Bushing Thermal Expansion Calculations

Dimensional relationships between the bushing tip and cavity must be maintained if optimum part appearance is to be achieved. In molding applications where a sprue gate style bushing is used, witness lines on the molded parts will form a step if the bushing tip extends into the cavity area. In pin gating bushing applications, pressure drops, shear rates, resin flow and gate vestige are dependent on the proper relationship between tip and gate. The differential thermal expansion between the bushing and the mold plates can alter this dimensional relationship and must be taken into account when establishing the room temperature location of the bushing tip. Absolute control of this critical dimensional relationship is essential to final molded part quality.

Bushing Thermal Expansion Evaluation

A preliminary evaluation of the thermal expansion characteristics of the bushing and system is the first required step in establishing proper bushing tip location. Expected operating temperatures and expansion coefficients of the bushing and the various plates through which it passes must be reviewed. Note the reference locations where differential expansion between the bushing seat and the mold cavity will occur. The drawing and data shown illustrate this evaluation process.

In the bushing applications shown, the length of the bushing from the head seating area to the cavity (Points "A" and "B") is expanding at a far higher rate the mold plates and will alter the relationship between tip and gate. The differential expansion in this area must determined and a corresponding correction made in mounting location.

Bushing Thermal Expansion Calculations

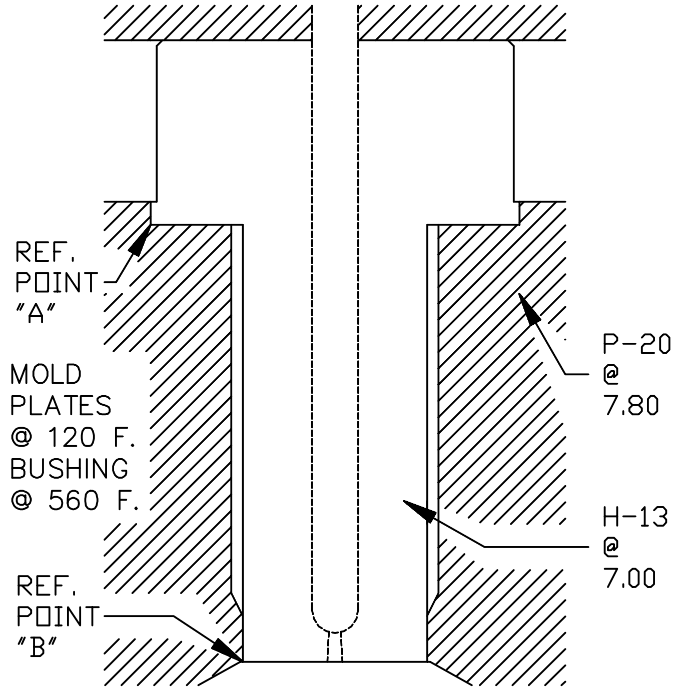
Two methods of determining differential expansion and establishing the desired room temperature bushing tip location are provided on the adjacent page.

The first method shown utilizes a graph from which the actual expansion per inch of bushing may be selected for any given operating temperature. This expansion can then be multiplied by the length of the bushing affected to obtain the total change in bushing length. This graphical method provides sufficient accuracy for most common runnerless applications involving standard length bushings.

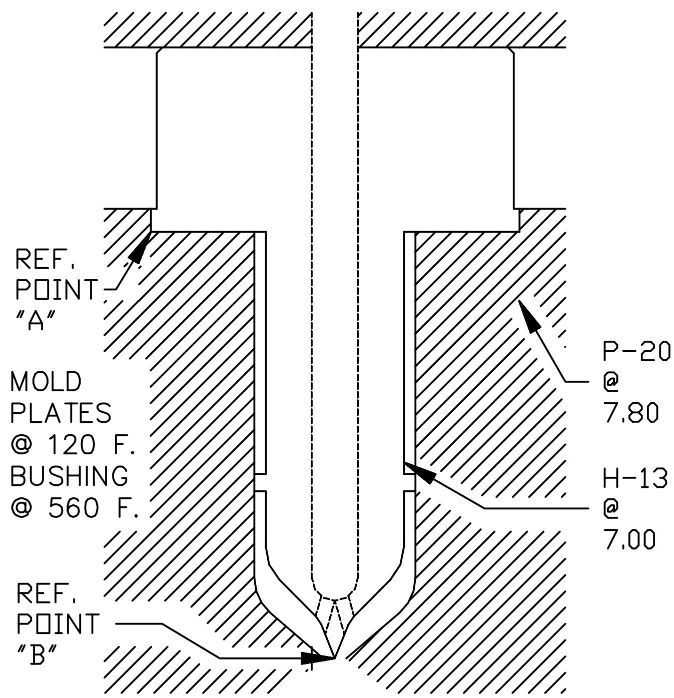
The second method requires calculation of expansion based on the actual expansion coefficient and bushing operating temperature. This calculation procedure provides reasonable accuracy in establishing room temperature location of the bushing tip.

For more accurate calculations, a separate calculation for both the bushing and plate must be carried out. By subtracting plate expansion from bushing expansion true differential expansion can be obtained. Establishing the room temperature location of the tip based on true differential expansion provides more accurate results and is preferred for molds involving long bushings and in molds requiring more precise bushing tip location to obtain maximum control of the gating characteristics.

Regardless of the calculation method used, additional adjustment will be required to fine tune the molding process.



Typical Sprue Gate Bushing Design Detailing The Required Thermal Expansion Review Data



Typical Pin Gate Bushing Design Detailing The Required Thermal Expansion Review Data

Bushing Thermal Expansion Calculations

Graphical Expansion Solution

The graph on the right establishes values for bushing expansion in inches per inch of length at operating temperature. The graph and the simple procedures outlined below provide a reasonably accurate value for total bushing expansion. The data supplied applies to all “SOLUTION” bushings manufactured of standard H-13 tool steel.

