Appendices

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I - Troubleshooting

During troubleshooting, experience plays an important factor. In the event there is a problem that you cannot solve, seek help. Do not sacrifice production or quality; ask. This list is only a reference; use it judiciously.

Brittle parts - The parts become brittle or break

Possible Causes	*Actions*
1. Resin is too cold	1.a. Increase backpressure. 1.b. Increase melt temperature.
2. Material degradation in the barrel	2.a. Reduce melt temperature. 2.b. Reduce backpressure. 2.c. Reduce the injection rate. 2.d. Purge, if necessary.
3. Material contamination	3.a. Verify material in the hopper. 3.b. Purge, if necessary.
4. Material degradation during the drying process	4. Decrease dryer time and/or temperature.
5. Moisture in the material	5. Verify moisture content, dry properly.

Bubbles (voids) - Air trapped inside the part

Possible Causes	*Actions*
1. Moisture in the material	1. Check moisture content, dry properly.
2. Material is too hot	2. Decrease the melt temperature by adjusting to a suitable barrel temperature profile.
3. Inadequate venting	3. Ensure that the mold has adequate and clean vents.
4. Internal bubbles caused by shrinkage	4.a. Increase backpressure and/or hold pressure. 4.b. Decrease the melt temperature.

Weld line - Lines on the part formed by two or more melt flows joining together

Possible Causes	*Actions*
1. Low mold temperature	1. Increase mold temperature.
2. Material is too cold	2. Increase melt temperature.
3. Low injection rate	3. Increase speed. Injection time should be significantly reduced.
4. Humid resin	4. Dry material properly.

Fading - Inadequate color

Possible Causes	*Actions*
1. Degraded material in the barrel	1. Purge the barrel.
2. High melt temperature	2. Decrease melt temperature by adjusting to a suitable barrel temperature profile.
3. Contaminated material	3. Check the material.
4. Inadequate vents	4. Clean existing vents or ventilate mold properly.

Burns - Marks on the part due to degradation

Possible Causes	*Actions*
1. High injection speed	1. Decrease injection speed.
2. High backpressure	2. Decrease backpressure.
3. Inadequate vents	3.a. Verify that there are vents. 3.b. Clean vents.
4. Problems in mold design (material suffers friction, causing degradation)	4.a. Change the location of the gate. 4.b. Ensure that the part has generous radii (no sharp corners).
5. Nozzle hole is too small or clogged	5. Replace or clean the nozzle.
6. High screw recovery	6. Decrease screw recovery speed.
7. High melt temperature	7. Decrease the melt temperature by adjusting to a suitable barrel temperature profile.

Cloudiness - Cloudy appearance in parts (more noticeable in clear parts)

Possible Causes	*Actions*
1. Material contamination	1.a. Check material and change if necessary. 1.b. Increase melt temperature.
2. Gases or moisture in the resin	2.a. Dry material properly. 2.b. Ventilate mold properly.
3. Material is too cold	3. Increase the melt temperature.
4. Mold is too cold	4. Increase mold temperatures.
5. Mold release	5. Eliminate the use of mold release.

Flash - Excess plastic around the parting line

Possible Causes	*Actions*
1. High hold pressure	1. Decrease hold pressure.
2. Mold is too hot	2. Lower mold temperatures.
3. Inadequate closing force	3. Increase tonnage.
4. High melt temperature	4. Lower the melt temperature.
5. Late transfer position to hold	5. Adjust to an appropriate transfer position and compensate by adjusting the same distance to the recovery position.
6. Material with moisture	6. Improve drying.

Flow lines - Marks in the direction of the melt flow

Possible Causes	*Actions*
1. Low mold temperature	1. Increase the mold temperature.
2. Material is too cold	2. Increase the melt temperature.
3. Inadequate runner/gate	3. Check the size of runner and gates, and request a redesign.
4. High injection speed	4. Decrease injection rate.
5. Humid resin	5. Dry material properly.

Worm-shaped jetting on the surface of the part

Possible Causes	*Actions*
1. Gates too small	1. Verify and request a gate redesign.
2. Poorly localized gate	2. Request a redesign.
3. Injection speed too high	3. Slow down the injection rate.
4. Small nozzle hole	4. Replace nozzle.

Surface delamination – Layer separation on the surface of the pieces

Possible Causes	*Actions*
1. Contaminated material	1. Check the material and replace, if necessary.
2. Low melt temperature	2. Adjust to a suitable barrel temperature profile.
3. Melt mixture is not uniform	3. Increase backpressure.
4. Low mold temperature	4. Increase mold temperature.
5. Low injection rate	5. Increase speed. Injection time should be significantly reduced.

Incomplete Shot - Parts are not completely filled

Possible Causes	*Actions*
1. Low hold pressure	1. Increase hold pressure.
2. Short hold time	2. Increase hold time.
3. Unbalanced cavities	3. Balance the fill and redesign the mold, if necessary.
4. Low melt temperature	4. Increase the melt temperature by adjusting to an appropriate temperature profile.
5. Small runners/gates	5. Request a redesign of runners and/or gates.
6. Low mold temperature	6. Increase mold temperature.
7. Low recovery position	7. Verify that the transfer position is adequate, and then increase the recovery position.

