Control Plastics Inc. 377 Oyster Point Blvd #10 SSF CA 94080
800-600-2010 www.controlplastics.com sales@controlplastics.com

COMPROMISE FOR DESIGN—Achieving the optimum part design

The goal in designing a new part/product is to make the best compromise from all the factors available, You need to weigh ALL the facts and ALL the needs: The designer determines the QUALITY, the PRICING and the CONSISTENCY.

The toolmakers, and molders are stuck with the design they are handed. They can only try to optimize the situation. This design process is iterative. As you go through each section, and make a tentative decision, you need to go back to all of the prior sections to see how they have been affected.

1 PART DESIGN AND FUNCTION....Most critical is—Can it do what is needed? Did you Talk to the Customers (VOICE OF THE CUSTOMER)?, Marketing?, Sales?, Finance?, Production? They all have different needs and wants. And they are all important.

2 MATERIAL SELECTION...Plastic (thermoset or thermoplastic? Amorphous or Crystalline? Rigid or elastomeric?) Metal? Wood? Ceramic? Cloth? Where is it used----- Indoors, Outdoors? Chemical exposures? FDA requirements? UL requirements? ISO requirements? nsf requirements—and on and on----- Lots of choices, and more than one material will likely work. The process you pick will also affect the material—and vice versa. See the attached checklist to make sure you have considered all of the factors

3 PROCESS REQUIREMENTS.. How will you make it? Injection molding? (overmold?, 2 shot?, Structural foam?), Die casting? Investment casting? Sand casting? Gravity casting? Aluminum extrusion? Plastic extrusion? MIM (metal injection molding)? Blow molding? RIM (Reaction Injection Molding)?, Stamping (4 slide, progressive, deep draw)? Laser cut or NCT and bend)? Machining? Each process will require a different adjustment to the ideal functional design.

4 TOOLING DESIGN AND FUNCTION..Most processes require tooling. And the part design needs to be adjusted for the tooling requirements. Also, the desired life of the tool can affect the design requirements of the tool and the part design.

5 SECONDARY OPERATIONS, AUTOMATION, and ASSEMBLY (Ultrasonic, heat, dielectric, and mechanical) FINISHING (pad print?, silk screen?, hot stamp?,painting?, plating?) Everything you sequentially do with this part, will come back to affect the part design. They all need to be considered BEFORE you start any tooling.

6 QUALITY CONTROL and CONSISTENCY. The part needs to be readily inspected and measured. We need to go through steps of Validation and verification. The easier you make this process, the more likely it will be checked on a regular basis

7 END OF LIFE and ENVIRONMENTAL concerns. This is becoming more and more of a critical concept. And it does affect the part design, and the materials chosen to make the part from. The parts can affect the environment, just as the environment can affect the part.

8 Be Careful where you get help and information. If you go to an Architect with a problem, you will likely be given a building as a solution. You will get different "help" from Processing engineers, Assembly managers, Toolmakers, Material suppliers—et al.

COMMON ISSUES IN INJECTION MOLDING

There are some very common issues that reoccur in many parts…So we need to be concerned about the following:

INTERNAL RADII. All plastics are "notch sensitive".. Any internal corner can create a stress riser—Even if we have almost no internal stresses, this is a highly likely cause for an impact failure…

Solution: Add radiused corners at all internal corners. No problem—EXCEPT ---- larger radii will effectively increase the wall section…And we can get a sink issue. There are several guidelines about the optimum radius at the inside corners—and they hold true—up to the point of causing sink.

GATING The two weakest places on an injection molded part are the gate locations and the weld line.

The gate is the place of highest fill pressure, and hence the highest internal stresses are there. The gate location and type can also influence flatness and warp, weld lines, needed secondary operations after molding, molecular orientation of the polymer(and more)…

WELD LINE The plastic flow will separate when flowing around a core in the mold (hole, window, etc.). When it gets to the far side of the hole, the material has to meld (weld) back together… There are many reasons this area is weaker: The plastic is cooling as it flows, so the fronts of material may not fully melt back together. There can be trapped air at the weld lines—and this prevents the material from melting together (You can actually get "dieseling", or burning, when you compress trapped air).. Also, any of the fillers, or reinforcing agents (glass fiber, for instance) do not cross the weld line. They only come up to the weld line. At best, your weld line is only about 95% of the strength of the UNFILLED material.