1 Find the bushing operating temperature on the Y axis of the graph for the area of the torpedo where differential expansion must be determined.

2 Locate the horizontal intersection of this temperature point with the plot line of expansion versus temperature.

3 Read the expansion value in inches per inch of heated length from the X axis directly below this point.

4 Multiply the expansion value obtained by the inches of heated length where differential expansion occurs. This value represents the total expansion of the bushing during operation and can be used to establish room temperature bushing tip location.

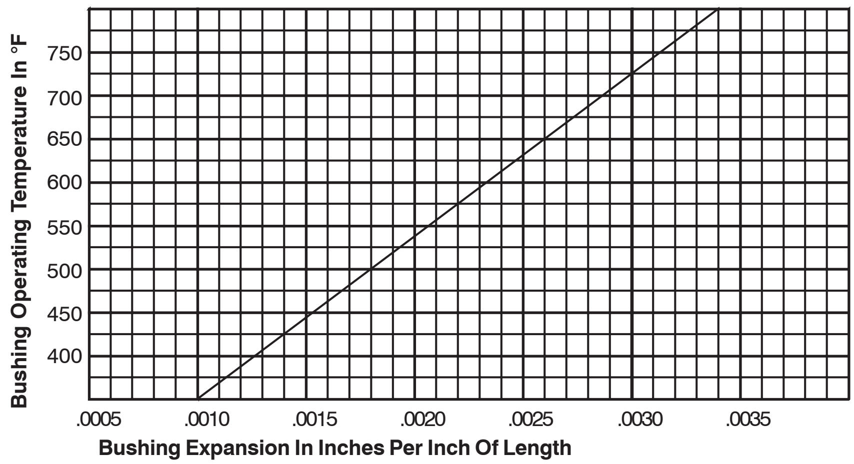
Calculated Expansion Solution

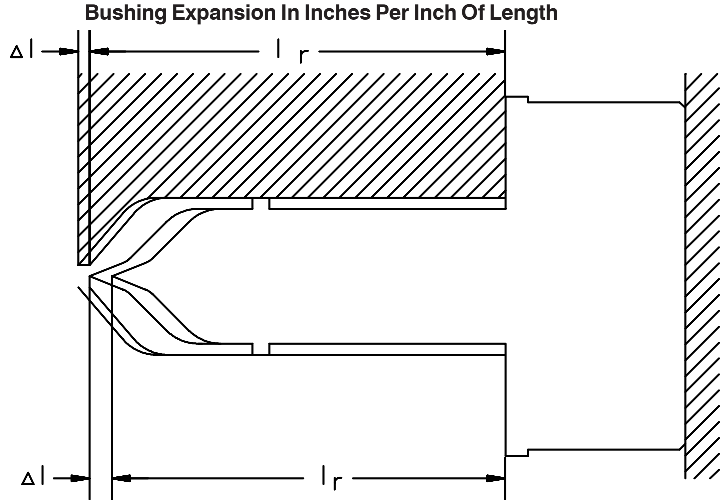
The equation provided permits calculation of bushing expansion based on the expansion coefficient of the materials used in the bushing and mold. Short bushings only require calculations for bushing expansion. Applications requiring longer bushing lengths should include the additional calculations for mold plate expansion which must be subtracted from torpedo expansion to obtain actual differential expansion between the bushing and the plates.

1 Select the appropriate bushing expansion coefficient from the table of values provided. The expansion coefficient is expressed in values of 10^{-6} requiring the decimal be shifted 6 places to the left.

2 In the equation, substitute appropriate values for expansion coefficient, length, and temperatures.

3 Solve the equation for the length change total in inches and use this figure to determine the room temperature location of the bushing in the mold. If additional accuracy is required, proceed to the additional steps 4 through 6.





4 Select the appropriate mold plate expansion coefficient from the table of values provided. The expansion coefficient is expressed in values of 10^{-6}, requiring the decimal be shifted 6 places to the left.

5 In the equation, substitute appropriate values for mold plate expansion coefficient, affected length, and temperatures.

6 Solve the equation for plate length change in inches and subtract this figure from the previously calculated length change value for the bushing. The final value obtained is the true differential expansion which will occur during system operation and provides the most accurate adjustment of room temperature bushing tip location.

If the length of the bushing has several areas where differential expansion rates vary, these calculations can be repeated for each area and then added together to obtain the total.

Regardless of the calculation method used, additional adjustment will be required to fine tune the molding process.

Thermal Expansion Equation

$$\Delta l = \infty * l_r * (t_o - t_r)$$

Δl = **Length Change Total**

∞ = **Coefficient Of Expansion**

l_r = **Length @ Room Temp.**

t_o = **Operating Temperature**

t_r = **Room Temperature**

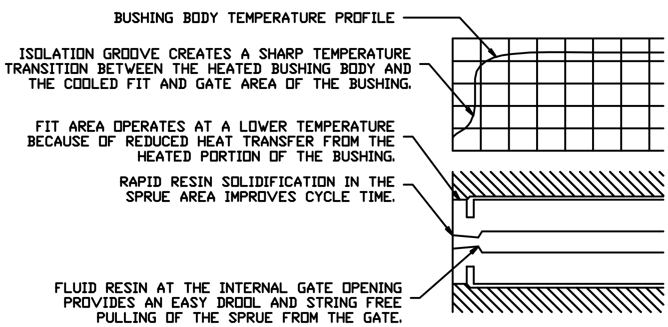
Expansion Coefficient For Common Tool Materials	
H-13 7.00	S-7 7.60
D-2 6.63	A-2 7.19
P-20 7.80	BeCu 9.70

Expansion coefficients (**∞**) are expressed in units of (in. / in. / °F. x 10^{-6}).

