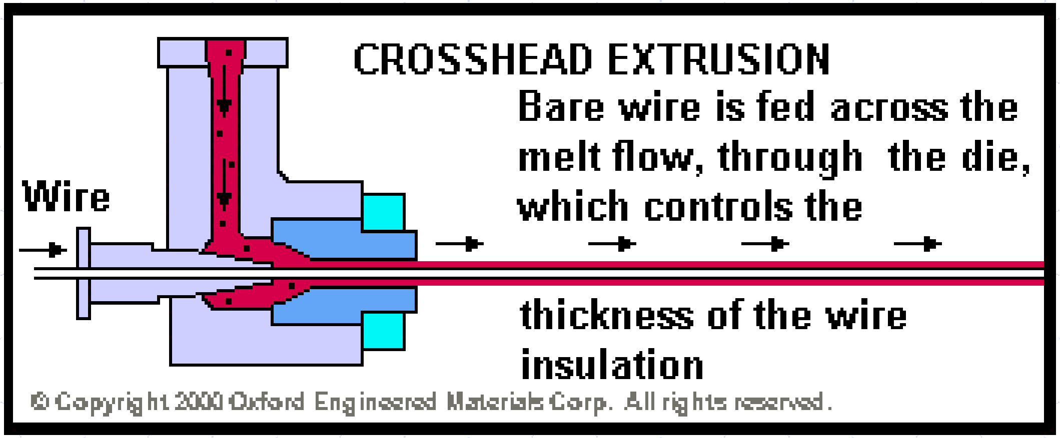
CROSSHEAD EXTRUSION
Bare wire is fed across the melt flow, through the die, which controls the thickness of the wire insulation
Wire
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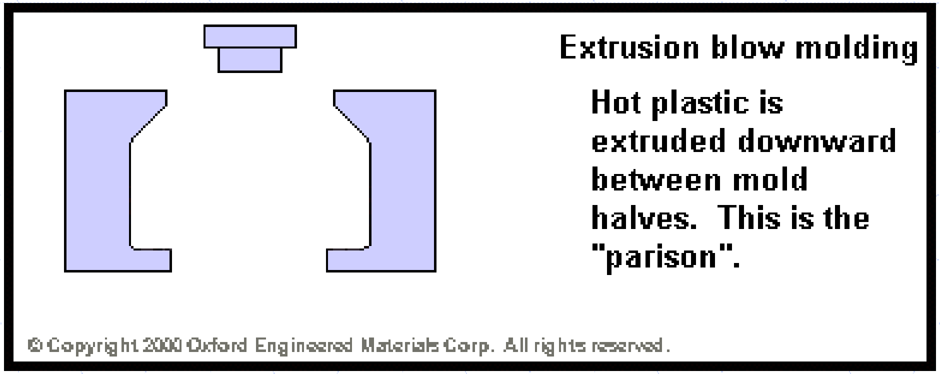
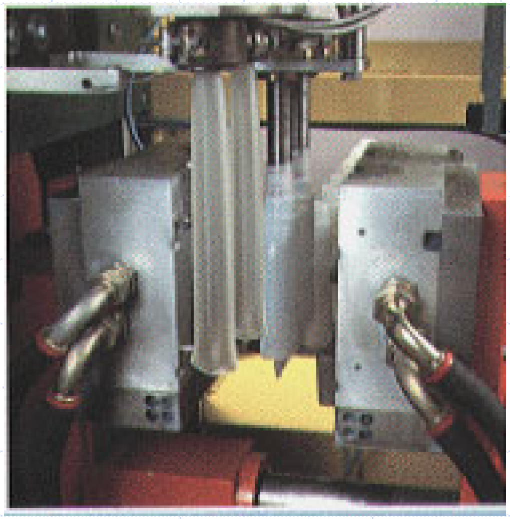
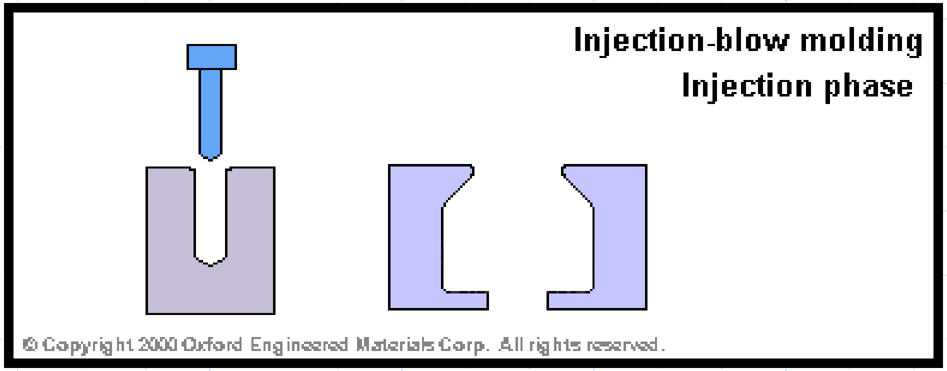
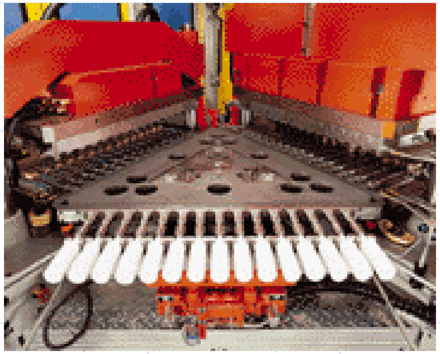
Blow Molding

Extrusion, Injection, Stretch Blow molding

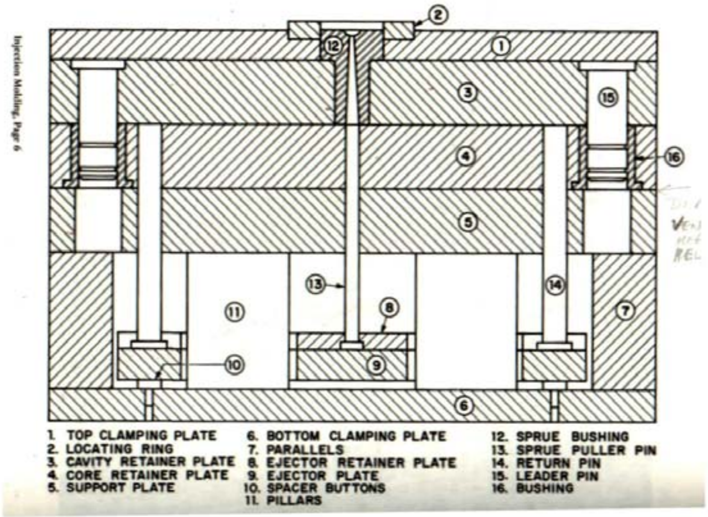




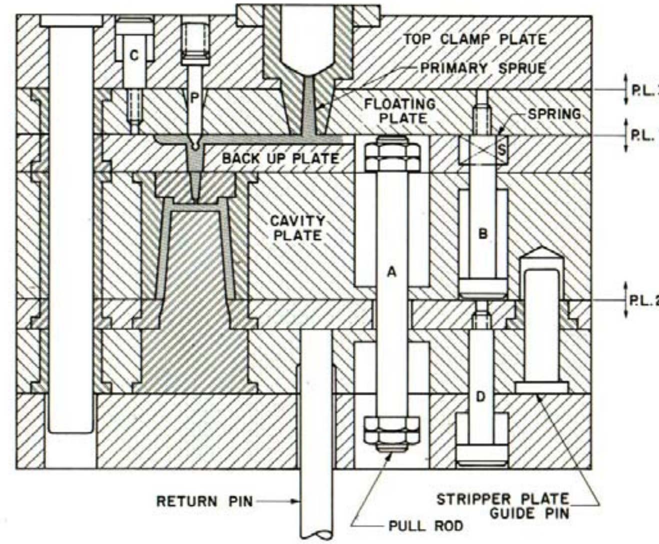




TOOLING >>> Mold Types



Two Plate mold



Three Plate Mold

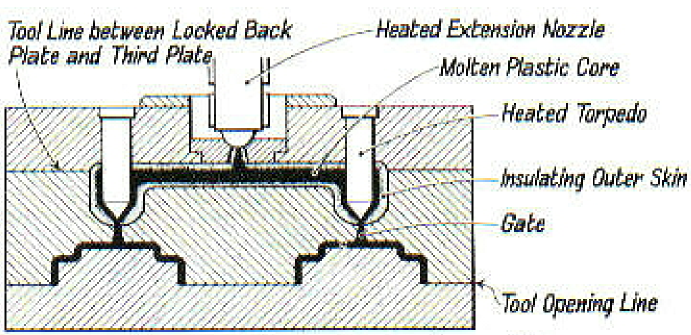
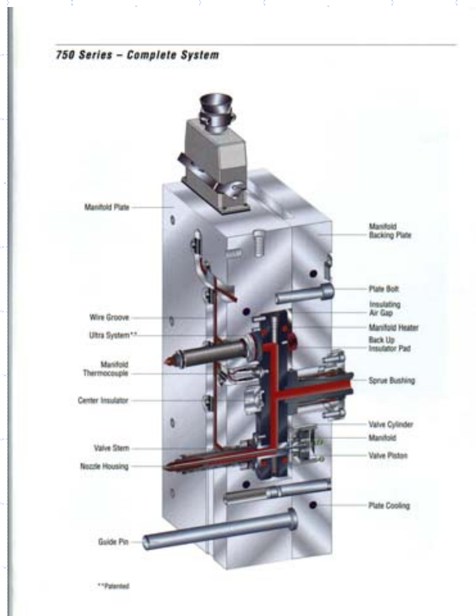
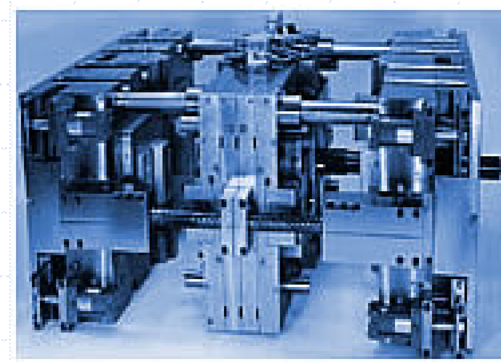


Fig. 5.208. Principle of Insulated-runner Tool.

Insulated Runner Mold



Hot Runner Manifold>>



Stack Mold

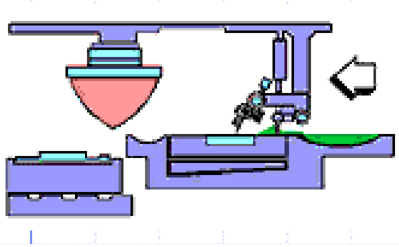
SPI Mold Classifications

Class 101	1MM cycles or more
Class 102	Not exceeding 1MM
Class 103	Under 500,000 cycles
Class 104	Under 100,000 cycles
Class 105	Not exceeding 500

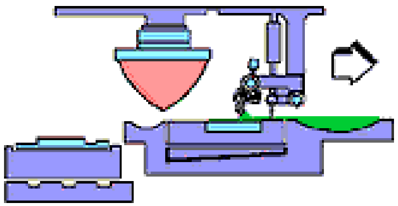
ASSEMBLY & SECONDARY OPERATIONS

- Ultrasonic Welding (Crystalline Vs. Amorphous)
- RF welding
- Spin Welding
- Solvent/Adhesive Bonding
- Mechanical Fastening
- Friction Fitting

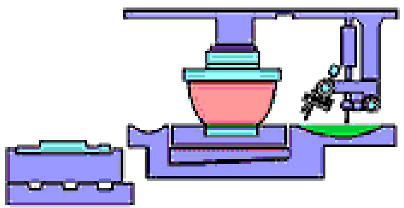
Decorating & Printing



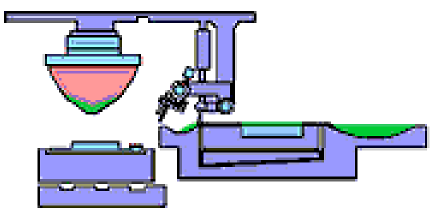
1. In standard open inkwell pad printing, the spatula scoops ink out of the inkwell and over the entire cliché plate surface with the doctor blade lifted off the surface.



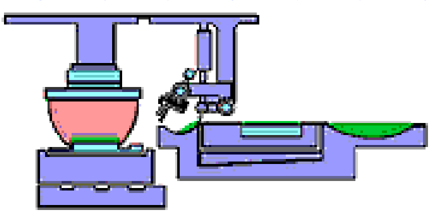
2. The pad slide moves to the right as the doctor blade removes excess ink from the cliché.



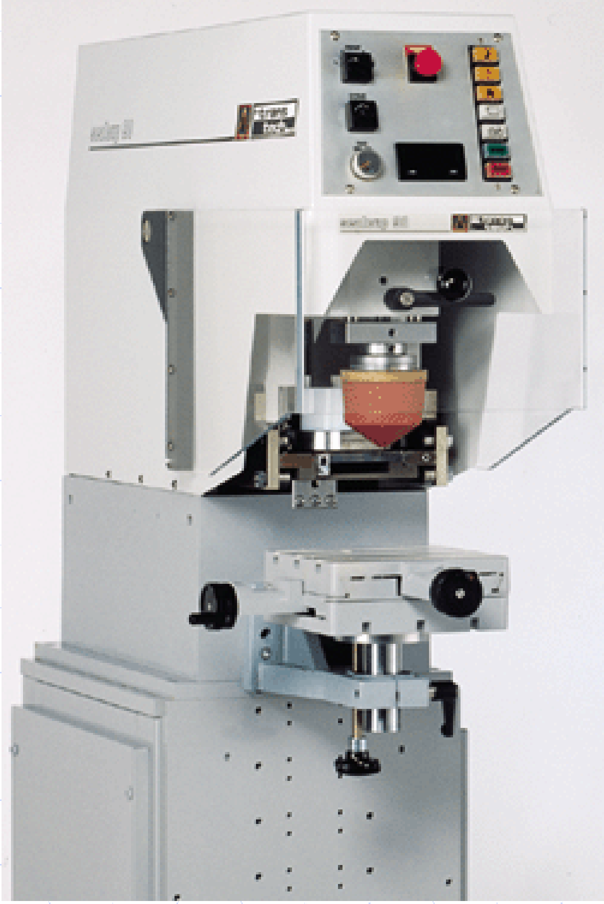
3. The transfer pad, or tampon, is then pressed against the inked plate and lifted.



4. As the transfer pad (now holding image) moves left toward the object to be printed, new ink is deposited onto the plate.



