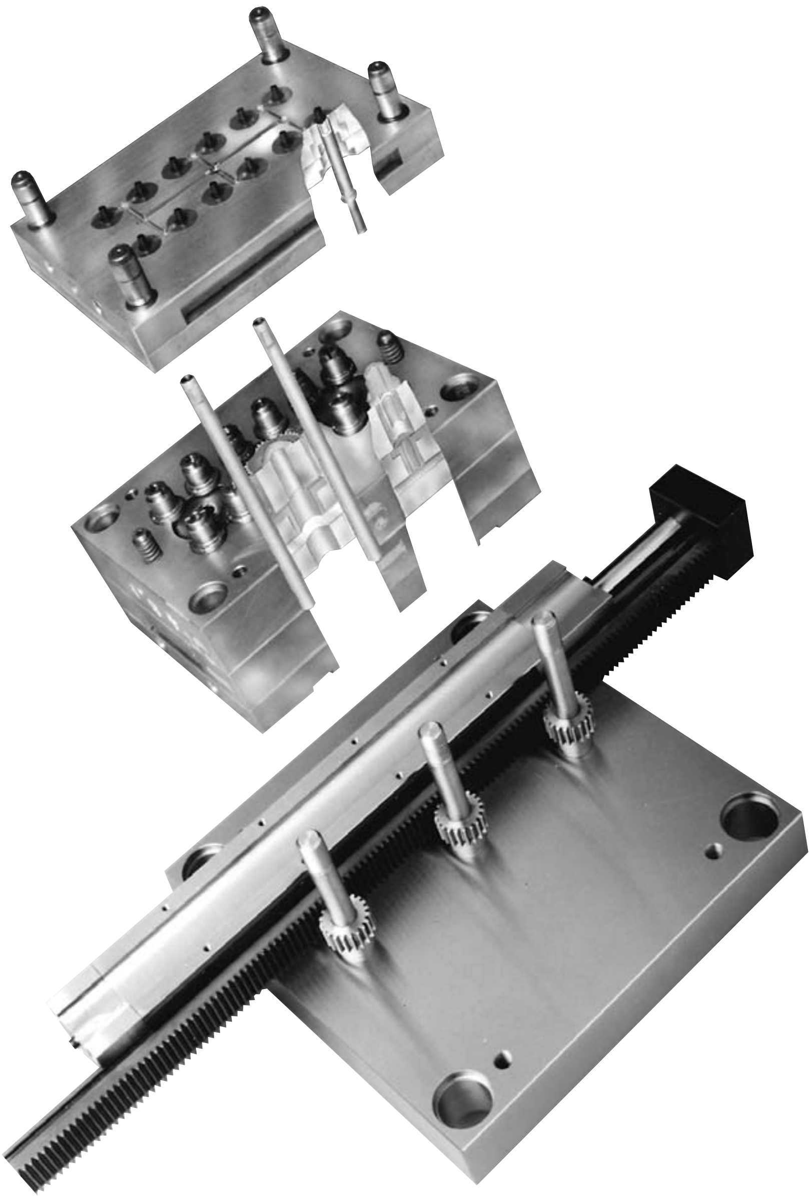
ENGINEERING DESIGN GUIDE

D-M-E Hydraulic Unscrewing Device

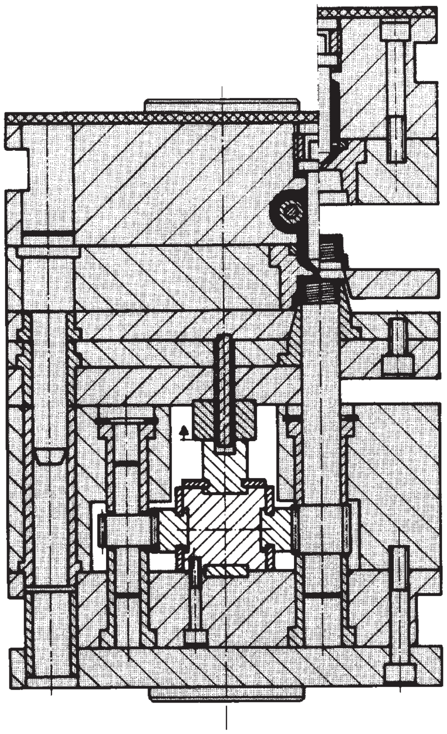


D-M-E
Every step of the way

D-M-E Hydraulic Unscrewing Device

Hydraulic Unscrewing Device

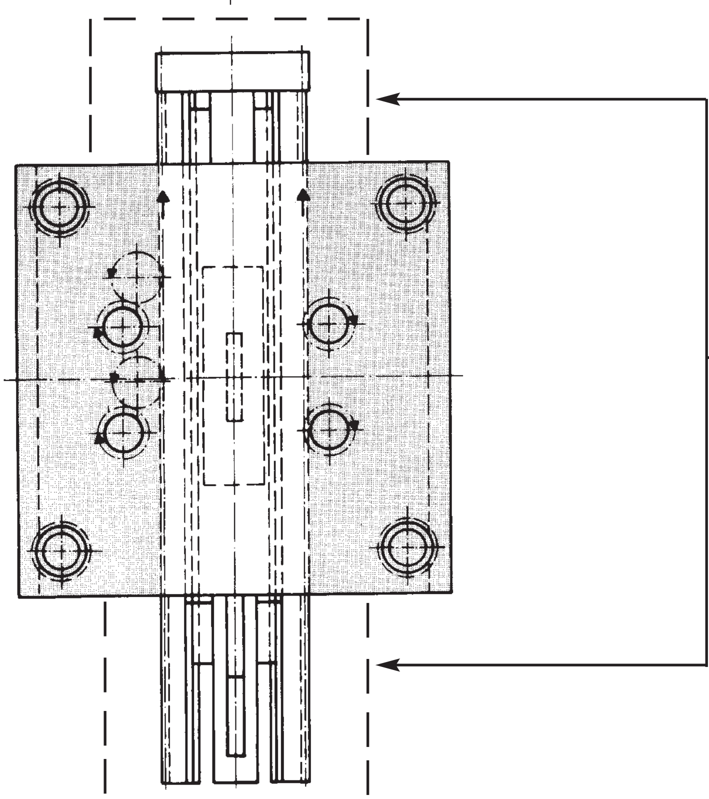
Without guiding thread with cam



Safety Considerations

Mold maker must fabricate stationary boxes over the rack areas which move to protect against injury to personnel. Mold maker must also put safety interlocks to prevent movement of unscrewing device if these protection boxes are removed for any reason.

Also, sheet metal should be used to cover gear areas to prevent gear damage from loose debris falling between the racks and gears.



Safety Protection Box

Safety Protection Box (see outer dotted lines indicated at left) fabricated by mold maker should completely cover movement of Unscrewing Device.

The following application notes are to assist in the selection of drive gears and the D-M-E Hydraulic Cylinder components associated with Unscrewing mold applications. D-M-E Company provides these application notes as a suggested method based upon prior applications and experience. D-M-E Company assumes no liability for the construction or design of said mold or dimensional stability of parts produced from these notes except the workmanship and integrity of the components supplied by the D-M-E Company.

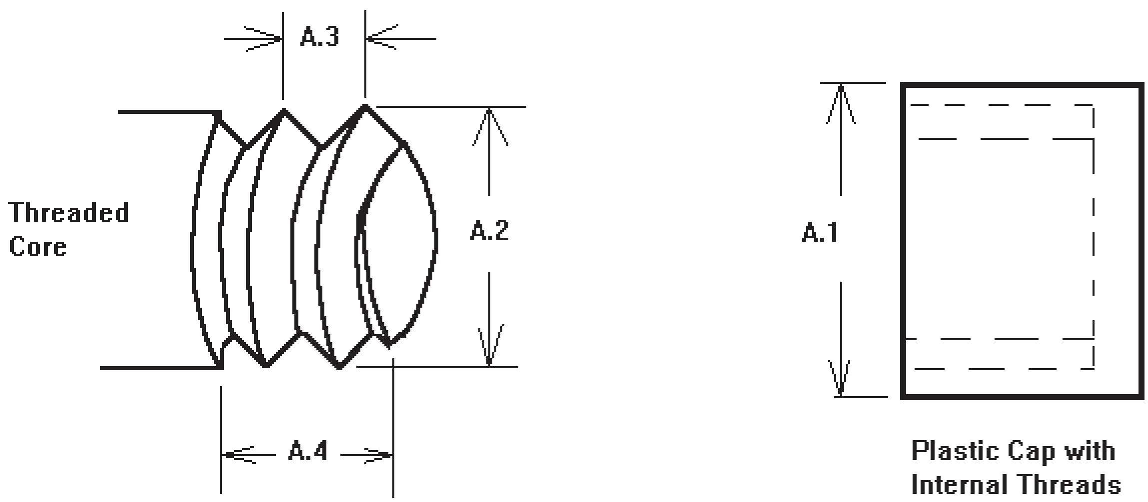
A tip for using this workbook

Record Information

❏ ___________ This box symbol will appear in the application notes and requires information to be recorded in the provided underlined space.

A. ENTER IN APPLICATION INFORMATION FOR THE CAPS

HYDRAULIC UNSCREWING CUSTOMER CAP INFORMATION



A.1 = Plastic Cap Maximum Outside Diameter
A.2 = Threaded Core Maximum Outside Diameter of the Threads
A.3 = Threaded Core Thread Lead { = 1 / Pitch where Pitch = # Threads/unit distance }
A.4 = Threaded Core Maximum Threaded Length

❏ ___________ **A.1)** Enter the maximum outside dia. of Cap in **Inches**

❏ ___________ **A.2)** Enter the maximum outside Thread dia. in **Inches**

❏ ___________ **A.3)** Enter the Thread Lead in **Inches/Thread** (example: 8 threads per inch would be = 0.125 Inches/Thread)

❏ ___________ **A.4)** Enter threaded length of cap in **Inches**

❏ ___________ **A.5)** Enter the maximum Injection Molding Cavity Pressure that will not be exceeded (Typical Injection Molding Machines generate up to 20,000 PSI Max at the barrel)

❏ ___________ **A.6)** Enter the maximum Hydraulic Pressure available (maximum is 2,175 PSI)

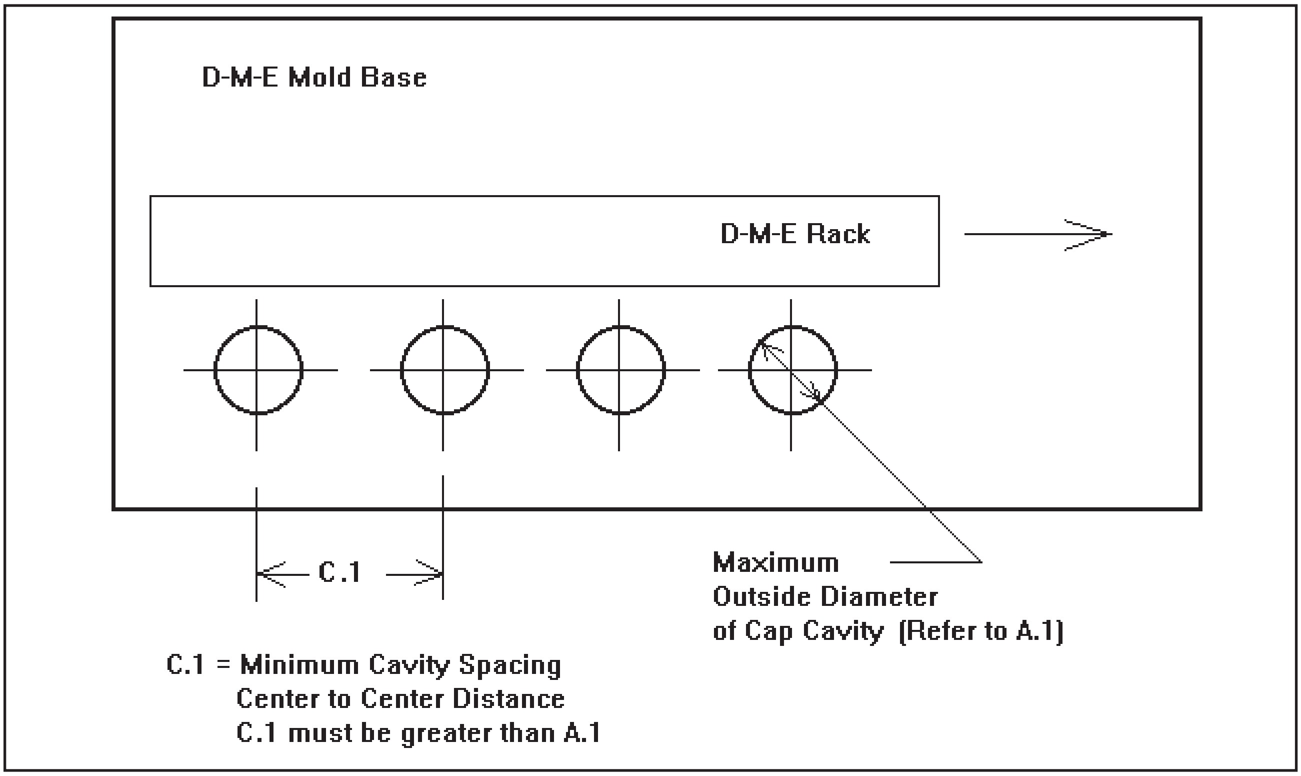
❏ ___________ **A.7)** Enter the desired number of cavities in the mold

B. CALCULATE THE NUMBER OF THREADS OR REVOLUTIONS REQUIRED TO REMOVE THE THREADED CORE

❏ ___________ **B.1)** Enter the number of Threads or Revolutions to remove the Threaded Core

$$\text{Revolutions (threaded core)} = \frac{\text{Thread Length}}{\text{Thread Lead}} + \text{safety} = \frac{[A.4]}{[A.3]} + (\text{minimum .5 revolutions})$$

C. SELECT THE MINIMUM SPACING BETWEEN CAP CAVITIES



❏ ___________ **C.1)** Enter the minimum Cavity Spacing, Center to Center Distance in **Inches** (If the cavity blocks are not available or the value is unknown, See Appendix A - Typical Cavity Spacing Calculation Procedure and Tables, use Appendix A - Procedure 1 "Theory," Procedure 2 - "Step by Step Calculation Method," or Procedure 3 - "Look-up Table Method.")

- [C.1] must be greater than [A.1] and the steel must support [A.5] maximum injection molding cavity pressure. This value is not based on the drive gear diameter which will be considered later.

D. CALCULATING THE UNSCREWING TORQUE FOR ONE CAVITY

❏ ___________ **D.1)** Enter the Torque in Inch-Pounds (in-lb$_f$) required to unscrew the threaded core. (See Appendix B - Typical Unscrewing Force Calculation Procedure and Tables, use Procedure 1 "Calculation Method" or Procedure 2 "Look-up Table Method.")

E. SELECTING A MINIMUM DIAMETER DRIVE SHAFT FOR THE THREADED CORE IN INCHES

❑ ___________ **E.1)** Enter the minimum shaft Diameter for the Threaded Core in Inches (See Appendix C - "Shaft Considerations," Procedure 1 "Calculation Method" or Procedure 2 "Look-up Table Method.")

- The minimum shaft diameter is the smallest reduced diameter allowed. Shafts may have to be a larger diameter to accommodate steps for thrust bearings, etc.
- Use the Torque calculated in [D.1] which is in inch-pounds force

❑ ___________ **E.2)** Calculate the Static Thrust the shaft must support due to Max. Cavity Pressure

$$\text{Max. Thrust } (lb_f) = \frac{[\text{Max. Cavity Diameter}]^2 \times \pi}{4} \times \text{Max. Cavity Pressure}$$

$$= [A.1]^2 \times [A.5] \times 0.785398$$

- You need to decide if a step or angle on the shaft is required to support this load. A typical minimum step to support a thrust bearing would increase diameter [E.1] by 1/4".
- For Gears listed in Appendix D, the maximum RPM will be 458 RPM for the smallest Pitch Diameter Gear and is less for larger gears. The dynamic thrust is typically minimal compared to the static thrust during injection pressures.

❑ ___________ **E.3)** Enter the minimum shaft diameter size where the gear will be slid over.

F. SELECTING THE PITCH DIAMETER OF THE DRIVE GEAR - USE 20 DEGREE PRESSURE ANGLE GEARS ONLY

❑ ___________ **F.1)** Enter the Pitch Diameter of the Drive Gear to be used in **Inches**. (See Appendix D - Table of Standard Gears)

The Gear will have to meet or exceed the following criteria:

- gear revolutions for stroke length ⩾ [B.1] required revolutions
- max. gear torque ⩾ [D.1] unscrewing torque for one cavity
- Internal gear bore dia. ⩾ [E.3] minimum shaft dia.

