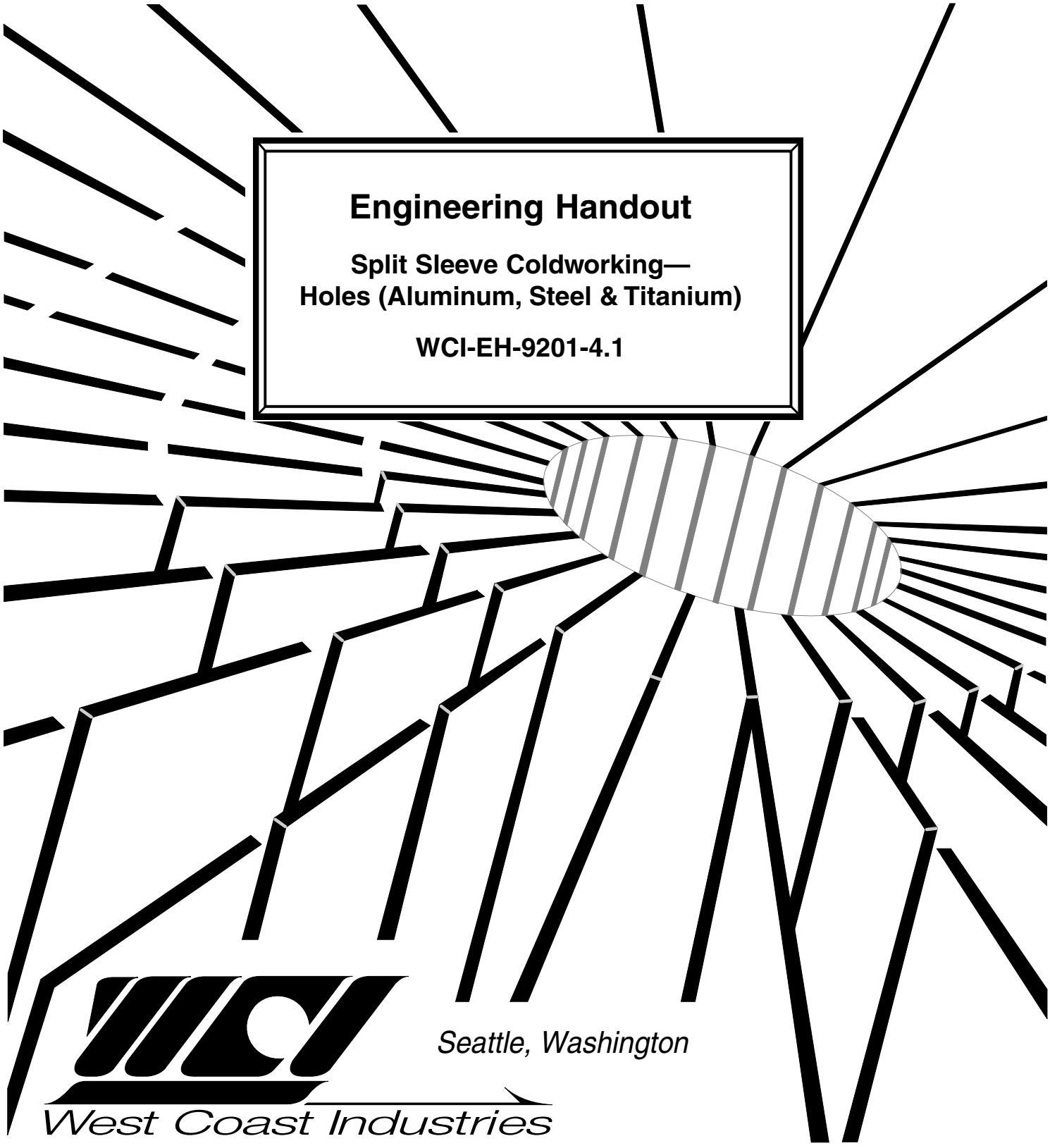
Engineering Handout

Split Sleeve Coldworking—
Holes (Aluminum, Steel & Titanium)

WCI-EH-9201-4.1



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1 Scope

1.1 This engineering handout is a reference document describing the split sleeve coldworking process. This document describes the implementation procedures in detail and is recommended for use in conjunction with our customers' specified Engineering drawings or other Engineering authority.