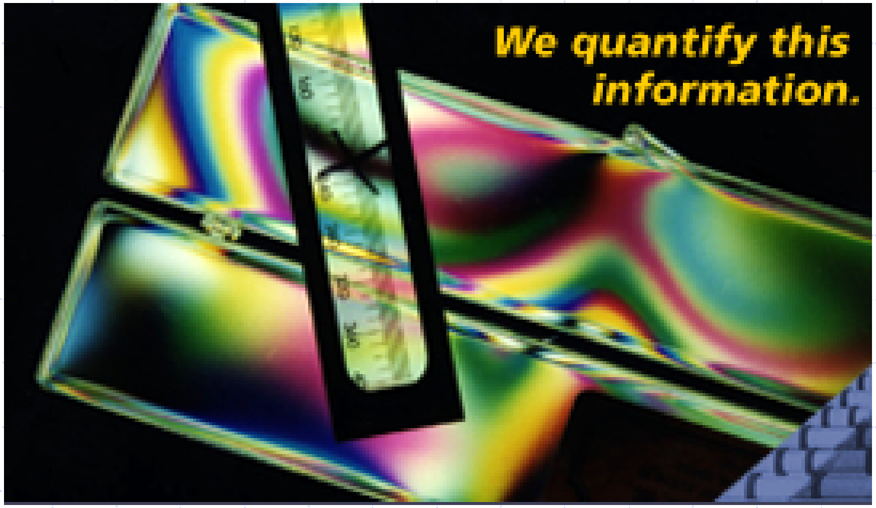
5. With the new image now slightly tacky, the pad descends to the part, leaves the imprint, and the process is then repeated

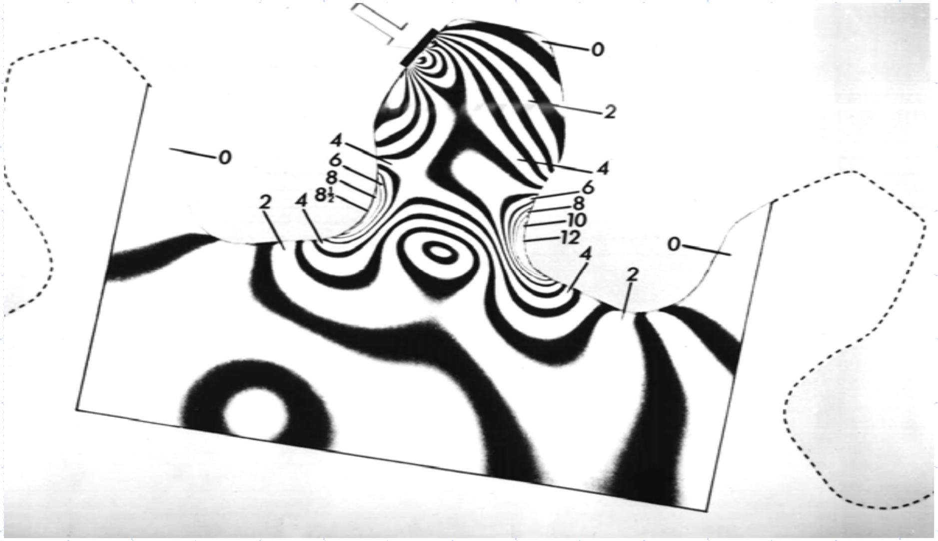


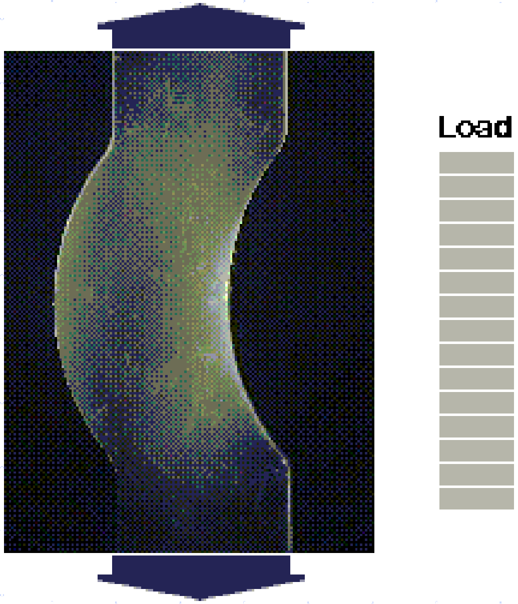
TESTING & FAILURE ANALYSIS

- Mechanical Properties
- Thermal Properties
- Electrical Properties
- Weathering
- Optical Properties
- Material Characterization Tests
- Chemical properties
- Flammability
- Failure Analysis

Photoelastic Pattern







PLASTICS PART COSTING

PART COST = MATERIAL COST + MOLDING COST + SET UP COST

PART COST = 2.24 $/PC

Material Cost = Part weight/454 * Material cost / material yield/100

Part Weight:	454	grams	454/454 * 1.0 / .95 = **1.05 $/PC**
Material cost:	1.00	$/#	
Material Yield:	95	%	

Molding Cost = Machine HR. Rate / 3600/Cycle time * No. of cavities / machine utilization/100 / process yield/100

Machine Hr. Rate:	60	$/HR	60 / (3600/60*1) / .90 / .95 = **1.16 $/PC**
Cycle time:	60	seconds	
No. of cavities:	1	Cavity	
Machine utilization:	90	%	
Process Yield:	95	%	

Set Up Cost = Set up cost / Order quantity

$ 300 / 10,000 = **0.03 $/PC**

Where to Get More Information

- ## BOOKS

  SPE Book Store, www.4spe.org
  IMM Book Club, www.immnet.com
  Hanser Gardner Publications, www.hansergardner.com

- ## SEMINARS

  University of Massachusetts Lowell Continuing Studies and Corporate Education, Lowell, MA
  www.continuinged.uml.edu/plastics
  Society of Manufacturing Engineers, www.sme.org
  SPE Educational Seminars, www.4spe.org
  Techtrax, www.techtrax.net

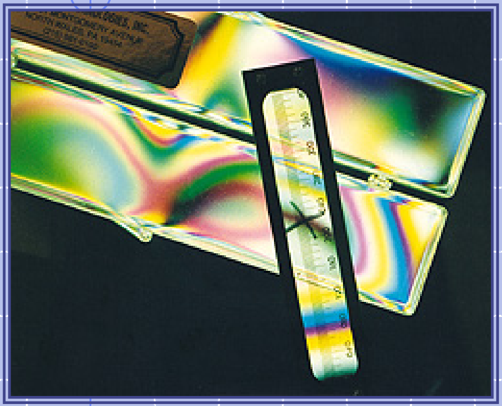
- ## TRADE PUBLICATIONS

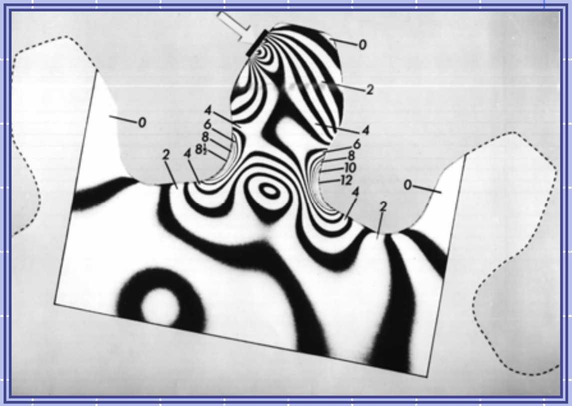
Injection Molding Magazine	immnet.com
Plastics Engineering	www.4spe.org
Plastics Technology	www.plasticstechnology.com
Modern Plastics	www.modernplas.com

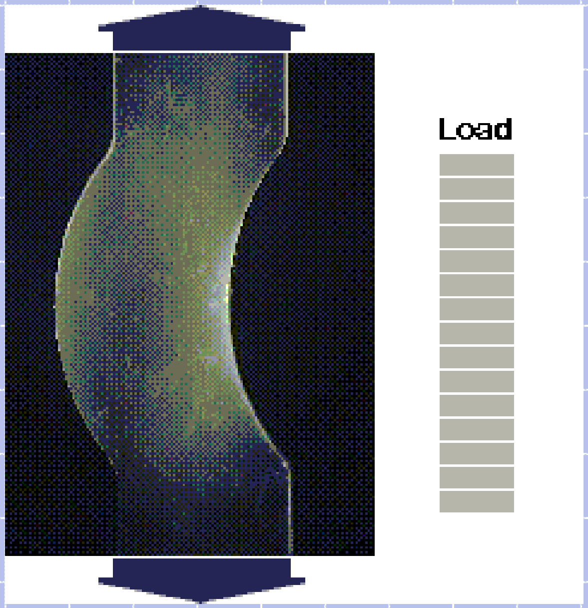
- ## INTERACTIVE TRAINING PROGRAMS

  Paulson Training Programs, Inc. www.paulson-training.com
  A. Routsis Associates Inc. www.traininteractive.com

Molded-in Stress in Optical Polycarbonate Applications







Topics of discussion

- Current methods of measuring molded-in stresses in molded polycarbonates & Industry standards.
- How is this data being used?
- Pros and Cons of current testing methods.
- Industries perception – Perceived value or inconclusive?

Polycarbonate Solvent stress Analysis

GE Plastics test Method T-77

- This test, developed by GE plastics, is used mainly for evaluating residual stress in molded parts. The test can also determine effect of external stress or stresses resulting from molded-in inserts or press-fit items.
- The combination of two solvents, **Methanol** and **Ethyl Acetate**, is used in various proportions. Effect of this mixture on specimen is observed when exposed for specified time period.

Heat Reversion Technique

- This test is conducted by simply placing the entire specimen or a portion of the specimen in a thermostatically controlled, circulating air oven and subjecting it to a predetermined temperature for a specified time. The specimens are visually examined for a variety of attributes.

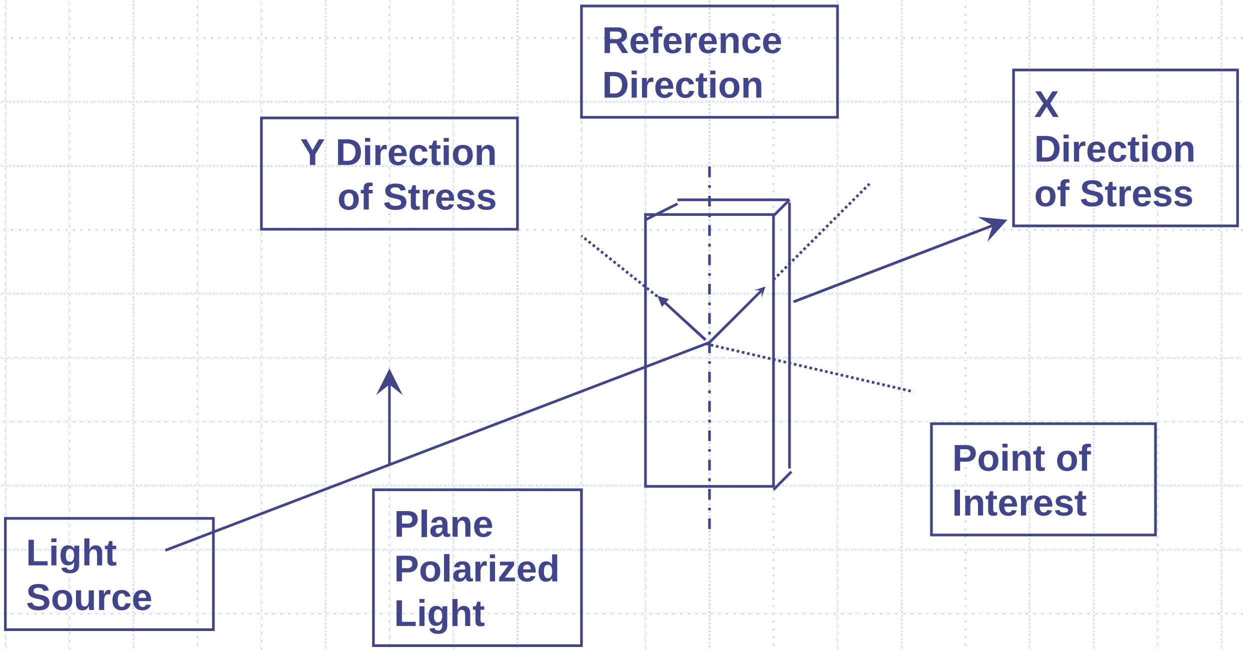
- The degree and severity of warpage, blistering, wall separation, fish scaling, and distortion in the gate area of the molded parts indicate stress level. Stresses and molecular-orientation effects in the plastic material are relieved, and the plastic starts to revert to a more stable form.

- The temperature at which this begins to occur is important. If changes start below the heat distortion temperature (HDT) of the material, high level of stress and flow orientation are indicated.

Principles of Photoelasticity

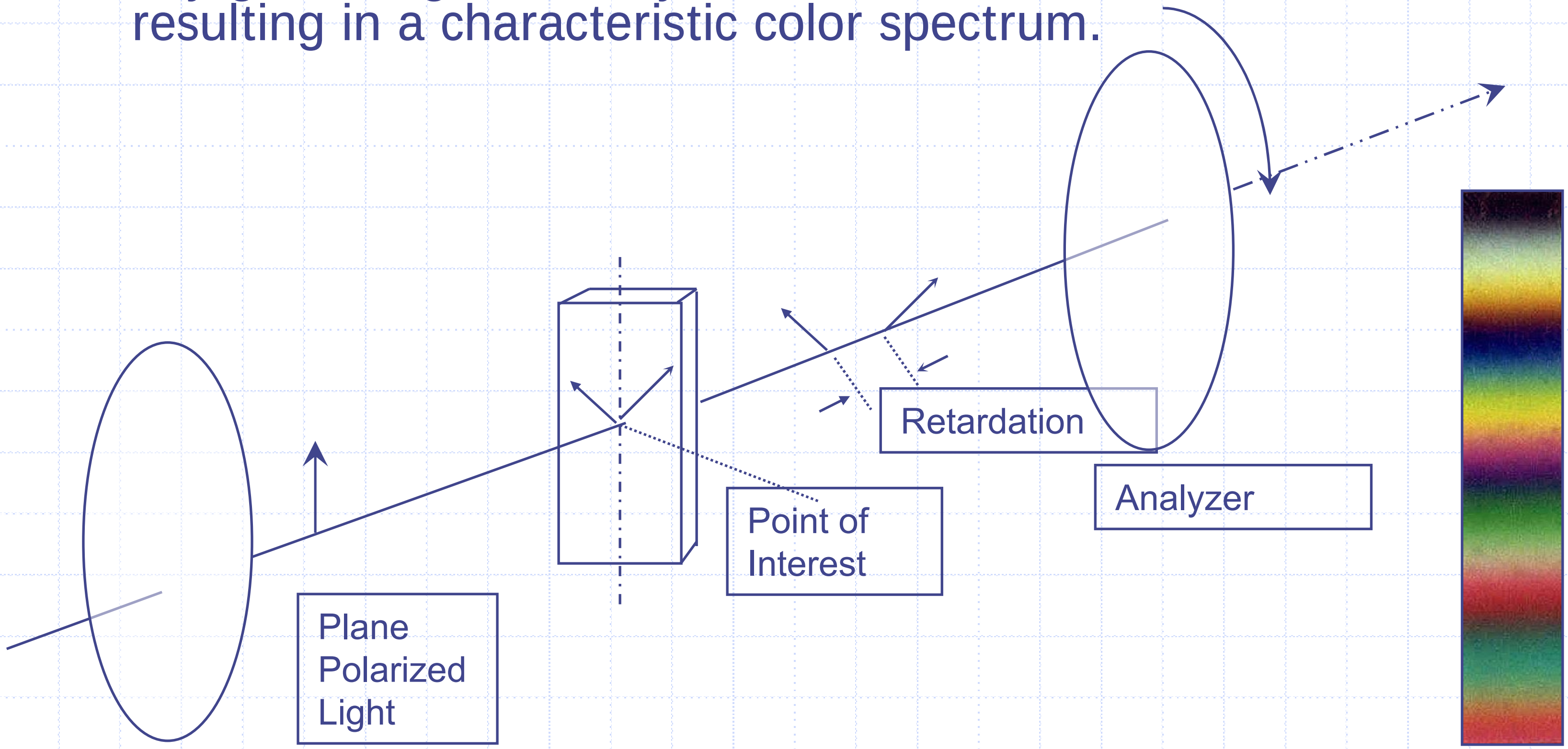
- When polarized light passes through a material that is stressed, the light splits into two divergent polarized beams vibrating in different planes (x and y) along the direction of the principal stresses.

- This phenomenon, which results in ***two different indices of refraction***, is known as ***birefringence***.



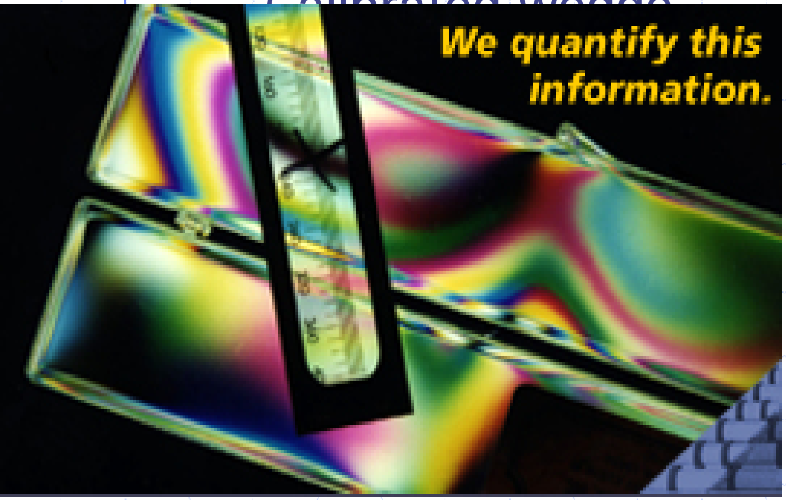
Principles of Photoelasticity

- By rotating the second polarizing filter (***analyzer***), the user can control the amount (***intensity***) of light allowed to pass through. The components of the two light waves that do pass through at any given angle of analyzer rotation interfere with each other, resulting in a characteristic color spectrum.



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



Links to articles....

- **Measuring Residual Stress In Transparent Plastics**
  http://www.devicelink.com/mpb/archive/97/01/001.html
- **Stress Crack Test: Makrolon moldings**
  http://plastics.bayer.de/AG/AE/literature/fulltext/index.jsp
- **Polycarbonate: Molded Part Internal Stress**
  http://www.diamondpolymers.com/techcenter/guides/pc_stresstest.pdf

PLASTICS FAILURE ANALYSIS AND TESTING

Vishu Shah
Consultek

Topics

Failure Analysis

Why do Plastics parts fail?