❑ ___________ **F.2)** Record the Gear's Diametral Pitch

❑ ___________ **F.3)** Record the Gear's Internal Bore Diameter

❑ ___________ **F.4)** Record the Gear's Pitch Circle Perimeter

❑ ___________ **F.5)** Record the Gear's Outside Diameter

G. MAKE FINAL CAVITY SPACING DECISION

❏ ____________ **G.1)** Select Cavity Spacing in **Inches**

Use the following items for minimum spacing
- Cavity Spacing must be > [A.1]
- Cavity Spacing must be ⩾ [C.1] if cavity/stripper inserts, use required clearance
- Cavity Spacing must be ⩾ [F.5] plus clearance (use an 1/8" minimum)
- Cavity Spacing must be ⩾ O.D. of Thrust Bearings used plus clearance
- Cavity Spacing must be ⩾ Required Plastic Flow Channel Requirements

H. MAXIMUM # OF CAVITIES IN ONE STRAIGHT LINE FOR HYDRAULIC CYLINDERS BASED ON THE SELECTED GEAR:

H.1) Available Hydraulic Cylinder Lengths

PISTON DIA. inches	(mm)	SHAFT DIA. inches	(mm)	STROKE inches	(mm)	SUPPORT LENGTH inches	(mm)	CAT. REF. #
.984"	(25)	.630"	(16)	11.81"	(300)	13.85"	(352)	ZG-25-300
.984"	(25)	.630"	(16)	15.74"	(400)	17.79"	(452)	ZG-25-400
.984"	(25)	.630"	(16)	19.68"	(500)	21.73"	(552)	ZG-25-500
1.574"	(40)	.866"	(22)	11.81"	(300)	13.85"	(352)	ZG-40-300
1.574"	(40)	.866"	(22)	15.74"	(400)	17.79"	(452)	ZG-40-400
1.574"	(40)	.866"	(22)	19.68"	(500)	21.73"	(552)	ZG-40-500
2.480"	(63)	1.417"	(36)	15.74"	(400)	18.46"	(469)	ZG-63-400
2.480"	(63)	1.417"	(36)	19.68"	(500)	22.40"	(569)	ZG-63-500

❏ ____________ **H.2)** Calculate the minimum stroke needed to unscrew the cap in **Inches**

- This also = minimum length of rack to extend past all gears. SAE Racks are designed to obtain full stroke for gears mounted within Cylinder Support Length

minimum stroke = Selected Gear Pitch Circle Perimeter × # of revolutions required
[H.2] = [F.4] × [B.1]

H.3) Calculate the maximum number of cavities per cylinder length in one straight line
(See Appendix E - Maximum Number of Cavities and Examples)

= Integer {Support Length (from table) ÷ (Cavity,Gear,Design Spacing) [G.1]} + 1

- *[H.2] must be < Stroke (from table) to be valid*

❏ ____________ **H.3.1)** Enter the Max # of cavities for Cylinder # ZG-25-300 = Int { 13.85 / [G.1]} + 1
This value is 0 and unusable if [H.2] ⩾ 11.81" stroke

❏ ____________ **H.3.2)** Enter the Max # of cavities for Cylinder # ZG-25-400 = Int { 17.79 / [G.1]} + 1
This value is 0 and unusable if [H.2] ⩾ 15.74" stroke

❏ ____________ **H.3.3)** Enter the Max # of cavities for Cylinder # ZG-25-500 = Int { 21.73 / [G.1]} + 1
This value is 0 and unusable if [H.2] ⩾ 19.68" stroke

❏ ____________ **H.3.4)** Enter the Max # of cavities for Cylinder # ZG-40-300 = Int {13.85 / [G.1]} + 1
This value is 0 and unusable if [H.2] ⩾ 11.81" stroke

❏ ___________ **H.3.5)** Enter the Max # of cavities for Cylinder # ZG-40-400 = Int { 17.79 / [G.1]} + 1
This value is 0 and unusable if [H.2] ⩾ 15.74" stroke

❏ ___________ **H.3.6)** Enter the Max # of cavities for Cylinder # ZG-40-500 = Int { 21.73 / [G.1]} + 1
This value is 0 and unusable if [H.2] ⩾ 19.68" stroke

❏ ___________ **H.3.7)** Enter the Max # of cavities for Cylinder # ZG-63-400 = Int { 18.46 / [G.1]} + 1
This value is 0 and unusable if [H.2] ⩾ 15.74" stroke

❏ ___________ **H.3.8)** Enter the Max # of cavities for Cylinder # ZG-63-500 = Int { 22.40 / [G.1]} + 1
This value is 0 and unusable if [H.2] ⩾ 19.68" stroke

- *NOTE:* If there is no usable values due to [H.2] ⩾ stroke, then a cogwheel which increases the stroke's linear movement through using gear ratios will have to be designed. It is beyond the scope of this document to discuss, but a design engineer may be able to find a workable combination.
- Also, if too much of the stroke is used for [H.2], then there will be very little to provide stripper height which supplies "BUMP" to assist in shaking off the cap.

I. MAX. # OF CAVITIES FOR HYDRAULIC CYLINDERS BASED ON ITS PISTON DIAMETER

❏ ___________ **I.1)** Calculate the Hydraulic Force Required per Cavity (lb_f)

- *(NOTE: x1.5 is a 50% safety factor; if x1.0 there would be no safety factor)*

$$= \frac{\text{Unscrewing Torque (in-lb}_f\text{)}}{\text{Gear Pitch Radius (in)}} \times 1.5 = \frac{[D.1]}{[F.1] / 2} \times 1.5 = \frac{[D.1]}{[F.1]} \times 3.0$$

I.2) Calculate the Maximum # of Cavities that the Cylinders can Unscrew
= Integer (Area of Cylinder's Piston × Hydraulic Press / Hydraulic Force Req. per Cavity)

$$= \text{Integer} \left\{ \frac{(\pi \times \text{Piston Dia}^2 / 4) \times [A.6]}{[I.1]} \right\}$$

- *NOTE:* When taking the Integer, do not round up. (Ex. if = Integer{2.734} then = 2)

❏ ___________ **I.2.1)** Calculate Maximum Number of Cavities for Cylinders ZG - 25 - XXX
= Integer { 0.760466 in^2 × [A.6] / [I.1] }

❏ ___________ **I.2.2)** Calculate Maximum Number of Cavities for Cylinders ZG - 40 - XXX
= Integer { 1.9458051 in^2 × [A.6] / [I.1] }

❏ ___________ **I.2.3)** Calculate Maximum Number of Cavities for Cylinders ZG - 63 - XXX
= Integer { 4.8305128 in^2 × [A.6] / [I.1] }

J. MAKE A LIST OF CYLINDERS WHICH CAN BE USED

J.1) For Single Row of Cavities and One-Cylinder Applications, check box if conditions TRUE

	Max.	In-Between	Min.
❏ For Cylinder # ZG-25-300 Conditions	[I.2.1] ⩾	[H.3.1] *or Less* ⩾	[A.7]
❏ For Cylinder # ZG-25-400 Conditions	[I.2.1] ⩾	[H.3.2] *or Less* ⩾	[A.7]
❏ For Cylinder # ZG-25-500 Conditions	[I.2.1] ⩾	[H.3.3] *or Less* ⩾	[A.7]
❏ For Cylinder # ZG-40-300 Conditions	[I.2.2] ⩾	[H.3.4] *or Less* ⩾	[A.7]
❏ For Cylinder # ZG-40-400 Conditions	[I.2.2] ⩾	[H.3.5] *or Less* ⩾	[A.7]
❏ For Cylinder # ZG-40-500 Conditions	[I.2.2] ⩾	[H.3.6] *or Less* ⩾	[A.7]
❏ For Cylinder # ZG-63-400 Conditions	[I.2.3] ⩾	[H.3.7] *or Less* ⩾	[A.7]
❏ For Cylinder # ZG-63-500 Conditions	[I.2.3] ⩾	[H.3.8] *or Less* ⩾	[A.7]

J.2) For two Rows of Cavities and One-Cylinder Applications, check box if conditions TRUE

		Max.	In-Between	Min.
❏ For Cylinder # ZG-25-300	Conditions	[I.2.1] $\geqslant$	2 × [H.3.1] *or Less* $\geqslant$	[A.7]
❏ For Cylinder # ZG-25-400	Conditions	[I.2.1] $\geqslant$	2 × [H.3.2] *or Less* $\geqslant$	[A.7]
❏ For Cylinder # ZG-25-500	Conditions	[I.2.1] $\geqslant$	2 × [H.3.3] *or Less* $\geqslant$	[A.7]
❏ For Cylinder # ZG-40-300	Conditions	[I.2.2] $\geqslant$	2 × [H.3.4] *or Less* $\geqslant$	[A.7]
❏ For Cylinder # ZG-40-400	Conditions	[I.2.2] $\geqslant$	2 × [H.3.5] *or Less* $\geqslant$	[A.7]
❏ For Cylinder # ZG-40-500	Conditions	[I.2.2] $\geqslant$	2 × [H.3.6] *or Less* $\geqslant$	[A.7]
❏ For Cylinder # ZG-63-400	Conditions	[I.2.3] $\geqslant$	2 × [H.3.7] *or Less* $\geqslant$	[A.7]
❏ For Cylinder # ZG-63-500	Conditions	[I.2.3] $\geqslant$	2 × [H.3.8] *or Less* $\geqslant$	[A.7]

- *NOTE:* In J.1 and J.2, the **Max.** value is based on the number of cavities that the Hydraulic Cylinder can unscrew based on the Force only. The **In-Between** value is based only on the amount of stroke and support length available from the Hydraulic Cylinder. The **Min.** is based on customer Application needs. The "***or Less***" comment in J.1 and J.2 is stated because ***it is possible to have the*** **Max. < In-Between**, in which the **In-Between** value would have to be selected as a less or smaller value, but kept larger or equal to the **Min.** value. The conditions could still be met and remain TRUE in this situation.

J.3) If None of the above conditions worked, if it is primarily limited by the I.2.X value, a larger Pitch Diameter gear will reduce the amount of unscrewing force and decrease H.3.X but may also increase the cavity spacing. If H.3.X is the limiting factor, then the Pitch Diameter would have to be decreased, which will decrease the I.2.X value. Decreasing this value may make it impossible to have enough strength in the gear. You may have to reconsider the number of cavities and change this value to fit the design parameters.

K. SELECT THE HYDRAULIC CYLINDER WHICH WILL BE USED

❏ ____________ **K.1)** Enter the D-M-E Catalog Cylinder Number to be used

(*NOTE:* Avoid using the last few inches of stroke to increase the life of the cylinder seals, if possible. Use limit switches to prevent cylinder from achieving full travel.)

❏ ____________ **K.2)** Enter the Total Number of Cavities that will be used

❏ ____________ **K.3)** Enter the number of rows of cavities to be used (either 1 or 2)

❏ ____________ **K.4)** Calculate the minimum Hydraulic Unscrewing Force needed (lb_f)
= Hydraulic Force required per Cavity × # of Cavities = [I.1] × [K.2]

❏ ____________ **K.5)** Calculate the min. Hydraulic Pressure to supply the Cylinder (max. = 2175 PSI)
Maximum Available was [A.6]

$$= \frac{\text{Hydraulic Unscrewing Force } (lb_f)}{\text{Cylinder's Piston Area } (in^2)} = \frac{[K.4]}{\pi \times (\text{Piston Dia})^2/4}$$

For Cat # ZG-25-XXX = [K.4] / (0.760466 in^2)

For Cat # ZG-40-XXX = [K.4] / (1.9458051 in^2)

For Cat # ZG-63-XXX = [K.4] / (4.8305128 in^2)

❏ ____________ **K.6)** Calculate the "Required Stroke" that the unscrewing Action will use in **Inches**

= Gears Pitch Circle Perimeter × # of revolutions = [F.4] × [B.1]

❏ ____________ **K.7)** Calculate the available "Stripper Stroke" for moving the Stripper Plate (provides "BUMP")

For Cat # ZG-XX-300 the total available stroke = 11.81"
For Cat # ZG-XX-400 the total available stroke = 15.74"
For Cat # ZG-XX-500 the total available stroke = 19.68"

= Total Available Stroke for Cat # [K.1] − Unscrewing Action Inches [K.6]

L. CONTROL CAM CALCULATIONS – ANGLES THAT WILL BE PUT ON THE CAM RISER IN DEGREES (SEE DIAGRAM ON PG. 10)

❏ ____________ **L.1)** Calculate the Moving Cam Angle (α) *NOTE:* Moves main stripper Plate
*** Place calculator in Degree Mode

α = Tan^{-1} {Thread Lead / (Gear Pitch Diameter $\times\pi$) }

= Tan^{-1} {Thread Lead / Gear Pitch Circle Perimeter }

= Tan^{-1} { [A.3] / [F.4] } in Degrees

Example: Let's say [A.3] = 0.125 Inches / Thread and
[F.4] = 4.712 Inches Perimeter for the Gear

α = Tan^{-1} { [A.3] / [F.4] } in Degrees
= Tan^{-1} { 0.125 / 4.712 } in Degrees
= Tan^{-1} { 0.026528013 } in Degrees
= 1.519586822 in Degrees

Note: by pressing your calculator button DD ➔ DMS or [Inverse] [° ' "] button you should obtain your answer in degrees - minutes and seconds
= 1° 31' 10.51" (Degrees - Minutes - Seconds)

If not, as long as your calculator was in degrees you can do the following:
For the Degree number 1.519586822

Step 1 - Find Degrees
Take the value to the left of the decimal = 1. which equals 1 Degree

Step 2 - Find Minutes
Take the fractional part left, 0.519586822
multiply by 60 minutes = 0.519856822 x 60 = 31.17520929
Take the value to the left of the decimal = 31. which equals 31 Minutes

Step 3 - Find the Seconds
Take the fractional part left, 0.17520929
multiply by 60 seconds = 0.17520929 x 60 = 10.5125574 Seconds
Round to two decimal places = 10.51" Seconds

Step 4 - Put the Angle together
α = 1 degree 31 minutes 10.51 seconds or 1° 31' 10.51"

❏ ____________ **L.2)** Enter the Desired Stripper Height in Inches *NOTE:* Provides "Bump" or moves the anti-rotational stripper plate

Typically about 1-1/2 times the Thread Lead [A.3] minimum

❏ ____________ **L.3)** Calculate Stripper Cam Angle (β)

*** Place calculator in Degree Mode; Stripper Stroke = [K.7] – unused stroke. Try to leave at least 2" of unused stroke which will be stopped by a limit switch to increase internal cylinder seal life.

β = Tan^{-1} { Stripper Height / Stripper Stroke } in Degrees

= Tan^{-1} { [L.2] / ([K.7] – unused Stroke) }

M. RECORD FINAL DESIGN PARAMETERS WHICH WILL BE USED

Catalog Dimensions of Hydraulic Cylinders

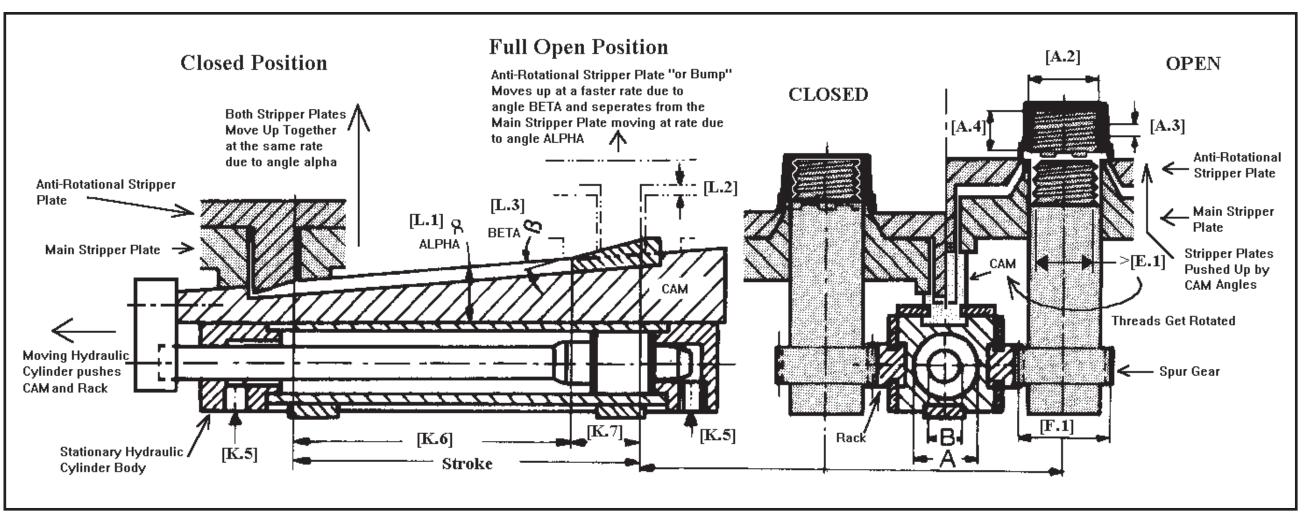
PISTON DIA. inches	(mm)	SHAFT DIA. inches	(mm)	STROKE inches	(mm)	SUPPORT LENGTH inches	(mm)	CAT. REF. #
.984"	(25)	.630"	(16)	11.81"	(300)	13.85"	(352)	ZG-25-300
.984"	(25)	.630"	(16)	15.74"	(400)	17.79"	(452)	ZG-25-400
.984"	(25)	.630"	(16)	19.68"	(500)	21.73"	(552)	ZG-25-500
1.574"	(40)	.866"	(22)	11.81"	(300)	13.85"	(352)	ZG-40-300
1.574"	(40)	.866"	(22)	15.74"	(400)	17.79"	(452)	ZG-40-400
1.574"	(40)	.866"	(22)	19.68"	(500)	21.73"	(552)	ZG-40-500
2.480"	(63)	1.417"	(36)	15.74"	(400)	18.46"	(469)	ZG-63-400
2.480"	(63)	1.417"	(36)	19.68"	(500)	22.40"	(569)	ZG-63-500

The above table summarizes the catalog dimensions for the D-M-E Catalog # you selected in [K.1].