Advanced Sprue Gate Configurations

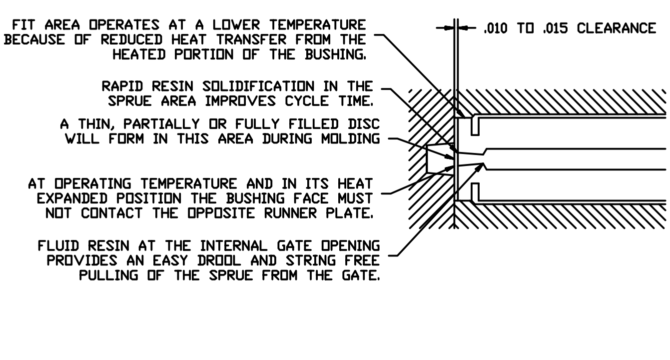
Duratherm has perfected a number of advanced techniques which improve processing and part quality in sprue gate bushing applications. The use of our thermal isolation groove is a key feature of our recommended sprue configurations. The isolation groove minimizes the transfer of heat from the bushing body into the gate area, creating a sharp temperature transition between heated bushing body and the fitted cooled area of the gate. This isolation groove also improves heat uniformity over the bushing body by reducing heat losses into the fit and gate area of the bushing. The resulting heat reduction at the gate causes rapid resin solidification in the sprue and at the part or runner surface. The reduced bushing face temperature also eliminates the undesirable rippling and discoloration which often occurs at the bushing face area of the molded part.

Thermal Isolation Groove
(U.S and foreign patents pending)



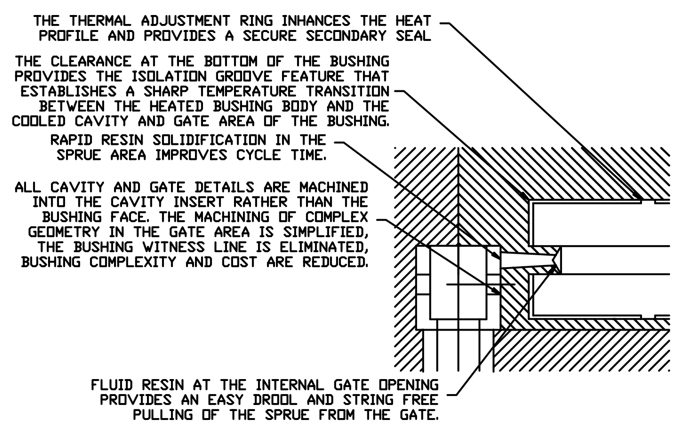
In molding applications where the bushing is used in a sprue gate configuration to gate into a subrunner it is imperative that the bushing face does not contact the opposite runner plate during operation. Avoiding this contact will reduce heat losses from the bushing and will eliminate damage to the front face of the bushing. Duratherm recommends that in addition to the allowance for heat expansion, that an additional allowance of .010 to .015 be added to insure that the bushing does not contact the runner plate. This clearance will usually result in the formation of a filled or partially filled thin disc on the runner at the runner parting line.

Bushing Face Contact Avoidance



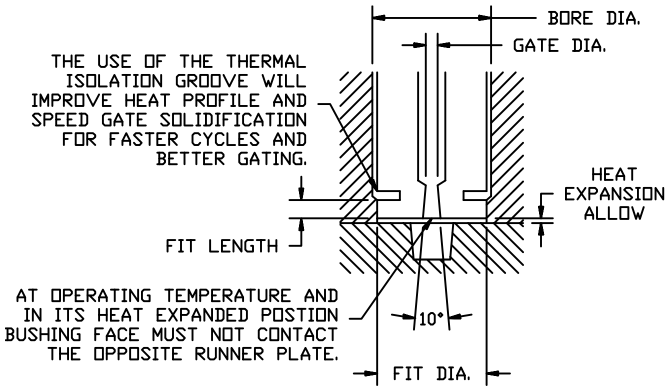
Duratherm has recently developed a novel reverse seat approach for gating into profiled part surfaces. The bushing bore is machined short of the cavity surface leaving a stub standing on the bottom surface of the bore. The gate is machined into the stub rather than the bushing. The melt passage is machined completely through the bushing and is sized to fit over the gate stub. This approach eliminates the need for machining the bushing face and instead allows all complicated geometry to be machined into the cavity insert. In addition to simplifying tool manufacture and maintenance, this gating method eliminates surface mismatch and witness lines between bushing face and cavity surface, improves cooling in the gate area and improves the bushings heat profile by reducing heat losses into the gate area of the tool. The drawing and photographs illustrate the method and results obtained when the method was incorporated into the tooling for a six inch long glass filled nylon part. This same approach can be used for sprue gating into runners and has also been applied to various pin gating applications.