VENTING. We all learned that only one type of matter can occupy a space, at one time. IF we want to fill a cavity with plastic, we need to get the air removed. This can be done by properly placed vent locations — which will ensure we are getting air removed at the last places to fill, as well as all along the fill path. We can even make the venting positive (vacuum venting). Improper venting severely limits the processing window, and can affect the overall strength of the part.

RIBS. When ribs intersect a wall, they give us a locally thicker area. This can be a cause of sinks. Rules of thumb are to make sure the ribs (including radii on internal corners) are no more than 50% of the wall it intersects.

BOSSES. Bosses have center core pins surrounded by plastic. The pins cannot always carry the heat away as fast as the surrounding steel—so the pin heats up. This can create sink marks. There are lots of little tricks to help alleviate the potential sink marks

SINK MARKS and SHRINKAGE. All plastic materials get smaller in volume when the solidify (transition from liquid to solid). The amount of shrinkage depends upon:

The material—Amorphous (shrink less) or Crystalline, Reinforcements (glass fibers, minerals used in the plastic

- --Flow or Cross flow directions. Flow direction usually has lower shrinkage than cross flow
- --Wall sections. Thicker parts have more shrink.
- --Mold Temperatures.

When you start to get sinks in a part, the plastic no longer contacts the mold surface…You actually create a vacuum between the plastic part and the mold cooling surfaces. The rule of thumb is to run the mold as warm as possible to still get the heat transfer needed, and achieve the desired cycle. This allows for better packing of the part.

Plastics are very good heat insulators. As parts get thicker, the cooling time goes up logarithmically . the longer a plastic stays hot, the more shrinkage it will exhibit. If the design rules are "stretched", the processer usually needs to increase packing and holding pressures, increase speeds, and cool down the material stock temperature and mold temperature (creating a compromise for surface uniformity and weld lines).

All of this creates HIGHER INTERNAL STRESSES.

HIGH INTERNAL STRESSES

Ok—You have gotten past the initial set of compromises. You have a pretty good idea of part design and have been through the first iterations of compromise…. Main remaining concern is INTERNAL STRESS LEVELS

First—What is the definition of a "good "plastic part?: It needs to look good, meet tolerances, and have LOW INTERNAL STRESS.

High internal stress gives you the following:

- Lower impact strengths
- Lower heat distortion resistance
- Lower chemical resistance
- Low dimensional stability, and warp
- Lower environmental stress cracking resistance
- Worse low temperature properties---

Not a one of these makes a better part… So what causes high internal stresses, and how do we prevent them?

In general, the harder we have to pack out an injection molded part (higher pressures, and longer holding times), the more internal stresses we build into the part… Why do we build these high internal stresses into the part? .. Most of the time, we do so to make up for bad part design….And the most common culprit is sink…

Because of the importance, I will repeat myself---. Plastics get smaller in volume when they cool from liquid to solid. This is referred to as shrinkage. Every material has a shrinkage range. The longer the material stays hot in the mold, the more shrinkage occurs… When you have details, such as ribs, bosses, improper thickness transitions (try to keep a transition distance of at least 5 times the change in thickness), they create a localized thicker area. This area takes longer to cool, so you get more shrinkage in the thicker area. This will give you a "sink". This sink can be measureable (often at the intersection of a rib to a wall), or just slight enough to cause a surface gloss difference (often at the parting line where you have a thinner wall section for the interlocks).

Customers don't like sinks or the gloss changes (even though they have caused them by their design). Molders try to accommodate by increasing injection and holding pressures, and adjusting mold temperatures. They can minimize the sinks with these tricks—but at the expense of increasing the internal stress levels

Please note the attached Checklist. This lists many of the factors you need to consider and balance, in order to make a GOOD PLASTIC PART..