1.2 Split sleeve coldworking is performed on holes in highly stressed areas to increase the fatigue life of structural members. Coldworking expands the hole diameter, thereby creating a radial plastic flow of material which produces high residual compressive stresses around the hole. The residual compressive zone, depending upon variables such as material and applied expansion levels, will usually extend out from approximately one radius to one diameter from the hole.

1.2.1 The expansion process is accomplished by inserting a tapered mandrel into a hole lined with a longitudinally split, disposable, stainless steel sleeve. The sleeve has a coating of dry film lubricant on the internal surface to lower the applied load (pull-force) required to draw the mandrel through the hole. As the mandrel is pulled back through the sleeve, the hole is expanded.

1.3 This engineering handout will support and in some cases enhance customer supplied documents.

1.4 Aluminum (80 ksi Max.) - Differing applied expansion levels (see paragraph 2.4 for a definition of Applied Expansion) are required for the various aluminum alloy coldworking processes supported by this document.

1.5 Titanium and Steel Alloys (250 ksi Max.) - These metal alloys require applied expansion levels between 4.5 and 6.7 percent (5.5 percent nominal) using the mandrels and sleeve thicknesses defined in Section 5 for CA Tooling. See paragraph 2.4, for the definition of Applied Expansion.

1.6 Dissimilar Materials - Aluminum alloys in multi-material stackups with titanium and steel alloys should be expanded to the range specified for the fatigue critical material.

1.7 Special Applications - Some applications require the use of tooling not found in this specification. Tooling to support these special applications fall into the following categories:

1.7.1 Any application where a material different from those specified in paragraphs 1.4 and 1.5 is used.

1.7.2 Any application requiring the use of an applied expansion level different from that specified in the appropriate tooling tables referred to in paragraph 1.4, e.g., lug configurations which require a lower applied expansion level due to short edge-margin. See paragraph 2.3, for the definition of edge-margin.

1.7.3 Any application requiring special tooling or procedures not described in this document, e.g., special access restriction requirements. See paragraph 2.12, for the definition of access restriction.

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2 Definitions

2.1 Material Stackup - The combined thickness of a structure through which a hole is located, or the total length of a bore. Material stackup is important when determining the correct tooling required for a task, ie. mandrel length, puller unit stroke length, sleeve length, and nosecap length. A stackup of material shall have complete faying surface contact during start hole preparation, coldworking, and final hole sizing operations. For minimum stackup requirements, see paragraph 3.7, Backup Block.

2.2 Puller Stroke - The total movement required to pull a mandrel, including the tapered portion and major diameter, through a given material stackup. Ref. Table 2-01.

2.3 Edge Margin - Edge margin (e/D) is the ratio of the shortest distance between the center of the hole and the edge of the part. Reworking of fastener holes tends to reduce the edge margin. Fatigue testing has shown edge margins of 1.75 or greater are preferred. Use of an interference fit fastener is recommended for edge margins between 1.25 and 1.75. Ref. Fig. 2-01.

$$\text{edge margin} = \frac{e}{D}$$

e = distance from edge of part to center of hole

D = final hole diameter

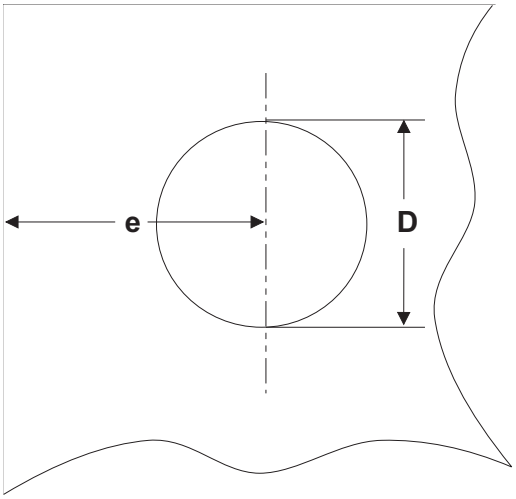


Figure 2-01 — Edge Margin Spacing

2.4 Applied Expansion - CW_{AE}, is the total amount of expansion a hole experiences during coldworking, expressed as a percentage of the start hole diameter. The required expansion level is a function of hole diameter and may decrease for hole diameters up to 3¾". See paragraphs 1.4 and 1.5 for standard applied expansion values.

$$CW_{AE} = \frac{A-B}{B} \times 100$$

CW=Coldworking
AE=Applied Expansion B=Start Hole Diameter
A=Mandrel Major Diameter + (2 x Sleeve Thickness)