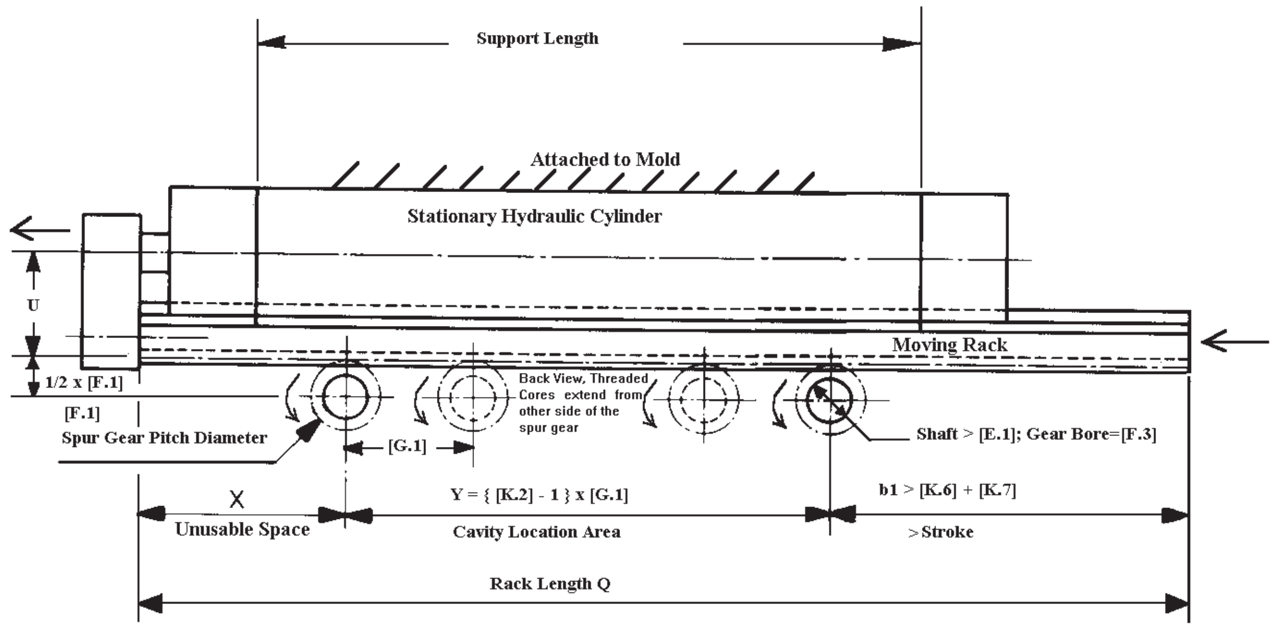
For convenience, re-record the pertinent design parameters below.

FROM THIS DESIGN GUIDE				FROM CATALOG PAGE FOR THE RACK YOU SELECTED	
A.2	________	K.2	________	Rack length	Q: ________
A.3	________	K.3	________		
A.4	________	K.5	________	Distance from center of hydraulic cylinder to the racks pitch line	U: ________
E.1	________	K.6	________		
F.1	________	K.7	________		
F.3	________	L.1	________		
G.1	________	L.2	________		
K.1	________	L.3	________		

The following Application Diagram shows how the cam riser will have to be shaped.

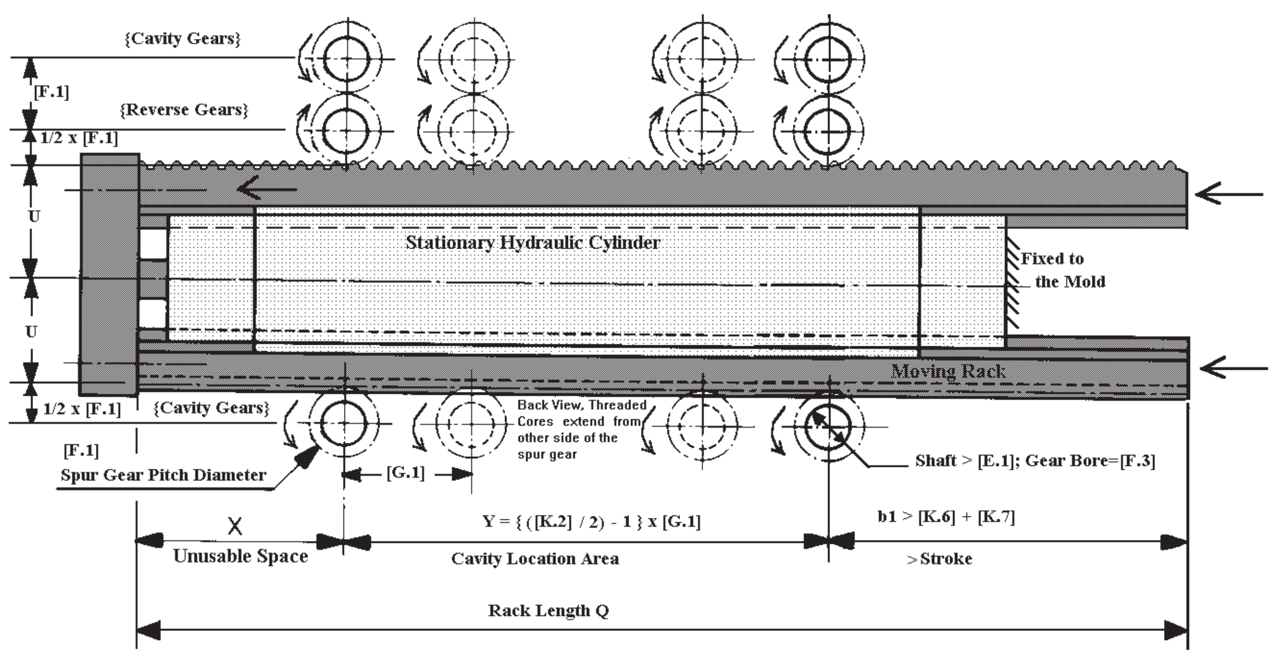


If [K.3] = 1 then it is a Single-Row Application; see the following diagram:

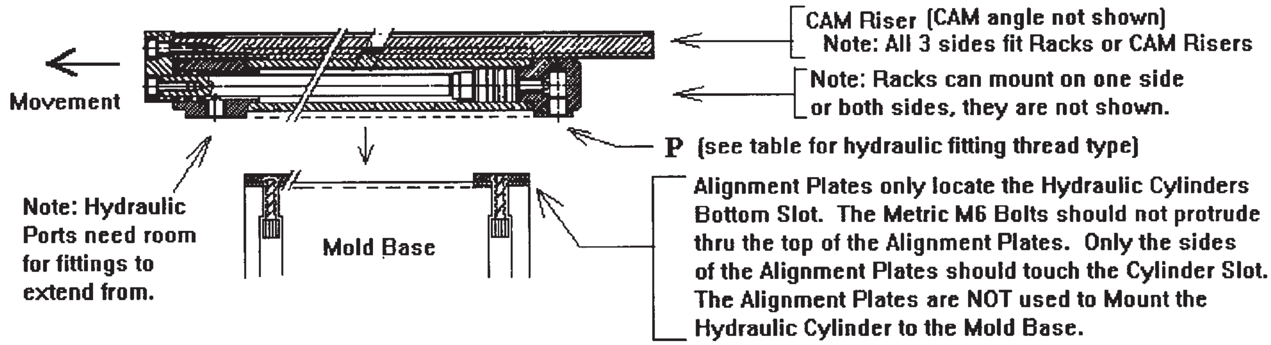


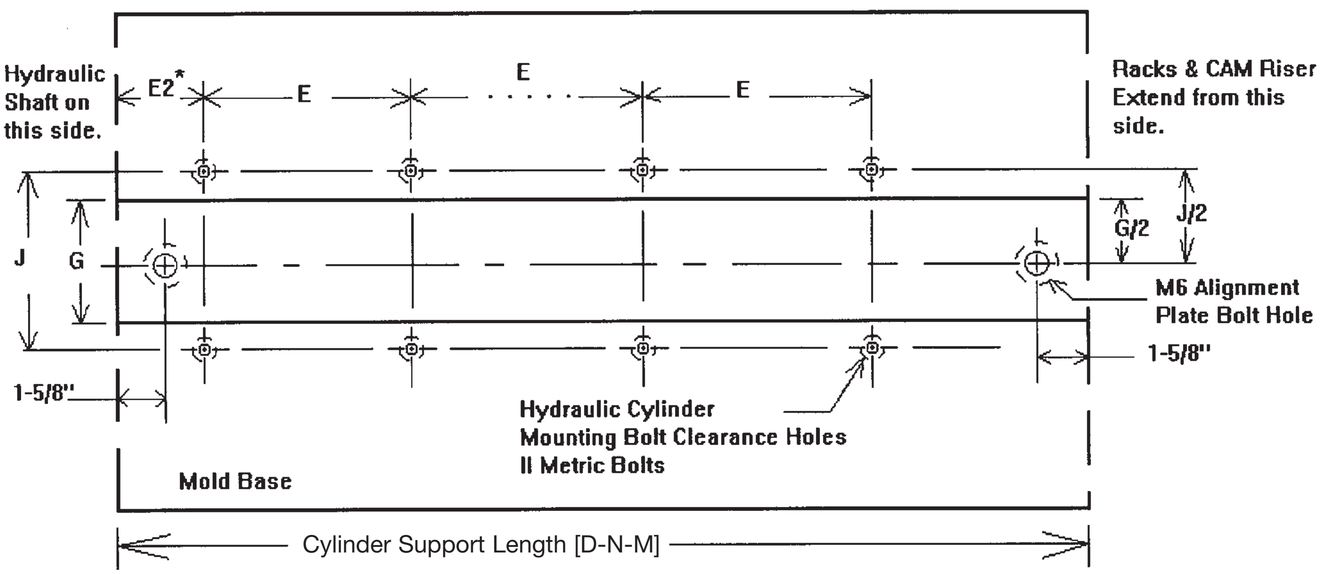
Note: Dimension U = Distance from the Center of the Hydraulic Cylinder to the Pitch Line of the Rack, Q is the Catalog Rack Length (See the Catalog)

If [K.3] = 2 then it is a Two-Row Application; see the following diagram:



Note: Dimension U = Distance from the Center of the Hydraulic Cylinder to the Pitch Line of the Rack, Q is the Catalog Rack Length (See the Catalog)
Also, 2 x U + 2 x [F.1] > [G.1] , this is to meet minimum cavity spacing requirements

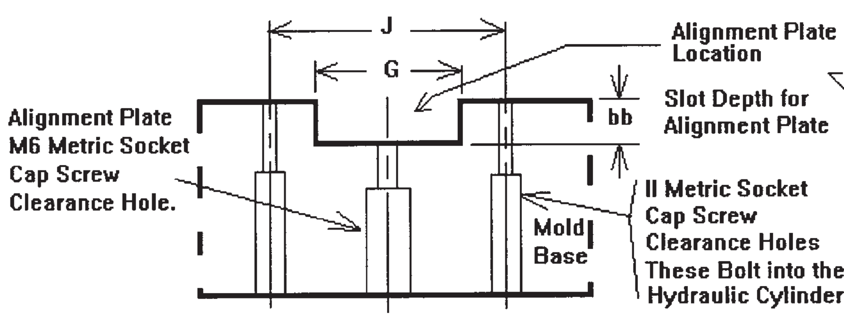


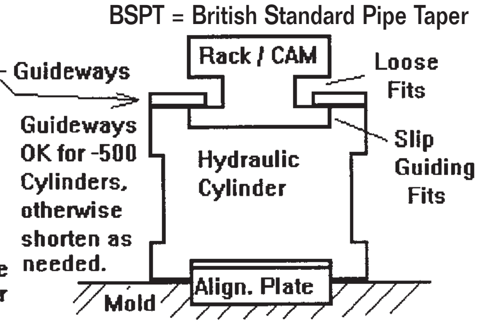


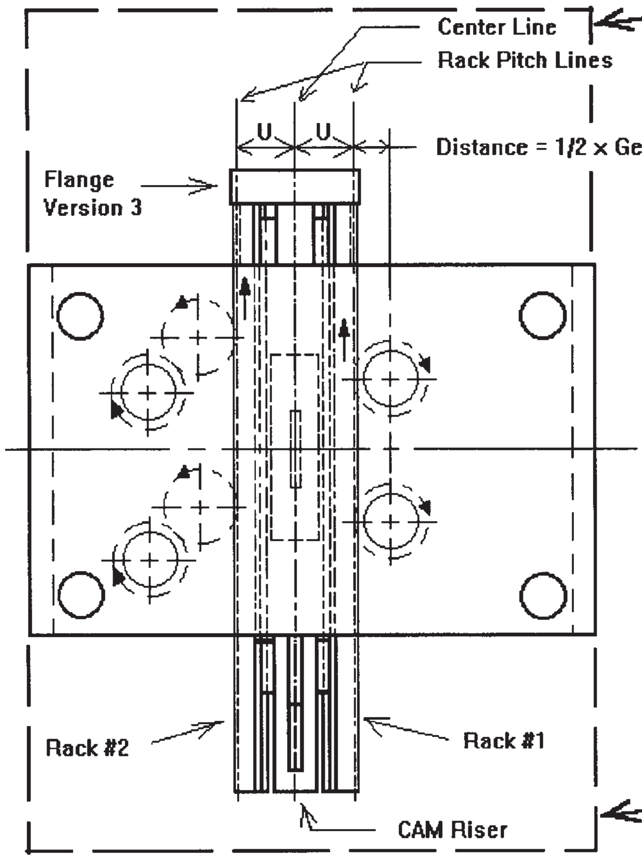
* – Note: Use E1 value instead of E2 if Hydraulic Cylinder Ports face the side instead of straight down

Cylinder #	E2	E #	E Inches	G	J	(D-N-M)	II #	II Cap Screw	bb	P	*E1
ZG-25-300	2.598"	3	3.150"	0.787"	1.339"	13.85"	8	M5	1/8"	1/4" BSPT	2.202"
ZG-25-400	4.567"	3	3.150"	0.787"	1.339"	17.79"	8	M5	1/8"	1/4" BSPT	4.173"
ZG-25-500	3.386"	5	3.150"	0.787"	1.339"	21.73"	12	M5	1/8"	1/4" BSPT	2.992"
ZG-40-300	2.598"	3	3.150"	1.181"	1.732"	13.85"	8	M5	1/8"	1/2" BSPT	2.205"
ZG-40-400	4.567"	3	3.150"	1.181"	1.732"	17.79"	8	M5	1/8"	1/2" BSPT	4.173"
ZG-40-500	3.386"	5	3.150"	1.181"	1.732"	21.73"	12	M5	1/8"	1/2" BSPT	2.992"
ZG-63-400	4.882"	3	3.150"	1.969"	2.756"	18.46"	8	M8	5/16"	3/4" BSPT	4.488"
ZG-63-500	3.701"	5	3.150"	1.969"	2.756"	22.40"	12	M8	5/16"	3/4" BSPT	3.307"

BSPT = British Standard Pipe Taper







SAFETY CONSIDERATIONS

Safety Consideration - Mold Maker MUST fabricate boxes over the rack areas which move to protect against injury to personel. Mold Maker MUST also put safety interlocks to prevent movement of Unscrewing Device if these protection boxes are removed for any reason.

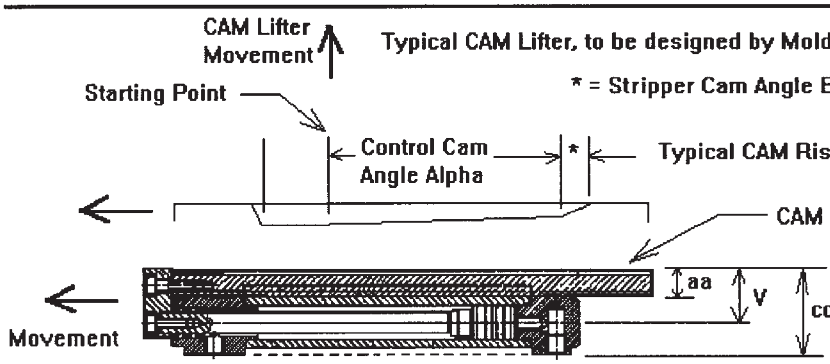
Also, sheet metal should be used to cover areas where the gears are to prevent gear damage from loose debris falling between the gears and racks.

SAE Racks DP = Diametral Pitch, 20 Deg.Press. Angle

For Hydraulic Cylinder # ZG-25-XXX
Rack # ZZ 25 01 DP = 12 U = 1.500"

For Hydraulic Cylinder # ZG-40-XXX
Rack # ZZ 40 01 DP = 12 U = 1.750"

For Hydraulic Cylinder # ZG-63-XXX
Rack # ZZ 63 01 DP = 12 U = 2.625"

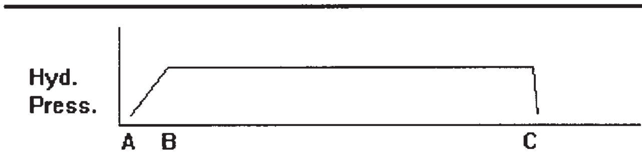


SAE CAM Risers

For Hydraulic Cylinder # ZG-25-XXX
CAM Riser # ZL 25 01 aa= 1.181" V= 1.949" cc= 2.855"

For Hydraulic Cylinder # ZG-40-XXX
CAM Riser # ZL 40 01 aa= 1.575" V= 2.539" cc= 3.641"

For Hydraulic Cylinder # ZG-63-XXX
CAM Riser # ZL 63 01 aa = 2.362" V = 3.937" cc = 5.827"



Hydraulic Pressure/Flow should be ramped from point A to B The Hydraulic Flow should be limited so that from B to C a Maximum Rack travel speed of 18" per second is NOT exceeded. Limit switches should be positioned by the mold builder at points B and C to start and stop the travel.