This paper was intended to be a simplified overview of the many factors required in designing a good plastic part. There are a lot more details available from the many design guides from the raw material suppliers. Many of the articles/ brochures that I have found useful over the years, have been put on our web site—

PACKAGING CONSIDERATIONS
BARRIER PROPERTIES ________________
H2O (WALL THICKNESS) ________________
CO2 ________________
NITROGEN ________________
ETHYLENE OXIDE ________________
GAS ________________
OTHER
BIO-DEGRADATION ________________
BACTERIAL/FUNGI RESISTANCE ________________
OUTGASSING (Electronics+Painting Foams) ________________
SPECIFIC GRAVITY (BASIC MATERIAL) ________________
SPECIFIC GRAVITY (FOAM) ________________
RADIATION OPACITY ________________
SURFACE FEEL (Tacky, Dry, Slippery, Smooth, Rough)__________
SOUND DAMPENING ________________
OPTICS
CLEAR, OPAQUE, TRANSLUCENT (THICKNESS)_____________
BIREFRINGENCE ________________
DIFFUSIVITY ________________
REFRACTIVE INDEX (ND) ________________
HAZE (AT WHAT THICKNESS) ________________
TRANSMISSION (AT WHAT THICKNESS/WAVE LENGTH) ________________
CRITICAL ANGLE (IE) ________________
REFLECTIVITY ________________
FINISH (SCRATCH / DIG) ________________
APPEARANCE CHARACTERISTICS
COLOR (PIGMENT/DYE/PEARLSCENT/FLUORSCENT/PHOSPHORESCENT) ________________
FINISH (SPE=SI NUMBER/OPTICAL/TEXTURED/(MOLD TECH/EDM BLASTED)/RMS) ________________
SURFACE UNIFORMITY ________________
SECONDARY OPERATIONS
DECORATING ________________
MOLD SPRAY ALLOWED ________________
SILK SCREEN ________________
HOT STAMP ________________
LABELS ________________
PAINT ________________
PLATE (Vacuum, Electro, Electroless) ________________
FLAME SPRAY ________________
ELECTROSTATIC COATING ________________
FLUIDIZE BED COAT ________________
BLAST/HONE ________________
MECHANICAL ________________
DRILLING, TAPPING, CUTTING ________________
ULTRASONICS, VIBRATORY+SPIN WELDING, DIELECTRIC ________________
HEAT STAKING ________________
ADHESIVES (HOT MELTS, PRESSURE SENSITIVE, SOLVENT) ________________
SCREWS (SELF TAP, CAPSERTS) ________________
INSERTS (EXPANSION, PRESS IN, ULTRASONIC) ________________
SNAP FITS ________________
INTERFERENCE FITS ________________
STRESS RELIEF / HEAT OR RADIATION CROSS LINKING / POST MOLD ORIENTING) ________________
MOLDING CONSIDERATIONS
ENCAPSULATION ________________
MATERIAL SHRINKAGE+SHRINKAGE RANGE________________
TOLERANCES ________________
SINK, VOIDS ________________
POST MOLD SHRINKAGE & CRYSTALLIZATION______________
ORIENTATION ________________
MOLDED IN STRESSES (FOAM) ________________
SHEAR SENSITIVITY ________________
VISCOSITY AND FLOW LENGTH ________________
HEAT STABILITY ________________
MOLD SPRAY ________________
REGRIND ALLOWED (PROPERTY CHANGES DUE TO CROSSLINKING OR VIS BREAKING) ________________

MATERIAL CHECKLIST
EXPECTED PART LIFE __________________
USE OF PART __________________
LIABILITY IF FAILURE __________________
ELECTRICALS
SURFACE + VOLUME RESISTANCE __________________
DIELECTICE STRENGTH – SHORT TERM __________________
DIELECTICE CONSTANT_____HERTZ______________________
DISSIPATION FACTOR _____HERTZ______________________
ARC RESISTANCE __________________
ANTI-STATIC PROPERTIES __________________
SHIELDING __________________
ELECTRICAL GROUNDINGS __________________
MECHANICALS
COMPRESSIVE MODULUS __________________
HOURS UNDER LOAD __________________
TENSILE STRENGTH __________________
TENSILE/FLEXURAL MODULUS __________________
ELONGATION __________________
CREEP RESISTANCE __________________
ABRASION/SCRATCH RESISTANCE __________________
TEAR STRENGTH __________________
FATIGUE RESISTANCE __________________
VIBRATION TESTS __________________
HINGE CAPABILITY (MOLDED IN/COINED) __________________
SHEAR STRENGTH __________________
COEFFICIENT OF FRICTION (STATIC/DYNAMIC) __________________
HOOP STRENGTH (BURST PRESSURE) __________________
IMPACT (IZOD/DROP) __________________