2.5 Retained Expansion - CW_{RE}, is the ratio of total increase in hole size after coldworking, expressed as a percentage of the start hole diameter. This value is variable and proportional to the yield strength of the material being coldworked. Generally, greater life improvement is observed with higher retained expansion values.

$$CW_{RE} = \frac{A-B}{B} \times 100$$

CW=Coldworking
A=Measured Hole Diameter after coldworking
RE=Retained Expansion B=Start Hole Diameter

2.6 Major Mandrel Diameter - The largest mandrel diameter which, in conjunction with the sleeve thickness, provides the proper amount of applied expansion to coldwork a hole. This dimension is critical to the process. Ref. Fig. 2-02.

2.7 Minor Mandrel Diameter - The mandrel dimension which, when combined with the split sleeve thickness, allows insertion into the start hole. Ref. Fig. 2-02.

2.8 Taper - Taper is the section of mandrel on either side of the major diameter which enhances the coldwork process. The taper on the frontside of the major diameter aides the installation of the split sleeve and insertion into the hole to be coldworked. The taper on the backside of the major diameter controls the pull-force required to coldwork the hole. Ref. Fig. 2-02.

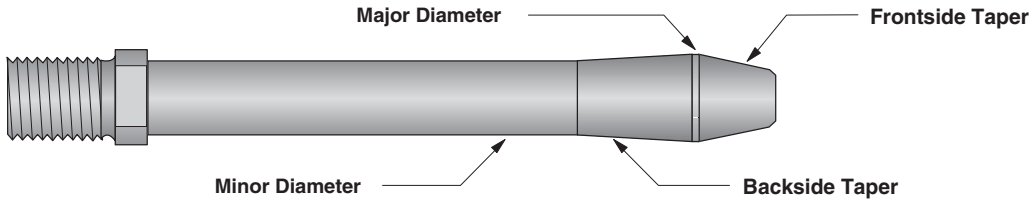


Figure 2-02 — Mandrel

2.9 Pull Force - The amount of force required to pull a mandrel through a particular material is dependant upon the hole diameter, material stackup and material properties. Ref. Table 2-02.

2.10 Start Hole Diameter - The measured size of the hole prior to coldworking. Important for ensuring the proper coldworking of the hole. Hole must be measured dimensionally throughout the hole bore and checked for concentricity or roundness. Holes not meeting the dimensional specifications stated in the particular table, will not provide the desired fatigue enhancement. Start holes must also be within 2° of normal to the surface, and have a surface roughness of 125 rms or smoother.

2.11 Existing Hole Diameter - The measured hole diameter determines which coldworking toolset is utilized for a hole. Proper examination of the hole is important in order to ensure the maximum benefit from coldworking. Important factors to look for are fatigue indicators such as cracks, out of roundness, and a tapered bore. Holes slightly oval in shape or with a tapered bore, may be coldworked if dimensions are within start hole tolerances.

2.12 Access Restriction - A term used to refer to areas which contain obstructions that prevent the coldworking of holes utilizing standard tooling. These obstructions may be backside to the hole, frontside to the hole, or laterally to the hole. For these types of restrictions, utilize either an Hydraulic Offset or Puller Gun/Offset Adapter. Ref. Fig. 2-03.

2.12.1 Restricted Backside Clearance - Obstructions on the backside of the hole which prevent the full insertion of the mandrel and sleeve into the hole prior to coldworking.