Appendix List

Appendix A – Typical Cavity Spacing

Procedure 1 – Theory for Stress Calculations Using Thick Walled Pressure Vessel Calculations

Table 32 - Formulas for thick walled vessels under internal pressure, pg 504
Ref: Formulas for Stress and Strain, Fifth Edition Roark & Young, McGraw Hill
Cylinderical Shell or Disk
Case 1A. Uniform internal radial pressure, q (PSI), longitudinal pressure zero or externally balanced; for a disk or shell

b = outside radius of the closure cap or cavity to injection mold
a = minimum outside radius of steel needed to support the injection molded cap
note a > b
a is an unknown value in inches to be solved for
b is the known outer closure cap radius to be injection molded
q = maximum injection molding pressure (typically 20,000 PSI rarely 30,000 PSI)
E = Youngs Modulus of Elasticity (Typically for Mold steel is 29,400,000 PSI or 29.4E6)
v = Poisson's ratio (Typically for mold steel it is 0.27)
l = length of the closure cap or cavity in inches
delta b = the change in radius under load in inches of the cap (Typically for mold design it should be less than 0.001" for the diameter)

$$\Delta b = \frac{q \cdot b}{E} \cdot \left(\frac{a^2 + b^2}{a^2 - b^2} + v \right)$$

From Roark & Young, Formulas for Stress and Strain
delta b = deflection of the cavity wall allowable

Solve the equation in terms of a =

$$\left[\begin{array}{l} \frac{1}{(-\Delta b \cdot E + q \cdot b + q \cdot b \cdot v)} \cdot b \cdot \sqrt{\Delta b^2 \cdot E^2 - 2 \cdot \Delta b \cdot E \cdot q \cdot b \cdot v - q^2 \cdot b^2 + q^2 \cdot b^2 \cdot v^2} \\ \frac{-1}{(-\Delta b \cdot E + q \cdot b + q \cdot b \cdot v)} \cdot b \cdot \sqrt{\Delta b^2 \cdot E^2 - 2 \cdot \Delta b \cdot E \cdot q \cdot b \cdot v - q^2 \cdot b^2 + q^2 \cdot b^2 \cdot v^2} \end{array} \right]$$

Select the above equation for a = that gives a non-imaginary positive number.
If the solution is imaginary, then the deflection delta b is probably too small.

EXAMPLE PROBLEM:

$E := 29000000$	Youngs Modulus for steel in PSI
$v := 0.27$	Poisson's Ratio for steel
$q := 20000$	Maximum Injection Pressure in PSI
$\Delta b := 0.001$	Maximum deflection allowed for the cap radius, typically 0.001 inches maximum deflection for mold walls, per "Injection Molds and Molding" pg 61 2nd Ed. Joeseph B. Dym, Van Nostrand Reinhold
$capdia := \frac{45}{25.4}$	45mm Cap Diameter converted from millimeters to inches by dividing by 25.4 mm/inches
$b := \frac{capdia}{2}$	Cap Radius in inches
$b = 0.886$	Cap Radius in inches

$$a := \frac{-1}{(-\Delta b \cdot E + q \cdot b + q \cdot b \cdot v)} \cdot b \cdot \sqrt{\Delta b^2 \cdot E^2 - 2 \cdot \Delta b \cdot E \cdot q \cdot b \cdot v - q^2 \cdot b^2 + q^2 \cdot b^2 \cdot v^2}$$

$a = 2.25$ Minimum Outside Radius which must be greater than $b = 0.886$

$wallthick := \frac{2 \cdot a - 2 \cdot b}{2}$ $Outdia := 2 \cdot a$

$betwcav := 2 \cdot wallthick$

$wallthick = 1.364$ $capdia = 1.772$ $Outdia = 4.5$ $betwcav = 2.728$ Dimensions in Inches

We need to confirm the hoop stress then compare this value to the materials Endurance Limit

$$max\sigma2 := q \cdot \left(\frac{a^2 + b^2}{a^2 - b^2} \right)$$

$max\sigma2 = 2.734 \cdot 10^4$ Max Hoop Stress = 27,340 PSI

Procedure 2 – Step by Step Procedure for Calculating Cavity Spacing Using **Procedure 1**

Step 1 – Calculate if Cavity Deflection design criteria is possible

q = Max. Cavity Pressure [A . 5]
b = Cap Outside diameter , [A . 1] in inches
Δb = Minimum Cavity Deflection Design Parameter, Typically set less than or equal to 0.001" for the cavity wall
E = Modulus of Elasticity for the Cavity Material, for steels it is typically 29,000,000 PSI
ν = Possions Ratio for the Cavity Material, for steels it is typically 0.27
Min Deflection O.D. = Min. Outside Diameter of Cavity Steel to meet the Min. Deflection Criteria, the formula is as follows:

$$\text{Min Deflection O.D.} = \frac{-2 * b}{(-\Delta b * E + q * b + q * b * \nu)} * \sqrt{\Delta b^2 * E^2 - 2 * \Delta b * E * q * b * \nu - q^2 * b^2 + q^2 * b^2 * \nu^2}$$

Lookup Table for Step 1 & 2: *** = means that cavity deflections ≤ 0.001" not possible, E=29,000,000; ν = 0.27; Δb = 0.001"

[A.1]	Max.Cavity Pres 20,000 PSI [A.5]			Max.Cavity Pres 15,000 PSI [A.5]			Max.Cavity Pres 10,000 PSI [A.5]			Max.Cavity Pres 5,000 PSI [A.5]		
Cap Dia.	Min. O.D.	Between	Stress PSI	Min. O.D.	Between	Stress PSI	Min. O.D.	Between	Stress PSI	Min. O.D.	Between	Stress PSI
.5	.600	.100	110,909	.572	.072	112,170	.546	.046	113,916	.522	.022	116,190
.6	.750	.150	91,111	.707	.106	92,226	.668	.068	93,503	.632	.032	96,315
.7	.912	.212	77,353	.849	.148	78,691	.794	.094	79,783	.744	.044	82,122
.8	1.088	.288	67,081	1.000	.200	68,333	.924	.124	69,876	.858	.058	71,553
.9	1.281	.380	58,991	1.160	.260	60,370	1.060	.160	61,658	.974	.074	63,410
1.0	1.492	.492	52,625	1.330	.330	54,017	1.201	.201	55,208	1.093	.093	56,375
1.1	1.727	.626	47,306	1.513	.412	48,637	1.347	.247	50,039	1.213	.113	51,295
1.2	1.988	.788	42,929	1.707	.508	44,311	1.499	.299	45,688	1.335	.135	47,078
1.3	2.282	.982	39,218	1.917	.616	40,543	1.658	.358	41,918	1.460	.160	43,270
1.4	2.617	1.218	36,037	2.142	.742	37,373	1.823	.423	38,753	1.587	.187	40,090
1.5	3.006	1.506	33,263	2.386	.886	34,605	1.996	.496	35,951	1.716	.216	37,390
1.6	3.464	1.864	30,848	2.650	1.050	32,210	2.176	.576	33,540	1.848	.248	34,938
1.7	4.019	2.318	28,716	2.940	1.240	30,069	2.364	.664	31,419	1.983	.283	32,727
1.8	4.716	2.916	26,821	3.259	1.458	28,169	2.561	.761	29,526	2.120	.320	30,829
1.9	5.637	3.738	25,127	3.612	1.712	26,477	2.768	.868	27,819	2.259	.359	29,178
2.0	6.960	4.960	23,600	4.008	2.008	24,947	2.985	.985	26,293	2.401	.401	27,665
2.1	9.160	7.060	22,219	4.455	2.356	23,570	3.213	1.113	24,915	2.546	.446	26,283
2.2	14.344	12.144	20,964	4.969	2.770	22,315	3.453	1.253	23,666	2.694	.494	25,020
2.3	***	***	***	5.570	3.270	21,167	3.707	1.407	22,518	2.845	.545	23,866
2.4	***	***	***	6.287	3.888	20,118	3.976	1.576	21,464	2.999	.599	22,811
2.5	***	***	***	7.172	4.672	19,149	4.261	1.761	20,499	3.156	.656	21,845
2.6	***	***	***	8.307	5.707	18,258	4.564	1.964	19,609	3.316	.716	20,959
2.7	***	***	***	9.861	7.161	17,431	4.888	2.188	18,782	3.480	.780	20,123
2.8	***	***	***	12.213	9.413	16,664	5.235	2.435	18,014	3.647	.847	19,357
2.9	***	***	***	16.553	13.653	15,950	5.608	2.708	17,300	3.817	.917	18,654
3.0	***	***	***	31.015	28.015	15,283	6.011	3.011	16,634	3.991	.991	17,991
3.1	***	***	***	***	***	***	6.449	3.349	16,010	4.170	1.070	17,354
3.2	***	***	***	***	***	***	6.928	3.728	15,424	4.352	1.520	16,770
3.3	***	***	***	***	***	***	7.454	4.154	14,876	4.538	1.238	16,223
3.4	***	***	***	***	***	***	8.038	4.638	14,358	4.728	1.328	15,710
3.5	***	***	***	***	***	***	8.691	5.191	13,871	4.923	1.423	15,220
3.6	***	***	***	***	***	***	9.431	5.831	13,411	5.122	1.522	14,763
3.7	***	***	***	***	***	***	10.281	6.581	12,976	5.326	1.626	14,328
3.8	***	***	***	***	***	***	11.274	7.474	12,563	5.535	1.735	13,916
3.9	***	***	***	***	***	***	12.461	8.561	12,172	5.750	1.850	13,520
4.0	***	***	***	***	***	***	13.920	9.920	11,800	5.969	1.969	13,151
4.1	***	***	***	***	***	***	15.788	11.688	11,446	6.194	2.094	12,798
4.2	***	***	***	***	***	***	18.320	14.120	11,109	6.426	2.226	12,458
4.3	***	***	***	***	***	***	22.081	17.781	10,788	6.663	2.363	12,137
4.4	***	***	***	***	***	***	28.688	24.288	10,482	6.906	2.506	11,833
4.5	***	***	***	***	***	***	46.523	42.023	10,189	7.157	2.657	11,538
4.6	***	***	***	***	***	***	***	***	***	7.414	2.814	11,259
4.7	***	***	***	***	***	***	***	***	***	7.679	2.979	10,990
4.8	***	***	***	***	***	***	***	***	***	7.951	3.151	10,734
4.9	***	***	***	***	***	***	***	***	***	8.232	3.332	10,487
5.0	***	***	***	***	***	***	***	***	***	8.522	3.522	10,249

Step 2 – Calculate the Cavity Material Stress PSI which is the Maximum Hoop Stress

$$\text{Max. Hoop Stress} = q * \frac{O.D.^2 + I.D.^2}{O.D.^2 - I.D.^2}$$

where q = Maximum Injection Molding Pressure in PSI, [A .5]
and O.D. = Min O.D. as calculated in Step 1
and I.D. = Cap Diameter in Inches, [A.1]

Step 3 – Check if Stress levels meet the Design Stress criteria for the Cavity Steel being used.
If not, increase the O.D. of the Cavity Insert until it meets the criteria.

TYPICAL DESIGN CRITERIA:

Use an endurance limit for the cavity steel which allows the number of injection molding cycles to occur before cavity steel fatigue type failure occurs.

Endurance Limit, Machine Surface = 35% - 40% of Ultimate Strength (U.S.),
Ground Surface<50% U.S., the Endurance Limit should also be less than 75% of
the Cavity Steel Yield Strength (Y.S.)

DESIGN STRESS THAT CAN BE USED:

Design Stress = Endurance Limit < 40% U.S. < 75% Y.S. of the Cavity Steel

For H-13 Rc=44 at 800F, U.S. = 171,000 PSI, Y.S. = 138,000 PSI; Design Stress < 68,400 PSI

For H-13 Rc=15 at 70F, U.S. = 97,000 PSI, Y.S. = 54,000 PSI; Design Stress < 38,800 PSI

For Hobbing Steel P-5, Case Hardened between Rc = 59 – 67 and P-5 Core Hardness of Rc =
15 – 25 at 70F, U.S. = 95,000 PSI, Y.S. = 60,000 PSI;
Design Stress < 38,000 PSI, Modulus of Elasticity 30×10^6 PSI (30E6)

CALCULATE THE MINIMUM DESIGN STRESS O.D.

$$\text{Min. Design Stress O.D.} = \sqrt{\frac{\left(\dfrac{q * I.D.^2}{\text{Design Stress}} + I.D.^2\right)}{\left(1 - \dfrac{q}{\text{Design Stress}}\right)}}$$

Where q = Max. Inject. Press. [A.5], I.D. = Cap Dia. [A.1], use Design Stress of Cavity Material

LOOK-UP TABLE for Step 3: Using P-5 Harden material with Design Stress = 38,000 PSI

[A.1]	Max.Cavity Pres 20,000 PSI [A.5]			Max.Cavity Pres 15,000 PSI [A.5]			Max.Cavity Pres 10,000 PSI [A.5]			Max.Cavity Pres 5,000 PSI [A.5]		
Cap Dia.	Min. O.D.	Between	Stress PSI	Min. O.D.	Between	Stress PSI	Min. O.D.	Between	Stress PSI	Min. O.D.	Between	Stress PSI
.5	0.898	0.398	38,000	0.759	0.259	38,000	0.655	0.155	38,000	0.571	0.071	38,000
.6	1.077	0.477	38,000	0.911	0.311	38,000	0.786	0.186	38,000	0.685	0.085	38,000
.7	1.257	0.557	38,000	1.063	0.363	38,000	0.917	0.217	38,000	0.799	0.099	38,000
.8	1.436	0.636	38,000	1.214	0.414	38,000	1.047	0.247	38,000	0.913	0.113	38,000
.9	1.616	0.716	38,000	1.366	0.466	38,000	1.178	0.278	38,000	1.027	0.127	38,000
1.0	1.795	0.795	38,000	1.518	0.518	38,000	1.309	0.309	38,000	1.142	0.142	38,000
1.1	1.975	0.875	38,000	1.670	0.570	38,000	1.440	0.340	38,000	1.256	0.156	38,000
1.2	2.154	0.954	38,000	1.822	0.622	38,000	1.571	0.371	38,000	1.370	0.170	38,000
1.3	2.334	1.034	38,000	1.973	0.673	38,000	1.702	0.402	38,000	1.484	0.184	38,000
1.4	2.513	1.113	38,000	2.125	0.725	38,000	1.833	0.433	38,000	1.598	0.198	38,000
1.5	2.693	1.193	38,000	2.277	0.777	38,000	1.964	0.464	38,000	1.712	0.212	38,000
1.6	2.872	1.272	38,000	2.429	0.826	38,000	2.095	0.495	38,000	1.826	0.226	38,000
1.7	3.052	1.352	38,000	2.581	0.881	38,000	2.226	0.526	38,000	1.941	0.241	38,000
1.8	3.231	1.431	38,000	2.732	0.932	38,000	2.357	0.557	38,000	2.055	0.255	38,000
1.9	3.411	1.511	38,000	2.884	0.984	38,000	2.488	0.588	38,000	2.169	0.269	38,000
2.0	3.590	1.590	38,000	3.036	1.036	38,000	2.619	0.619	38,000	2.283	0.283	38,000
2.1	3.770	1.670	38,000	3.188	1.088	38,000	2.750	0.650	38,000	2.397	0.297	38,000
2.2	3.949	1.749	38,000	3.340	1.140	38,000	2.880	0.680	38,000	2.511	0.311	38,000
2.3	4.129	1.829	38,000	3.491	1.191	38,000	3.011	0.711	38,000	2.625	0.325	38,000
2.4	4.308	1.908	38,000	3.643	1.243	38,000	3.142	0.742	38,000	2.740	0.340	38,000
2.5	4.488	1.988	38,000	3.795	1.295	38,000	3.273	0.773	38,000	2.854	0.354	38,000
2.6	4.667	2.067	38,000	3.947	1.347	38,000	3.404	0.804	38,000	2.968	0.368	38,000
2.7	4.847	2.147	38,000	4.099	1.399	38,000	3.535	0.835	38,000	3.082	0.382	38,000
2.8	5.026	2.226	38,000	4.250	1.450	38,000	3.666	0.866	38,000	3.196	0.396	38,000
2.9	5.206	2.306	38,000	4.402	1.502	38,000	3.797	0.897	38,000	3.310	0.410	38,000
3.0	5.385	2.385	38,000	4.554	1.554	38,000	3.928	0.928	38,000	3.425	0.425	38,000
3.1	5.565	2.465	38,000	4.706	1.606	38,000	4.059	0.959	38,000	3.539	0.439	38,000
3.2	5.744	2.544	38,000	4.858	1.658	38,000	4.190	0.990	38,000	3.653	0.453	38,000
3.3	5.924	2.624	38,000	5.009	1.709	38,000	4.321	1.021	38,000	3.767	0467	38,000
3.4	6.103	2.703	38,000	5.161	1.761	38,000	4.452	1.052	38,000	3.881	0.481	38,000
3.5	6.283	2.783	38,000	5.313	1.813	38,000	4.583	1.083	38,000	3.995	0.495	38,000
3.6	6.462	2.862	38,000	5.465	1.865	38,000	4.714	1.114	38,000	4.109	0.509	38,000
3.7	6.642	2.942	38,000	5.617	1.917	38,000	4.844	1.144	38,000	4.224	0.524	38,000
3.8	6.821	3.021	38,000	5.768	1.968	38,000	4.975	1.175	38,000	4.338	0.538	38,000
3.9	7.001	3.101	38,000	5.920	2.020	38,000	5.106	1.206	38,000	4.452	0.552	38,000
4.0	7.180	3.180	38,000	6.072	2.072	38,000	5.237	1.237	38,000	4.566	0.566	38,000
4.1	7.360	3.260	38,000	6.224	2.124	38,000	5.368	1.268	38,000	4.680	0.580	38,000
4.2	7.539	3.339	38,000	6.376	2.176	38,000	5.499	1.299	38,000	4.794	0.594	38,000
4.3	7.719	3.419	38,000	6.527	2.227	38,000	5.630	1.330	38,000	4.908	0.608	38,000
4.4	7.898	3.498	38,000	6.679	2.279	38,000	5.761	1.361	38,000	5.023	0.623	38,000
4.5	8.078	3.578	38,000	6.831	2.331	38,000	5.892	1.392	38,000	5.137	0.637	38,000
4.6	8.257	3.657	38,000	6.983	2.383	38,000	6.023	1.423	38,000	5.251	0.651	38,000
4.7	8.437	3.737	38,000	7.135	2.435	38,000	6.154	1.454	38,000	5.365	0.665	38,000
4.8	8.616	3.816	38,000	7.286	2.486	38,000	6.258	1.485	38,000	5.479	0.679	38,000
4.9	8.796	3.896	38,000	7.438	2.538	38,000	6.416	1.516	38,000	5.593	0.693	38,000
5.0	8.975	3.975	38,000	7.590	2.590	38,000	6.547	1.547	38,000	5.708	0.708	38,000

Step 4 – Select the Cavity Insert O.D. that will be used.