Sink - Depressions or sunken areas in sections of the parts

Possible Causes	*Actions*
1. Low injection rate	1. Increase speed. Injection time should be significantly reduced.
2. Inadequate design of the mold and/or part	2. Redesign part (uniform wall thicknesses are required).
3. Low melt temperature	3. Increase melt temperature with a suitable temperature profile.
4. Gas trapped in the mold	4. Vent the mold properly.
5. Low hold pressure	5. Increase hold pressure.
6. Excessive mold temperature causes shrinkage	6. Lower the temperature of the mold.
7. Low hold time	7. Increase hold time.
8. Low mold temperature causing premature gate freezes	8. Increase the temperature of the mold.

The parts stick to the cavity

Possible Causes	*Actions*
1. Scratched cavity	1. Polish in the direction of demolding.
2. Static	2. Demagnetize the cavity.
3. High hold pressure	3. Decrease the hold pressure.
4. Short cooling time	4. Increase cooling time.
5. Shrinking in the wrong direction	5. Set the temperature of the core so it is higher than the cavity temperature.
6. Insufficient draft and/or detachment angle	6. Consider changes in part and/or mold design.

The parts stick to the core

Possible Causes	*Actions*
1. High hold pressure	1. Decrease the hold pressure.
2. High core temperature	2. Adjust the mold temperatures.
3. High melt temperature	3. Lower the melt temperature with a suitable temperature profile.
4. Insufficient draft and/or detachment angle	4. Consider changes in part and/or mold design.
5. Static	5. Demagnetize the cavity.

Silver lines - Imperfections on the surface of the parts

Possible Causes	*Actions*
1. Moisture in the resin	1. Dry the material properly.
2. Obstruction in the nozzle	2. Clean the nozzle.
3. High injection speed	3. Slow down the injection rate.
4. High melt temperature	4. Lower the melt temperature with an appropriate barrel temperature profile.
5. Nozzle is too hot	5. Lower nozzle temperature.
6. Contaminated resin	6. Check the material; replace it if necessary.
7. Gates are too small	7. Increase gate size.

Buckling - Twisting or curving of the parts due to uneven shrinkage

Possible Causes	*Actions*
1. Hot parts upon ejection	1.a. Lower the mold temperature. 1.b. Increase the cooling time.
2. Uneven part cooling	2. Adjust the temperatures of the mold faces.
3. Non-uniform wall thickness	3. Redesign the part.
4. Parts are overpacked	4. Decrease the hold pressure.

Maximum injection pressure limit alarm

Possible Causes	*Actions*
1. Blocked cavity	1. Stop the machine. Check and clean the mold.
2. Injection stage set to fill too much.	2. Reduce the recovery position to about 95% of the mold.

Cushion lower limit alarm

Possible Causes	*Actions*
1. Dirty or defective check ring	1. Check and clean or replace.
2. Melt leaking between sprue bushing and nozzle tip	2. Check if any of the components are scratched and/or crushed, if the hole diameters are incorrect, or if the contact radii are incorrect. If so, replace them.
3. The melt is leaking into the mold, either as flash, filtration between actuators, or within the hot runner system.	3. Check, and if so, make the repair or correction as soon as possible. Failure to do so could result in extensive damage to the mold.

Cushion upper limit alarm

Possible Causes	*Actions*
1. Blocked cavity or a clogged gate.	1. Check and clean.
2. If it's a hot-runner mold, it could be that a hot tip is clogged or damaged.	2. Check, clean or replace.

Recovery time limit alarm

Possible Causes	*Actions*
1. Inconsistent resin flow, which may be due to the heat from the barrel affecting the feed throat, causing material to clump.	1a. Reduce the temperature of the heat zone near the feed throat. 1b. Check the water flow in the throat of the barrel. If it's clogged, correct it. 1c. Check the temperature of the water in the throat of the barrel and reduce it if it is too high.
2. The feed hopper is running out of resin.	2. Check and correct the material supply.

II - *Universal* Mold Data

Remember that these parameters are for the mold and the plastic. To be used they must be transferred or converted into injection machine parameters.

1. mold name and number
2. name and type of material
3. filling time to get a fill of about 95%
4. weight of the parts at the time of transfer, with the hold turned off
5. plastic pressure at the time of transfer
6. total cycle time
7. hold time
8. hold pressure
9. total weight or total injection volume
10. cooling time
11. mold temperatures
12. flow and water to the mold
13. water temperatures entering the mold
14. water temperatures exiting the mold
15. water pressures entering the mold
16. water pressures exiting the mold
17. melt temperature entering the mold
18. time it takes to open the mold and eject the parts
19. time to completely close the mold
20. recovery volume

III - *Universal Molding*^{TM} Equations

1- Drying

Drying hopper volume:

To determine the size of a dryer hopper, you need to know:
- the material consumption in lb/hr or kg/hr
- the drying time in hours
- the bulk density of the plastic resin in lb/ft^3 or kg/m^3.