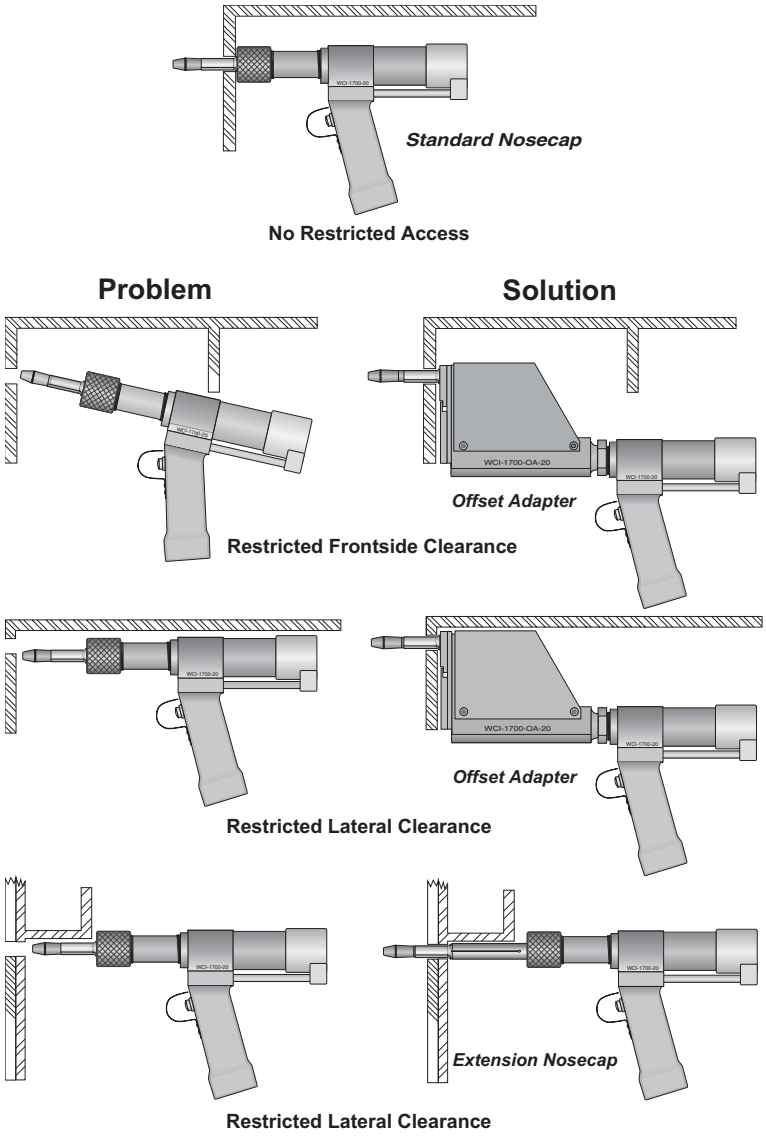


Figure 2-03 — Restricted Access Problems and Solutions

2.12.2 Restricted Frontside Clearance - Obstructions on the frontside of the hole prevent the insertion of standard coldwork tooling into the hole.

2.12.3 Restricted Lateral Clearance - Obstructions located laterally to the hole which prevent the utilization of standard coldwork tooling.

2.13 Fatigue - A phenomenon in which materials crack and fracture, when subjected to cyclic stresses well below their maximum static strength.

2.14 ***CrackArrestor*** - A toolset designed to be utilized in conjunction with stop drill structural repairs. Stop drilling is an operation performed to prevent further growth of fatigue cracks. Incorporating coldworking with stop drill repairs, enhances the repair by adding the benefits of coldworking to the repair. See Section 9.

2.15 Satellite Holes - A satellite hole is the smaller of two holes which has less than 0.40 inch distance between the edges of the holes. The smaller holes should be filled with a steel pin prior to coldworking the larger hole. The steel pin shall have a diameter less than the start hole diameter, but not greater than 0.002" under the start hole size. The purpose of these pins is to prevent the collapse of these holes during the coldworking of the larger hole. Ref Fig. 2-04.

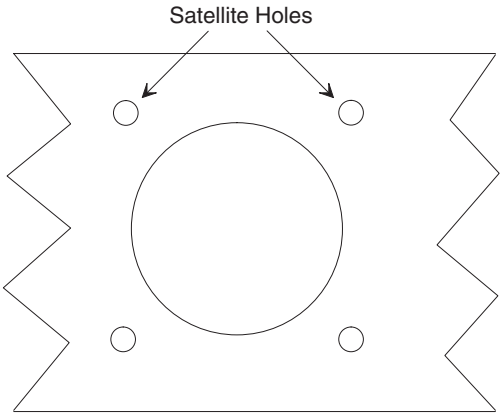


Figure 2-04 — Satellite Holes

2.16 Axial Ridge - An axial ridge on the bore of the hole is formed by plastic flow of material into the logitudinal split of the sleeve during coldworking. As an indicator of coldworking, it is normally removed by post-size reaming. However, the ridge is an acceptable condition, and may be left intact if post sizing of the hole is not required for fastener installation. If necessary, the axial ridge height may be reduced by coldworking the hole a second time using the same mandrel and new sleeve. The sleeve split shall be rotated 90° from the axial ridge location. Additionally, holes subject to low cycle fatigue may require that the sleeve split be positioned away from the area of highest stress levels. Ref. Fig. 4-07.