Select the largest O.D. value from: Min. Deflection O.D. or Min. Design Stress O.D.

NOTE: *** = means that cavity deflections ≤ 0.001" are not possible for this condition

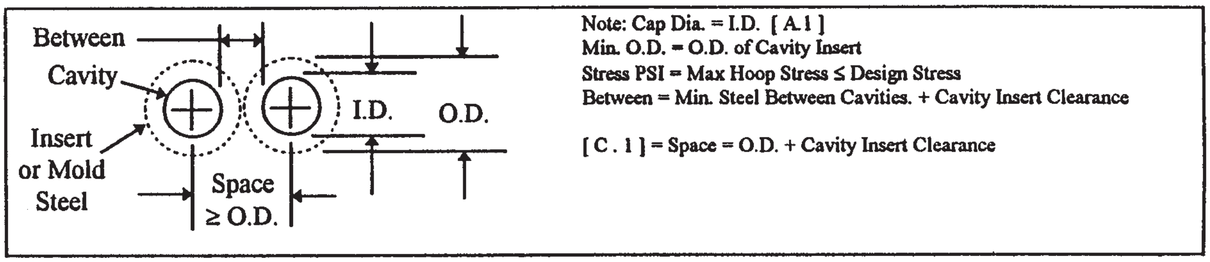
[A.1]	Max.Cavity Pres 20,000 PSI [A.5]			Max.Cavity Pres 15,000 PSI [A.5]			Max.Cavity Pres 10,000 PSI [A.5]			Max.Cavity Pres 5,000 PSI [A.5]		
Cap Dia.	Min. O.D.	Between	Stress PSI	Min. O.D.	Between	Stress PSI	Min. O.D.	Between	Stress PSI	Min. O.D.	Between	Stress PSI
.5	0.898	0.398	38,000	0.759	0.259	38,000	0.655	0.155	38,000	0.571	0.071	38,000
.6	1.077	0.477	38,000	0.911	0.311	38,000	0.786	0.186	38,000	0.685	0.085	38,000
.7	1.257	0.557	38,000	1.063	0.363	38,000	0.917	0.217	38,000	0.799	0.099	38,000
.8	1.436	0.636	38,000	1.214	0.414	38,000	1.047	0.247	38,000	0.913	0.113	38,000
.9	1.616	0.716	38,000	1.366	0.466	38,000	1.178	0.278	38,000	1.027	0.127	38,000
1.0	1.795	0.795	38,000	1.518	0.518	38,000	1.309	0.309	38,000	1.142	0.142	38,000
1.1	1.975	0.875	38,000	1.670	0.570	38,000	1.440	0.340	38,000	1.256	0.156	38,000
1.2	2.154	0.954	38,000	1.822	0.622	38,000	1.571	0.371	38,000	1.370	0.170	38,000
1.3	2.334	1.034	38,000	1.973	0.673	38,000	1.702	0.402	38,000	1.484	0.184	38,000
1.4	2.617	1.218	36,037	2.125	0.725	38,000	1.833	0.433	38,000	1.598	0.198	38,000
1.5	3.006	1.506	33,263	2.386	.886	34,605	1.996	.496	35,951	1.716	.216	37,390
1.6	3.464	1.864	30,848	2.650	1.050	32,210	2.176	.576	33,540	1.848	.248	34,938
1.7	4.019	2.318	28,716	2.940	1.240	30,069	2.364	.664	31,419	1.983	.283	32,727
1.8	4.716	2.916	26,821	3.259	1.458	28,169	2.561	.761	29,526	2.120	.320	30,829
1.9	5.637	3.738	25,127	3.612	1.712	26,477	2.768	.868	27,819	2.259	.359	29,178
2.0	6.960	4.960	23,600	4.008	2.008	24,947	2.985	.985	26,293	2.401	.401	27,665
2.1	9.160	7.060	22,219	4.455	2.356	23,570	3.213	1.113	24,915	2.546	.446	26,283
2.2	14.344	12.144	20,964	4.969	2.770	22,315	3.453	1.253	23,666	2.694	.494	25,020
2.3	***	***	***	5.570	3.270	21,167	3.707	1.407	22,518	2.845	.545	23,866
2.4	***	***	***	6.287	3.888	20,118	3.976	1.576	21,464	2.999	.599	22,811
2.5	***	***	***	7.172	4.672	19,149	4.261	1.761	20,499	3.156	.656	21,845
2.6	***	***	***	8.307	5.707	18,258	4.564	1.964	19,609	3.316	.716	20,959
2.7	***	***	***	9.861	7.161	17,431	4.888	2.188	18,782	3.480	.780	20,123
2.8	***	***	***	12.213	9.413	16,664	5.235	2.435	18,014	3.647	.847	19,357
2.9	***	***	***	16.553	13.653	15,950	5.608	2.708	17,300	3.817	.917	18,654
3.0	***	***	***	31.015	28.015	15,283	6.011	3.011	16,634	3.991	.991	17,991
3.1	***	***	***	***	***	***	6.449	3.349	16,010	4.170	1.070	17,354
3.2	***	***	***	***	***	***	6.928	3.728	15,424	4.352	1.520	16,770
3.3	***	***	***	***	***	***	7.454	4.154	14,876	4.538	1.238	16,223
3.4	***	***	***	***	***	***	8.038	4.638	14,358	4.728	1.328	15,710
3.5	***	***	***	***	***	***	8.691	5.191	13,871	4.923	1.423	15,220
3.6	***	***	***	***	***	***	9.431	5.831	13,411	5.122	1.522	14,763
3.7	***	***	***	***	***	***	10.281	6.581	12,976	5.326	1.626	14,328
3.8	***	***	***	***	***	***	11.274	7.474	12,563	5.535	1.735	13,916
3.9	***	***	***	***	***	***	12.461	8.561	12,172	5.750	1.850	13,520
4.0	***	***	***	***	***	***	13.920	9.920	11,800	5.969	1.969	13,151
4.1	***	***	***	***	***	***	15.788	11.688	11,446	6.194	2.094	12,798
4.2	***	***	***	***	***	***	18.320	14.120	11,109	6.426	2.226	12,458
4.3	***	***	***	***	***	***	22.081	17.781	10,788	6.663	2.363	12,137
4.4	***	***	***	***	***	***	28.688	24.288	10,482	6.906	2.506	11,833
4.5	***	***	***	***	***	***	46.523	42.023	10,189	7.157	2.657	11,538
4.6	***	***	***	***	***	***	***	***	***	7.414	2.814	11,259
4.7	***	***	***	***	***	***	***	***	***	7.679	2.979	10,990
4.8	***	***	***	***	***	***	***	***	***	7.951	3.151	10,734
4.9	***	***	***	***	***	***	***	***	***	8.232	3.332	10,487
5.0	***	***	***	***	***	***	***	***	***	8.522	3.522	10,249

Step 5 – If Cavity Deflection Design and Design Stress is possible, calculate the steel between two cavities

between = Cavity Insert O.D. − b
where Cavity Insert O.D. = value chosen in Step 4 in Inches
and b = Cap Outside diameter, [A.1] in inches

This does not take into consideration any material clearance between Cavity Inserts, an additional 1/8" minimum is normally added to the between value.

Step 6 – Record the Minimum Cavity Spacing Value that will be used in [C.1]



Procedure 3 – LOOK-UP TABLE using Specified Parameters and following **Procedure 2**

P-5 Cavity Insert Material; Core Hardness Rc = 15 – 25; Case Hardness Rc = 59 to 67
for High-strength low-alloy structural steels, Modulus of Elasticity E ⩾ 29,000,000 PSI;
Possions Ratio $\upsilon = 0.27$
$\Delta b \leqslant$ 0.001" maximum cavity deflection
Ultimate Strength ⩾ 95,000 PSI, Yield Strength ⩾ 60,000 PSI; Use Design Stress = 38,000 PSI

Min. O.D. = Minimum O.D. of the Cavity Insert
Between = Minimum Steel between Cavity Inserts with no clearance,
(typical Cavity Insert Clearance ~1/8")
Stress PSI = Cavity Insert Stress under Injection Pressure

NOTE: Center to Center Cavity Spacing = [C.1] ⩾ Min. O.D. + Cavity Insert Clearance (typically ~1/8")

*** = means that cavity deflections ⩽0.001" are not possible for this condition

[A.1]	Max.Cavity Pres 20,000 PSI [A.5]			Max.Cavity Pres 15,000 PSI [A.5]			Max.Cavity Pres 10,000 PSI [A.5]			Max.Cavity Pres 5,000 PSI [A.5]		
Cap Dia.	Min. O.D.	Between	Stress PSI	Min. O.D.	Between	Stress PSI	Min. O.D.	Between	Stress PSI	Min. O.D.	Between	Stress PSI
.5	0.898	0.398	38,000	0.759	0.259	38,000	0.655	0.155	38,000	0.571	0.071	38,000
.6	1.077	0.477	38,000	0.911	0.311	38,000	0.786	0.186	38,000	0.685	0.085	38,000
.7	1.257	0.557	38,000	1.063	0.363	38,000	0.917	0.217	38,000	0.799	0.099	38,000
.8	1.436	0.636	38,000	1.214	0.414	38,000	1.047	0.247	38,000	0.913	0.113	38,000
.9	1.616	0.716	38,000	1.366	0.466	38,000	1.178	0.278	38,000	1.027	0.127	38,000
1.0	1.795	0.795	38,000	1.518	0.518	38,000	1.309	0.309	38,000	1.142	0.142	38,000
1.1	1.975	0.875	38,000	1.670	0.570	38,000	1.440	0.340	38,000	1.256	0.156	38,000
1.2	2.154	0.954	38,000	1.822	0.622	38,000	1.571	0.371	38,000	1.370	0.170	38,000
1.3	2.334	1.034	38,000	1.973	0.673	38,000	1.702	0.402	38,000	1.484	0.184	38,000
1.4	2.617	1.218	36,037	2.125	0.725	38,000	1.833	0.433	38,000	1.598	0.198	38,000
1.5	3.006	1.506	33,263	2.386	.886	34,605	1.996	.496	35,951	1.716	.216	37,390
1.6	3.464	1.864	30,848	2.650	1.050	32,210	2.176	.576	33,540	1.848	.248	34,938
1.7	4.019	2.318	28,716	2.940	1.240	30,069	2.364	.664	31,419	1.983	.283	32,727
1.8	4.716	2.916	26,821	3.259	1.458	28,169	2.561	.761	29,526	2.120	.320	30,829
1.9	5.637	3.738	25,127	3.612	1.712	26,477	2.768	.868	27,819	2.259	.359	29,178
2.0	6.960	4.960	23,600	4.008	2.008	24,947	2.985	.985	26,293	2.401	.401	27,665
2.1	9.160	7.060	22,219	4.455	2.356	23,570	3.213	1.113	24,915	2.546	.446	26,283
2.2	14.344	12.144	20,964	4.969	2.770	22,315	3.453	1.253	23,666	2.694	.494	25,020
2.3	***	***	***	5.570	3.270	21,167	3.707	1.407	22,518	2.845	.545	23,866
2.4	***	***	***	6.287	3.888	20,118	3.976	1.576	21,464	2.999	.599	22,811
2.5	***	***	***	7.172	4.672	19,149	4.261	1.761	20,499	3.156	.656	21,845
2.6	***	***	***	8.307	5.707	18,258	4.564	1.964	19,609	3.316	.716	20,959
2.7	***	***	***	9.861	7.161	17,431	4.888	2.188	18,782	3.480	.780	20,123
2.8	***	***	***	12.213	9.413	16,664	5.235	2.435	18,014	3.647	.847	19,357
2.9	***	***	***	16.553	13.653	15,950	5.608	2.708	17,300	3.817	.917	18,654
3.0	***	***	***	31.015	28.015	15,283	6.011	3.011	16,634	3.991	.991	17,991
3.1	***	***	***	***	***	***	6.449	3.349	16,010	4.170	1.070	17,354
3.2	***	***	***	***	***	***	6.928	3.728	15,424	4.352	1.520	16,770
3.3	***	***	***	***	***	***	7.454	4.154	14,876	4.538	1.238	16,223
3.4	***	***	***	***	***	***	8.038	4.638	14,358	4.728	1.328	15,710
3.5	***	***	***	***	***	***	8.691	5.191	13,871	4.923	1.423	15,220
3.6	***	***	***	***	***	***	9.431	5.831	13,411	5.122	1.522	14,763
3.7	***	***	***	***	***	***	10.281	6.581	12,976	5.326	1.626	14,328
3.8	***	***	***	***	***	***	11.274	7.474	12,563	5.535	1.735	13,916
3.9	***	***	***	***	***	***	12.461	8.561	12,172	5.750	1.850	13,520
4.0	***	***	***	***	***	***	13.920	9.920	11,800	5.969	1.969	13,151
4.1	***	***	***	***	***	***	15.788	11.688	11,446	6.194	2.094	12,798
4.2	***	***	***	***	***	***	18.320	14.120	11,109	6.426	2.226	12,458
4.3	***	***	***	***	***	***	22.081	17.781	10,788	6.663	2.363	12,137
4.4	***	***	***	***	***	***	28.688	24.288	10,482	6.906	2.506	11,833
4.5	***	***	***	***	***	***	46.523	42.023	10,189	7.157	2.657	11,538
4.6	***	***	***	***	***	***	***	***	***	7.414	2.814	11,259
4.7	***	***	***	***	***	***	***	***	***	7.679	2.979	10,990
4.8	***	***	***	***	***	***	***	***	***	7.951	3.151	10,734
4.9	***	***	***	***	***	***	***	***	***	8.232	3.332	10,487
5.0	***	***	***	***	***	***	***	***	***	8.522	3.522	10,249

Appendix B – Typical Unscrewing Torque Calculation Procedure and Tables

Procedure 1 – Calculation Method

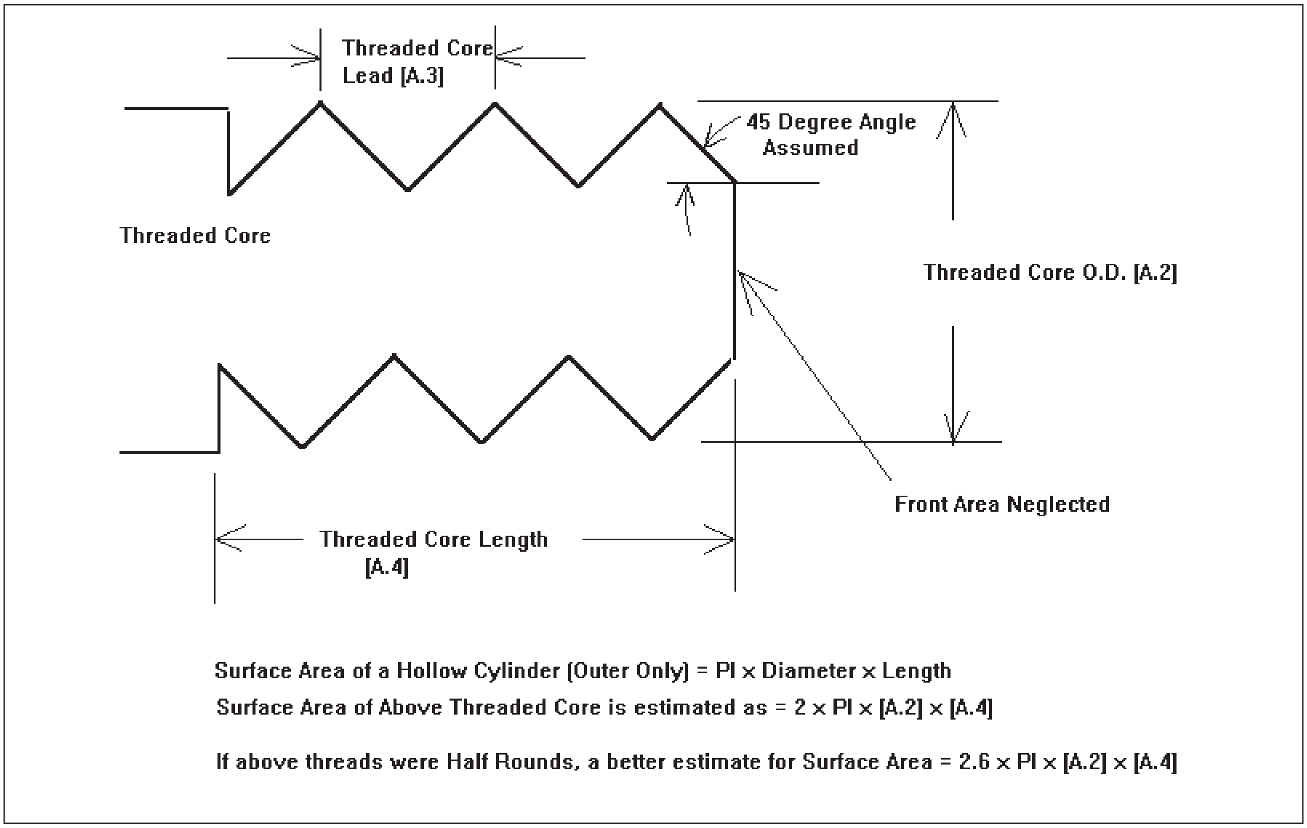
These figures should only be used as a guideline as many other factors will affect the calculation. (Material variation of dimensions, material shrinkage, core surface area, temperature, lubricant/friction, etc.)