Reverse Seat Sprue Gate
(U.S and foreign patents pending)

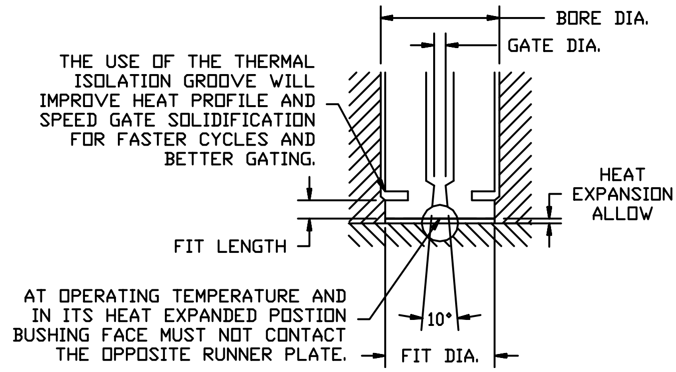


Bushing Sprue Gate Configurations

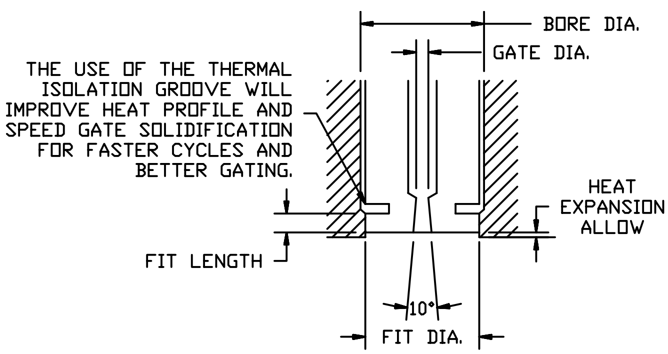
Gating A Trapezoidal Runner With Sprue Gate



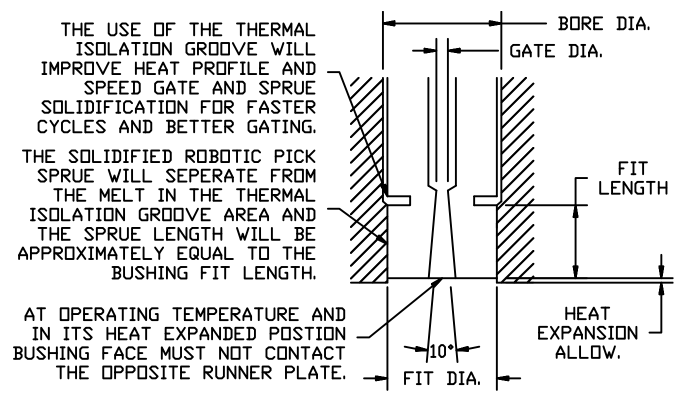
Gating A Round Runner With Sprue Gate



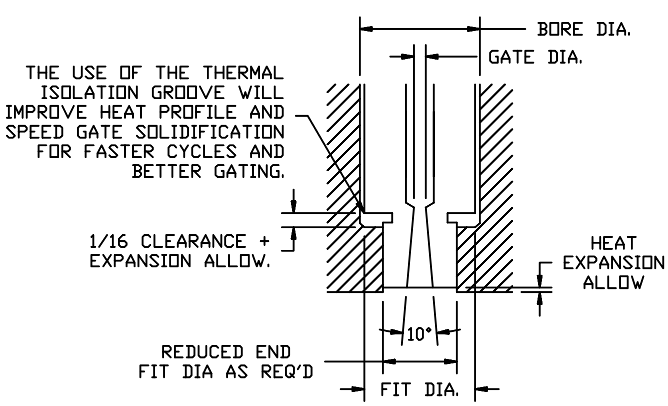
Direct Gating Flat Part Surface With Sprue Gate



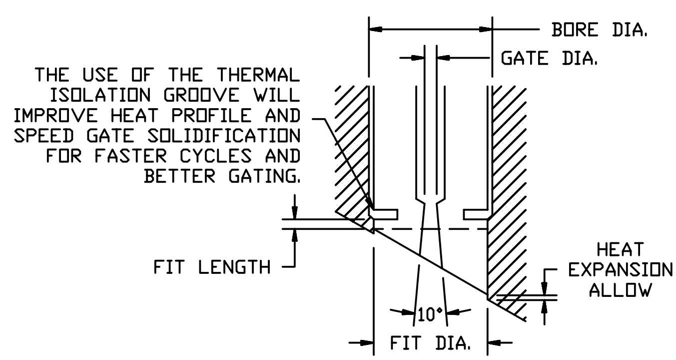
Robotic Pick Length Sprue Gating Into Parts And Runners



Direct Gating Part With Reduced End Sprue Gate



Direct Gating Into Irregular Part Surface With Sprue Gate



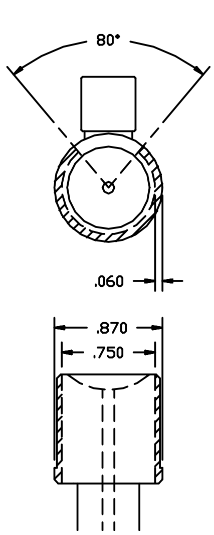
Bushing Fit Diameter	Mold Fit Diameter	Preferred Mold Bore Diameter	Typical Gate Diameter
.500 +.000 -.001	.500 +.0005 -.0000	.563	.040 - .080
.625 +.000 -.001	.625 +.0005 -.0000	.688	.060 - .100
.750 +.000 -.001	.750 +.0005 -.0000	.813	.080 - .100
.875 +.000 -.001	.875 +.0005 -.0000	.938	.080 - .100
1.000 +.000 -.001	1.000 +.0005 -.0000	1.063	.080 - .100
1.250 +.000 -.001	1.250 +.0005 -.0000	1.313	.100 - . 250
1.500 +.000 -.001	1.500 +.0005 -.0000	1.563	.100 - .250

Bushing Head Keying Modifications

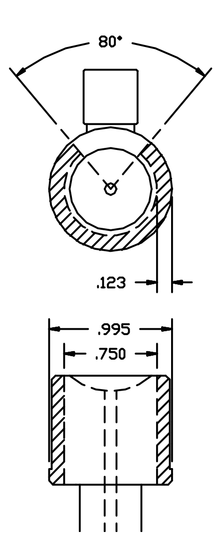
Position keys are often required to maintain a radial relationship between the bushing tip and the gate. This positioning requirement usually consists of drilled holes or milled slots in the head of the bushing which are designed to mate with a positioning key.