I. With virgin material:

$$\text{Volume} = \text{consumption x } \frac{\text{drying time}}{\text{bulk density}}$$

II. With virgin and regrind material:

$$\text{Volume} = T * C * \left({}^{\%V}/_{D_{virgin}} + {}^{\%R}/_{D_{regrind}} \right)$$

Where:

T = drying time (hours)
C = resin consumption (lb/hr or kg/hr)
D_{virgin} = virgin material density (lb/ft^3 or kg/m^3)
$D_{regrind}$ = regrind density (lb/ft^3 or kg/m^3)
$\%V$ = % of virgin
$\%R$ = % of regrind

Dry air flow from the dryer:

Flow = material flow factor * consumption

Maximum material factor
= 1cfm / (1lb of material/hr)
= (63 liters/min) / (1kg of material/hr)

Delta temperature:

$$\Delta T_{Fahrenheit} = 9/5 * \Delta T_{Celsius}$$
$$\Delta T_{Celsius} = 5/9 * \Delta T_{Fahrenheit}$$

Recovery consumption:

Recovery consumption =
(injection shot weight) / (recovery time)

Material consumption:

Material consumption=
(total amount of material) / (process cycle time)

2- Cooling

Removed heat:

Removed heat =

$$\frac{(\text{total quantity of material}) \ * \ (\text{energy required for the material})}{(\text{process cycle time})}$$

Empirical equation to determine the required water flow of a chiller:

$$\text{gmp} = \frac{24 * (chiller\ tons)}{Delta\ T}$$

Where:

- gpm = gallons of water per minute
- chiller tons = chiller tons required to cool the mold
- Delta T (°F) = outlet water temperature – inlet water temperature

Extended cooling time:

Extended cooling time =
recommended cooling time x 1.3

Calculated method to determine the cooling time (*E*):

$$E = -\frac{G^2}{2\pi\alpha}\ln\left(\frac{\pi}{4}\frac{(T_{\mathrm{x}} - T_{\mathrm{M}})}{(T_m - T_{\mathrm{M}})}\right)$$

Where:

T_x = deflection temperature
T_M = mold temperature
T_{m} = melt temperature

G = part thickness
α = thermal diffusivity

Material	α	T_m (°F)	T_M (°F)	T_X (°F)
ABS	0.000185	475	135	203
CA, CAP	0.000181	400	110	192
CAB	0.0002	400	110	201
HIPS	0.000059	440	85	185
IONOM	0.000148	440	85	125
LDPE	0.000176	390	75	113
MDPE	0.000194	340	75	155
HDPE	0.000217	480	75	186
PA 6, 6/6	0.000109	530	150	356
PC	0.000132	560	180	280
PET	0.000138	540	120	153
PP	0.000077	470	105	204
PPO/PS	0.000144	530	185	234
PPS	0.000166	630	210	210
PS g.p.	0.000087	420	85	180
PSU	0.000149	700	250	345
PVC	0.000107	380	85	156
PVC rig	0.000123	380	85	174
SAN	0.000088	450	150	225

Pressure loss (Delta *P*) and water temperature loss (Delta *T*):

Delta *P* =
inlet water pressure – outlet water pressure

Delta *T* =
outlet water temperature – inlet water temperature

3- Clamp

Clamping force:

Clamping force = (pressure factor of the melt) x (projected area)

US ton = 2000 lbf
Metric ton = 1.10 x US ton
US ton = 8.90 Kilo-Newtons (kN)
Metric ton = 9.81 Kilo-Newtons (kN)

Material	**US ton/in^2**		**kN/cm^2**	
Polypropylene	1.5	3.5	2.1	4.8
High density polyethylene	1.5	2.5	2.1	3.5
Low density polyethylene	1.0	2.0	1.4	2.8
Nylon 66	3.0	5.0	4.1	6.9
Polycarbonate	3.0	5.0	4.1	6.9
Flexible PVC	1.5	2.5	2.1	3.5
Rigid PVC	2.0	3.0	2.8	4.1
Polystyrene	2.0	4.0	2.8	5.5

Thin wall calculation, *TW*:
A thin wall calculation is a factor that represents fill difficulty. This factor takes into consideration the distance that the melt must travel and how narrow those passages are. This factor is represented by the following equation:

$$\text{Thin wall calculation} = \frac{(\text{farthest flow path})}{(\text{thinnest wall on the path})}$$

TW	**Criteria**
≥ 200	Use the highest pressure factor. Force = (projected area) x (**highest** pressure factor)
≤ 100	Use the smallest pressure factor. Force = (projected area) x (**smallest** pressure factor)
between 100 and 200	Interpolate between pressure factors. Force = (projected area) x (**interpolated** pressure factor)

Lateral action resulting in additional clamping force:

These wedges are manufactured at an angle, φ, and only a fraction of this lateral force will be seen in the direction of the closing wedges. This resulting force in the direction of the press is determined by multiplying the lateral force by the tangent of the wedge's angle:

Force as a result of lateral action = lateral force x tan(φ)

4- Injection unit

Density and specific density:

$$\text{Density} = \frac{\text{mass}}{\text{volume}}$$

$$\text{Specific density} = \frac{\text{material density}}{\text{water density}}$$

Where the density of water is 1 g/cm^3 at room temperature.