f) Residual pressure (PSI) {1/100 of maximum injection molding cavity pressure}

$$RP = \frac{[A.5]}{100}$$

g) Effective core surface area (square inches)

- Flat end of Threaded core neglected, ×2 value for 45° Triangle Thread Shape



$$SA = [A.2] \times \pi \times [A.4] \times 2$$

$$SA = [A.2] \times [A.4] \times 6.2832$$

h) Unscrewing torque (in-lbs)

$$UT = RP \times SA \times \frac{[A.2]}{2}$$

Procedure 2 – Look-up Table Method (calculations based on Procedure 1)

Table of Unscrewing Torques – O.D. Threads Inches [A.2] versus Thread Length Inches [A.4]
Values in Table Inch-Pounds force (in-lb$_f$) which could = [D.1]
Maximum Injection Cavity Pressure is set to 20,000 PSI = [A.5]

[A.2] O.D. Thread	[A.4] Thread Length 1/16	1/8	3/16	1/4	5/16	3/8	7/16	1/2	5/8	3/4	7/8	1	1 1/4	1 1/2	1 3/4	2	2 1/4	2 1/2
1/8	.6	1.2	1.8	2.5	3.1	3.7	4.3	4.9	6.1	7.4	8.6	9.8	12.3	14.7	17.2	19.6	22.1	24.5
1/4	2.5	4.9	7.4	9.8	12.3	14.7	17.2	19.6	24.5	29.5	34.4	39.3	49.1	58.9	68.7	78.5	88.4	98.2
3/8	5.5	11.0	16.6	22.1	27.6	33.1	38.7	44.2	55.2	66.3	77.3	88.4	110.4	132.5	154.6	176.7	198.8	220.9
1/2	9.8	19.6	29.5	39.3	49.1	58.9	68.7	78.5	98.2	117.8	137.4	157.1	196.3	235.6	274.9	314.2	353.4	392.7
5/8	15.3	30.7	46.0	61.4	76.7	92.0	107.4	122.7	153.4	184.1	214.8	245.4	306.8	368.2	429.5	490.9	552.2	613.6
3/4	22.1	44.2	66.3	88.4	110.4	132.5	154.6	176.7	220.9	265.1	309.3	353.4	441.8	530.1	618.5	706.9	795.2	883.6
7/8	30.1	60.1	90.2	120.3	150.3	180.4	210.5	240.5	300.7	360.8	420.9	481.1	601.3	721.6	841.8	962.1	1,082.4	1,202.6
1	39.3	78.5	117.8	157.1	196.3	235.6	274.9	314.2	392.7	471.2	549.8	628.3	785.4	942.5	1,099.6	1,256.6	1,413.7	1,570.8
1 1/8	49.7	99.4	149.1	198.8	248.5	298.2	347.9	397.6	497.0	596.4	695.8	795.2	994.0	1,192.8	1,391.6	1,590.4	1,789.2	1,988.0
1 1/4	61.4	122.7	184.1	245.4	306.8	368.2	429.5	490.9	613.6	736.3	859.0	981.7	1,227.2	1,472.6	1,718.1	1,963.5	2,208.9	2,454.4
1 3/8	74.2	148.5	222.7	297.0	371.2	445.5	519.7	594.0	742.4	890.9	1,039.4	1,187.9	1,484.9	1,781.9	2,078.9	2,375.8	2,672.8	2,969.8
1 1/2	88.4	176.7	265.1	353.4	441.8	530.1	618.5	706.9	883.6	1,060.3	1,237.0	1,413.7	1,767.1	2,120.6	2,474.0	2,827.4	3,180.9	3,534.3
1 5/8	103.7	207.4	311.1	414.8	518.5	622.2	725.9	829.6	1,037.0	1,244.4	1,451.8	1,659.2	2,073.9	2,488.7	2,903.5	3,318.3	3,733.1	4,147.9
1 3/4	120.3	240.5	360.8	481.1	601.3	721.6	841.8	962.1	1,202.6	1,443.2	1,683.7	1,924.2	2,405.3	2,886.3	3,367.4	3,848.5	4,329.5	4,810.6
1 7/8	138.1	276.1	414.2	552.2	690.3	828.3	966.4	1,104.5	1,380.6	1,656.7	1,932.8	2,208.9	2,761.2	3,313.4	3,865.6	4,417.9	4,970.1	5,522.3
2	157.1	314.2	471.2	628.3	785.4	942.5	1,099.6	1,256.6	1,570.8	1,885.0	2,199.1	2,513.3	3,141.6	3,769.9	4,398.2	5,026.5	5,654.9	6,283.2
2 1/8	177.3	354.7	532.0	709.3	886.6	1,064.0	1,241.3	1,418.6	1,773.3	2,127.9	2,482.6	2,837.3	3,546.6	4,255.9	4,965.2	5,674.5	6,383.8	7,093.1
2 1/4	198.8	397.6	596.4	795.2	994.0	1,192.8	1,391.6	1,590.4	1,988.0	2,385.6	2,783.3	3,180.9	3,976.1	4,771.3	5,566.5	6,361.7	7,156.9	7,952.2
2 3/8	221.5	443.0	664.5	886.0	1,107.5	1,329.0	1,550.5	1,772.1	2,215.1	2,658.1	3,101.1	3,544.1	4,430.1	5,316.2	6,202.2	7,088.2	7,974.2	8,860.3
2 1/2	245.4	490.9	736.3	981.7	1,227.2	1,472.6	1,718.1	1,963.5	2,454.4	2,945.2	3,436.1	3,927.0	4,908.7	5,890.5	6,872.2	7,854.0	8,835.7	9,817.5
2 5/8	270.6	541.2	811.8	1,082.4	1,353.0	1,623.6	1,894.2	2,164.8	2,705.9	3,247.1	3,788.3	4,329.5	5,411.9	6,494.3	7,576.6	8,659.0	9,741.4	10,823.8
2 3/4	297.0	594.0	890.9	1,187.9	1,484.9	1,781.9	2,078.9	2,375.8	2,969.8	3,563.7	4,157.7	4,751.7	5,939.6	7,127.5	8,315.4	9,503.3	10,691.2	11,879.1
2 7/8	324.6	649.2	973.8	1,298.4	1,623.0	1,947.5	2,272.1	2,596.7	3,245.9	3,895.1	4,544.3	5,193.4	6,491.8	7,790.2	9,088.5	10,386.9	11,685.3	12,983.6
3	353.4	706.9	1,060.3	1,413.7	1,767.1	2,120.6	2,474.0	2,827.4	3,534.3	4,241.2	4,948.0	5,654.9	7,068.6	8,482.3	9,896.0	11,309.7	12,723.5	14,137.2
3 1/8	383.5	767.0	1,150.5	1,534.0	1,917.5	2,301.0	2,684.5	3,068.0	3,835.0	4,601.9	5,368.9	6,135.9	7,669.9	9,203.9	10,737.9	12,271.8	13,805.8	15,339.8
3 1/4	414.8	829.6	1,244.4	1,659.2	2,073.9	2,488.7	2,903.5	3,318.3	4,147.9	4,977.5	5,807.0	6,636.6	8,295.8	9,954.9	11,614.1	13,273.2	14,932.4	16,591.5
3 3/8	447.3	894.6	1,341.9	1,789.2	2,236.5	2,683.9	3,131.2	3,578.5	4,473.1	5,367.7	6,262.3	7,156.9	8,946.2	10,735.4	12,524.6	14,313.9	16,103.1	17,892.4
3 1/2	481.1	962.1	1,443.2	1,924.2	2,405.3	2,886.3	3,367.4	3,848.5	4,810.6	5,772.7	6,734.8	7,696.9	9,621.1	11,545.4	13,469.6	15,393.8	17,318.0	19,242.3
3 5/8	516.0	1,032.1	1,548.1	2,064.1	2,580.2	3,096.2	3,612.2	4,128.2	5,160.3	6,192.4	7,224.4	8,256.5	10,320.6	12,384.7	14,448.9	16,513.0	18,577.1	20,641.2
3 3/4	552.2	1,104.5	1,656.7	2,208.9	2,761.2	3,313.4	3,865.6	4,417.9	5,522.3	6,626.8	7,731.3	8,835.7	11,044.7	13,253.6	15,462.5	17,671.5	19,880.4	22,089.3
3 7/8	589.7	1,179.3	1,769.0	2,358.6	2,948.3	3,538.0	4,127.6	4,717.3	5,896.6	7,075.9	8,255.3	9,434.6	11,793.2	14,151.9	16,510.5	18,869.2	21,227.8	23,586.5
4	628.3	1,256.6	1,885.0	2,513.3	3,141.6	3,769.9	4,398.2	5,026.5	6,283.2	7,539.8	8,796.5	10,053.1	12,566.4	15,079.6	17,592.9	20,106.2	22,619.5	25,132.7
4 1/8	668.2	1,336.4	2,004.6	2,672.8	3,341.0	4,009.2	4,677.4	5,345.6	6,682.0	8,018.4	9,354.8	10,691.2	13,364.0	16,036.8	18,709.7	21,382.5	24,055.3	26,728.1
4 1/4	709.3	1,418.6	2,127.9	2,837.3	3,546.6	4,255.9	4,965.2	5,674.5	7,093.1	8,511.8	9,930.4	11,349.0	14,186.3	17,023.5	19,860.8	22,698.0	25,535.3	28,372.5
4 3/8	751.7	1,503.3	2,255.0	3,006.6	3,758.3	4,509.9	5,261.6	6,013.2	7,516.5	9,019.8	10,523.1	12,026.4	15,033.0	18,039.6	21,046.2	24,052.8	27,059.4	30,066.0
4 1/2	795.2	1,590.4	2,385.6	3,180.9	3,976.1	4,771.3	5,566.5	6,361.7	7,952.2	9,542.6	11,133.0	12,723.5	15,904.3	19,085.2	22,266.0	25,446.9	28,627.8	31,808.6
4 5/8	840.0	1,680.0	2,520.0	3,360.0	4,200.0	5,040.0	5,880.1	6,720.1	8,400.1	10,080.1	11,760.1	13,440.1	16,800.2	20,160.2	23,520.2	26,880.3	30,240.3	33,600.3
4 3/4	886.0	1,772.1	2,658.1	3,544.1	4,430.1	5,316.2	6,202.2	7,088.2	8,860.3	10,632.3	12,404.4	14,176.4	17,720.5	21,264.7	24,808.8	28,352.9	31,897.0	35,441.1
4 7/8	933.3	1,866.5	2,799.8	3,733.1	4,666.4	5,599.6	6,532.9	7,466.2	9,332.7	11,199.3	13,065.8	14,932.4	18,665.5	22,398.6	26,131.7	29,864.8	33,597.9	37,331.0
5	981.7	1,963.5	2,945.2	3,927.0	4,908.7	5,890.5	6,872.2	7,854.0	9,817.5	11,781.0	13,744.5	15,708.0	19,635.0	23,561.9	27,488.9	31,415.9	35,342.9	39,269.9

Table of Unscrewing Torques - O.D. Threads Inches [A.2] versus Thread Length Inches [A.4]
Values in Table Inch-Pounds force (in-lb$_f$) which could = [D.1]
Maximum Injection Cavity Pressure is set to 15,000 PSI = [A.5]

[A.2] O.D. Thread	[A.4] Thread Length																	
	1/16	1/8	3/16	1/4	5/16	3/8	7/16	1/2	5/8	3/4	7/8	1	1 1/4	1 1/2	1 3/4	2	2 1/4	2 1/2
1/8	.5	.9	1.4	1.8	2.3	2.8	3.2	3.7	4.6	5.5	6.4	7.4	9.2	11.0	12.9	14.7	16.6	18.4
1/4	1.8	3.7	5.5	7.4	9.2	11.0	12.9	14.7	18.4	22.1	25.8	29.5	36.8	44.2	51.5	58.9	66.3	73.6
3/8	4.1	8.3	12.4	16.6	20.7	24.9	29.0	33.1	41.4	49.7	58.0	66.3	82.8	99.4	116.0	132.5	149.1	165.7
1/2	7.4	14.7	22.1	29.5	36.8	44.2	51.5	58.9	73.6	88.4	103.1	117.8	147.3	176.7	206.2	235.6	265.1	294.5
5/8	11.5	23.0	34.5	46.0	57.5	69.0	80.5	92.0	115.0	138.1	161.1	184.1	230.1	276.1	322.1	368.2	414.2	460.2
3/4	16.6	33.1	49.7	66.3	82.8	99.4	116.0	132.5	165.7	198.8	231.9	265.1	331.3	397.6	463.9	530.1	596.4	662.7
7/8	22.5	45.1	67.6	90.2	112.7	135.3	157.8	180.4	225.5	270.6	315.7	360.8	451.0	541.2	631.4	721.6	811.8	902.0
1	29.5	58.9	88.4	117.8	147.3	176.7	206.2	235.6	294.5	353.4	412.3	471.2	589.0	706.9	824.7	942.5	1,060.3	1,178.1
1 1/8	37.3	74.6	111.8	149.1	186.4	223.7	260.9	298.2	372.8	447.3	521.9	596.4	745.5	894.6	1,043.7	1,192.8	1,341.9	1,491.0
1 1/4	46.0	92.0	138.1	184.1	230.1	276.1	322.1	368.2	460.2	552.2	644.3	736.3	920.4	1,104.5	1,288.5	1,472.6	1,656.7	1,840.8
1 3/8	55.7	111.4	167.1	222.7	278.4	334.1	389.8	445.5	556.8	668.2	779.6	890.9	1,113.7	1,336.4	1,559.1	1,781.9	2,004.6	2,227.3
1 1/2	66.3	132.5	198.8	265.1	331.3	397.6	463.9	530.1	662.7	795.2	927.8	1,060.3	1,325.4	1,590.4	1,855.5	2,120.6	2,385.6	2,650.7
1 5/8	77.8	155.5	233.3	311.1	388.9	466.6	544.4	622.2	777.7	933.3	1,088.8	1,244.4	1,555.5	1,866.5	2,177.6	2,488.7	2,799.8	3,110.9
1 3/4	90.2	180.4	270.6	360.8	451.0	541.2	631.4	721.6	902.0	1,082.4	1,262.8	1,443.2	1,804.0	2,164.8	2,525.5	2,886.3	3,247.1	3,607.9
1 7/8	103.5	207.1	310.6	414.2	517.7	621.3	724.8	828.3	1,035.4	1,242.5	1,449.6	1,656.7	2,070.9	2,485.0	2,899.2	3,313.4	3,727.6	4,141.7
2	117.8	235.6	353.4	471.2	589.0	706.9	824.7	942.5	1,178.1	1,413.7	1,649.3	1,885.0	2,356.2	2,827.4	3,298.7	3,769.9	4,241.2	4,712.4
2 1/8	133.0	266.0	399.0	532.0	665.0	798.0	931.0	1,064.0	1,330.0	1,596.0	1,861.9	2,127.9	2,659.9	3,191.9	3,723.9	4,255.9	4,787.9	5,319.8
2 1/4	149.1	298.2	447.3	596.4	745.5	894.6	1,043.7	1,192.8	1,491.0	1,789.2	2,087.4	2,385.6	2,982.1	3,578.5	4,174.9	4,771.3	5,367.7	5,964.1
2 3/8	166.1	332.3	498.4	664.5	830.7	996.8	1,162.9	1,329.0	1,661.3	1,993.6	2,325.8	2,658.1	3,322.6	3,987.1	4,651.6	5,316.2	5,980.7	6,645.2
2 1/2	184.1	368.2	552.2	736.3	920.4	1,104.5	1,288.5	1,472.6	1,840.8	2,208.9	2,577.1	2,945.2	3,681.6	4,417.9	5,154.2	5,890.5	6,626.8	7,363.1
2 5/8	202.9	405.9	608.8	811.8	1,014.7	1,217.7	1,420.6	1,623.6	2,029.5	2,435.3	2,841.2	3,247.1	4,058.9	4,870.7	5,682.5	6,494.3	7,306.0	8,117.8
2 3/4	222.7	445.5	668.2	890.9	1,113.7	1,336.4	1,559.1	1,781.9	2,227.3	2,672.8	3,118.3	3,563.7	4,454.7	5,345.6	6,236.6	7,127.5	8,018.4	8,909.4
2 7/8	243.4	486.9	730.3	973.8	1,217.2	1,460.7	1,704.1	1,947.5	2,434.4	2,921.3	3,408.2	3,895.1	4,868.9	5,842.6	6,816.4	7,790.2	8,763.9	9,737.7
3	265.1	530.1	795.2	1,060.3	1,325.4	1,590.4	1,855.5	2,120.6	2,650.7	3,180.9	3,711.0	4,241.2	5,301.4	6,361.7	7,422.0	8,482.3	9,542.6	10,602.9
3 1/8	287.6	575.2	862.9	1,150.5	1,438.1	1,725.7	2,013.3	2,301.0	2,876.2	3,451.5	4,026.7	4,601.9	5,752.4	6,902.9	8,053.4	9,203.9	10,354.4	11,504.9
3 1/4	311.1	622.2	933.3	1,244.4	1,555.5	1,866.5	2,177.6	2,488.7	3,110.9	3,733.1	4,355.3	4,977.5	6,221.8	7,466.2	8,710.6	9,954.9	11,199.3	12,443.7
3 3/8	335.5	671.0	1,006.4	1,341.9	1,677.4	2,012.9	2,348.4	2,683.9	3,354.8	4,025.8	4,696.7	5,367.7	6,709.6	8,051.6	9,393.5	10,735.4	12,077.3	13,419.3
3 1/2	360.8	721.6	1,082.4	1,443.2	1,804.0	2,164.8	2,525.5	2,886.3	3,607.9	4,329.5	5,051.1	5,772.7	7,215.8	8,659.0	10,102.2	11,545.4	12,988.5	14,431.7
3 5/8	387.0	774.0	1,161.1	1,548.1	1,935.1	2,322.1	2,709.2	3,096.2	3,870.2	4,644.3	5,418.3	6,192.4	7,740.5	9,288.6	10,836.7	12,384.7	13,932.8	15,480.9
3 3/4	414.2	828.3	1,242.5	1,656.7	2,070.9	2,485.0	2,899.2	3,313.4	4,141.7	4,970.1	5,798.4	6,626.8	8,283.5	9,940.2	11,596.9	13,253.6	14,910.3	16,567.0
3 7/8	442.2	884.5	1,326.7	1,769.0	2,211.2	2,653.5	3,095.7	3,538.0	4,422.5	5,307.0	6,191.5	7,075.9	8,844.9	10,613.9	12,382.9	14,151.9	15,920.9	17,689.9
4	471.2	942.5	1,413.7	1,885.0	2,356.2	2,827.4	3,298.7	3,769.9	4,712.4	5,654.9	6,597.3	7,539.8	9,424.8	11,309.7	13,194.7	15,079.6	16,964.6	18,849.6
4 1/8	501.2	1,002.3	1,503.5	2,004.6	2,505.8	3,006.9	3,508.1	4,009.2	5,011.5	6,013.8	7,016.1	8,018.4	10,023.0	12,027.6	14,032.2	16,036.8	18,041.5	20,046.1
4 1/4	532.0	1,064.0	1,596.0	2,127.9	2,659.9	3,191.9	3,723.9	4,255.9	5,319.8	6,383.8	7,447.8	8,511.8	10,639.7	12,767.6	14,895.6	17,023.5	19,151.4	21,279.4
4 3/8	563.7	1,127.5	1,691.2	2,255.0	2,818.7	3,382.4	3,946.2	4,509.9	5,637.4	6,764.9	7,892.3	9,019.8	11,274.8	13,529.7	15,784.7	18,039.6	20,294.6	22,549.5
4 1/2	596.4	1,192.8	1,789.2	2,385.6	2,982.1	3,578.5	4,174.9	4,771.3	5,964.1	7,156.9	8,349.8	9,542.6	11,928.2	14,313.9	16,699.5	19,085.2	21,470.8	23,856.5
4 5/8	630.0	1,260.0	1,890.0	2,520.0	3,150.0	3,780.0	4,410.0	5,040.0	6,300.1	7,560.1	8,820.1	10,080.1	12,600.1	15,120.1	17,640.2	20,160.2	22,680.2	25,200.2
4 3/4	664.5	1,329.0	1,993.6	2,658.1	3,322.6	3,987.1	4,651.6	5,316.2	6,645.2	7,974.2	9,303.3	10,632.3	13,290.4	15,948.5	18,606.6	21,264.7	23,922.7	26,580.8
4 7/8	700.0	1,399.9	2,099.9	2,799.8	3,499.8	4,199.7	4,899.7	5,599.6	6,999.6	8,399.5	9,799.4	11,199.3	13,999.1	16,798.9	19,598.8	22,398.6	25,198.4	27,998.2
5	736.3	1,472.6	2,208.9	2,945.2	3,681.6	4,417.9	5,154.2	5,890.5	7,363.1	8,835.7	10,308.4	11,781.0	14,726.2	17,671.5	20,616.7	23,561.9	26,507.2	29,452.4