2.17 Hole Spacing Requirement - Hole spacing may be determined by measuring the distance between the centerlines of adjacent holes. Hole spacing less than 3 diameters, should be examined, considering material movement, prior to coldworking. See paragraph 2.15, for the definition of Satellite Holes. Ref. Fig. 2-05.

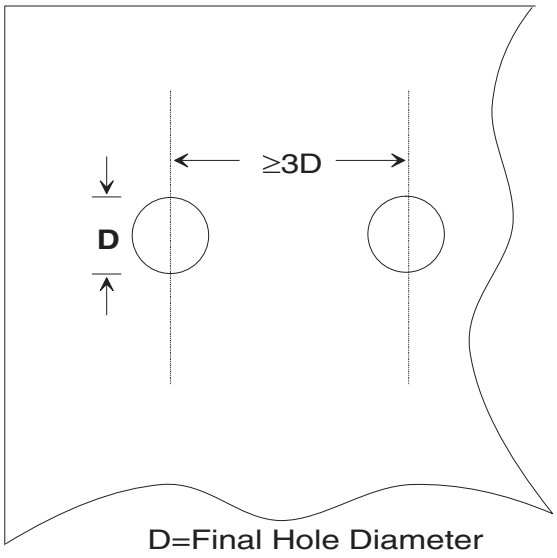


Figure 2-05 — Hole Spacing Requirements

2.18 Countersunk Holes - It is recommended that start holes not be countersunk or spot faced prior to coldworking. If a countersunk hole is to be coldworked, the hole should be processed using the next larger toolset if possible. The hole can then be processed to engineering requirements after coldworking. Contact West Coast Engineering if hole cannot be processed per this specification.

TABLE 2-01 Puller Dimensions

Puller Model No	Stackup (inches)	A (inches)	B (inches)
WCI-1700 For Mandrel Sizes 4-0-N thru 16-3-N Pull Force - 9,200 lbs. with 10,000 psi hydraulic pressure	1.0	9.7	3.0
	1.5	10.7	3.5
	2.0	11.7	4.0
	2.5	12.7	4.5
	3.0	13.7	5.0
	3.5	14.7	5.5
WCI-1800 For Mandrel Sizes 14-0-N thru 30-3-N Pull Force - 27,600 lbs. with 10,000 psi hydraulic pressure	1.0	12.6	5.2
	1.5	13.6	5.7
	2.0	14.6	6.2
	2.5	15.6	6.7
	3.0	16.6	7.2
	7.0	24.6	11.2
WCI-1900 For Mandrel Sizes 32-0-N thru 56-3-N Pull Force - 38,000 lbs. with 10,000 psi hydraulic pressure	1.0	13.6	5.8
	1.5	14.6	6.3
	2.0	15.6	6.8
	2.5	16.6	7.3
	3.0	17.6	7.8
	7.0	25.6	11.8

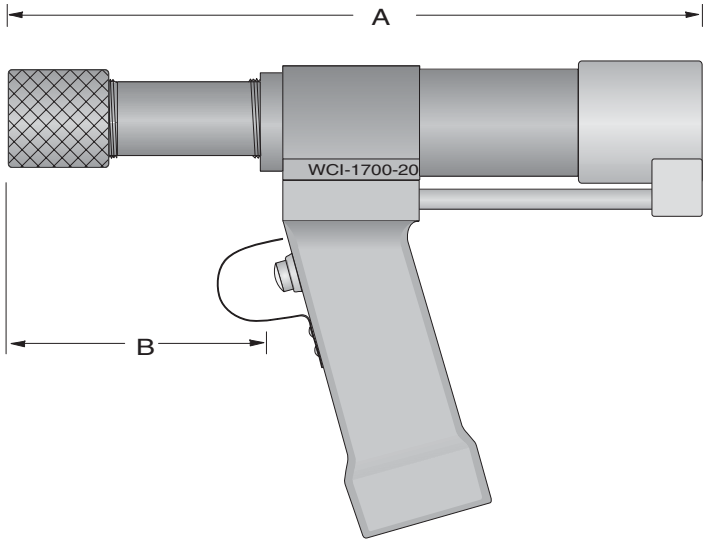


TABLE 2-02 Approximate Pull Force Requirements

Nominal Hole Diameter (inches)	Approximate Puller Unit Pull Force Requirements In Aluminum Alloys
1/8 to 3/16	1,500
13/64 to 1/4	2,500
17/64 to 5/16	3,000
21/64 to 3/8	4,000
25/64 to 3/4	10,000
49/64 to 1	14,000

3 Tooling Description

3.1 Hydraulic Powerpak - An air actuated powerpak supplies up to 10,000 psi of hydraulic pressure to the puller gun during the coldwork process.