Injection speed and flow:

$$\text{Injection speed} = \frac{\text{distance}}{\text{time}}$$

$$\text{Injection flow} = \frac{\text{volume}}{\text{time}}$$

$$\text{Injection flow} = \frac{(\text{screw diameter})^2 * {}^{\pi}/_{4} * (\text{displacement})}{\text{time}}$$

Barrel utilization:

Barrel utilization (%U) is a comparison between the maximum capacity of the injection unit and the capacity required to fill the mold.

$$\%U = \%\ \text{of Utilization} = \frac{(\text{volume used})}{(\text{volume the barrel is capable of})} * 100\%$$

Where:

volume used = the volume programmed to the mold's requirements

volume the barrel is capable of = the maximum recovery volume of the screw

Recovery position:

The recovery position is the place the screw should reach in order to fill the mold.

$$\text{Recovery position} = \text{transfer position} + \text{injection displacement}$$

Combining the equations of weight, density, and volume, we summarize:

$$\text{Injection displacement} = \frac{1.27W}{\rho D^2}$$

$$\text{Recovery position} = \text{transfer position} + \frac{1.27W}{\rho D^2}$$

Where:

ρ = specific density of the melt (gr/cm^3)

W = weight of parts and runner (gr)

D = diameter of the injection screw (cm)

Note that this equation does not consider that, during injection, only about 95% of the mold is filled. This excess is ignored due to the fact that, during the injection stage, some material always sneaks to the other side of the check ring, whether during check ring closure or as a result of leaks between the check ring and the barrel.

Discharge density:

This density is more precise for determining the recovery positions, since it considers several factors:

- mass
- volume
- melt temperature
- back pressure
- melt leaks through the check ring during injection.

Discharge density is calculated in an existing process by measuring the injected volume and the total injected weight. The injected volume is determined using the cylinder equation:

Volume = area x length

Where:

$$\text{Area} = (\text{screw diameter})^2 * {}^{\pi}/_{4}$$

Length = recovery position – cushion position

The injection weight is determined by weighing the molded parts plus the runner (if one exists).

Discharge density =

$$\frac{\text{total injection weight}}{((\text{screw diameter})^2 \text{ x } \pi/4) \text{ x } (\text{recovery position} - \text{cushion position})}$$

If the discharge density is known, the injection displacement and the recovery position equations would look like this:

$$\text{Injection displacement}_{95} = 95\% \frac{1.27W}{\rho_d D^2}$$

Recovery position =

$$\text{transfer position} + 95\% * \frac{1.27W}{\rho_d\, D^2}$$

Where:

ρ_d = discharge density (g/cm³)
W = weight of the parts with the runner (g)
D = diameter of the injection screw (cm)

Rheology by power:
Peak power – The maximum power reached by the injection unit, usually at the transfer position (change from injection to hold).

Peak power =
average injection flow x pressure at the transfer position

Average injection flow – This flow is a function of the volume injected during the injection stage and the injection time.

Average injection flow =
injection volume / injection time

<u>Rheology by viscosity</u>:
Change in speed V_x, in the direction of Y;

$$\text{Shear rate} = \dot{\delta} = \frac{\text{change in speed}}{\text{distance}} = \frac{\Delta V_x}{\Delta Y}$$

Shear stress = viscosity x shear rate

$$\tau = \mu \text{ x } \dot{\delta}$$

Relative viscosity = plastic pressure x injection time

$$\text{Relative shear rate} = \frac{1}{\text{injection time}}$$

Intensification ratio, R_i =
plastic pressure, P_p / hydraulic pressure, P_H

$$\mu_R = P_H R_i T$$
$$\mu_R = P_P T$$

<u>Approximated rheology</u>:

Initiation of the injection time plateau

$T_{plateau} = T_{min} + (T_{max} - T_{min}) / 9$

Conventional molding industries

$T_{intermediate} = T_{min} + (T_{max} - T_{min}) / 18$

Industries that mold sensitive materials

$T_{sensitive} = T_{min} + (T_{max} - T_{min}) / 12$

High-volume injection industries

$T_{fast} = T_{min} + (T_{max} - T_{min}) / 36$

Where:

T_{min} - injection time for the maximum injection speed
T_{max} - injection time for the minimum injection speed
$T_{plateau}$ - injection time where the plateau starts on the graph

<u>Fill balance</u>:
Sum of the weight of all cavities:

$$W_T = \sum_{\#\,cav.}^{1} W_i \, , \; i = 1 \text{ to \# of cavities}$$

Volume deviation for each cavity, Vd_i

$$Vd_i = \left[\frac{W_i}{\left(W_T/_{\#cavities}\right)} - 1\right] 100\%, \; i = 1 \text{ to \# of cavities}$$

<u>% injection volume by stage</u>:

$$\% \text{ volume at injection stage} = \frac{\text{recovery position} - \text{transfer position}}{\text{recovery position} - \text{cushion position}} * 100$$

If you are using a control system with ***Universal*** parameters and working with volume instead of position, apply this formula:

$$\% \text{ volume at injection stage} = \frac{\text{recovery volume} - \text{transfer volume}}{\text{recovery volume} - \text{cushion volume}} * 100\%$$

% volume at hold stage =
100% - % volume at injection stage

IV - General Procedures for *Universal Molding*™

I. Sizing and Initial Data

1. Determine the clamping force → _____________
2. Determine the required injection volume → _____________
3. Select an approximated total cycle → _____________
4. Determine the approximate resin consumption per hour → _____________
5. Resin brand and type → _____________
6. Colorant brand and type → _____________
7. Colorant % →___________
8. Regrind %→____________