Reasons behind part failures

- Material selection
- Design
- Process
- Service Conditions

ANALYZING FAILURES – STEPS AND TOOLS

CONCURRENT ENGINEERING TO PREVENT FAILURES

Types of Failures

- Mechanical
- Thermal
- Chemical
- Environmental

Testing

- Mechanical properties
- Thermal properties
- Electrical properties
- Melt Index test
- Color measurement
- Weathering Properties
- UL Flammability testing
- Material Identification Techniques
- End Product testing

Material Selection

Material Selection Pitfalls

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

Failure resulting from improper material selection

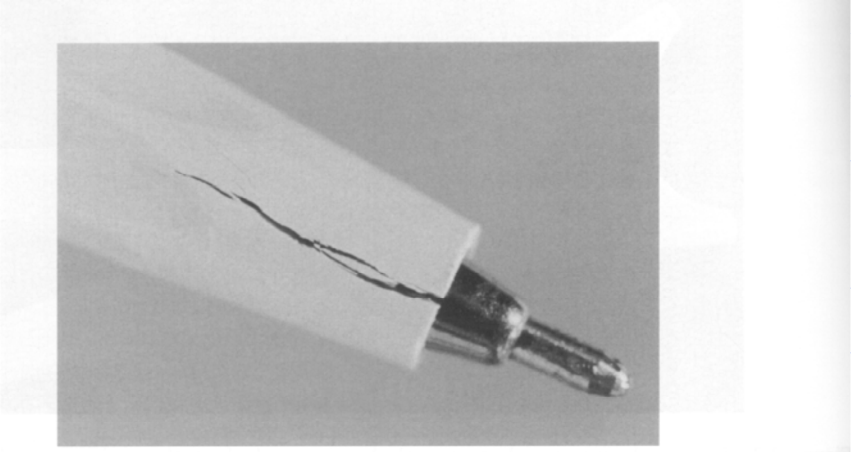


Figure 4-35 Impact polystyrene ballpoint pen barrel that cracked first or second time pen was used

Design

Most Common Mistakes in Design of Plastics

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

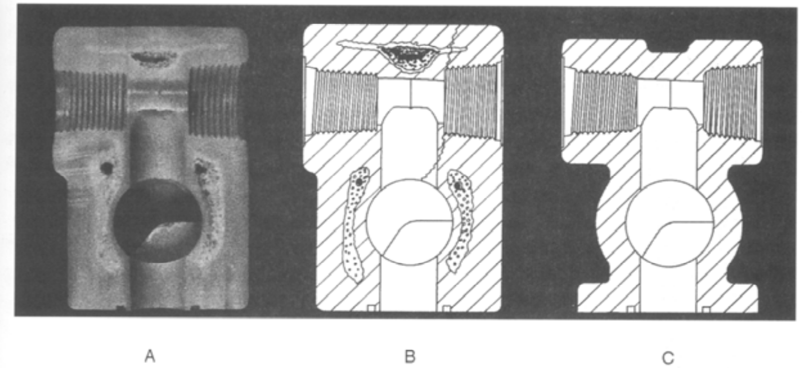


Figure 4-13 A. Acetal valve body design problem—photograph of interior ([1] Fig. 1, reproduced with permission). B. Diagram showing voids in acetal valve of Fig. 4-13A ([1] Fig. 2, reproduced with permission). C. Diagram showing improved design of acetal valve ([1] Fig. 3, reproduced with permission)

Process

Most Common Process Induced Failures

- Drying of material
- Molded-in stresses
- Knit lines
- Degradation
- Shrinkage voids
- Regrind level
- Contamination

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
- 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

Types Of Failures

- Mechanical
- Thermal
- Chemical
- Environmental

Failure Analysis Steps & Tools

- Visual Analysis…..Knit line, Degradation, Discoloration, User Abuse, Examination under magnifier, Broken surface
- Stress analysis, Photoelastic analysis, strain gage
- Simple tests…..Material Identification
- Mechanical testing
- Nondestructive testing
- Advance Tests…….FTIR, DSC, TGA Microtoming(microstructural analysis), Pyrolysis(Burn out)

IDENTIFICATION ANALYSIS

Why Identify?

- Competitive product identification
- Failure analysis
- Verification at later date
- Separation of Plastics by type for recycling/reprocessing
- Identify stored and unmarked materials, foils etc.
- Development of new materials
- Discover forgeries and imitations
- Validate material specification

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PLASTICS IDENTIFICATION CHART

PLASTIC MATERIALS

PRESS A SOLDERING IRON OR A HOT ROD (500 F) AGAINST THE SAMPLE

- SOFTENS → **THERMOPLASTICS**
- **THERMOSETS**

THERMOSETS

BURN A SMALL CORNER OF THE SAMPLE

- SELF-EXTINGUISHING
- CONTINUES TO BURN

MATERIAL / OBSERVATIONS	DAP	MELAMINE FORMALDEHYDE	PHENOL FORMALDEHYDE	UREA FORMALDEHYDE	POLYESTER	SILICONE	EPOXY
COLOR OF FLAME	YELLOW	YELLOW WITH BLUE TIP	YELLOW	YELLOW WITH GREENISH BLUE EDGE	YELLOW WITH BLUE EDGES	BRIGHT YELLOW	YELLOW
ODOR	FAINT ODOR OF PHENOL	FISH LIKE	PHENOL	FORMALDEHYDE	SOUR CINNAMON	NONE	PUNGENT AMINE
OTHER CHARACTERISTICS	BLACK SMOKE	SWELLS AND CRACKS	MAY OR MAY NOT BE SELF-EXTING.	SWELLS AND CRACKS	BLACK SMOKE WITH SOOT	CONTINUES TO BURN	BLACK SMOKE

THERMOPLASTICS

DROP A SMALL SAMPLE IN WATER

- FLOATS → PP,PE
- SINKS → ALL OTHERS

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	....

ALL OTHERS → BURN A SMALL CORNER OF THE SAMPLE

- NO FLAMES: PTFE, CTFE, PVF, FEP → DRIPS (YES / NO)
- CONTINUES TO BURN: ABS, ACRYLICS, ACETALS, CELLULOSE ACETATE, CELLULOSE ACETATE BUTYRATE, CELLULOSE PROPIONATE, CELLULOSE NITRATE, POLYSTYRENE, POLYURETHANE, POLYESTER → DRIPS (YES / NO)
- SELF-EXTINGUISHING: NYLON, POLYCARBONATE, PPO, POLYSULFONE, PVC → DRIPS (YES / NO)

No flames

MATERIAL / OBSERVATIONS	FEP (drips: yes)	CTFE (drips: yes)	PTFE (drips: no)	PVF (drips: no)
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

MATERIAL / OBSERVATIONS	ABS	ACETAL	ACRYLICS	CELLULOSE ACETATE	CELLULOSE ACETATE BUTYRATE	CELLULOSE PROPIONATE	POLYSTYRENE	POLYESTER	CELLULOSE NITRATE	POLYURETHANE
DRIPS	YES	YES	YES	YES	YES	YES	YES	YES	NO	NO
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	PALE YELLOW	YELLOW
ODOR	ACRID	FORMALDEHYDE	FRUITY/ FLORAL	VINEGAR	RANCID BUTTER	BURNT SUGAR	ILLUMINATING GAS OR MARIGOLD	BURNING RUBBER	CAMPHOR	FAINT APPLE
SPEED OF BURNING SLOW < 3 INCHES FAST > 3 PER MIN.	SLOW	SLOW	FAST	SLOW	SLOW	FAST	FAST	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	SAMPLE BURNS COMPLETELY	SLIGHT BLACK SMOKE

Self-extinguishing

MATERIAL / OBSERVATIONS	NYLON	POLYSULFONE	POLYCARBONATE	PPO	PPS	PVC
DRIPS	YES	YES	YES	NO	NO	NO
COLOR OF FLAME	BLUE WITH YELLOW TIP	ORANGE	ORANGE OR YELLOW	YELLOWISH ORANGE	YELLOW-ORANGE	YELLOW WITH GREEN EDGES
ODOR	BURNT WOOL OR HAIR	ODOR OF SULFUR	PHENOL	PHENOL	FAINT ROTTEN EGGS	HYDROCHLORIC ACID
SPEED OF BURNING SLOW < 3 INCHES FAST > 3 PER MIN.	SLOW	FAST	SLOW	SLOW	SLOW	SLOW
OTHER CHARACTERISTICS	FROTHS	BLACK SMOKE WITH SOOT	BLACK SMOKE WITH SOOT	DIFFICULT TO IGNITE SMOKE	METALLIC SOUND WHEN DROPPED	WHITE SMOKE

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ID Chart
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MELT INDEX TEST

- Melt Index test measures the rate of extrusion of thermoplastic material through an orifice of specific length and diameter under prescribed conditions of temperature and pressure.
- Melt Index value is reported in grams per 10 minutes for specific condition.
- Distinguishes between the different grades of a polymer.

Information on Web.......

USEFUL LINKS

GENERAL INFORMATION

		www.
Web Watch directory	Anything & everything Plastics	plasticsnews.com/subscriber/webwatch/wwindex.html
Plastics.com	Plastics related commercial website	plastics.com
.Commerx	Plastics related commercial website	.commerxplasticsnet.com
Processzone .com	Plastics related commercial website	processzone.com
Polysort	Plastics related commercial website	polysort.com
GE Plastics Design Solution Ctr	Plastics design help	geplastics.com/resins/designsolution
Injection Molding magazine	Magazine's website	immnet.com
Plastics News magazine	Magazine's website	plasticsnews.com
Modern Plastics magazine	Magazine's website	modplas.com
Plastics Technology Magazine	Magazine's website	plasticstechnology.com
Molding Systems	Magazine's website	moldingsystems.com
Macrogalleria	Polymer Chemistry made simple	prc.usm.edu/macrog/index.htm
Medical Device Link	Medical Plastics Information	devicelink.com
Qplastics.com	Plastics related commercial website	qplastics.com
Studyweb	Polymer Processing information	studyweb.com
Plastics Mall	Plastics related commercial website	plasticsmall.com
Vinyl World	PVC related information	plasticsforum.com/vinylworld/index.html
Plastics Resource	Recycling information/Plastics 101	pasticsresource.com
Teaching Plastics	Virtual Plastics classroom	teachingplastics.org

MATERIAL SEARCH

Matweb	Excellent source for material search	matweb.com
IDES	Free data sheets	freemds.com
MSDS search	MSDS data sheets	msdssearch.com
Conversion Help	Very useful conversion tool	matweb.com/conversion.htm
Weight Calculator	Easy to use part weight calculator	matweb.com/weight-calculator.htm
SD Plastics	Funny and useful website	sdplastics.com
Plaspec material search	Material selection database	plaspec.com

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

Plastics Identification & Material Selection Process

Vishu Shah
Consultek

IDENTIFICATION ANALYSIS

Why Identify?

- Competitive product identification
- Failure analysis
- Verification at later date
- Separation of Plastics by type for recycling/reprocessing
- Identify stored and unmarked materials, foils etc.
- Development of new materials
- Discover forgeries and imitations
- Validate material specification

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

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PLASTICS IDENTIFICATION CHART

PLASTIC MATERIALS

PRESS A SOLDERING IRON OR A HOT ROD (500 F) AGAINST THE SAMPLE

SOFTENS → THERMOPLASTICS

→ THERMOSETS

THERMOSETS

BURN A SMALL CORNER OF THE SAMPLE

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

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

DROP A SMALL SAMPLE IN WATER

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	....

SINKS → ALL OTHERS

BURN A SMALL CORNER OF THE SAMPLE

NO FLAMES

PTFE
CTFE
PVF
FEP

DRIPS

MATERIAL / OBSERVATIONS	FEP (YES)	CTFE (YES)	PTFE (NO)	PVF (NO)
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

ABS, ACRYLICS
ACETALS
CELLULOSE ACETATE
CELLULOSE ACETATE BUTYRATE
CELLULOSE PROPIONATE
CELLULOSE NITRATE
POLYSTYRENE
POLYURETHANE
POLYESTER

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 ≤ 3 INCHES FAST > 3 PER MIN.	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

NO

MATERIAL / OBSERVATIONS	CELLULOSE NITRATE	POLY-URETHANE
COLOR OF FLAME	PALE YELLOW	YELLOW
ODOR	CAMPHOR	FAINT APPLE
SPEED OF BURNING SLOW ≤ 3 INCHES FAST > 3 PER MIN.	FAST	FAST
OTHER CHARACTERISTICS	SAMPLE BURNS COMPLETELY	SLIGHT BLACK SMOKE

SELF-EXTINGUISHING

NYLON
POLYCARBONATE
PPO
POLYSULFONE
PVC

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 ≤ 3 INCHES FAST > 3 PER MIN.	SLOW	FAST	SLOW
OTHER CHARACTERISTICS	FROTHS	BLACK SMOKE WITH SOOT	BLACK SMOKE WITH SOOT

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 ≤ 3 INCHES FAST > 3 PER MIN.	SLOW	SLOW	SLOW
OTHER CHARACTERISTICS	DIFFICULT TO IGNITE SMOKE	METALLIC SOUND WHEN DROPPED	WHITE SMOKE

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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...next slide

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
  Continuous Use Temperature (Relative thermal Index)
- **Regulatory Performance**
  Flammability (UL 94)
  High Voltage Arc Tracking
  FDA

Source: GE Plastics

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.

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, pocl 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; speake 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, grille 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; switcl
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

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

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

Other Important Considerations

- Cost
- Product design
- Tooling
- Shrinkage
- Secondary Operations
- Assembly
- Interpreting Data Sheets
- Prototyping and Testing

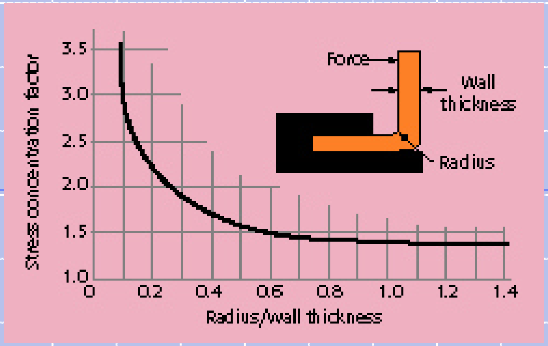
Material Selection using Web

- Matweb www.matweb.com
- Ides www.freemds.com
- Plaspec www.plaspec.com

- Consultek www.consultekusa.com

Plastics Part Design for Injection Molding

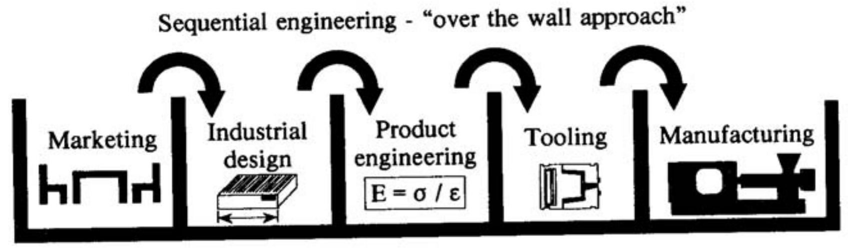
Vishu Shah



CURRICULUM

- Polymer Chemistry Basics and Material Selection Process
- Plastics Material Identification Techniques
- Concurrent Engineering, Plastics Part Design Process overview
- Manufacturing Considerations – Design For Molding
- Manufacturing Considerations – Design For Molding
- Basic Part Design
- Basic Part Design
- Basic Part Design, Prototyping and Testing
- Design For Assembly and review of assembly techniques
- Tooling Considerations

CONCURRENT ENGINEERING



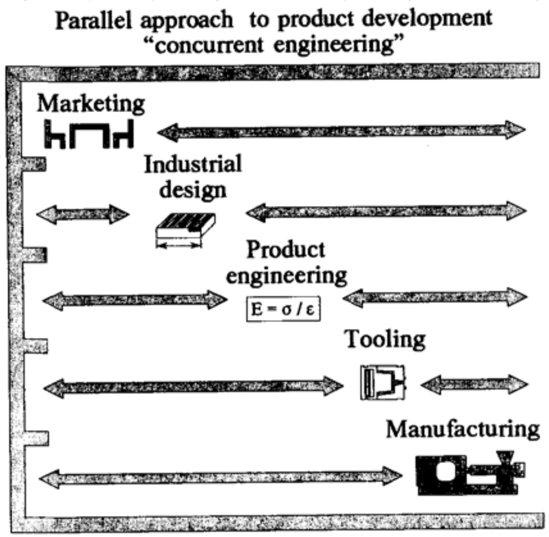


Figure 3.4. "Parallel" or "Concurrent Engineering" approaches to product design reduce development time, improves quality, and minimizes the potential for unanticipated production or performance problems.

Manufacturing

Considerations For

Injection Molded Plastic Parts

Design For Manufacturing/Molding (DFM)

- **Mold filling**
- **Weld lines / Knit lines**
- **Shrinkage**
- **Ejection**

Basic Part Design

Wall Thickness considerations

Why is uniform wall thickness important?