"SOLUTION" bushings can be modified to provide these positioning features provided that the machining of holes and slots is limited to the hatched areas indicated in the drawings below. Note that specific machining limitations apply to each head and body configuration.

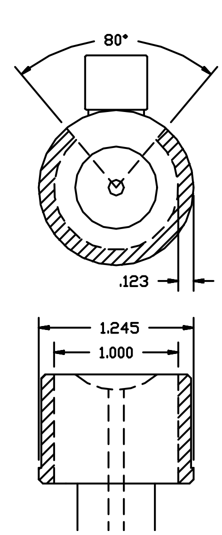
.870 In. Head With .500 Bushings



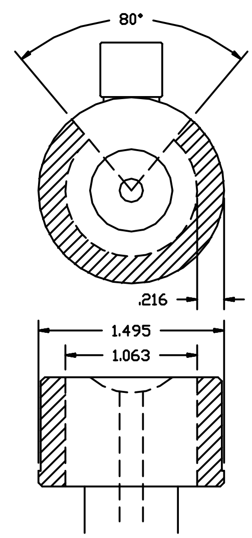
.995 In. Head With .500 Bushings



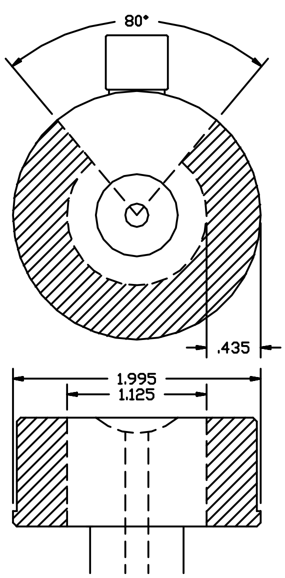
1.245 In. Head With .625 & .750 Bushings



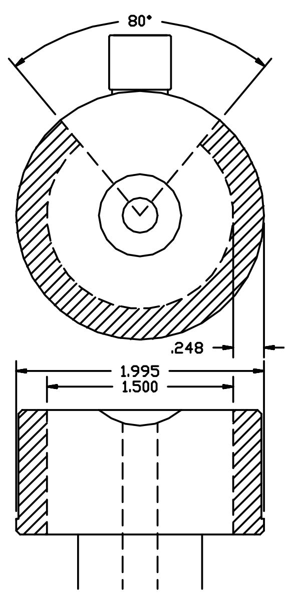
1.495 Head With .625 And .750 Bushings



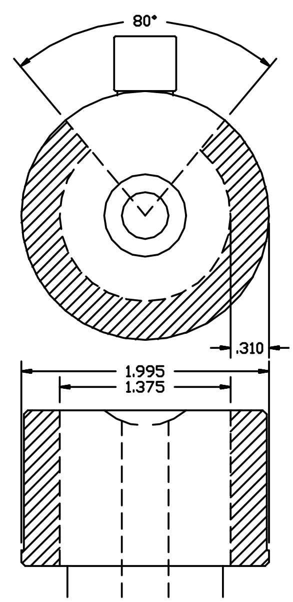
1.995 Head With .750 And .875 Bushings



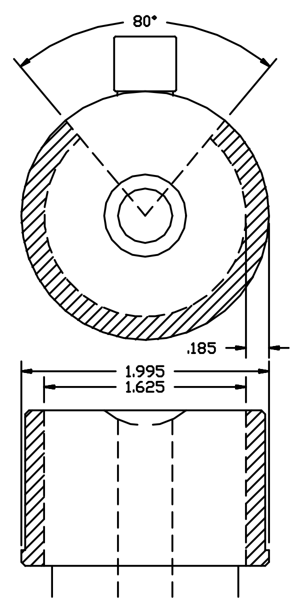
1.995 Head With 1.000 Bushings



1.995 Head With 1.250 Bushings



1.995 Head With 1.500 Bushings



Bushing Tip And Head Modifications

Bushing Machining Operations

A variety of standard machining operations can be carried out on "SOLUTION" bushings. Recommended machining operations include turning, milling, grinding and EDM work. Extra care must be taken to secure the leads during lathe operations because the long length of attached leads can pose a considerable hazard to the operator. In addition the leads can be easily damaged during lathe turning. The use of any type of coolant material is not recommended unless extreme caution is used to isolate the leads from the coolant area. Coolants entering the lead area can degrade the electrical properties of the leads and bushing.

Bushing Tip End Modifications

"SOLUTION" bushings ordered with extra stock are designed for subsequent machining by the moldmaker or molder. The ability to perform additional machining on the tip allows the customer to readily implement "SOLUTION" sprue bushings in the majority of existing molds. In addition, this machining stock option allows the bushing to be customized for use in a variety of special gating applications.