TEMPERATURE
HIGHEST USE TEMPERATURE (LOADED/STATIC) __________________
LOWEST USE TEMPERATURE (LOADED/STATIC) __________________
HOURS AT HIGHEST TEMPERATURE-- LTHA __________________
COEFFICIENT OF EXPANSION ________________
THERMAL CONDUCTIVITY ________________
MOISTURE
ENVIRONMENTAL HUMIDITY __________________
WATER ABSORPTION __________________
WATER ADSORPTION __________________
HYDROLYSIS RESISTANCE __________________
FLAMABILITY
UL 94 /746 CLASSIFICATION __________________
UL HEAT DISTORTION __________________
OUTDOOR EXPOSURE
U.V. (LIFE) __________________
CHEMICAL __________________
MOISTURE __________________
CHEMICALS
EXPOSURE TIME/TEMPERATURE __________________
LOAD WHEN EXPOSED __________________
STRESS CRACKING RESISTANCE __________________
ACIDS (STRONG/WEAK) __________________
ORGANIC SOLVENTS __________________
ALKALAIS (STRONG/WEAK) __________________
GREASES / OILS / LUBRICANTS __________________
PERSPIRATION, BODY FLUIDS __________________
OTHER PLASTICS __________________
FOODS (FDA) __________________
MEDICINES (ALCOHOLS/BLOOD) __________________
COSMETICS __________________
PAINTS/COATINGS/ADHESIVES/ CLEANING __________________
DEIOIZED H2O __________________
POTABLE WATER (NSF) __________________
GREY WATER (SEWAGE) __________________
Consider both the effect of the environment on the plastic and vice versa
STERILIZATION __________________
GAS (ETO) / RADIATION / CHEMICAL __________________
STEAM (TEMPERATURE / PRESSURE / TIME __________________
RoHS, REACH, NSF,FDA , EPA __________________
EN (ISO), EPA, ASTM, WEEE Specifications __________________
ENVIRONMENTAL STRESS CRACKING __________________

PART DESIGN CONSIDERATIONS

SPRUE (CONVENTIONAL/HOT) SIZE __________________
SPRUE PULLER (Z OR UNDERCUT) __________________
COLD SLUG WELL - (SIZE) __________________
RUNNER BAR (MATERIAL/HARDNESS) __________________
BACK-UP PLATES (1 7/8" MIN) OR INSERTS (MATERIAL HARDNESS) __________________
(BLIND-THRU) POCKETS __________________
Material hardness finish surface-treatment special Mfg.
CAVITY INSERTS____
CORE IINSERTS____
(H-12, S-7, P-20, ALUMINUM, BE/CU, O-1, A-10, M-2, P-4)
All hardened inserts are to be stress relieved (double drawn). When Feasible, stress relieve inserts after EDMing.
GATES – (Round Edge, Trapezoidal Edge, Rectangular Edge, Half Round Edge, Tapered – ½ Edge, Tapered-Full Edge, Sub Gate, Thru Ej. Pin, Pin Point, Diaphram, Flash, Fan, Ring, Pool, Tab.
SIZE________ LAND ________
EJECTION – (PINS- DME – std., Pins-High Speed, Sleeves-Std/Special, Blades, Plate, Double Action, Hot-side, Cammed Ejectors, Kicking Ejectors, Spring Loaded, Multiple (via Springs & Jiffy Locks), Guided Ej. Plate (Required with All Sleeves & Pins under .062")
PARTING LINE (Regular/Stepped)___________________________
SIDE ACTIONS (With Positive Return & Full Locking) – (A-Side/B-Side, Angle Pin, Hydraulic, Air, Cam, Cammed Ejectors, Kicking Ejectors, Interlocking, Automatic Unscrewing, Collapsing Cores, Stilson Core, Hand Loaded – Core/Slide, Molded In Inserts (All HL or
Molded In Inserts must fit in only one side of the mold, in only one Direction, and in only one location.