- Sink marks, Warpage, Voids, Molded-in Stress, Long cooling time, Even material flow

What causes non-uniform wall thickness?

- Corners.................Add radii
- Transition areas.............taper over distance
- General Ignorance..........Get educated
- Outright stupidity...........Genocide??????

Application Requirements

- Structural requirements, strength, impact, fatigue etc influenced by wall thickness
- Electrical loads also impact on wall thickness

Moldability

- Size of the part and ability of the material to fill determines the minimum wall thickness

Agency requirements

- Must meet minimum wall thickness specifications....example...UL flammability rating

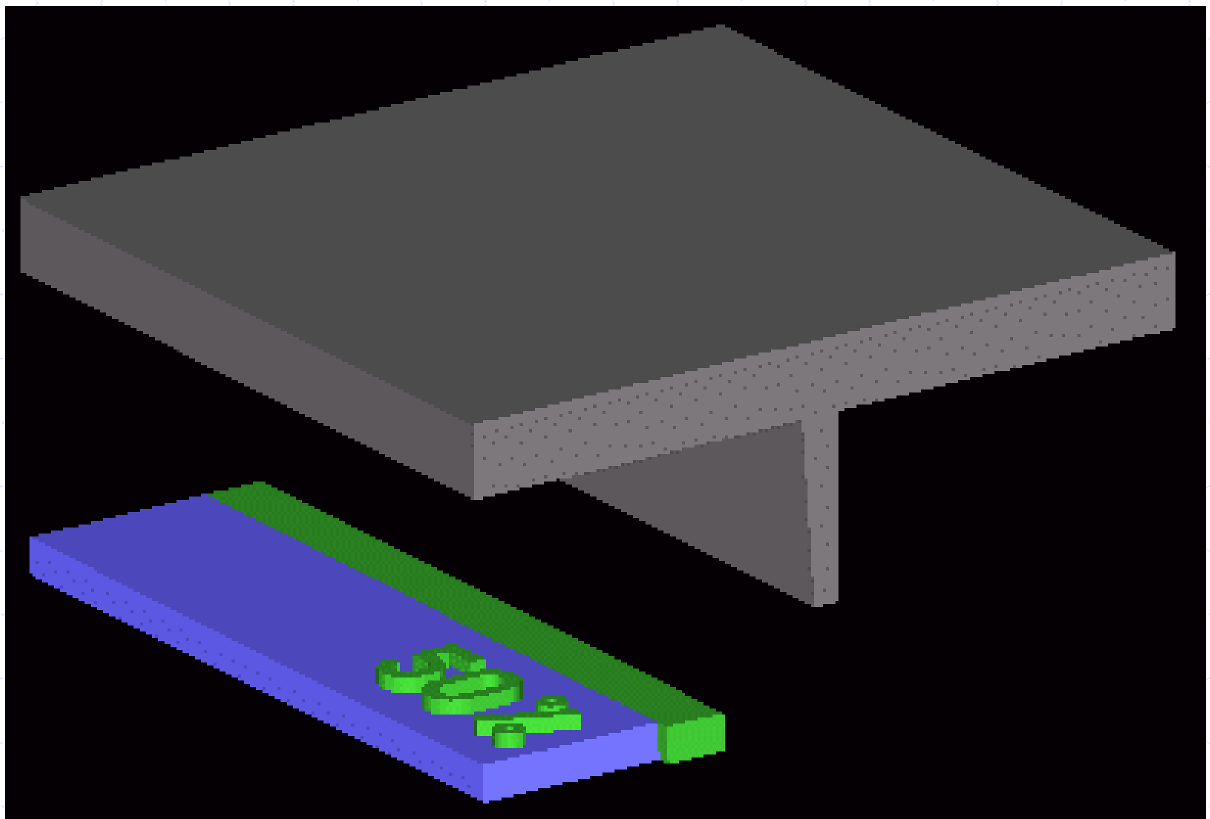
Cost and performance considerations

- Current threshold is approx 1 mil or .040 inches
- Thin wall molding techniques

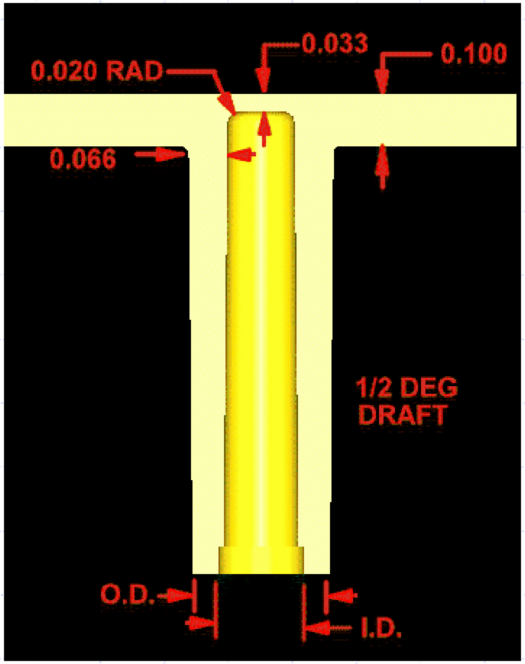
THE DIVINE 66% RULE

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.

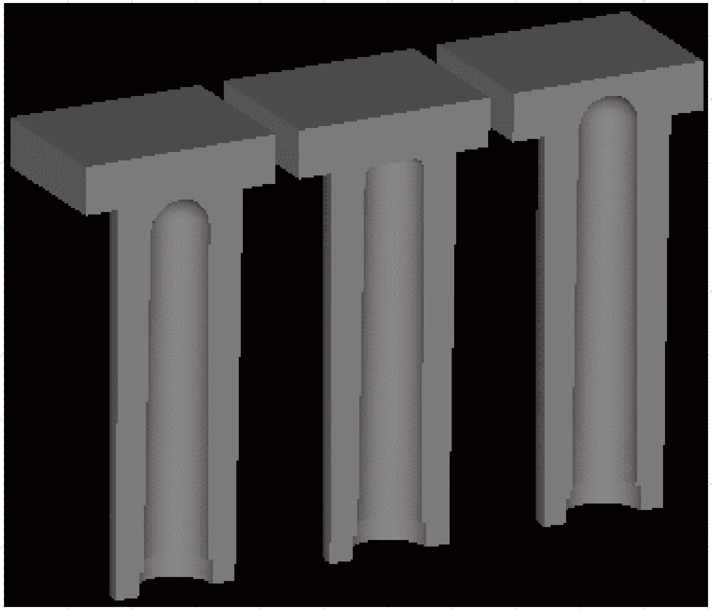


Boss



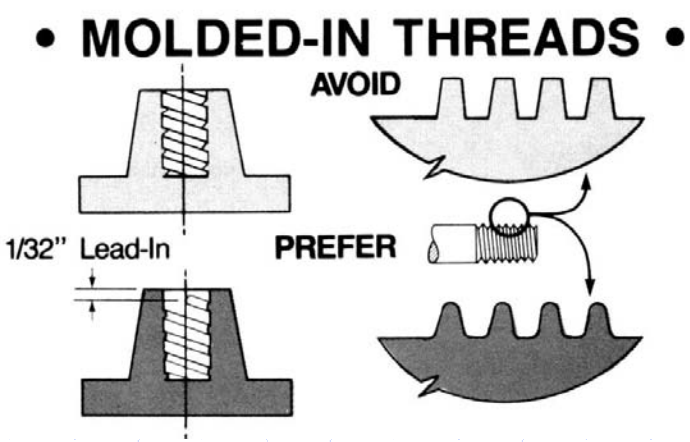
Note that the the boss wall is 66% of the nominal wall thickness. The core pin up the center penetrates 50-66% of the way through the nominal wall.

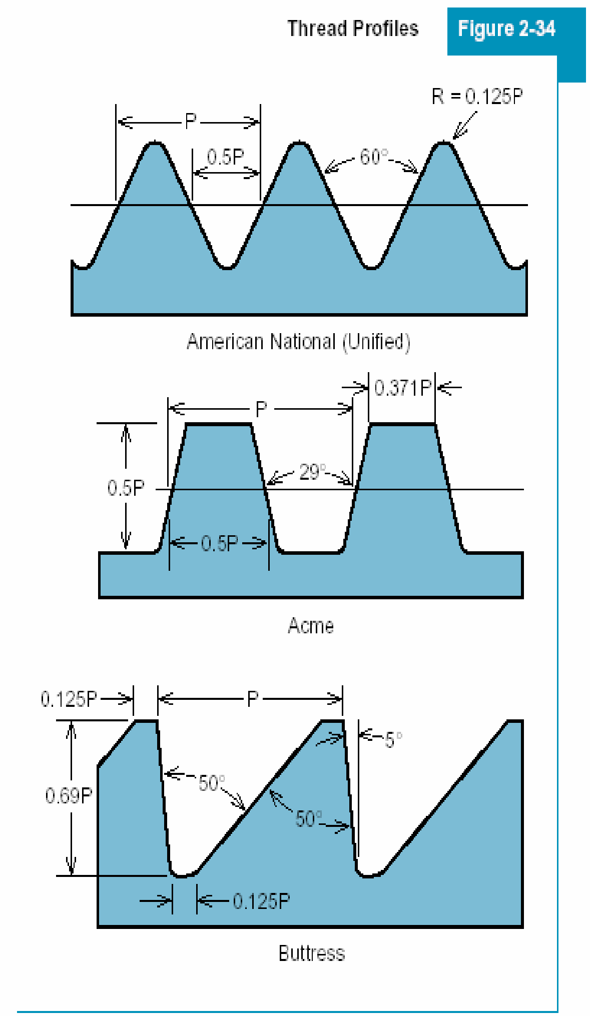
Note the circular sink marks
created by the failure to properly core out the boss



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.

PROTOTYPING TECHNIQUES

- Hand fabrication and machining
- Printing (Solid Object printer)
- Stereo Lithography (SLA)
- Selective Laser sintering (SLS)
- Part Casting techniques
- Soft tooling
- Hard tooling

All about RP

www.cc.utah.edu/~asn8200/rapid.html

WELCOME TO THE RAPID PROTOTYPING HOME PAGE

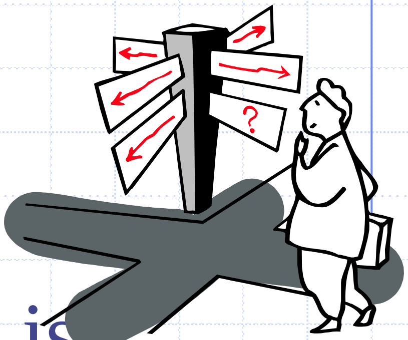
"Your link to the world of Rapid Prototyping" since July, 1995

Last update: ***February 13, 2002*** . This document is updated frequently in an effort to keep up with the latest developments in the fast paced field of Rapid Prototyping (aka Desktop Manufacturing, Solid Freeform Fabrication, or Layered Manufacturing). The sign indicates items that have been added since the last update.

Also visit: The Rapid Tooling Home Page.

TABLE OF CONTENTS

Tooling Considerations



How can one design a part so that tooling is:

- Easy to build
- Cost effective
- Efficient in terms of cycle time and operation
- Less complex
- Long lasting

Design For Assembly (DFA)

Advantage>>>>>>PLASTICS

- Variety of fastening methods……..Press fit, Snap fit, Bonding, Welding
- Ability to manufacture complex geometries
- Ability to use various manufacturing processes
- lower cost assembly techniques
- Automation
- No post secondary operations (Such as deburring, finishing)
- Reduce number of components
- Lower overall product cost

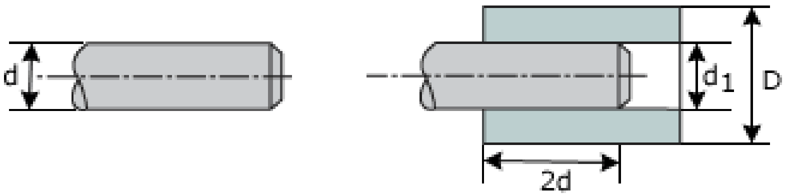
Press Fit Assembly

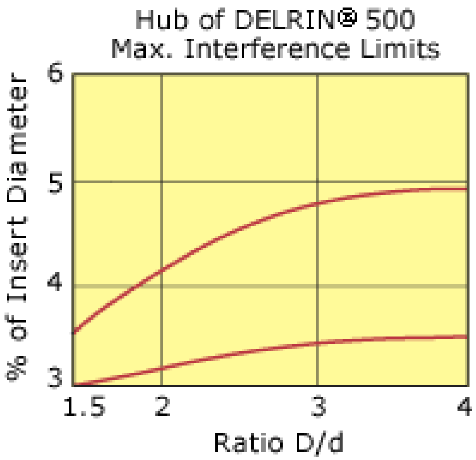
Material Considerations

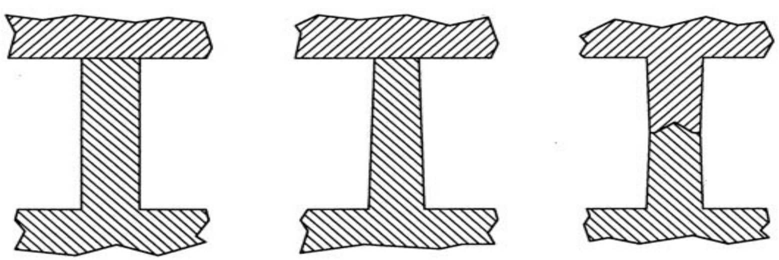
- **Ductile materials preferred**
- **Low stress level desired (Calculate)**
- **Use materials with similar coefficient of thermal expansion**

Design Considerations

- **Use interference limit graphs from material suppliers**
- **Draft angle as small as possible**
- **Smooth Vs. knurled or splined shaft**







Hole produced with zero draft results in uniform stress distribution but is difficult to eject

Single core pin with draft angle results in non-uniform stress distribution for press fits

Two telescoping core pins with minimum draft as an option

Figure 6.3. Core pins with excessive draft result in non-uniform stress distributions for press fit hubs. Hubs with zero draft are more difficult to mold. The telescoping core pins offer a balance in terms of stress distribution and moldability.

Part Design to Enhance Flow and Shape

Design part with ample curve to enhance flow

Design part with minimum number of projections and cored sections

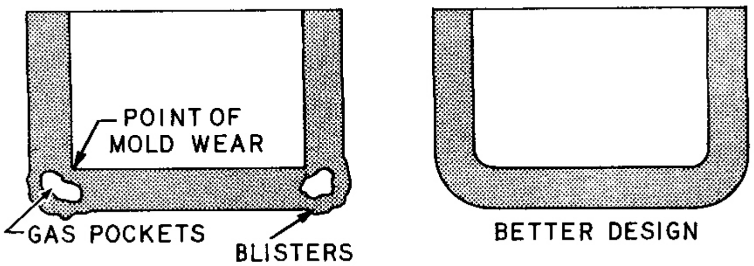
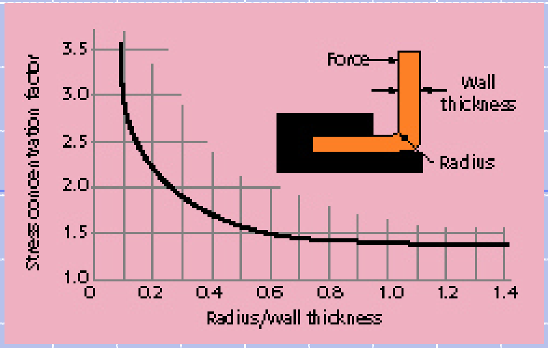


Figure 3–10. Streamlining of the plastic part will help to prevent gas pockets.