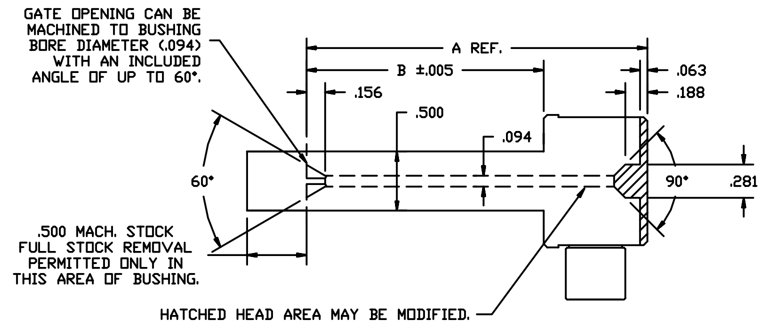
Bushing Head Modifications

Customer machining of the bushing head area is not a recommended procedure other than for the standard machining operations used when keying the head to the mold. In cases where a special head configuration is required the prudent customer will request a custom bushing design. If head modification is absolutely necessary, the machining recommendations shown must be followed in order to avoid cutting into the heating element area or weakening the bushing head construction. The hatched area of the head indicates machining limits for each standard bushing diameter.

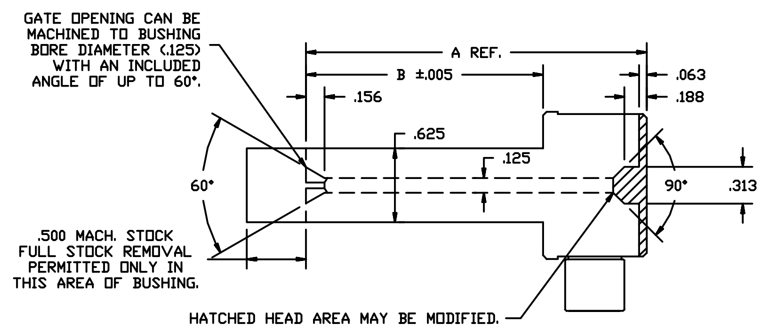
Welding Repairs And Modifications

Welding operations can be used in both repair and modification but should only be done by welders experienced with precision tool and die welding. Standard bushings are constructed of H13 tool steel and H13 compatible welding rod must be used as filler. In the case of bushings made from other alloys insure that the appropriate filler materials is used. Special care must be taken to avoid melting through the bushing wall. Use minimum weld current settings and prevent excessive heat buildup during welding operations.

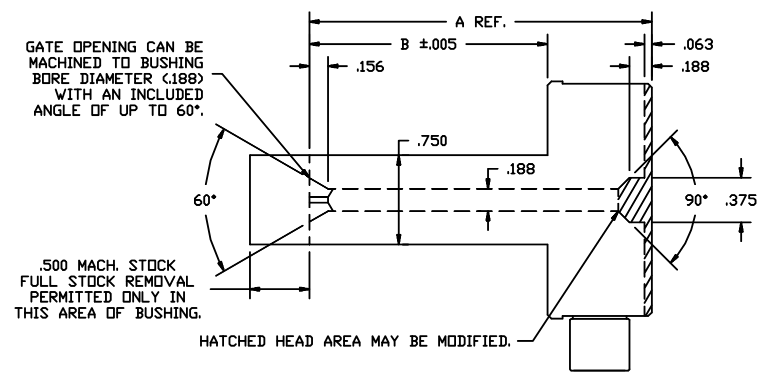
Tip And Head Modifications For .500 Bushings



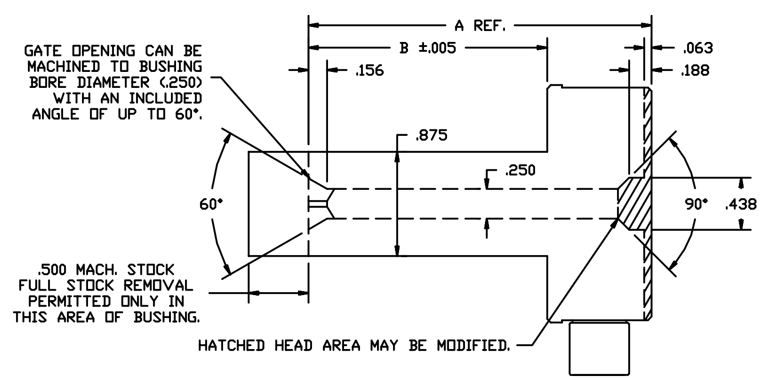
Tip And Head Modifications For .625 Bushings