Table of Unscrewing Torques - O.D. Threads Inches [A.2] versus Thread Length Inches [A.4]
Values in Table Inch-Pounds force (in-lb$_f$) which could = [D.1]
Maximum Injection Cavity Pressure is set to 10,000 PSI = [A.5]

[A.2] O.D.	[A.4] Thread Length																	
Thread	1/16	1/8	3/16	1/4	5/16	3/8	7/16	1/2	5/8	3/4	7/8	1	1 1/4	1 1/2	1 3/4	2	2 1/4	2 1/2
1/8	.3	.6	.9	1.2	1.5	1.8	2.1	2.5	3.1	3.7	4.3	4.9	6.1	7.4	8.6	9.8	11.0	12.3
1/4	1.2	2.5	3.7	4.9	6.1	7.4	8.6	9.8	12.3	14.7	17.2	19.6	24.5	29.5	34.4	39.3	44.2	49.1
3/8	2.8	5.5	8.3	11.0	13.8	16.6	19.3	22.1	27.6	33.1	38.7	44.2	55.2	66.3	77.3	88.4	99.4	110.4
1/2	4.9	9.8	14.7	19.6	24.5	29.5	34.4	39.3	49.1	58.9	68.7	78.5	98.2	117.8	137.4	157.1	176.7	196.3
5/8	7.7	15.3	23.0	30.7	38.3	46.0	53.7	61.4	76.7	92.0	107.4	122.7	153.4	184.1	214.8	245.4	276.1	306.8
3/4	11.0	22.1	33.1	44.2	55.2	66.3	77.3	88.4	110.4	132.5	154.6	176.7	220.9	265.1	309.3	353.4	397.6	441.8
7/8	15.0	30.1	45.1	60.1	75.2	90.2	105.2	120.3	150.3	180.4	210.5	240.5	300.7	360.8	420.9	481.1	541.2	601.3
1	19.6	39.3	58.9	78.5	98.2	117.8	137.4	157.1	196.3	235.6	274.9	314.2	392.7	471.2	549.8	628.3	706.9	785.4
1 1/8	24.9	49.7	74.6	99.4	124.3	149.1	174.0	198.8	248.5	298.2	347.9	397.6	497.0	596.4	695.8	795.2	894.6	994.0
1 1/4	30.7	61.4	92.0	122.7	153.4	184.1	214.8	245.4	306.8	368.2	429.5	490.9	613.6	736.3	859.0	981.7	1,104.5	1,227.2
1 3/8	37.1	74.2	111.4	148.5	185.6	222.7	259.9	297.0	371.2	445.5	519.7	594.0	742.4	890.9	1,039.4	1,187.9	1,336.4	1,484.9
1 1/2	44.2	88.4	132.5	176.7	220.9	265.1	309.3	353.4	441.8	530.1	618.5	706.9	883.6	1,060.3	1,237.0	1,413.7	1,590.4	1,767.1
1 5/8	51.8	103.7	155.5	207.4	259.2	311.1	362.9	414.8	518.5	622.2	725.9	829.6	1,037.0	1,244.4	1,451.8	1,659.2	1,866.5	2,073.9
1 3/4	60.1	120.3	180.4	240.5	300.7	360.8	420.9	481.1	601.3	721.6	841.8	962.1	1,202.6	1,443.2	1,683.7	1,924.2	2,164.8	2,405.3
1 7/8	69.0	138.1	207.1	276.1	345.1	414.2	483.2	552.2	690.3	828.3	966.4	1,104.5	1,380.6	1,656.7	1,932.8	2,208.9	2,485.0	2,761.2
2	78.5	157.1	235.6	314.2	392.7	471.2	549.8	628.3	785.4	942.5	1,099.6	1,256.6	1,570.8	1,885.0	2,199.1	2,513.3	2,827.4	3,141.6
2 1/8	88.7	177.3	266.0	354.7	443.3	532.0	620.6	709.3	886.6	1,064.0	1,241.3	1,418.6	1,773.3	2,127.9	2,482.6	2,837.3	3,191.9	3,546.6
2 1/4	99.4	198.8	298.2	397.6	497.0	596.4	695.8	795.2	994.0	1,192.8	1,391.6	1,590.4	1,988.0	2,385.6	2,783.3	3,180.9	3,578.5	3,976.1
2 3/8	110.8	221.5	332.3	443.0	553.8	664.5	775.3	886.0	1,107.5	1,329.0	1,550.5	1,772.1	2,215.1	2,658.1	3,101.1	3,544.1	3,987.1	4,430.1
2 1/2	122.7	245.4	368.2	490.9	613.6	736.3	859.0	981.7	1,227.2	1,472.6	1,718.1	1,963.5	2,454.4	2,945.2	3,436.1	3,927.0	4,417.9	4,908.7
2 5/8	135.3	270.6	405.9	541.2	676.5	811.8	947.1	1,082.4	1,353.0	1,623.6	1,894.2	2,164.8	2,705.9	3,247.1	3,788.3	4,329.5	4,870.7	5,411.9
2 3/4	148.5	297.0	445.5	594.0	742.4	890.9	1,039.4	1,187.9	1,484.9	1,781.9	2,078.9	2,375.8	2,969.8	3,563.7	4,157.7	4,751.7	5,345.6	5,939.6
2 7/8	162.3	324.6	486.9	649.2	811.5	973.8	1,136.1	1,298.4	1,623.0	1,947.5	2,272.1	2,596.7	3,245.9	3,895.1	4,544.3	5,193.4	5,842.6	6,491.8
3	176.7	353.4	530.1	706.9	883.6	1,060.3	1,237.0	1,413.7	1,767.1	2,120.6	2,474.0	2,827.4	3,534.3	4,241.2	4,948.0	5,654.9	6,361.7	7,068.6
3 1/8	191.7	383.5	575.2	767.0	958.7	1,150.5	1,342.2	1,534.0	1,917.5	2,301.0	2,684.5	3,068.0	3,835.0	4,601.9	5,368.9	6,135.9	6,902.9	7,669.9
3 1/4	207.4	414.8	622.2	829.6	1,037.0	1,244.4	1,451.8	1,659.2	2,073.9	2,488.7	2,903.5	3,318.3	4,147.9	4,977.5	5,807.0	6,636.6	7,466.2	8,295.8
3 3/8	223.7	447.3	671.0	894.6	1,118.3	1,341.9	1,565.6	1,789.2	2,236.5	2,683.9	3,131.2	3,578.5	4,473.1	5,367.7	6,262.3	7,156.9	8,051.6	8,946.2
3 1/2	240.5	481.1	721.6	962.1	1,202.6	1,443.2	1,683.7	1,924.2	2,405.3	2,886.3	3,367.4	3,848.5	4,810.6	5,772.7	6,734.8	7,696.9	8,659.0	9,621.1
3 5/8	258.0	516.0	774.0	1,032.1	1,290.1	1,548.1	1,806.1	2,064.1	2,580.2	3,096.2	3,612.2	4,128.2	5,160.3	6,192.4	7,224.4	8,256.5	9,288.6	10,320.6
3 3/4	276.1	552.2	828.3	1,104.5	1,380.6	1,656.7	1,932.8	2,208.9	2,761.2	3,313.4	3,865.6	4,417.9	5,522.3	6,626.8	7,731.3	8,835.7	9,940.2	11,044.7
3 7/8	294.8	589.7	884.5	1,179.3	1,474.2	1,769.0	2,063.8	2,358.6	2,948.3	3,538.0	4,127.6	4,717.3	5,896.6	7,075.9	8,255.3	9,434.6	10,613.9	11,793.2
4	314.2	628.3	942.5	1,256.6	1,570.8	1,885.0	2,199.1	2,513.3	3,141.6	3,769.9	4,398.2	5,026.5	6,283.2	7,539.8	8,796.5	10,053.1	11,309.7	12,566.4
4 1/8	334.1	668.2	1,002.3	1,336.4	1,670.5	2,004.6	2,338.7	2,672.8	3,341.0	4,009.2	4,677.4	5,345.6	6,682.0	8,018.4	9,354.8	10,691.2	12,027.6	13,364.0
4 1/4	354.7	709.3	1,064.0	1,418.6	1,773.3	2,127.9	2,482.6	2,837.3	3,546.6	4,255.9	4,965.2	5,674.5	7,093.1	8,511.8	9,930.4	11,349.0	12,767.6	14,186.3
4 3/8	375.8	751.7	1,127.5	1,503.3	1,879.1	2,255.0	2,630.8	3,006.6	3,758.3	4,509.9	5,261.6	6,013.2	7,516.5	9,019.8	10,523.1	12,026.4	13,529.7	15,033.0
4 1/2	397.6	795.2	1,192.8	1,590.4	1,988.0	2,385.6	2,783.3	3,180.9	3,976.1	4,771.3	5,566.5	6,361.7	7,952.2	9,542.6	11,133.0	12,723.5	14,313.9	15,904.3
4 5/8	420.0	840.0	1,260.0	1,680.0	2,100.0	2,520.0	2,940.0	3,360.0	4,200.0	5,040.0	5,880.1	6,720.1	8,400.1	10,080.1	11,760.1	13,440.1	15,120.1	16,800.2
4 3/4	443.0	886.0	1,329.0	1,772.1	2,215.1	2,658.1	3,101.1	3,544.1	4,430.1	5,316.2	6,202.2	7,088.2	8,860.3	10,632.3	12,404.4	14,176.4	15,948.5	17,720.5
4 7/8	466.6	933.3	1,399.9	1,866.5	2,333.2	2,799.8	3,266.5	3,733.1	4,666.4	5,599.6	6,532.9	7,466.2	9,332.7	11,199.3	13,065.8	14,932.4	16,798.9	18,665.5
5	490.9	981.7	1,472.6	1,963.5	2,454.4	2,945.2	3,436.1	3,927.0	4,908.7	5,890.5	6,872.2	7,854.0	9,817.5	11,781.0	13,744.5	15,708.0	17,671.5	19,635.0

Table of Unscrewing Torques - O.D. Threads Inches [A.2] versus Thread Length Inches [A.4]
Values in Table Inch-Pounds force (in-lb$_f$) which could = [D.1]
Maximum Injection Cavity Pressure is set to 5,000 PSI = [A.5]