II. Auxiliary Equipment

1. Water temperature control unit
   Determine the water flow to the mold → _____________
   Select an initial water temperature → _____________
2. Dryer
   Size the hopper dryer volume → _____________
   Size the dry air flow → _____________
   Drying temperature → _____________
3. Colorant additive
   % colorant required → _____________
   Determine the consumption of colorant/hour → _____________
4. Regrind additive
   % regrind required → _____________
   Determine the consumption of regrind/hour → _____________

III. Mold and Machine Sizing

1. Horizontal distance → ________ < _________ between bars
2. Vertical distance → _______ < ______ between bars
3. Closed distance → _______ > ______ minimum opening
4. Open distance → _______ < ______ maximum opening
5. Ejector pattern → _______ = _______

IV. Injection Molding Machine Sizing

1. Injection unit
   Determine % of utilization, *%U* → _____________
   Determine the transfer position → _____________

Determine the corresponding temperature profile →
____/____/____/_____
Determine the backpressure. Ex: 750 psi plastic (machine = plastic/R_i)
Determine the approximated relative position → __________

2. Nozzle tip
   Length → ______________
   Hole diameter → ______________
   Contact radius → ______________
3. Sprue bushing
   Hole diameter → ______________
   Contact radius → ______________

V. Initial process setup

1. Start and set the auxiliary equipment parameters
   - Dryer
   - Water temperature controller
   - Additive feeder
   - Hot runner temperature control
2. Injection unit
   - Start and set the barrel temperature zones
   - Set the backpressure
   - Set the recovery speed
   - Set the approximated recovery position
   - Set the extended cooling time
3. Press setup
   - Set mold opening positions and speeds
   - Set the mold protection
   - Set the movements of the ejectors
   - Set the movements of the cores, if applicable

VI. Determination of Machine Parameters

(once the auxiliary equipment is ready and temperatures have been reached)

1. Fill
   Determine the injection pressure limit → ______________
   Determine the ideal injection time → ______________
   Readjust the injection volume to about 95%
   Note the final recovery position → ______________
   Perform the flow balance lab

2. Hold
   Determine the hold pressure → _____________
   Determine the hold time → _____________
3. Cooling
   Determine the water temperature of the mold → _____________
   Fixed/Moving → _________/ _________
   Determine the cooling time → _____________
4. Recovery
   Adjust the recovery speed according to the new cooling time
   Note the recovery time → _____________
5. Recalculate the auxiliary equipment according to the new cycle time

VII. Convert to Universal Parameters

Auxiliary Equipment

1. *Water temperature control (gpm/lpm) to mold* →_____________
   Water temperatures to mold Fixed/Movable → ______/______
2. *Dryer*
   Hopper volume → _____________
   Dry air flow → _____________
   Drying temperature → _____________
3. *Additive feeder, % of colorant* → _________
   Color consumption per hour → _________
4. *Regrind ratio, %* → ___________
   Regrind consumption per hour → _____________

Mold Data

1. *Horizontal distance* → _____________
2. *Vertical distance* → _____________
3. *Closed mold height* → _____________
4. *Open mold height* → _____________
5. *Ejector pattern* → _____________
6. *Material* → _____________
7. *Color additive* → _____________

Injection Molding Machine – (m) machine / (u) ***Universal***

1. *Clamping force* → _____________
2. *Total cycle time* → _____________
3. *Material consumption per hour* → _____________
4. *Press platens*

Horizontal distance between tie bars → ______________
Vertical distance between tie bars → ______________
Verify the ejectors pattern → ______________
Maximum opening → ______________
Minimum opening → ______________

5. *Press setup*
   Mold opening position → ______________
   Mold opening and closing time → ______________
6. *Injection*
   % of barrel utilization → ______________
   Injection pressure limit → *(m)*________ *(u)*________
   Ideal injection velocity → *(m)*________ *(u)*________
   Transfer position → *(m)*________ *(u)*________
   Recovery position → *(m)*________ *(u)*________
   Temperature profile → _____/_____/_____/_____
7. *Hold*
   Hold pressure → *(m)*________ *(u)*________
   Hold time → ______________
8. *Cooling*
   Water temperature of the mold Fixed/Movable → ________/________
   Cooling time → _____________
9. *Recovery*
   Recovery speed → ______________
   Recovery time → ______________
   Backpressure → *(m)*________ *(u)*________

V – English Terms in Spanish

auger	tornillo sin fin
backpressure	contrapresión
barrel	barril
barrier screw	tornillo con barrera
blower	bomba
boost to hold	de inyección a empaque
cavity	cavidad
check ring	anilla
chiller	equipo de refrigeración
cold slugs	pedazos fríos
cores	noyos
cushion	colchón
dew point	temperatura de condensación/ temperatura de rocío
discharge factor	densidad de plastificación
drying hopper	tolva de secado
eject-on-the-fly	expulsión mientras el molde abre
ejector pins	botadores
ejector plates	platos de expulsión
fill time	tiempo de inyección
flash	rebaba
gate	bebedero
gate freeze	endurecimiento de bebederos
hold	empaque
hold pressure	presión de empaque
hold time	tiempo de empaque
hot runner	colada caliente
hot drop/hot tip	punta caliente
injection rate	flujo de llenado
injection screw	tornillo de inyección
injection speed	velocidad de llenado
jetting	chorreo
manifold	distribuidor
melt flow	flujo del fundido
melt flow number	índice de fluidez
melt pressure	presión del fundido
melt temperature	temperatura del fundido