Tip And Head Modifications For .750 Bushings

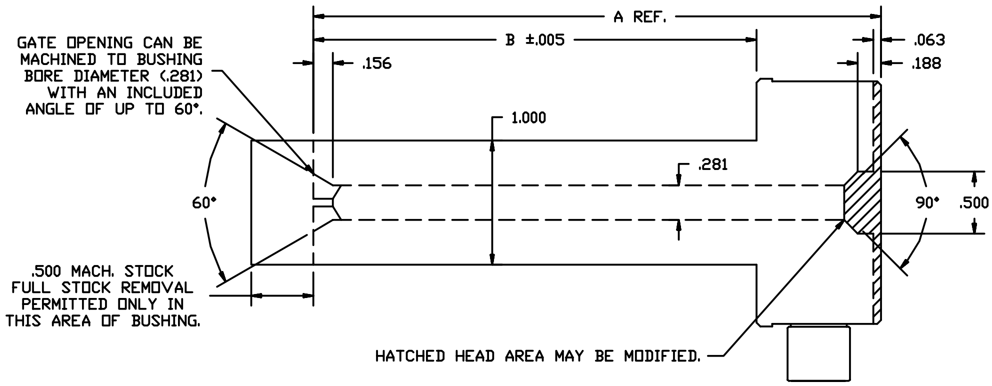


Tip And Head Modifications For .875 Bushings

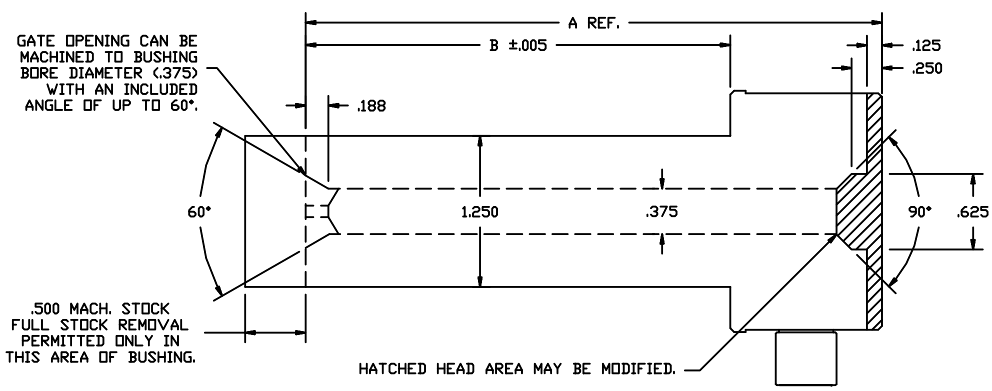


Bushing Tip And Head Modifications

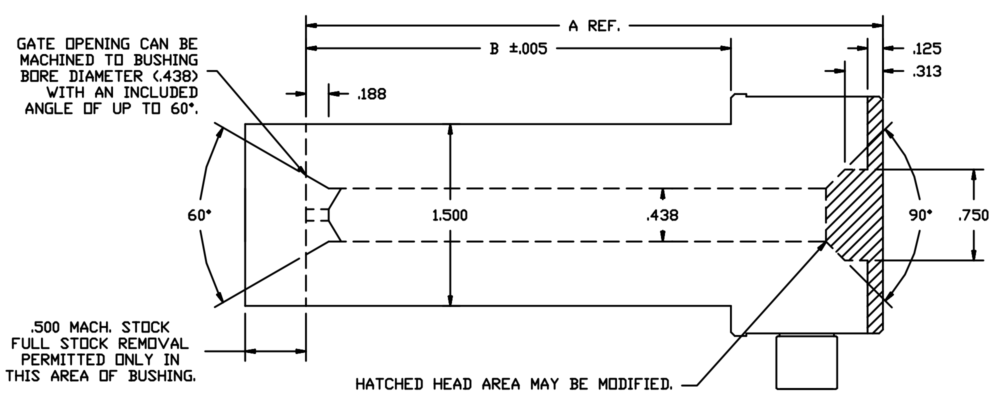
Tip And Head Modifications For 1.000 Bushings



Tip And Head Modifications For 1.250 Bushings

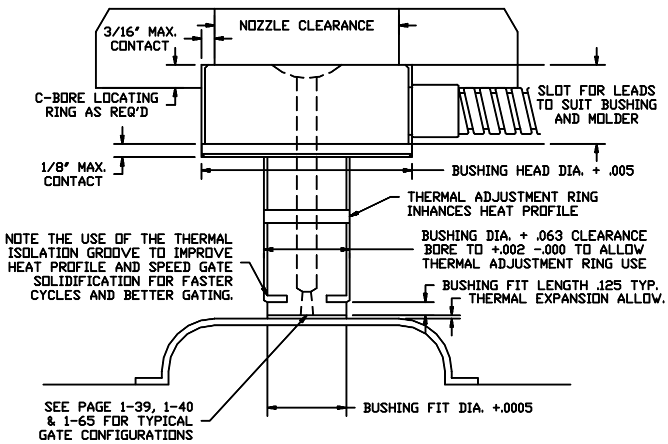


Tip And Head Modifications For 1.500 Bushings

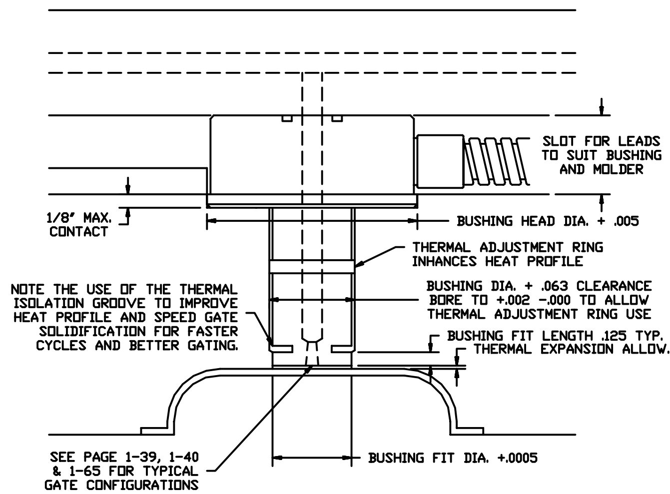


Bushing Installation Details

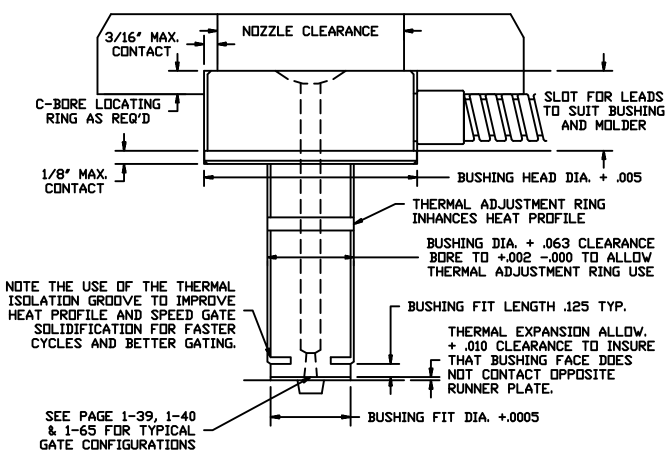
Sprue Bushing Installation For Sprue Gated Part