Tooling for Injection Molding

Vishu Shah



Curriculum

- **Polymer Chemistry - Plastics materials**
- **Injection Molding process**
- **Tooling Considerations**
  Mold Metallurgy, Runners, Gates, Sprue bushing, Sprue pullers
- **Mold Design and Simulation software**
- **Tooling considerations**
  Cooling, Venting
- **Tooling Considerations**
  Draft angles, Shrinkage, Mold polishing, Tool surface enhancement
- **Hot runner systems**
- **Rapid tooling techniques**

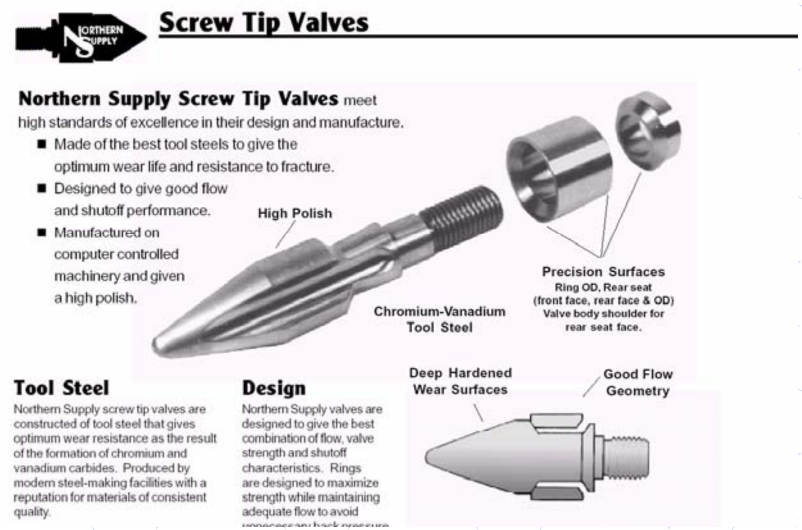
Screw - Barrel – Check Ring

Screw Material

- Nitrided
- D2

Barrel materials

- Nitrided
- Bimetallic



Reciprocating Screw Tip Assemblies 47

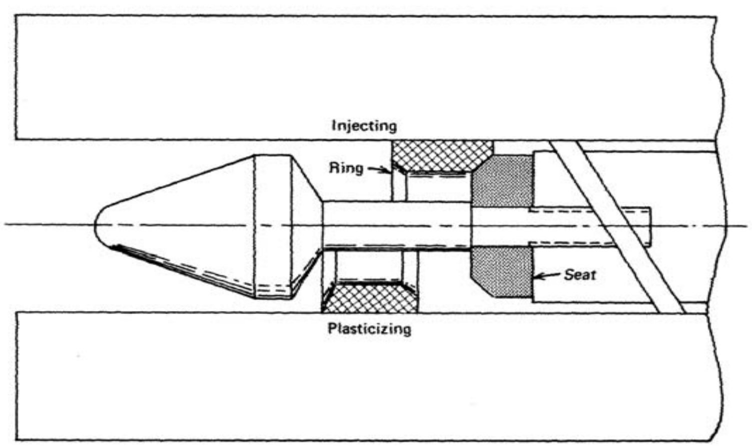


Figure 1-22 Ring type nonreturn valve for reciprocating screws.

Types Of Molds

- Two plate mold
- Three Plate mold
- Insulated hot runner mold
- Hot runner mold
- Stack mold

Hot Runner (Runnerless) Molds

In the hot runner mold, the runners are kept hot in order to keep the molten plastic in a fluid state at all times. This is a “Runnerless” molding process and hence the name. Hot runner molds are similar to the three plate molds, except that the runner section of the mold is not opened during the cycle. The heated runner plate (Manifold) is kept insulated from the rest of the relatively cooler mold.

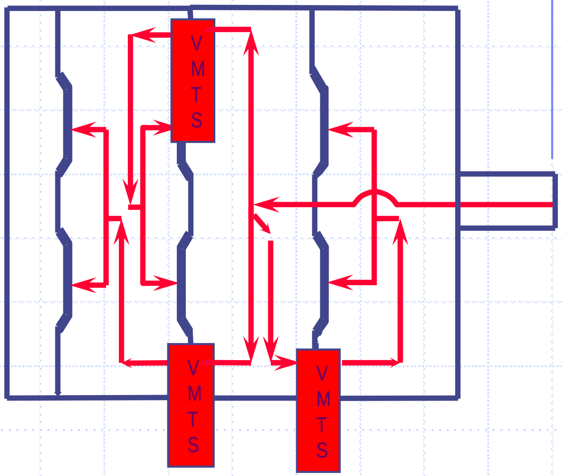
- No runner to separate from the molded parts
- No runners to either dispose of or regrind and reprocess
- Less possibility of contamination
- Hot drops carry consistent heat at processing temperature directly into the cavity
- Lower cycle (cooling) time – cooling time not runner dependent
- No robotics (or automation) needed for runner removal
- Possibly lower injection pressure
- No sprue/runner sticking problems
- Cleaner molding environment

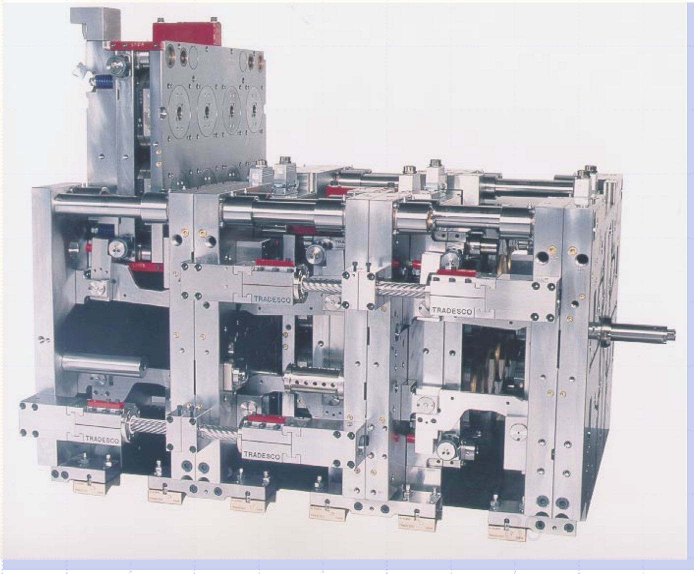
Innovations

A StackTeck® Company

- 3 Level Stack Mold

  - QPC design expandable to 4 level Stack Mold
  - 50% Increase in production over conventional 2 level stack molds
  - Fits into extended machine Shut Heights available today
  - Fully balanced Hot Runner System using Triple VMTS Technology
  - Suitable for Deep Draw Parts
  - Series Centering Mechanism





Major categories of applications in molds

- Mold Cavity and Core unit components
- Mold base plates
- Special function components (Slides, gibs, wear plates)

Material selection considerations

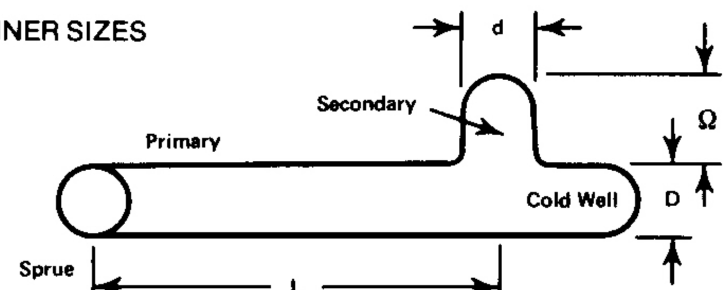
- Type of plastics to be molded….abrasive, corrosive etc
- Number of parts to be molded
- Surface finish of molded parts
- Cavity design requirements…metal to metal contacts etc.
- Method of cavity forming…Machining requirements
- Method of heat treating

Recommended runner sizes

Runners

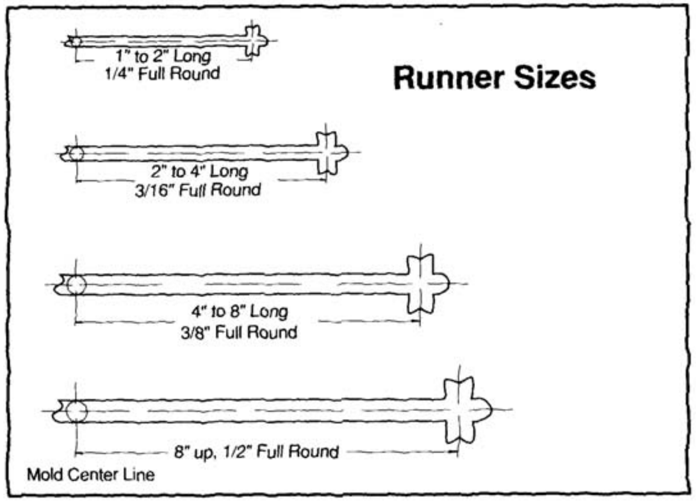
Full round runners are the most efficient for minimizing heat loss and pressure drops. *Trapezoidal* runners are satisfactory when dictated by design. *Half round* runners are not recommended. The diameter of the runner for various lengths of flow is shown in Figure IV.

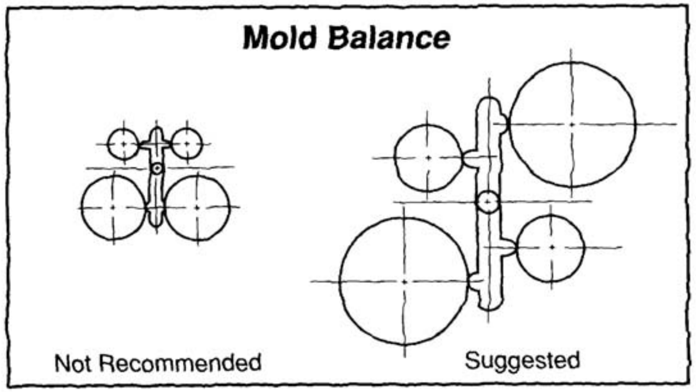
RUNNER SIZES



Primary Length (L)	Primary Diameter (D)
10" Long or Above	.375"
3"–10" Long	.312"
3" or Under	.250"
Secondary Length (l)	**Secondary Diameter (d)**
Up to 3"	.250"

Figure IV





Types of Gates

- Sprue Gate....used on large single cavity parts, cold slug issues
- Edge gate...Large surfaces, thin wall, keep parts attached
- Fan gate...minimize surface imperfections, reduce stress
- Sub gate...(Tunnel gate)...Automation
- Diaphragm gate...round part, avoid weld line
- Flash gate...similar to fan gate..much wider, low warpage
- Ring gate...hollow tubular parts, helps with core shift
- Tab gate...stress free part and optical clarity...acrylic lens
- Sub gate into ejector pin...no gate marks

Gating Considerations

Land Length:0.040 max. long land length creates excessive pressure drop, part filling problem

Steel safe: Start small and increase as needed

Gate size: Larger the gate..lower the stress

Gate placement: Cosmetic issues, Jetting

Sizing Vents

Figure 2 *Parting Line Venting*

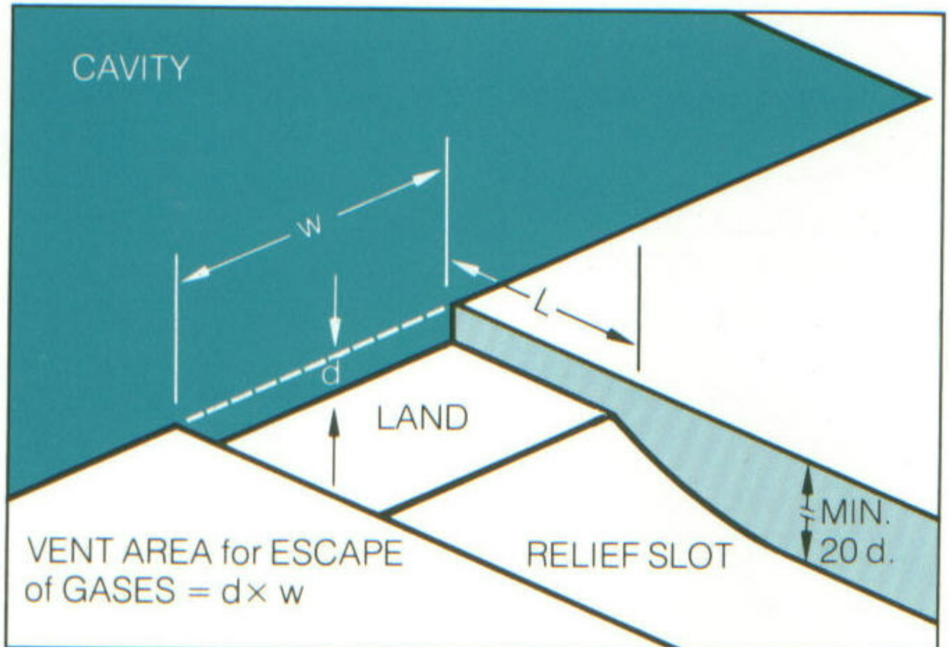


Table 1 *Vent dimensions—mils* (mm)*

	Depth	Land
"Delrin" acetal resin	1.5-2 (0.038-0.05)	40 (1.0)
"Zytel" nylon resin	0.5-1 (0.013-0.025)	30-60 (0.75-1.5)
"Minlon" engineering thermoplatic resin	2 (0.05)	30 (0.75)
GRZ (glass-reinforced "Zytel" nylon) resin	2 (0.05)	30 (0.75)
"Rynite" polyester resin	2 (0.05)	30 (0.75)

*1 mil = 0.001 inch

Width: As wide as possible

Minimum 0.125

Depth: 0.0005 to 0.002

Ask material supplier

Land: As short as possible

Relief slot (vent channel):

Minimum 20 x depth

Amount: 30% of the perimeter of the part

VENT THE RUNNER….

YOU CAN'T HAVE TOO MUCH VENTING!!!!!

Mold cooling

Tool Design/Cooling

GENERAL POLYMERS
Technical Service

☑ How does cooling work ?

- There are three methods for exchanging heat.
  - ➔ Radiation
  - ➔ Convection
  - ➔ Conduction

➔Hot plastic enters the mold, the heat moves by convection through the plastic until it comes to the surface of the mold.

- The heat is then conducted through the mold to the water cooling channels.
- There is a substantial amount of the heat that reaches the outside of the mold and is lost by radiation.

Flow rate

Minimum flow rate (GPM)

For good Reynolds Number (turbulent flow)….

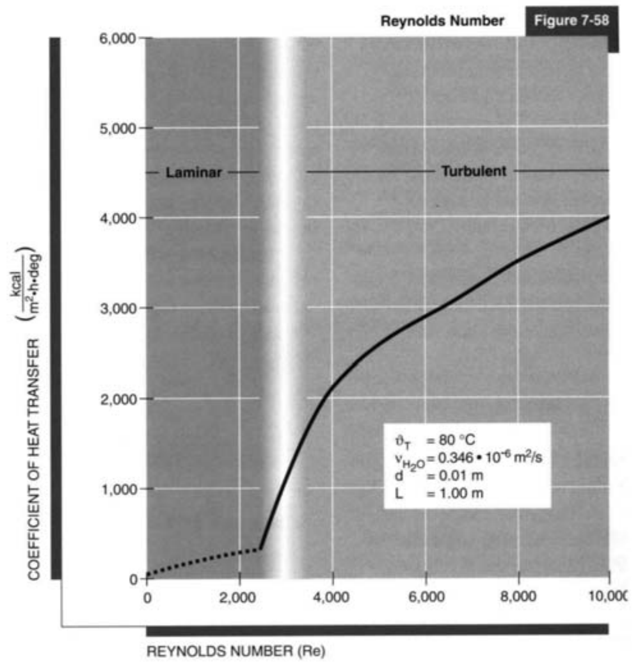
Minimum GPM = 3.5 x pipe I.D.

Example:

- Ten ½” lines in parallel
- All equal lengths into common manifolds

Min. GPM Required = ½ x 3.5 x 10 = 17.5*

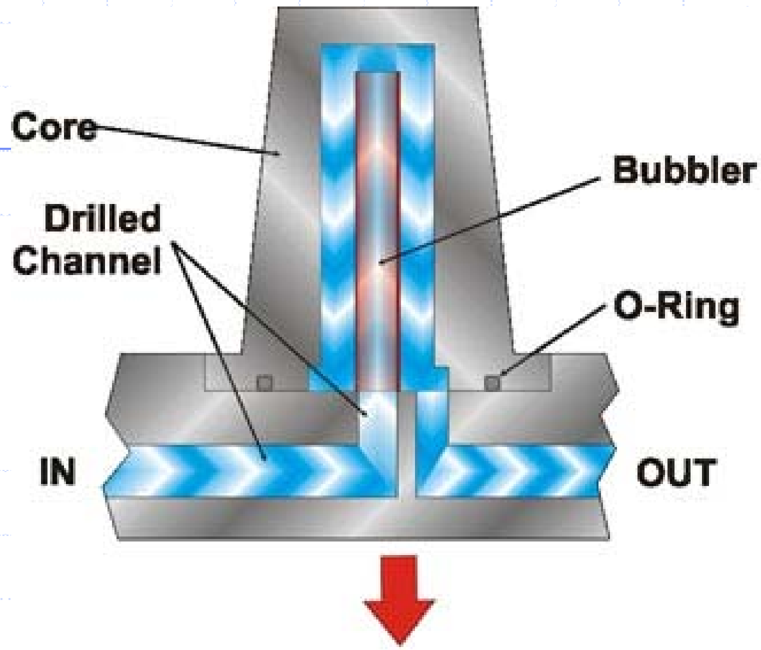
* Does not take into account heat load required to remove total heat from Plastic material.