mold protect	protección del cierre del molde
molecular weight	peso molecular
nozzle	boquilla
nozzle tip	punta de la boquilla
parting line	partición del molde
pellet	gránulo
plastic residence time	tiempo de residencia
recovery	plastificación
robot	brazo mecánico
runners	coladas
shear rate	cambio cortante/ velocidad cambiante
shear stress	esfuerzo cortante
shear thinning	licuar por fricción
shot size	volumen de llenado/volumen de la unidad de inyección
sprue	palo
sprue bushing	casquillo
stack mold	molde doble
stress	esfuerzo
suck-back	rechupe
tie bars	máquina con barras
tiebarless	máquina sin barras
transfer point	posición de transferencia
transfer pressure	presión de transferencia
valve gate	válvulas de bebederos
vents	ventosas

VI - Spanish Terms in English

anilla	check ring
barril	barrel
bebedero	gate
bomba	blower
boquilla	nozzle
botadores	ejector pins
brazo mecánico	robot
cambio cortante/ velocidad cambiante	shear rate
casquillo	sprue bushing
cavidad	cavity
chorreo	jetting
colada caliente	hot runner
coladas	runners
colchón	cushion
contrapresión	backpressure
de inyección a empaque	boost to hold
densidad de plastificación	discharge factor
distribuidor	manifold
empaque	hold
endurecimiento de bebederos	gate freeze
equipo de refrigeración	chiller
esfuerzo	stress
esfuerzo cortante	shear stress
expulsión mientras el molde abre	eject-on-the-fly
flujo de llenado	injection rate
flujo del fundido	melt flow
gránulo	pellet
índice de fluidez	melt flow number
licuar por fricción	shear thinning
máquina con barras	tie bars
máquina sin barras	tiebarless
molde doble	stack mold
noyos	cores
palo	sprue
partición del molde	parting line
pedazos fríos	cold slugs

peso molecular	molecular weight
plastificación	recovery
platos de expulsión	ejector plates
posición de transferencia	transfer point
presión de empaque	hold pressure
presión de transferencia	transfer pressure
presión del fundido	melt pressure
protección del cierre del molde	mold protect
punta caliente	hot drop/hot tip
punta de la boquilla	nozzle tip
rebaba	flash
rechupe	suck-back
temperatura de condensación/ temperatura de rocío	dew point
temperatura del fundido	melt temperature
tiempo de empaque	hold time
tiempo de inyección	fill time
tiempo de residencia	plastic residence time
tolva de secado	drying hopper
tornillo con barrera	barrier screw
tornillo de inyección	injection screw
tornillo sin fin	auger
válvulas de bebederos	valve gate
velocidad de llenado	injection speed
ventosas	vents
volumen de llenado/volumen de la unidad de inyección	shot size

VII - Operational Costs

2010 Machine operating cost per hour, with operator and profit margin (North American molders)

North America Tonnage Range	<50	50-99	100-299	300-499	500-749	750-999	1000-1499	1500-1999	2000-2999	3000+
Average (US$/hr)	$33.31	$35.24	$41.92	$52.13	$68.14	$83.22	$110.28	$119.95	$181.68	$230.00
Average (US$/sec.)	$0.009	$0.010	$0.012	$0.014	$0.019	$0.023	$0.031	$0.033	$0.050	$0.064

Note: - this is a reference; consult your finance department for more exact values.

- assume that a profit margin of 10 to 15% is included.

(Use only to estimate productivity gains, in US$)

Note: The cost could be divided into three types, Basic, Optional, and Special.

Basic	**Optional**	**Special**
Depreciation	Robot	Class 8 Clean Room
Building	TCU	Inspection or QC
Interest	Packing equipment	Engineering assistance
Maintenance	Special injector; LIM, two colors, high speed, ...	Tooling support
Electricity	Crane	Material testing
Water	Quick mold change	Packaging and labeling equipment
Miscellaneous	Special screw	Special product handling
Labor	Additive Feeder	Mold storage
Marginal benefits		Mold maintenance
Inspection and QC		
Material		
Waste		
Secondary services		
Mold		
Overhead		
Earnings		

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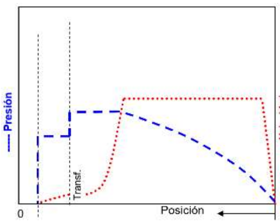
Answers

II. Injection Process Parameters

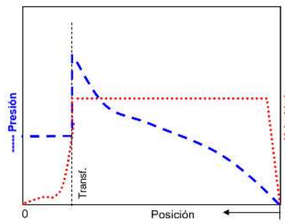
1) b. **2**) b. **3)** c. **4**) b, c. **5**) a. **6**) b. **7**) b, d. **8**) a, d. **9**) a. **10**) b. **11**) c, d.
12) b, c, d. **13**) a. **14**) b. **15**) b. **16**) b. **17**) a. **18**) b, c, d.