3.2 Puller Unit - West Coast Industries provides hydraulically actuated units in several sizes which pull the mandrel through the hole. The different sizes provide for different pull force requirements and stackup lengths to fit specific requirements. Ref. Table 2-01 & 2-02. A complete line of Hydraulic Offset Pullers are manufactured to facilitate the coldworking of special access restriction areas. The WCI-HP is a mechanical puller unit which utilizes a standard shop wrench to provide the pull force required to coldwork holes as a part of the standard stop drill repair, or special access restricted areas.

3.3 Offset Adapter - The offset adapter is a unit which attaches to the front of the puller, allowing the coldworking of holes which have an access restriction.

3.4 Nosecap - An assembly composed of a body, a jaw set, and a retainer. The nosecap retains the split sleeve in the hole as the mandrel is drawn through the sleeve. Extension nosecaps, whether standard or offset adapter, may be utilized in either restricted or unrestricted access areas. Ref. Fig. 3-01.

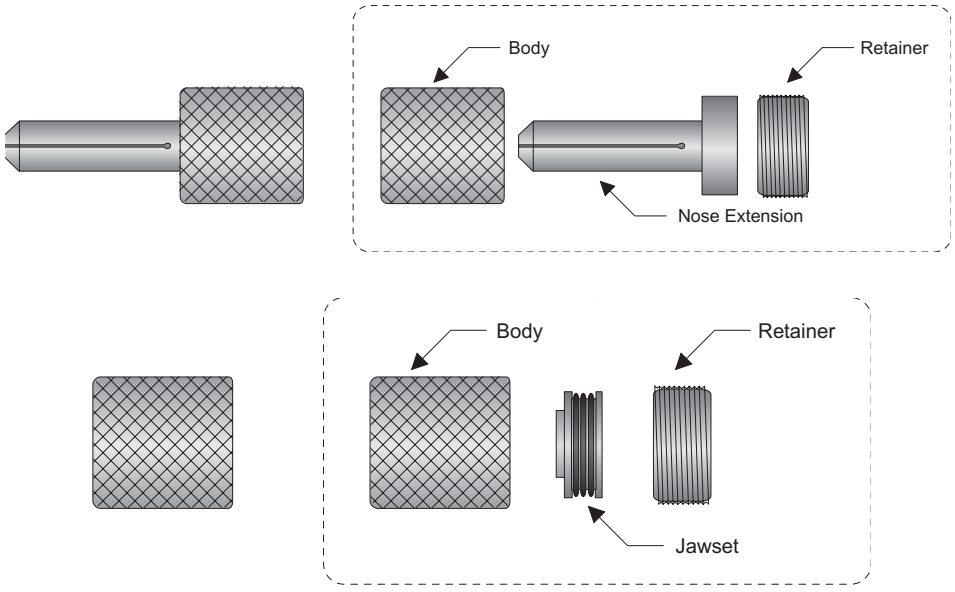


Figure 3-01—Extension and Flush Nosecaps

3.5 Mandrel - A mandrel is a tool manufactured from high strength steel with a tapered end. V1 mandrels are utilized in aluminum and mild steel applications, while V2 are used on titanium or high stength steel

applications. Most mandrels are one piece, but some larger mandrels above 1" in diameter are two pieces. ***These are ground as a set and may not be mixed.***

3.6 Split Sleeve - A rolled piece of stainless steel, with a longitudinal split. The internally prelubricated sleeve is used in conjunction with the mandrel to expand the hole. In all cases, total sleeve length must exceed the material stackup by $^{1}/_{32}$ inch minimum. When using multi-sleeve stackups, junctures between separate sleeves shall be a minimum of $^{1}/_{16}$ inch from any faying surface. Additionally, there shall be no sleeve juncture less than one start hole diameter from the back surface of the hole. Ref. Fig. 3-02.