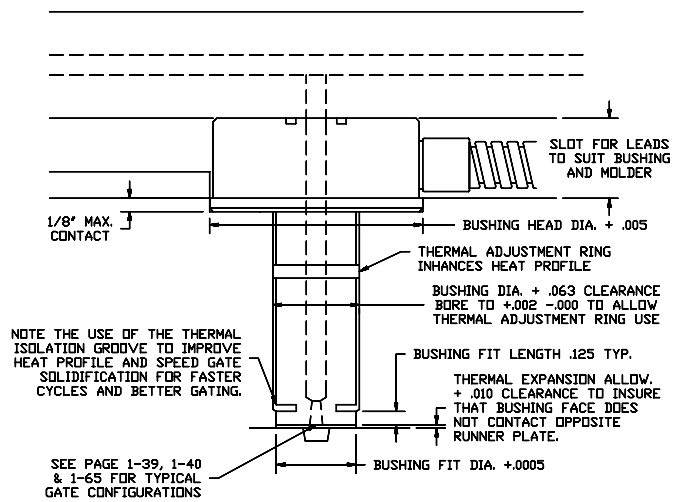
Manifold Bushing Installation For Sprue Gated Part



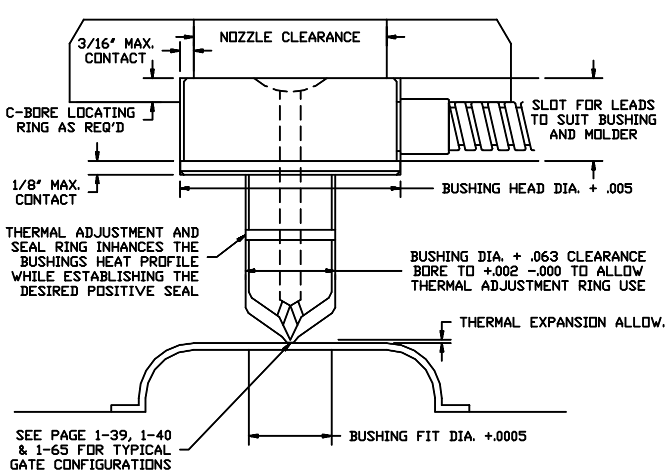
Sprue Bushing Installation For Sprue Gated Runner



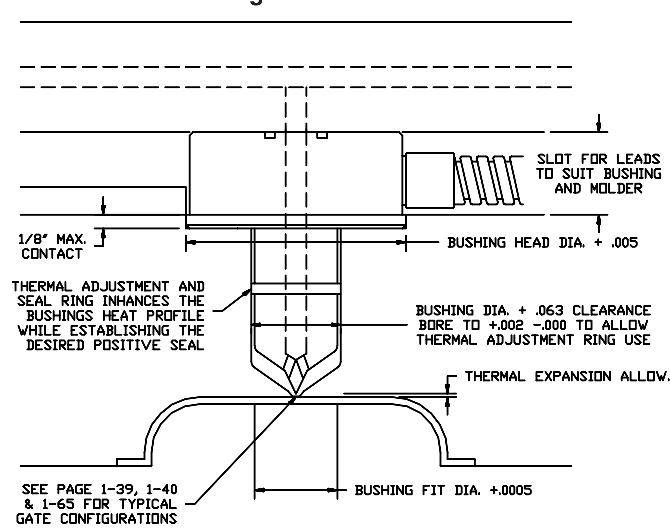
Manifold Bushing Installation For Sprue Gated Runner



Sprue Bushing Installation For Pin Gated Part



Manifold Bushing Installation For Pin Gated Part



Bushing Thermocouple Replacement Procedures

"SOLUTION" bushings have been designed to permit easy removal and replacement of damaged thermocouples. While care must be exercised during thermocouple replacement, most customers find the process can be accomplished with minimal effort.

Thermocouple Removal

The initial step in thermocouple replacement consists of removing the malfunctioning or damaged thermocouple.

Remove the outer cap and lead protection from the bushing to expose the lead and thermowell exit area of the bushing.

Grasp the cable with a needle nose pliers and firmly pull the cable end of the thermocouple out of the thermowell. Repeat this procedure until the cable end of the thermocouple is pulled completely from the well. Ensure that the probe is removed intact from the well and that the well is clear for installation of a new thermocouple. A length of .020 diameter music wire, formed in a radius at the end, can be pushed into the well to test insertion depth and for cleaning purposes.

Thermocouple Installation

Installation of a new thermocouple requires a bare probe length approximately equal to the bushing length. The previously removed thermocouple can be used as a guide to determine the required length of bare probe. Trim the grey protective sleeve to expose the required length of bare probe. Place the probe on a flat surface and trim by rolling a sharp knife or safety razor blade around the diameter. Avoid excessive pressure while trimming. Slide the trimmed portion off the probe.

Form the last inch or two of the tip end of the probe into a radius and insert the tip into the well. Forming of the thermocouple can be done by pulling the cable over a 5/16 inch diameter plastic rod with thumb pressure applied to the cable in a manner similar to that used in curling gift wrapping ribbon.

The location of the thermocouple well adjacent to the leads makes grasping the probe between thumb and finger for insertion rather awkward and we recommend finishing insertion with a small pair of needle nose pliers. Grasp the probe firmly with a small pair of needle nose pliers 1/8 to 3/16 inch above the thermowell and push the probe into the well. Repeat this process until the probe seats against the bottom of the well.

To complete the installation process, slide the outer cap and lead protection over the leads and reinstall the protective cap.