SAFETIES
BERMER RETURN __________________
DME RETURN __________________
MICROSWITCHES __________________
SPRING LOADED EJECTION __________________
OTHER __________________

COOLING
BASE ONLY __________________
(ALL PLATES) __________________
INTO EACH CAVITY & CORE __________________
(INDIVIDUAL CONTROL) __________________
FOUNTAINS __________________
BAFFLED INNER CORES __________________
HEAT SINKS __________________
HEAT PIPES __________________

RUNNERS - TYPE __________________
SIZE ___________(2ND)__________(3RD)__________
STREAMLINE/CONVENTIONAL/LAYOUT __________________

VENTING
VACUUM POPPETS __________________
VENT WELLS __________________
P/L EDGE VENTS __________________
THRU CORE/EJECTORS __________________
VACUUM EVACUATION __________________
SPARE PARTS __________________

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WALL THICKNESS/UNIFORMITY __________________
SINK/VOID POTENTIAL (CORING) __________________
RADII ON CORNERS __________________
DRAFT __________________
REINFORCING RIBS __________________
GATING (SIZE, LOCATION) __________________
WELD LINES (STRENGTH) __________________
PARTING LINE __________________
EJECTION (PINS, BLADES, SLEEVES, PLATES) __________________
SIDE ACTIONS (A-SIDE, MECH, HYDRAULIC, EJECTORS) __________________
HAND LOADED INSERTS __________________
STRESS RELIEVING/POST MOLD CROSSLINKING OR ORIENTING __________________
HOW IS PART USED? __________________
WHAT HAPPENS IF IT FAILS? __________________
EXPECTED FAILURE OR REJECT MODE? __________________
WILL PROPERTY CHANGES, DUE TO AGING, CAUSE PROBLEMS? __________________

FIXTURES NEEDED
COOLING __________________
TRIM __________________
Q.C. __________________

Q.C. & INSPECTION REQUIREMENTS
DIMENSIONS __________________
LINEAR __________________
HOLE DIAMETER __________________
CONCENTRICITY OR T.I.R. __________________
FLATNESS (BOW/WARP) __________________
PERPENDICULARITY __________________
CRITICAL/CONTROL DIMENSION & TOLERANCE FIT AND FUNCTION REQUIREMENTS __________________
(INITIAL DIMENSIONS VS. PART TO PART UNIFORMITY)______________

APPEARANCE
GATE TRIM __________________
SINKS __________________
VOIDS/BUBBLES __________________
FLASH __________________
PARTING LINE MATCH __________________
CLARITY __________________
SCRATCHES __________________
UNIFORMITY OF SURFACE __________________
FINGER PRINTS __________________
MOLD SPRAY __________________
FLOW LINES (PIGMENT ORIENTATION) __________________
WELD LINES __________________
BLACK SPECKS __________________
BURNS __________________
SPLAY/BLUSH __________________
EJECTOR MARKS __________________
AQL LEVEL __________________
SPECIAL TESTS __________________

PACKAGING
LAYERED (DIVIDERS) __________________
BULK __________________
TISSUE WRAP __________________
SEPARATE P.E. BAG __________________
FOAM PACK __________________
STACKED __________________
EGG CRATE __________________
SPECIAL TRAYS __________________
PARTS PER BOX __________________
PARTS PER BAG __________________

TOOLING CHECKLIST
NUMBER OF CAVITIES __________________
MATERIAL (PLASTIC) __________________
SHRINKAGE (FLOW, CROSS, FLOW) __________________
TOOL LIFE __________________
PRESS SIZE __________________
SHOT SIZE __________________
ESTIMATED CYCLE (PARTS/HOUR) __________________
MOLD TYPE (STANDARD, HOT RUNNER, 4 PLATE, INSULATED RUNNER __________________
MOLD SIZE (MINIMUM OF 2" AROUND CAVITIES) __________________
BASE MATERIAL (DME #1,2,3, ALUMINUM, H-13 __________________