3.6.1 Flared Sleeves - Flared sleeves are to be used with standard nosecaps, extension nosecaps, and offset adapter nosecaps.

3.6.2 Straight Sleeves - Straight sleeves are to be used in conjunction with flared sleeves in applications which require multiple sleeve stackups. The sleeve gaps should be arranged in such a manner that the splits are aligned, in order to facilitate sleeve removal after coldworking.

3.6.3 Do not reuse split sleeves, as they become distorted and lose lubrication during the coldwork process.

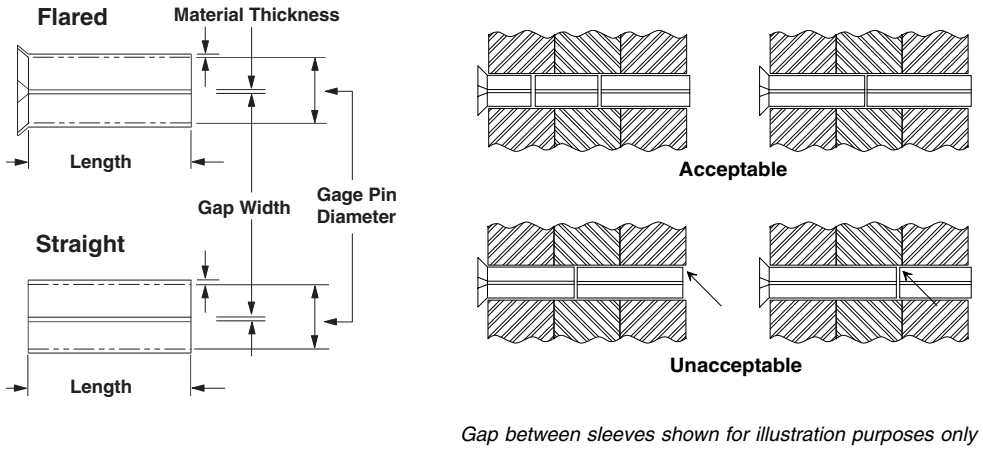


Figure 3-02 — Sleeve Geometry (Left) and Proper Sleeve Orientation (Right)

3.7 Backup Blocks - Aluminum backup blocks are used to increase the stackup thickness, preventing material buckle in thin materials. These blocks are commonly required for the coldworking of thin material stackups and shall be used when material stackup is less than one hole diameter in thickness. They are not required to be of the same alloy or temper as the part. Backup blocks shall have a hole meeting the same dimensional and finish requirements as the workpiece start hole, and are discarded after use (blocks may be reused if reamed to the next start hole size). Ref. Fig. 3-03.

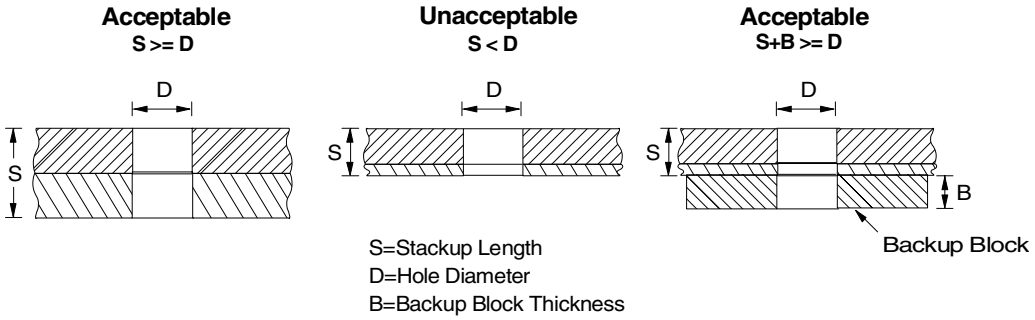


Figure 3-03 — Acceptable Stackup Thicknesses

3.8 Mandrel Wear Gage - The mandrel wear gage is used to check the mandrel major diameter for excessive wear prior to the coldworking operation. Failure to check the mandrel could result in holes not being coldworked to the correct expansion level. Ref. Fig. 3-04.

3.9 Gages - The aerospace industry utilizes four types of gages to verify hole sizes during the coldworking process. Ref. Fig. 3-05.