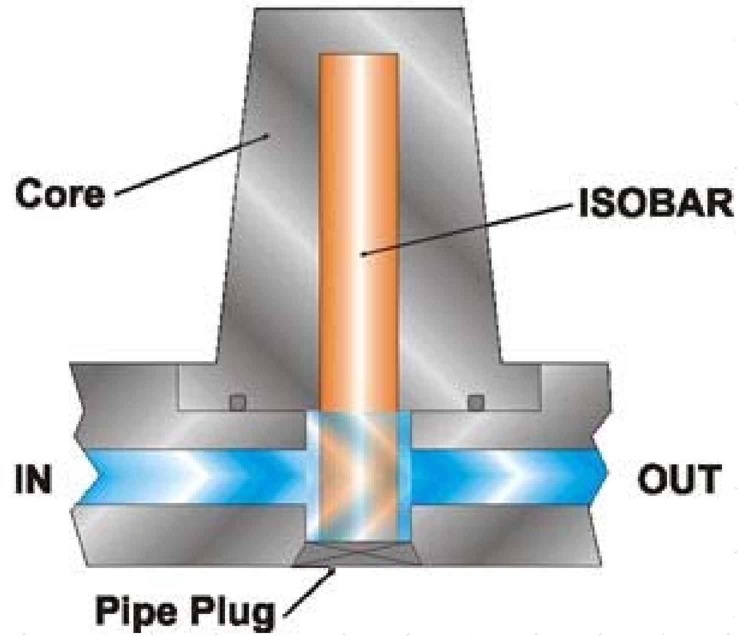


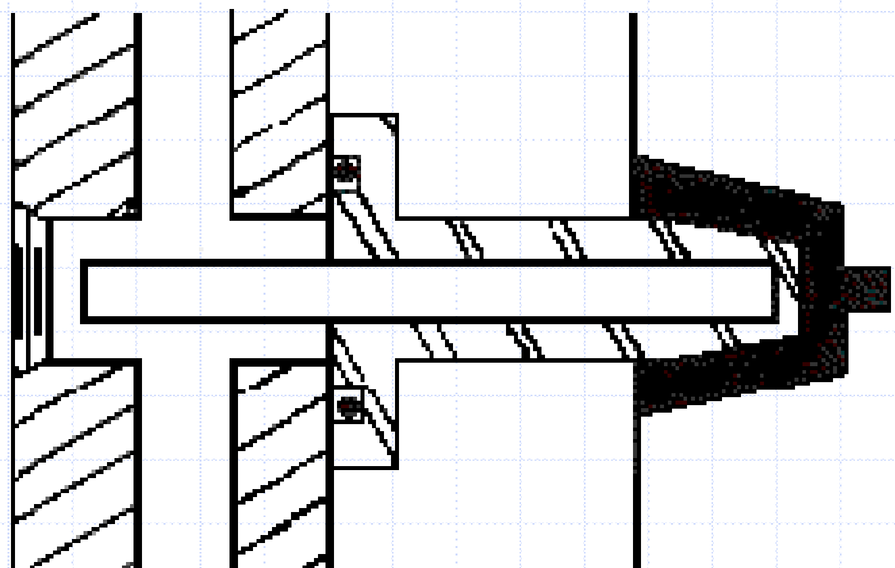
Coefficient of heat transfer as a function of Reynolds number for water.

Alternate Rule of Thumb: 7/16’ Diameter Waterline requires 1.5 GPM to achieve turbulent flow.

Heat Pipes

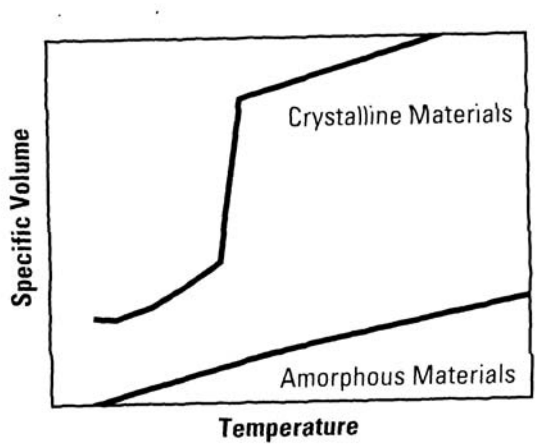

Core
Bubbler
Drilled Channel
O-Ring
IN
OUT


Core
ISOBAR
IN
OUT
Pipe Plug



Shrinkage - Crystalline vs. Amorphous material

Why do crystalline material have greater shrinkage than amorphous materials?



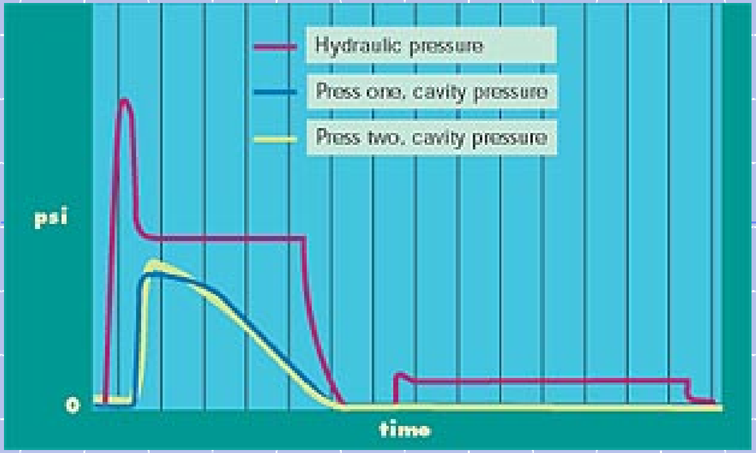
As the melt cools and changes from liquid to solid, there is a substantial decrease in specific volume in crystalline materials due to the crystalline structure of the polymer and therefore greater shrinkage.

PROTOTYPING TECHNIQUES

- Hand fabrication and machining
- Printing (Solid Object printer) 3D Systems
- Stereo Lithography (SLA) 3D Systems
- Selective Laser sintering (SLS) 3D systems
- Fused Deposition Modeling (FDM)Stratasys
- Part Casting techniques
- Soft tooling (Machining, Keltool, SLS process)
- Hard tooling

Scientific Injection Molding

Vishu Shah



What is Scientific Injection Molding?

- Science of Injection molding
- Everything substantiated by scientific data
- Scientific approach to establishing molding variables
- Understanding of four critical components
  - Material
  - Part Design
  - Tooling
  - Processing
- Every decision Must be backed by scientific data

CURRICULUM

- Polymer Chemistry Basics
- Part Design Fundamentals
- Overview of Basic Injection Molding process
- Drying, Material mixing, Coloring, Regrind Usage
- Major Process variables
- Decouple Molding, Universal Set Up Sheet
- Tooling Considerations, Venting, Cooling, Ejection
- Cycle Time Optimization,and Trouble shooting techniques
- Mold Flow Analysis, Productivity Improvements
- Modern Injection Molding Operation

Injection Molding.....simplified

Injection molding is a dynamic, non-linear process consisting of four sequential stages: plastication, filling, packing and ejection. In its simplest form an injection molding machine can be regarded as a large hydraulic pump, which, by virtue of a hydraulically controlled ram: transforms solid thermoplastic pellets into molten polymer (plastication), injects molten polymer into the mold cavity (filling), and pressurizes the cavity during polymer solidification (packing). Once the molded part has taken its final shape and allowed to cool, the mold is opened (ejection) and the process repeated

Source: Moldflow article

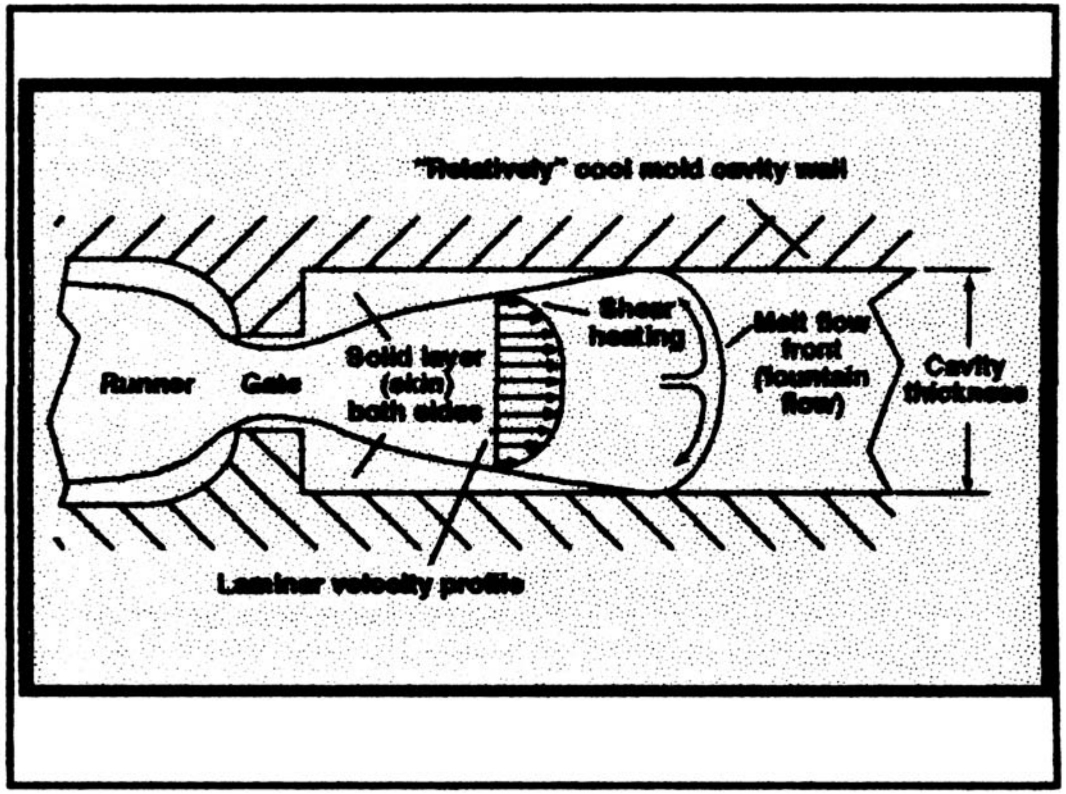
3 M's and 3 F's

Material is MELTED.........MIXED....&.........MOVED

FLOWED (INJECTED).........FORMED.........&.........FROZEN (COOLED)

Source: GE Plastics)

Fountain flow



Mold filling is non-isothermal process involving laminar fountain flow and solid layer formation at the cavity and core walls due to the effects of conductive cooling.

Materials Drying

Why do we need to dry Plastics Materials?

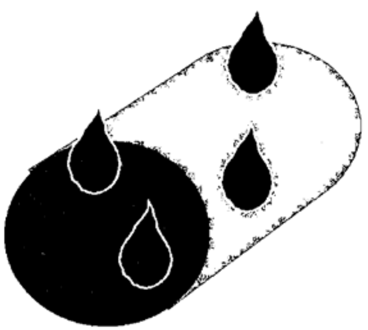
All Plastics, when exposed to atmosphere, will pick up moisture to a certain degree depending upon the humidity a[...]
type of the polymer.

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

Hygroscopic Pellet

Moisture is absorbed into the Pellet

Non-Hygroscopic Pellet



Surface Moisture

L/D and Compression Ratio

$$\frac{L}{D} = \frac{\text{Flight length of screw}}{\text{Outside diameter of screw}}$$

$$\text{Compression Ratio} = \frac{\text{Depth of feed section}}{\text{Depth of metering section}} = \frac{D_f}{D_m}$$

Figure 4C

Compression Ratio

GP Materials	3:1
PVC	1.4:1
Acetal	4:1

Major Process Variables

- Temperature
- Flow Rate (Injection velocity)
- Pressure
- Time

Interdependence of Variables ……..

Flow rate

All Plastics exhibit Non-Newtonian behavior………

Newtonian: Shear rate has no effect on viscosity…….Water

Non –Newtonian: Viscosity varies with shear rate

Plastics material’s viscosity decreases as shear rate increases

WHY IS THIS IMPORTANT??????

- Screw speed…….Lower viscosity at higher screw rpm
- Injection speed…..Flows easier with higher injection speed

Flow rate (Injection speed, velocity) = Time in seconds, measured from start of injection to transfer to pack/hold

Hydraulic pressure Vs. Plastic pressure

Hydraulic pressure : measure of how much force a machine can generate against the ram

Plastic (Melt) Pressure: Pressure generated in the nozzle of a molding machine usually derived from the intensification ratio of the machine

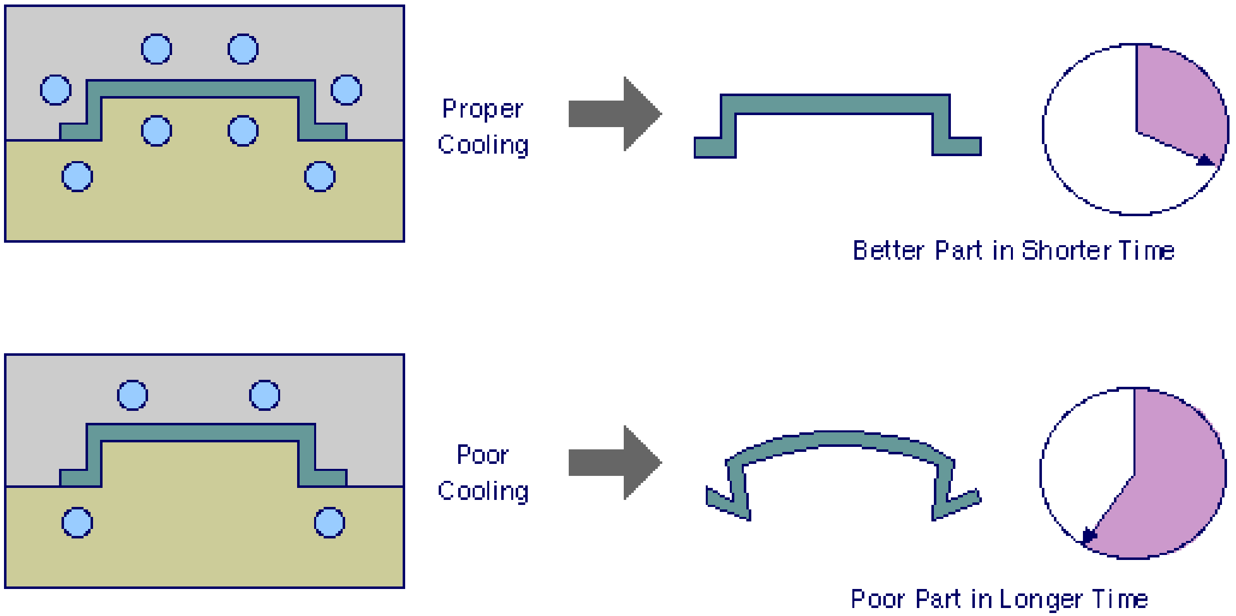
Cavity Pressure: Actual pressure in the cavity (Mold).

Cooling time

Mold cooling accounts for more than two-thirds of the total cycle time in the production of injection molded thermoplastic parts

Cooling time is a function of :

- mold wall temperature
- melt temperature
- material properties
- part wall thickness



Decoupled molding

- Conventional Molding

  Injection ------ Pack -------Hold

- Decouple Molding

  Decouple

  Injection ---Pack and Hold

  From

  Fill ---Pack and Hold

  95% -- 5%

Universal set up card

Actual Melt temperature ______________________________

Fill Data: Time____________ PPSI____________Weight_______

Pack & Hold Data: Time____________ PPSI____________Weight_______

Cooling data:

Temperatures____________________________________

Pressures (PSI)____

Flow rate (GPM)

The Universal Setup Card

Mold number, number of shots to date, part name, customer, date, molder's name, and any other information your plant may require.
Fill time for a part 95 to 99 percent full.
Weight and picture of part 95 to 99 percent full.
Transfer volume, transfer position, or cavity pressure (time and hydraulic pressure transfer modes are not recommended).
Nozzle melt pressure range for different lots at transfer volume, position, or cavity pressure.
First stage set melt pressure (nozzle); this is first stage set pressure times the intensification ratio.
Cycle time.
Quoted cycle time(s).
Gate seal time.
Pack and hold time.
Pack and hold melt pressure.
Shot size in volume.
Mold temperature, cooling channel map.
Water flow diagram, with gallons/minute of each channel, temperature of water in and out, and water pressure in and out.
Screw run time (average).
Mold open and closed time, cure time, or cooling times.
Melt temperature via hot probe.
Nozzle tip length, diameter, land length, radius, and type.
Hydraulic pressure vs. time response curve.
Cavity pressure integral at the gate and end of fill.