[A.2] O.D.	[A.4] Thread Length																	
Thread	1/16	1/8	3/16	1/4	5/16	3/8	7/16	1/2	5/8	3/4	7/8	1	1 1/4	1 1/2	1 3/4	2	2 1/4	2 1/2
1/8	.2	.3	.5	.6	.8	.9	1.1	1.2	1.5	1.8	2.1	2.5	3.1	3.7	4.3	4.9	5.5	6.1
1/4	.6	1.2	1.8	2.5	3.1	3.7	4.3	4.9	6.1	7.4	8.6	9.8	12.3	14.7	17.2	19.6	22.1	24.5
3/8	1.4	2.8	4.1	5.5	6.9	8.3	9.7	11.0	13.8	16.6	19.3	22.1	27.6	33.1	38.7	44.2	49.7	55.2
1/2	2.5	4.9	7.4	9.8	12.3	14.7	17.2	19.6	24.5	29.5	34.4	39.3	49.1	58.9	68.7	78.5	88.4	98.2
5/8	3.8	7.7	11.5	15.3	19.2	23.0	26.8	30.7	38.3	46.0	53.7	61.4	76.7	92.0	107.4	122.7	138.1	153.4
3/4	5.5	11.0	16.6	22.1	27.6	33.1	38.7	44.2	55.2	66.3	77.3	88.4	110.4	132.5	154.6	176.7	198.8	220.9
7/8	7.5	15.0	22.5	30.1	37.6	45.1	52.6	60.1	75.2	90.2	105.2	120.3	150.3	180.4	210.5	240.5	270.6	300.7
1	9.8	19.6	29.5	39.3	49.1	58.9	68.7	78.5	98.2	117.8	137.4	157.1	196.3	235.6	274.9	314.2	353.4	392.7
1 1/8	12.4	24.9	37.3	49.7	62.1	74.6	87.0	99.4	124.3	149.1	174.0	198.8	248.5	298.2	347.9	397.6	447.3	497.0
1 1/4	15.3	30.7	46.0	61.4	76.7	92.0	107.4	122.7	153.4	184.1	214.8	245.4	306.8	368.2	429.5	490.9	552.2	613.6
1 3/8	18.6	37.1	55.7	74.2	92.8	111.4	129.9	148.5	185.6	222.7	259.9	297.0	371.2	445.5	519.7	594.0	668.2	742.4
1 1/2	22.1	44.2	66.3	88.4	110.4	132.5	154.6	176.7	220.9	265.1	309.3	353.4	441.8	530.1	618.5	706.9	795.2	883.6
1 5/8	25.9	51.8	77.8	103.7	129.6	155.5	181.5	207.4	259.2	311.1	362.9	414.8	518.5	622.2	725.9	829.6	933.3	1,037.0
1 3/4	30.1	60.1	90.2	120.3	150.3	180.4	210.5	240.5	300.7	360.8	420.9	481.1	601.3	721.6	841.8	962.1	1,082.4	1,202.6
1 7/8	34.5	69.0	103.5	138.1	172.6	207.1	241.6	276.1	345.1	414.2	483.2	552.2	690.3	828.3	966.4	1,104.5	1,242.5	1,380.6
2	39.3	78.5	117.8	157.1	196.3	235.6	274.9	314.2	392.7	471.2	549.8	628.3	785.4	942.5	1,099.6	1,256.6	1,413.7	1,570.8
2 1/8	44.3	88.7	133.0	177.3	221.7	266.0	310.3	354.7	443.3	532.0	620.6	709.3	886.6	1,064.0	1,241.3	1,418.6	1,596.0	1,773.3
2 1/4	49.7	99.4	149.1	198.8	248.5	298.2	347.9	397.6	497.0	596.4	695.8	795.2	994.0	1,192.8	1,391.6	1,590.4	1,789.2	1,988.0
2 3/8	55.4	110.8	166.1	221.5	276.9	332.3	387.6	443.0	553.8	664.5	775.3	886.0	1,107.5	1,329.0	1,550.5	1,772.1	1,993.6	2,215.1
2 1/2	61.4	122.7	184.1	245.4	306.8	368.2	429.5	490.9	613.6	736.3	859.0	981.7	1,227.2	1,472.6	1,718.1	1,963.5	2,208.9	2,454.4
2 5/8	67.6	135.3	202.9	270.6	338.2	405.9	473.5	541.2	676.5	811.8	947.1	1,082.4	1,353.0	1,623.6	1,894.2	2,164.8	2,435.3	2,705.9
2 3/4	74.2	148.5	222.7	297.0	371.2	445.5	519.7	594.0	742.4	890.9	1,039.4	1,187.9	1,484.9	1,781.9	2,078.9	2,375.8	2,672.8	2,969.8
2 7/8	81.1	162.3	243.4	324.6	405.7	486.9	568.0	649.2	811.5	973.8	1,136.1	1,298.4	1,623.0	1,947.5	2,272.1	2,596.7	2,921.3	3,245.9
3	88.4	176.7	265.1	353.4	441.8	530.1	618.5	706.9	883.6	1,060.3	1,237.0	1,413.7	1,767.1	2,120.6	2,474.0	2,827.4	3,180.9	3,534.3
3 1/8	95.9	191.7	287.6	383.5	479.4	575.2	671.1	767.0	958.7	1,150.5	1,342.2	1,534.0	1,917.5	2,301.0	2,684.5	3,068.0	3,451.5	3,835.0
3 1/4	103.7	207.4	311.1	414.8	518.5	622.2	725.9	829.6	1,037.0	1,244.4	1,451.8	1,659.2	2,073.9	2,488.7	2,903.5	3,318.3	3,733.1	4,147.9
3 3/8	111.8	223.7	335.5	447.3	559.1	671.0	782.8	894.6	1,118.3	1,341.9	1,565.6	1,789.2	2,236.5	2,683.9	3,131.2	3,578.5	4,025.8	4,473.1
3 1/2	120.3	240.5	360.8	481.1	601.3	721.6	841.8	962.1	1,202.6	1,443.2	1,683.7	1,924.2	2,405.3	2,886.3	3,367.4	3,848.5	4,329.5	4,810.6
3 5/8	129.0	258.0	387.0	516.0	645.0	774.0	903.1	1,032.1	1,290.1	1,548.1	1,806.1	2,064.1	2,580.2	3,096.2	3,612.2	4,128.2	4,644.3	5,160.3
3 3/4	138.1	276.1	414.2	552.2	690.3	828.3	966.4	1,104.5	1,380.6	1,656.7	1,932.8	2,208.9	2,761.2	3,313.4	3,865.6	4,417.9	4,970.1	5,522.3
3 7/8	147.4	294.8	442.2	589.7	737.1	884.5	1,031.9	1,179.3	1,474.2	1,769.0	2,063.8	2,358.6	2,948.3	3,538.0	4,127.6	4,717.3	5,307.0	5,896.6
4	157.1	314.2	471.2	628.3	785.4	942.5	1,099.6	1,256.6	1,570.8	1,885.0	2,199.1	2,513.3	3,141.6	3,769.9	4,398.2	5,026.5	5,654.9	6,283.2
4 1/8	167.1	334.1	501.2	668.2	835.3	1,002.3	1,169.4	1,336.4	1,670.5	2,004.6	2,338.7	2,672.8	3,341.0	4,009.2	4,677.4	5,345.6	6,013.8	6,682.0
4 1/4	177.3	354.7	532.0	709.3	886.6	1,064.0	1,241.3	1,418.6	1,773.3	2,127.9	2,482.6	2,837.3	3,546.6	4,255.9	4,965.2	5,674.5	6,383.8	7,093.1
4 3/8	187.9	375.8	563.7	751.7	939.6	1,127.5	1,315.4	1,503.3	1,879.1	2,255.0	2,630.8	3,006.6	3,758.3	4,509.9	5,261.6	6,013.2	6,764.9	7,516.5
4 1/2	198.8	397.6	596.4	795.2	994.0	1,192.8	1,391.6	1,590.4	1,988.0	2,385.6	2,783.3	3,180.9	3,976.1	4,771.3	5,566.5	6,361.7	7,156.9	7,952.2
4 5/8	210.0	420.0	630.0	840.0	1,050.0	1,260.0	1,470.0	1,680.0	2,100.0	2,520.0	2,940.0	3,360.0	4,200.0	5,040.0	5,880.1	6,720.1	7,560.1	8,400.1
4 3/4	221.5	443.0	664.5	886.0	1,107.5	1,329.0	1,550.5	1,772.1	2,215.1	2,658.1	3,101.1	3,544.1	4,430.1	5,316.2	6,202.2	7,088.2	7,974.2	8,860.3
4 7/8	233.3	466.6	700.0	933.3	1,166.6	1,399.9	1,633.2	1,866.5	2,333.2	2,799.8	3,266.5	3,733.1	4,666.4	5,599.6	6,532.9	7,466.2	8,399.5	9,332.7
5	245.4	490.9	736.3	981.7	1,227.2	1,472.6	1,718.1	1,963.5	2,454.4	2,945.2	3,436.1	3,927.0	4,908.7	5,890.5	6,872.2	7,854.0	8,835.7	9,817.5

Appendix C – Shaft Considerations

Procedure 1 – **Calculation Method:** ASME Code equation for a solid shaft having little or no axial loading

$$d^3 = \frac{16}{\pi \times Ss} \times \sqrt{(Kb \times Mb)^2 + (Kt \times Mt)^2}$$

$$d \geqslant \sqrt[3]{\frac{16}{\pi \times Ss} \times \sqrt{(Kb \times Mb)^2 + (Kt \times Mt)^2}}$$

d = the minimum shaft diameter in Inches

Ss(allowable) = Shear Stress allowable in the shaft

For commercial steel shafting Ss = 6,000 PSI with a keyway, Ss= 8,000 PSI without keyway

For shaft material purchased under definite specifications

Ss = 30% of the elastic limit but not over 18% of the Ultimate Strength in tension for shafts without keyways

Ss = 22.5% of the elastic limit but not over 13.5% of the ultimate strength in tension for shafts with keyways

For stationary shafts with Loads suddenly applied

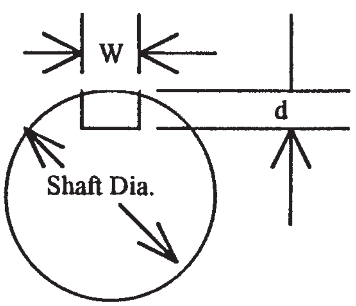
Kb = Combined shock and fatigue factor applied to bending moment
Kb = 1.5 to 2.0
Kt = Combined shock and fatigue factor applied to torsional moment
Kt = 1.5 to 2.0

Mb = Bending Moment Applied to the Shaft in Inch-Pounds

Mt = Torsional Moment of the shaft in Inch-Pounds

TYPICAL STANDARD KEYWAYS - For Reference only - See Gear Specifications that you will use

Dia. of Shaft	Standard Keyway Width W	Standard Keyway Depth d	Recommended Setscrew if used
5/16 to 7/16"	3/32"	3/64"	10-32
1/2 to 9/16"	1/8"	1/16"	1/4-20
5/8 to 7/8"	3/16"	3/32"	5/16-18
15/16 to 1-1/4"	1/4"	1/8"	3/8-16
1-5/16 to 1-3/8"	5/16"	5/32"	7/16-14
1-7/16 to 1-3/4"	3/8"	3/16"	1/2-13
1-13/16 to 2-1/4"	1/2"	1/4"	9/16-12
2-5/16 to 2-3/4"	5/8"	5/16"	5/8-11
2-13/16 to 3-1/4"	3/4"	3/8"	3/4-10
3-5/16 to 3-3/4"	7/8"	7/16"	7/8-9
3-13/16 to 4-1/2"	1"	1/2"	1-8



Procedure 2 – Look-up Table Method:

Table of Minimum Shaft Diameters using **Procedure 1**

Assume that the Bending Moment is negligible, therefore $Mb \cong 0$
Use Kt = 2.0 and Kb = 2.0 for heavy shock
Set the Torsional Moment Mt = [D.1] which is the unscrewing torque for one cavity

$$d \geqslant \sqrt[3]{\frac{32 \times [D.1]}{\pi \times Ss}}$$

NOTE: For Commercial Steel Shaft, Ss = 6,000 PSI keyway
Ss = 8,000 PSI without keyway

Also: π = 3.141592654

S - 7, Rc = 39 to 40
Yield Strength = 150,000 PSI
Tensile Strength = 180,000 PSI
Ss < Y.S. x .225 = 33,750 PSI
Ss < T.S. x .135 = 24,300 PSI *

H - 13, Rc = 44
Yield Strength at 800F = 138,000 PSI
Ultimate Strength at 800F = 171,000 PSI
Ss < Y.S. x .225 = 31,050 PSI
Ss < U.S. x .135 = 23,085 PSI *

H-13, annealed
Yield Strength at room temp = 54,000 PSI
Ultimate Strength room temp = 97,000 PSI
Ss < Y.S. x .225 = 12,150 PSI *
Ss < U.S. x .135 = 13,095 PSI

Typical Mold applications use an S-7 Hardened Core Material

Mt [D.1] Torsional Moment Torque Inch-Pounds	Commercial Steel Shaft Rm.Temp. With Keyway Minimum Dia. d Inches	S-7 Shaft Rc 39-58 Rm.Temp. with Keyway Minimum Dia. d Inches	H-13 Shaft Rc 44 at 800F with Keyway Minimum Dia. d Inches	H-13 Shaft Annealed Rm.Temp. with Keyway Minimum Dia. d Inches
10	.257	.161	.164	.203
20	.324	.203	.207	.256
30	.371	.233	.237	.293
40	.408	.256	.260	.322
50	.439	.276	.280	.347
60	.467	.293	.298	.369
70	.492	.308	.314	.389
80	.514	.322	.328	.406
90	.535	.335	.341	.423
100	.554	.347	.353	.438
200	.698	.438	.445	.551
300	.799	.501	.510	.631
400	.879	.551	.561	.659
500	.947	.594	.604	.748
600	1.006	.631	.642	.795
700	1.059	.665	.676	.837
800	1.107	.695	.707	.875
900	1.152	.723	.735	.910
1,000	1.193	.748	.761	.943
2,000	1.503	.943	.959	1.188
3,000	1.721	1.079	1.098	1.360
4,000	1.894	1.188	1.208	1.497
5,000	2.040	1.280	1.302	1.612
6,000	2.168	1.360	1.383	1.713
7,000	2.282	1.432	1.456	1.804
8,000	2.386	1.497	1.523	1.886
9,000	2.481	1.557	1.584	1.961
10,000	2.570	1.612	1.640	2.031
20,000	3.238	2.031	2.066	2.559
30,000	3.707	2.325	2.366	2.930
40,000	4.080	2.559	2.604	3.225
50,000	4.395	2.757	2.805	3.474

Appendix D – Table of Standard Gears

NOTE: European Modulus m_o units are (mm/tooth), m_o = (Pitch Diameter mm)/(# teeth)
U.S.A. Diametral Pitch units are (teeth/inches),
Diametral Pitch = (# teeth/Pitch Diameter inches)
m_o = 25.4/(U.S.A. Diametral Pitch)

Step 1 – Select the Service Factor of the gears

Service Factor = 1.6 for Heavy Shock for 17-24 Hours of operation +0.4 for grease lubrication of gears. Therefore, use a service factor of 2.0 total for typical unscrewing mold applications.

- *NOTE:* Service Factors for gears can be found in manufacturers' design sections, for use with their gears. Typically, you have a Service Factor for the type of Load and Operation Time for gears which ranges from 1.0 for no shock and 8-10 hours of operation per day to 1.6 for heavy shock and continuous 17-24 Hours per day. You also add a service factor for lubrication, typically, 0.0 for gears in an oil bath, 0.4 for grease, and 0.7 for intermittent lubrication. Service factors, gear material and speed of the gear operation are used to determine the maximum amount of torque for proper gear operation.

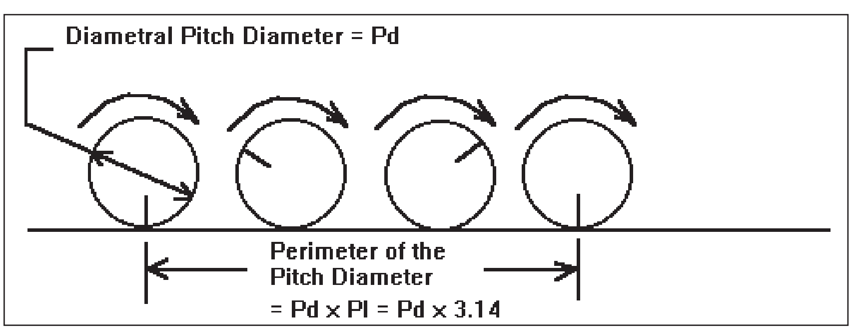
Step 2 – Determine the maximum Linear Speed of travel for the rack

The longest stroke is 19.68" long. Do not exceed this length in less than 1 second= 19.68"/second
Assumption: Maximum travel speed will be limited to 18"/second

Standard Gears - 20 Degree Pressure Angle - 12 Diametral Pitch

		> [E.3]		> [B.1]				> [D.1]		
Pitch Diameter = Pd Inches	# of Teeth	Internal Bore Dia. Inches	Pitch Circle Perimeter Inches= Pd x π	Revolutions for Stroke Length of 11.81"	Revolutions for Stroke Length of 15.74"	Revolutions for Stroke Length of 19.68"	Gear RPM based on 18"/second	Max. Torque in-lbf allowed with SF=2.0 and RPM listed * .20 C Std. Steel	.40 C Alloy H.T. Steel	Outside Dia. Inches
1.000" dia.	12	0.500	3.142"	3.75	5.00	6.26	344	81.0	162.0	1.16
1.083" dia.	13	0.625	3.403"	3.470	4.625	5.783	317	91.5	183.0	1.25
1.167" dia.	14	0.625	3.667"	3.220	4.292	5.366	295	116.5	233.0	1.33
1.250" dia.	15	0.625	3.927"	3.00	4.00	5.01	275	129.5	259.0	1.41
1.333" dia.	16	0.625	4.188"	2.819	3.758	4.699	258	139.2	278.4	1.50
1.500" dia.	***18***	***0.750***	***4.712"***	***2.500***	***3.34***	***4.17***	***229***	***161.0***	***322.0***	***1.66***
1.667" dia.	20	0.750	5.237"	2.255	3.005	3.757	206	194.5	389.0	1.83
1.750" dia.	21	0.750	5.498"	2.14	2.86	3.57	196	206.5	413.0	1.91
2.000" dia.	24	0.750	6.283"	1.87	2.50	3.13	172	238.5	477.0	2.16
2.333" dia.	28	0.750	7.330"	1.611	2.147	2.684	147	284.0	568.0	2.50
2.500" dia.	30	0.750	7.069"	1.50	2.00	2.50	138	306.0	612.0	2.66
3.000" dia.	36	0.750	9.425"	1.25	1.67	2.08	115	423.5	847.0	3.16
3.500" dia.	42	0.750	10.996"	1.07	1.43	1.78	98	500.5	1101.0	3.66

* **See actual gear manufacturer's specifications.**



NOTE: The Bold Italicized value in chart above indicates the common gear size used.

Appendix E – Example and Calculation Space for Maximum # of Cavities

= Integer {Support Length (hydraulic cylinder table) ÷ Cavity/Gear/Design Spacing [G.1] } +1

Piston Dia. inches (mm)	Shaft Dia. inches (mm)	Stroke inches (mm)	Support Length inches (mm)	Cat. Ref.#
.984" (25)	.630" (16)	11.81" (300)	13.85" (352)	ZG-25-300
.984" (25)	.630" (16)	15.74" (400)	17.79" (452)	ZG-25-400
.984" (25)	.630" (16)	19.68" (500)	21.73" (552)	ZG-25-500
1.574" (40)	.866" (22)	11.81" (300)	13.85" (352)	ZG-40-300
1.574" (40)	.866" (22)	15.74" (400)	17.79" (452)	ZG-40-400
1.574" (40)	.866" (22)	19.68" (500)	21.73" (552)	ZG-40-500
2.480" (63)	1.417" (36)	15.74" (400)	18.46" (469)	ZG-63-400
2.480" (63)	1.417" (36)	19.68" (500)	22.40" (569)	ZG-63-500

example: Let's say [G.1] = 3.1" and use support length of 21.73" for the hydraulic cylinder

NOTE: First compare the Following: [H.2] ≤ cylinder stroke. This condition allows enough stroke to completely unscrew the threaded core from the cylinder. If this condition is false, enter 0 into Col 5, then the next larger cylinder size calculation should be made.

Step 1: support length ÷ [G.1] (*NOTE:* Col 3)
21.73 ÷ 3.1 = 7.009677419

Step 2: Take the Integer of this value (*NOTE:* Col 4)
The integer of this = 7 (*NOTE:* do not round up, just remove the decimal value, even if the number was 0.745 then the integer value becomes 0)

Step 3: Add 1 to this value
Add 1 to this value = 7+1 = 8 (*NOTE:* Col 5)

Step 4: Record this number (complete calculations for all cylinder sizes)
8 is the maximum number of cavities that can be fit on one side of this cylinder

Calculation Area (*NOTE:* Col 5 is the Max. # of Cavities to be recorded on lines [H.3.1] thru [H.3.8])

[H.2] ≤ Stroke		Col 1	Col 2	Col 3	Col 4	Col 5	Cylinder
Copy [H.2]	Stroke	Support Length	Copy [G.1] value	= Col 1 ÷ Col 2	= Integer of Col 3	= Col 4 + 1	Catalog #
	11.81"	13.85"					ZG-25-300
	15.74"	17.79"					ZG-25-400
	19.68"	21.73"					ZG-25-500
	11.81"	13.85"					ZG-40-300
	15.74"	17.79"					ZG-40-400
	19.68"	21.73"					ZG-40-500
	15.74"	18.46"					ZG-63-400
	19.68"	22.40"					ZG-63-500

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