III. Process Graphs

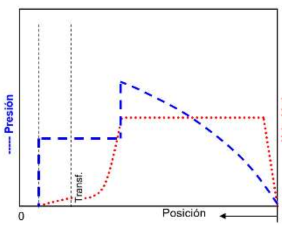
1) b. **2**) b. **(3)** c. **4**) b. **5**) c. **6**) a. **7**) c. **8**) c. **9**) b.
10)



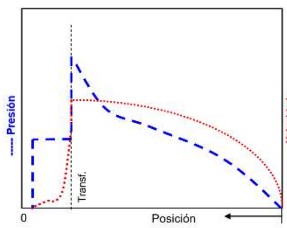
d) limited pressure



a) *zero cushion*



c)*premature transfer*



b) programmed speed was not reached

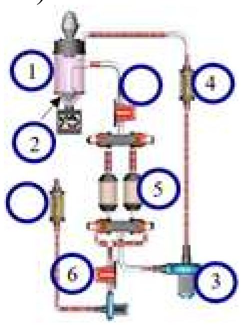
IV. Plastic Morphology

1) b. **2**) c. **(3)** c. **4**) a. **5**) c. **6**) c. **7**) c.

V. Auxiliary Equipment

1) b. **2**) c. **3**) a, c, e. **4**) b. **5**) a. **6**) b. **7**) c. **8**) b. **9**) b. **10**) a. **11**) a.
12) b. **13**) b. **14**) a.

15)



Blending and Material Handling

1) b. **2)** a.

Water Temperature Control to the Mold

1) b. **2)** b. **3)** c. **4)** a. **5)** b. **6)** a.

VI. Molding from the Desk

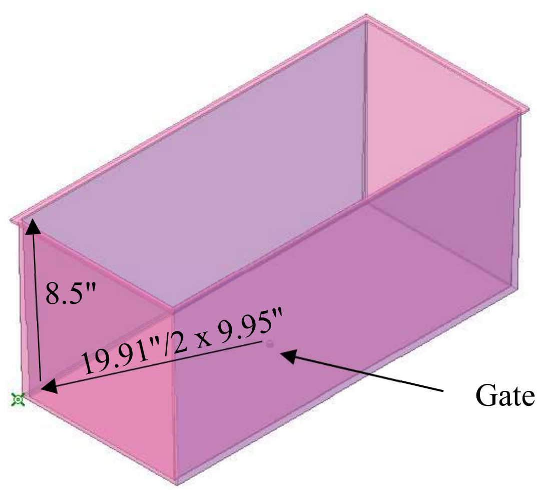
1) b. **2a**) b. **2b**) a. **2c**) a. **3**) d.

Injection Unit Sizing

1) b. **2**) a. **3**) a. **4**) a. **5**) a. **6**) c. **7**) a. **8**) d.

9a) Area = 19.4in x 8.9in = **173 in^2**

9b)



Farthest flow path = 8.5" + 9.95" = **18.45"**
Thinnest wall on the path = **0.08"**
Thin Wall - 18.45"/0.08" = **230**
PF = 230 > 200; the force factor would be **2.5 ton/in^2**

9c) Required clamping force = 173in^2 x 2.5 ton/in^2
= **433 US tons of force** (1 ton = 2000 lb)

9d) Consumption = 1100/50s x 3600s/1h x 1 lb/454 gr = **174 lb/hr**

9e) Required volume = 1100gr/0.92gr/cc = **1196 cc**

9f) %U = (1196cc/2480cc)*100% = **48%**

9g) ton$_{cooling}$ = 174 lb/hr / 50 lb/hr/ton = **3.5 ton$_{cooling}$**

9h) gpm = 3.5 ton$_{cooling}$ x 24 / 3^{o}F = **28gpm**

9i) %U = 48% and is between 35% and 65%.
The transfer would be between 12mm and 25mm.
Transfer = 25mm – 13mm (0.48-0.65)/0.3 = **17.6mm** = **0.69in**

9j) Recovery position = 1.27W/ δD^2 + Transfer
=1.27*1100gr/[0.92gr/cc*(9cm)^2] + 1.76cm = **20.51cm** = **8.07in**

9k) Start with **700 psi** (**47 bars**) plastic pressure.

9l) 5% of fill = 0.05*8.07in = **0.4 in**

9m) From the Material Data sheet = **410^{o}F**

9n) From a data sheet of a generic PS:

Injection	Nominal Value	Unit
Rear Temperature	424 to 480	°F
Middle Temperature	424 to 480	°F
Front Temperature	390 to 415	°F
Nozzle Temperature	415 to 469	°F
Mold Temperature	60 to 150	°F

Since the *%U* is almost 50%, use the average.

Feed zone = Compression zone = Metering zone = **452ºF**

Nozzle = (415ºF + 469ºF)/2 = **442ºF**

9o)

U%	T_r (# ciclos)
1%	140
2%	70
3%	47
4%	35
5%	28
6%	24
7%	20
8%	18
9%	16
10%	14
11%	13
12%	12
13%	11
14% - 15%	10
16% - 17%	9
18% - 19%	8
20% - 23%	7
24% - 27%	6
28% - 34%	5
35% - 46%	4
47% - 69%	3
>70%	2

Residence time (cycles) = **3 cycles**

Residence time(s) = 3 cycles x 50s/cycles = **150 seconds**

9p) Consumption = 174 lb/hr

Drying hopper volume = 174 lb/hr x 2 hours / 35 lb/ft^3

= **9.94 ft^3 = 281.5 liters**

9q) Dry air flow = 174lb/hr x 0.75 cfm/(lb/hr) = **130.5 cfm**

10) c.