Automation in Injection Molding

Tooling…………Subgates, Hot Runners

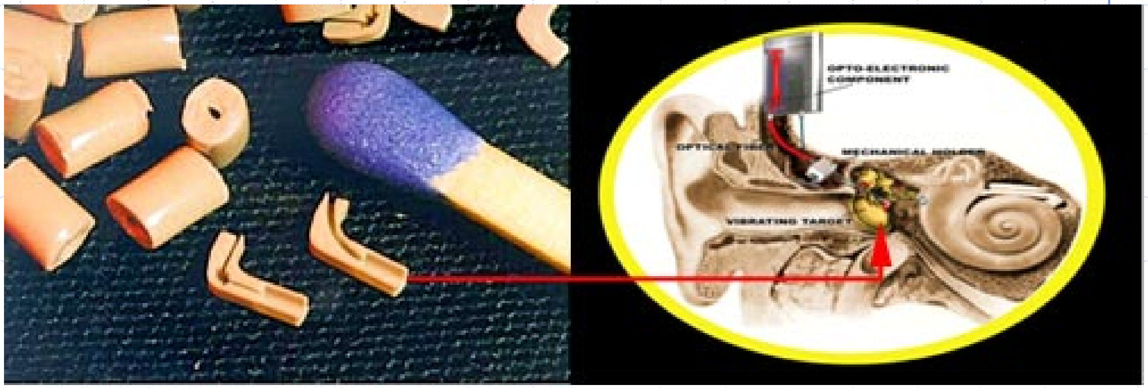
Part separators

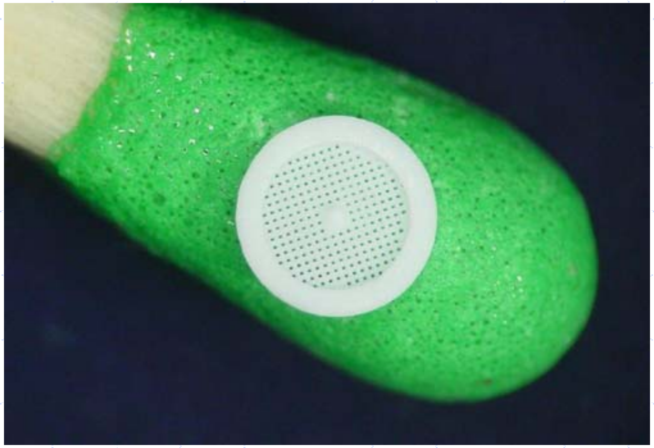
Regrind feedback

Robotics

"Lights Out" Molding

MICRO INJECTION MOLDING





Vishu Shah

Consultek

Topics

- What is "MICROMOLDING"
- Markets and applications for micromolding
- Machines for micromolding
- Materials for micromolding
- Tooling for Micromolding
- Part Extraction challenges
- Part Inspection
- What next?

How small is small?

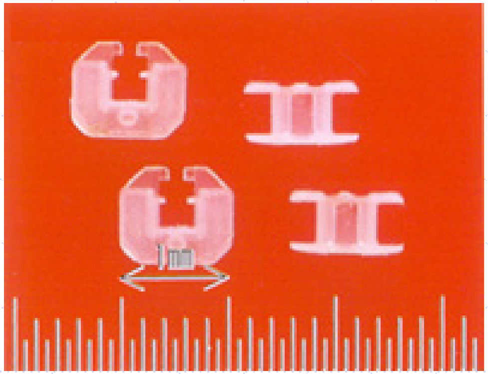
1 Nanometer = 0.001 micron

1 micron = 0.00004 in.

25 micron = 0.001 in.

50 micron = 0.002 in. Size of a human hair

1 mm = 0.040 in.



Bobbin

Material: Acetal

Wt: .0003 g

Or .3 mg

Size:

.044 x .025 x .038 in.

WHAT DEFINES A "MICRO" PART?

Less than 1/8 " overall dimension

For example, here are just some dimensions of microparts:

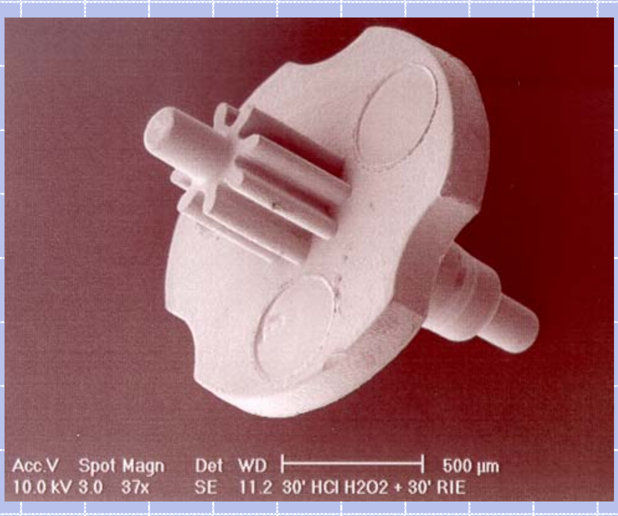
- Total part length of .060" (1.5mm)
- Gates down to 0.002" (0.05mm)
- Core pins of 0.0045" (0.11mm)
- Wall thickness down to .0015" (0.04mm)
- Cavity and Core TIR less than .0001" (.003mm)
- Overall part volume of 0.00013 grams
- **520 parts per plastic pellet!**

Markets and applications for micromolding

Microdrive Systems and Control

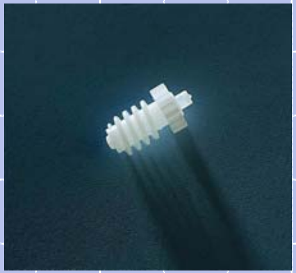
Potentiometer Gear

Material: PPA



Part weight: 0.0008 g Acetal
Stepper Motor axle for Watches

Gears



Injection Molding Machines for Micromolding

Typical concerns…….

- Material Plasticizing (Plastification)
- Material feeding
- Consistent shot size using standard check ring (reproducibility)
- Material freezing due to extremely small mass
- Shot size generally too large for micro parts
- Material degradation from long residence time
- Melt homogenization
- Static electricity Issues

Injection Molding machine designed specifically for Micromolding

- Clean room Module
- Optical inspection module
- Ionization module
- Part extraction (Handling) module
- Packaging Module

Materials for Micromolding

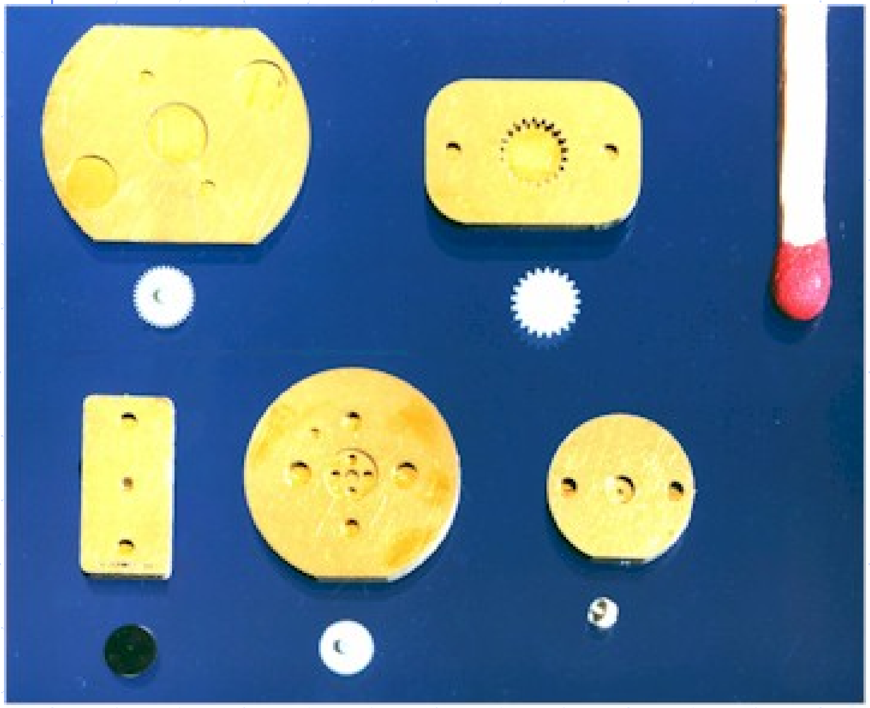
- LCP (Liquid Crystal polymers)
- Acetal
- Polyester
- Polycarbonate
- PEEK
- Glass and Mineral filled compounds adds to the rigidity and stability
- Hygroscopic materials like Nylons are not suitable for micromolding since they change size making it difficult to hold close tolerances

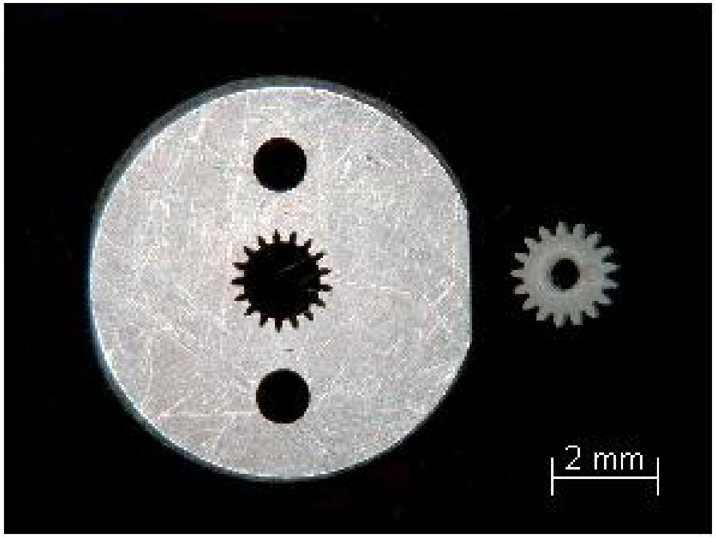
Tooling for Micromolding

Challenges in micro mold construction

- Physical limitation to how small one can cut or burn something, established by the geometric characteristics of the feature being formed
- Shear strength of the steel can not resist the pressures exerted by cutting head or in case of EDM surface finish is eroded beyond acceptable level
- Mechanical, thermal and chemical properties of the material being formed are affected

Tooling: LIGA technique





Limitations: Only vertical side walls possible

Structures up to 1.5mm high only

No draft allowed

Part Extraction Material handling and packaging

- parts too light to fall out of the mold
- Static electricity issue
- Special robotics and vacuum extraction into small tubes
- “ Reel to Reel” methods such as one used in semi conductor industry
- Assembler unwilling to pick parts one at a time out of a plastic bag
- Bowl fed or vibratory automated assembly systems tend to jam up

Part inspection

Video measuring system

OGP SMARTSCOPE

Resolution: 0.00025 mm (0.00001”) Standard

0.00001 mm (0.000004”) optional

SEEBREZ 6 x 6

Resolution: 0.0005 mm (0.00002”) STD

0.00001 mm (0.00001”) OPT

Quality control solutions Inc.

Future of Micromolding

What comes first?........ Chicken or the Egg???

How big is the market for micromolded parts?

Nano Technology…...Are we there yet?

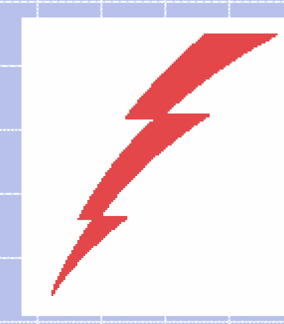
(1 nanometer = one millionth of a mm or .001 micron)

- **New territory for both molder and mold maker**
- **Lots of trial and error**
- **Propitiatory technology and expertise developed**
- **Prepare to spend R & D money and time**

Molders specializing in Micromolding

ALC Precision (American Laubsher Corp.) NY	www.alcprecision.com
Accumold, IA	www.accu-mold.com
Micromold, Inc. CA	www.micromoldinc.com
Makuta technics, IN	www.makuta.com
Precimold Inc. Canada	www.precimold.com
Rolla AG, Switzerland	www.rolla.ch
American precision Products, AL	www.injection-moldings.com
Sovrin Plastics, UK	www.sovrin.co.uk
Stack Plastics, CA	www.stackplastics.com
Micro Precision Products, CA	www.microprecisionproducts.com
Stamm, Switzerland	www.stamm.ch

Energy Efficient Injection Molding Operation



Babu Joseph

Edison

Vishu Shah

Consultek

Energy Efficiency

- EFFICIENCY - KWH / KG OF POLYSTYRENE
- 1 KWH / KG = 45.4 KWH / 100 POUNDS

HYDRAULIC

	FIXED	V.V / V.S
KWH / KG	0.82 TO 1.25	0.45 TO 0.65

SEMIHYDRAULIC

	HYBRIDS / PARTIAL ELECTRICS
KWH / KG	0.4 TO 0.6

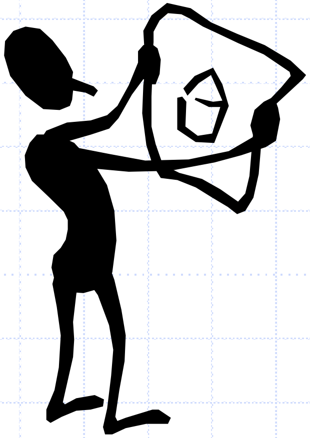
ALL ELECTRICS 0.2 KWH / KG

All Electric Molding Machines

- Technology developed in early 1980 in Japan
- Introduced in USA by Milacron in 1985 at NPE
- Initially available in 50 to 150 tons sizes only
- Today up to 2000 ton all-electric machines available
- Term All-Electric implies use of servomotors on both clamp and injection end
- 10 to 20% higher in cost
- Over 30 machine manufacturers offer all-electric machines
- **#1 advantage…..Energy Savings**

All Electric Molding Machines

- Energy savings form 25% to 60%
- Repeatability, Accuracy, Consistency
- No hydraulic oil…clean
- No cooling water cost
- Quiet
- Low maintenance



- Higher cost
- Torque related issues….Long Hold times…PVC
- Unscrewing molds?
- Core Pulls?

Side by Side Comparison

	Electric	Hybrid	Toggle /Hydraulic
Energy	Best	Better	Good/Poor
Accuracy/Repeat ability	Highest	High	Poor
Cleanliness	Excellent	OK	poor
Noise	Low	Medium	High
Maintenance	Low???	Medium	High
Use of existing molds	**Low adaptability**	Easy	Easy
Cost	High	Medium	Low

Energy savings With Variable Speed Drives

According to Plastics Technology, the **hydraulic pump-motor(s) account for 80%** of the total energy usage on an injection molding machine.

Even during periods of low hydraulic demand a maximum fixed-volume flow is produced. An example of the wasted energy at low demands is during the cooling stage of the cycle. During this cooling stage of the cycle, the motor(s) only need 20% rpm. **The fixed-speed system wastes considerable amounts of energy by making inefficient use of the hydraulic pump-motor(s).**

The motor conversion, from fixed-speed to variable-speed, enables the open loop injection molding process to be dependent on the demand for hydraulic fluid power. In return, there is a reduction in the use of kilowatt (kW) energy.

The basic concept of the system is simple: if the machine does not need the oil, don't pump it in the first place.