VII. Machine Rheology

1) b. **2**) c. **3)** c. **4**) b. **5**) c. **6**) a. **7**) a.

VIII. Determination of Injection Speed

1) a. **2**) b. **3**) b. **4**) (a) a. **5**) b. **6)** a, c. **7**) b. **8**) b, c. **9**) c. **10**) d.

IX. Verifying Fill Balance

1) c. **2**) b. **3)** a. **4**) a. **5**) d. **6**) b. **7**) a. **8**) b.

X. Determination of Hold Stage Parameters

1) a. **2**) b. **3**) b. **4**) c. **5**) a. **6)** a, c. **7)** b. **8)** a. **9)** c. **10)** a.

XI. Determination of Cooling Stage Parameters

1) b. **2**) b. **3**) d. **4**) a. **5**) a. **6**) a. **7**) d. **8**) b.
9)

$$\underbrace{\overline{D}_C}_{(1)} + \underbrace{\beta_0 T_M}_{(5)} + \underbrace{\beta_1 t}_{(2)} + \underbrace{\beta_2 T_F}_{(4)} + \underbrace{\beta_3 T_M t + \beta_4 T_M T_F + \beta_5 t T_F + \beta_6 T_M T_F t}_{(3)}$$

XII. Process Limits

1) a. **2**) b. **3**) a. **4**) a. **5**) b.

Index

Expert Opinions

"Universal Molding^{TM} is, in the Dominican Republic, an essential platform for the development of Dominican molders and the local industry has increasingly benefited by applying this knowledge to the improvement of its processes."

Miguel Calcaño, Plastics Consultant
HDI Inc., Dominican Republic

"One of Wallyco's greatest pleasures was always the research and professional development of young Puerto Ricans. If I'm not mistaken, it was in 2000 that we provided resin and machine time to Dr. Ivan Baiges' students; among those I remember Roberto Pastor. Days of more questions than answers, which laid the foundation for corroborating or denying stories of molders and understanding the science behind the technique. Yes science, not magic, black box, or dark art. Once the technique was verified, thanks to the help of people such as Drs. Gregorio Velez and Ivan, it was reduced to its minimum essence, and a verified process of the best practices was developed. It is written at the level of the user, the person who must improve the process without formal education. There have been many changes from 2000 to this day, which will continue as ***Universal Molding***^{TM} still has much to discover and teach. It is a great pride for me to have been involved in its beginnings, to have used its processes and to have trained as an instructor, and I wish Hector and ***Universal Molding***^{TM} to continue to help the plastics industry and all those young Puerto Ricans who want to better themselves and their homeland with their performance."

J. Wally Cruz, Engineer and Plastics Engineer Specialist

"Universal Molding^{TM} is an excellent tool, not only for understanding the process of injection molding, but also for understanding the behavior of different types of plastics, in a simple way but always with a scientific basis. As an ***MU***^{TM} student without any experience in the world of plastics, I was able to understand the groundwork and foundations of injection molding. Then, as an instructor, I could see how ***MU***^{TM} helped so many people and industries optimize their molding processes with amazing results, not only in quality but also in economy."

Laureano J. Rodríguez, Sr. Account Manager
West Contract Manufacturing

"At the beginning of the 2000s, I was part of the revolution that was barely beginning in Costa Rica about how to scientifically establish a process during my time at Abbott Laboratories, which later became Hospira, and is known today as ICU Medical. It was there that the first ***MU™*** exercise was done outside Puerto Rico, entirely in Spanish and, for the first time in Costa Rica, it showed a better way to obtain objective evidence about from where the validated parameters came in the injection molding process, making ***MU™*** the pioneer of this revolution in CR. After that, the course was opened to other companies in the industry in Costa Rica, and it has been taught year after year to the present day. Subsequently, from 2008 to 2014 I had the privilege and pleasure as a member of HDI, Inc. to participate in seminars and conferences alongside Héctor Dilán as a presenter."

Harold Gamboa Calderón, Sr. Account Manager - Distribution
PolyOne Corporation (Central America and Andean Region)

"I learned about ***Universal Molding™*** when I was just starting my professional career. Thanks to Héctor and the ***Universal Molding™,*** my learning curve in the field of injection molding was exponential. This gave me the necessary tools to apply science during the development of different molding processes and was my foundation for the future of my career in plastics engineering.

During those first steps with ***Universal Molding™***, together with Héctor, we managed to develop Rheology by Power, which moved away from rheology by viscosity, but at the same time obtained specific results in less time. Rheology by Power helps us greatly optimize the injection stage in a simple, short, and accurate way.

Now, after about 15 years working in the injection molding industry, I can say that ***Universal Molding™*** is the basis and the most useful learning tool for anyone working in this area.

Héctor, thank you for the confidence and opportunity to work with you when I was just getting started in the industry."

Billy Torres, Technical Services Manager
Microsystems UK