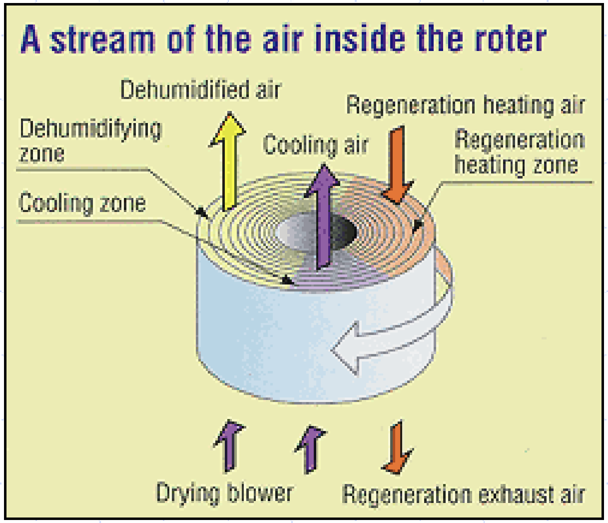
Energy savings with Auxiliary Equipment

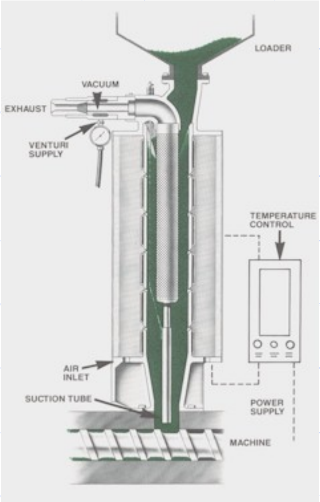
Auxiliary equipment **account for 20% of the total energy** consumption

- Dryers
- Grinders
- Mold heaters
- Chillers
- Water Management

Energy Savings Measures

- Use of hot return air for desiccant regeneration
  - Example…Moton Luxor line of Dryers
- Use of sensors and controls
  - Lower drying temperature when not in use
- Honeycomb rotary bed
  - Crystallized molecular sieves baked on to drying wheel
  - Efficient moisture absorption
  - Low air pressure (smaller bower)
  - Faster drying time
  - No dust
- Low pressure dryer (Vacuum dryer)
  - At low pressure boiling point drops to 133° F
  - Low temperature and vacuum removes moisture faster
- Compressed air – no desiccant dryer
  - Uses hot and compressed air to remove moisture
  - No regeneration heaters

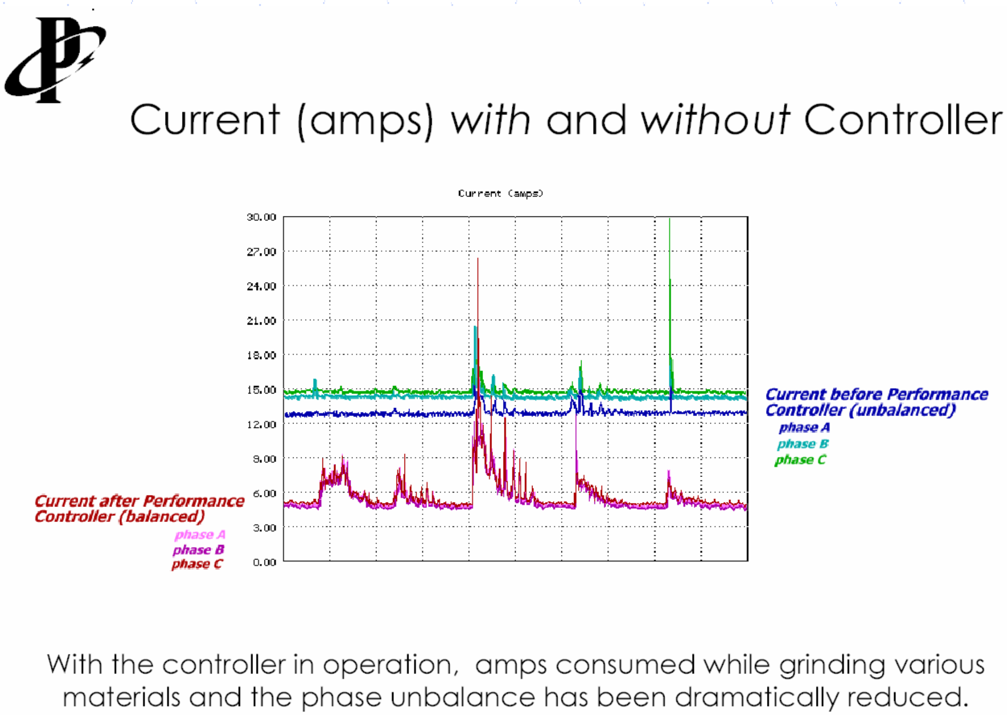




Cactus dryer

Granulators

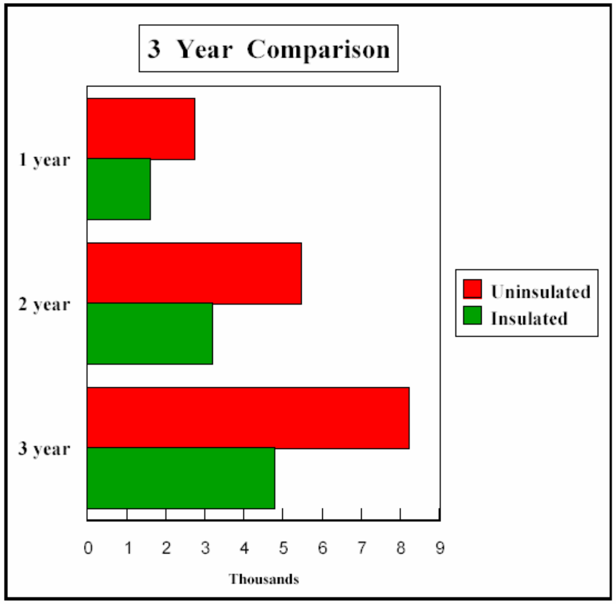
- Shut-down method (Watt Wattcher From IMS co.)
- Voltage reduction method (Performance Controller\MPG)
- RPM reduction



50% reduction in Power consumption

Insulation Blankets

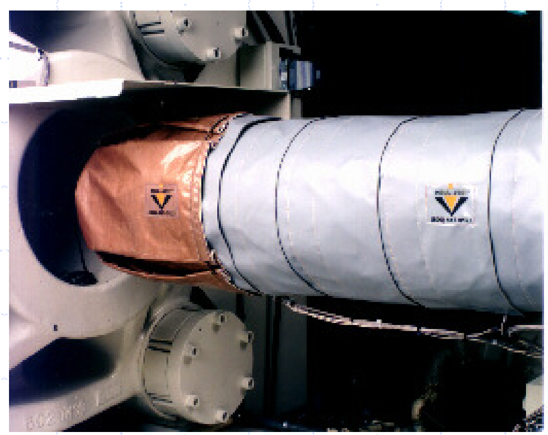
30% energy savings



Drool protection Disk or cover

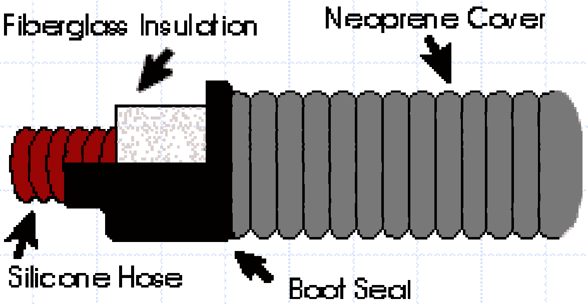
- Fast Start up
- Even Heat Profile
- Personnel Protection
- Extended Heater Band Life

200 Ton Milacron



Common Sense Approach

- Hot Runners Molds
- Long hold times……Gate freeze studies
- Multiple ejection
- Parts on the floor
- Material on the floor
- Insulated Dryer hoppers
- Leaky Dryer and air Hose
- Oil leaks
- End of jobs….turn off power



Gas Assist and Microcellular (MuCell®) Molding Process

Vishu Shah
Consultek

PLASTEC® WEST 2004
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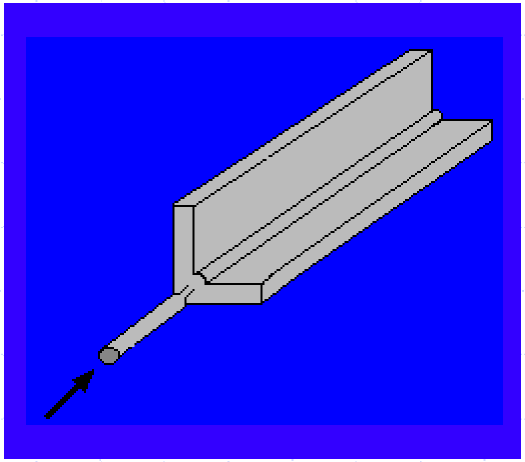
What is Gas Assist Injection Molding?

Gas Assist injection molding is a process enhancement to conventional injection molding, involving the injection of high pressure nitrogen gas into the resin melt stream immediately after injection of the resin. The intent is not to cause mixture of nitrogen and resin, but for the nitrogen to displace resin in gas channels and thicker sections of the molded product. The process is a high speed, low pressure injection method, enabled by short shooting the tool, and completing the resin filling phase by nitrogen gas, at a much lower pressures as compared to convention injection molding.



Advantages of Gas assist Molding

- **Cycle time reduction and lower production costs**
  - Lower clamp tonnage
  - Lower Injection pressures
  - Faster cycle due to hollow sections vs. solid section
  -

- **Design Freedom**
  - Large ribs possible and permissible
  - Long flow lengths without multiple drops

- **Quality Improvement**
  - Lower stress within the part
  - Better dimensional stability and part to part size variations
  - Elimination of sink marks and warpage and voids
  - Greater strength and rigidity
  - Reduced knit lines (No multiple drops necessary)

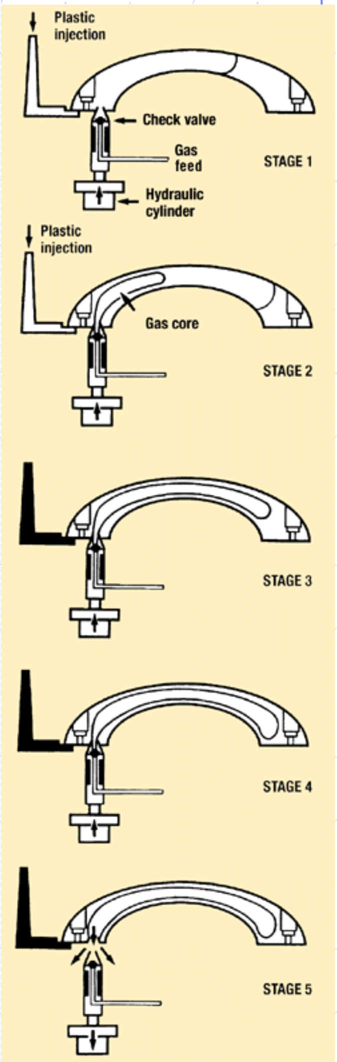
- **Material savings through weight reduction**
  - Hollow parts
- **Simplification of Tooling**
  - Elimination of lifters and undercuts

Gas Assist Process Basics

- **Short-shot molding.** A process in which certain features such as ribs or thick walls are cored out with gas in an otherwise solid molded part. This process gets its name from the method of only partially filling the cavity during the polymer injection phase of the cycle and then relying on the gas injection phase to fill out the remainder of the cavity with the material the gas bubble is displacing from the core.

- **Full-shot molding.** A process in which the mold is completely filled during the plastic injection phase. Gas is introduced into the cavity in this case only to provide local packing and to compensate for the effects of polymer volumetric shrinkage as the part cools.

- **Hollow molding.** A process in which all or nearly all of the part is cored out by the gas, in effect making the part itself the gas channel. This is the method most often used to make parts with large cross sections such as rods, tubes, and handles.



Source: MD&DI April 1998 article

Gas Delivery System

- Nitrogen Bottles
- Nitrogen Generators

- Central Nitrogen Systems

Part Design for Gas Assist

- Sizing of gas channels
- Gas channel layout
- Location of gas injection point(s)

Tooling Considerations

New Tooling

Injecting Through nozzle

Sprue gate preferred

Gate size and location is critical

Cannot use hot runner system

Injecting in Runner/part

Hot runner ok… Gas pin location very critical

Converting Existing tooling

Conventional Tooling Same considerations as new tooling

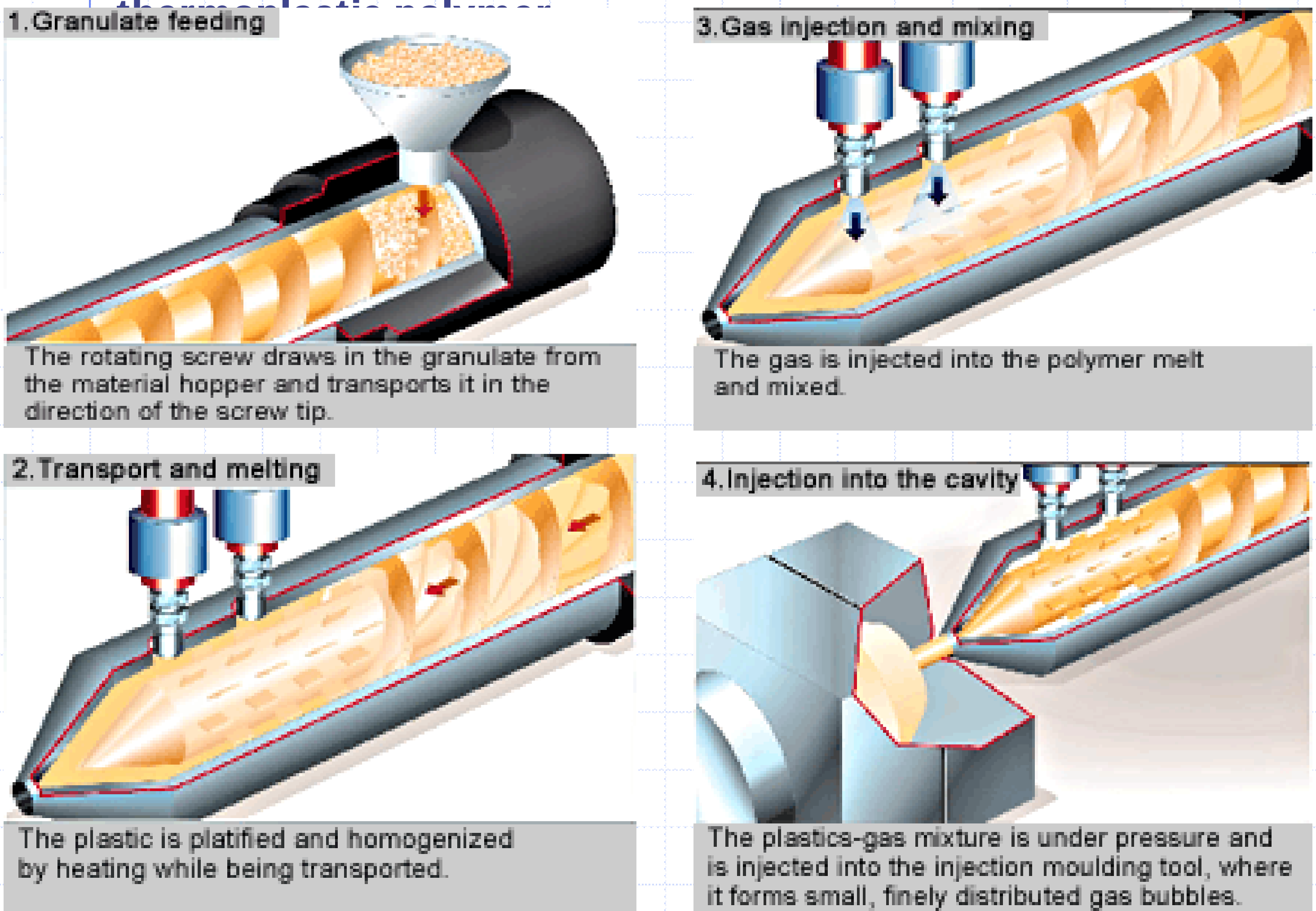
Hot Runner Tooling A) Inject gas through pins

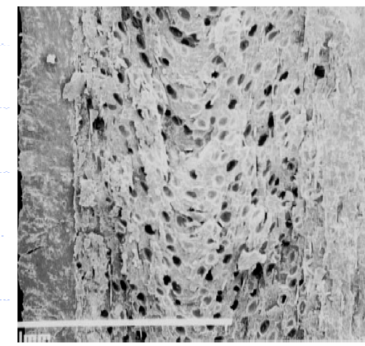
B) Eliminate hot runner

Venting, Cooling Shrinkage…….No special considerations

Mucell® Microcellular Technology

- **MuCell is the trade name of microcellular polymeric foam produced by Trexel's proprietary MuCell microcellular foam process. The MuCell process uses supercritical fluids (SCFs) of atmospheric gases--not chemical blowing agents to create evenly distributed and uniformly sized microscopic cells throughout a thermoplastic polymer**



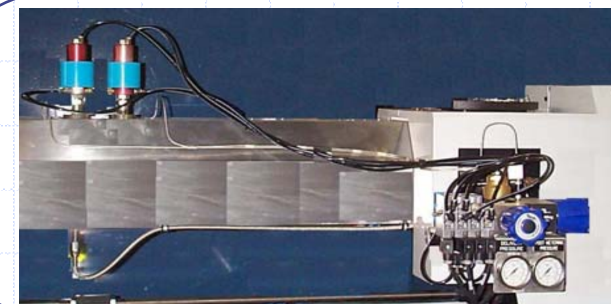


Micrograph showing average cell size of 10 microns (.0004 Inches)

MuCell Injection Molding Machine

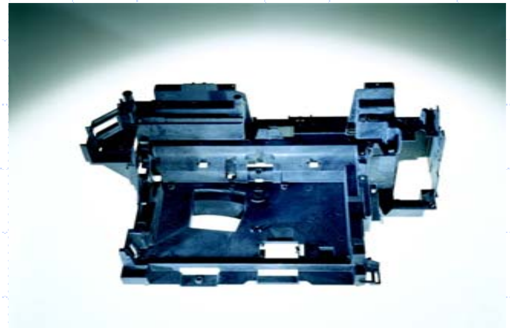
- Runs in both solid and MuCell molding

MuCell Interface Kit



SCF Delivery System

Applications



Weight reduced 10%

Cycle time - 20% - 30%

Machine size reduction up to 50%

HP Printer Chassis

Cycle time - 27%

Weight reduced - 8.5%

Cycolac CRT 3370 ABS - glass filled

In-Mold decoration

Conventional

Mucell