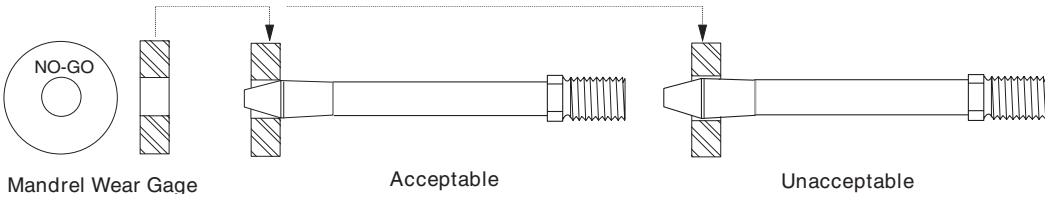


Figure 3-04 — Checking a Mandrel with the Mandrel Wear Gage

3.9.1 Start Hole Gage — The start hole gage is used to verify that the start hole is within tolerance.

3.9.2 Verification Gage — The verification gage is used to verify that the hole has been coldworked.

3.9.3 Combination Gage — The combination gage combines the above two gages into one unit. One end of the gage checks the pre-coldworked start hole while the other end verifies that the hole has been coldworked. Ref. Fig. 3-05

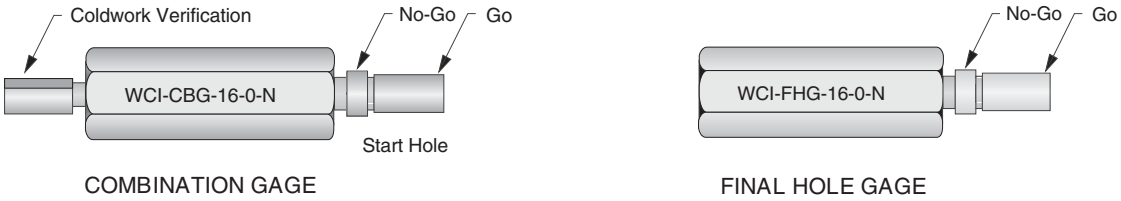


Figure 3-05 — Combination and Final Hole Gages

3.9.4 Final Hole Gage — The final hole gage is used to verify that the final hole diameter is within the specified tolerance. Ref. Figure 3-05

3.10 Start Drill — A conventional twist drill is used to produce a pilot hole compatible with the non-cutting pilot of the start reamer.

3.11 Start Reamer — The start reamer is used to properly size the pilot hole prior to the coldworking operation. Ref. Fig. 3-06.

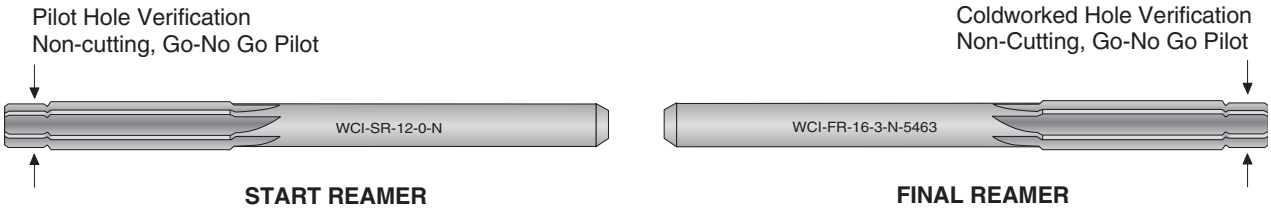


Figure 3-06 — Start and Final Reamers

3.12 Final Reamer — The final reamer is used to properly size the post coldworked hole. The non-cutting pilot of a final reamer is the same diameter as the verification gage. If the hole has not been properly coldworked, the reamer pilot will not enter the post coldworked hole. Ref. Fig. 3-06.

4 Split Sleeve Coldworking of Fastener Holes- Procedures

4.1 Split sleeve coldworking shall be performed after **all** material processing operations have been accomplished, ie. all forms of heat treating, localized hit forming operations (dimpling), and coining operations.

4.2 Determine the finished hole diameter as indicated by Engineering documents.

4.3 Using the final required hole size, determine the tool code from the applicable tooling table.

4.4 Using the tool code chosen above, select the proper toolset.

4.5 Select the appropriate restricted access tooling (if applicable) to complete the task (extension nosecap, offset adapter, hydraulic offset, and/or mandrel).

4.6 Assemble Tooling

4.6.1 Procedures for assembling standard system. Ref. Fig. 4-01.

WARNING

Insure puller is disconnected from powerpak and/or shop air prior to assembling/disassembling tooling

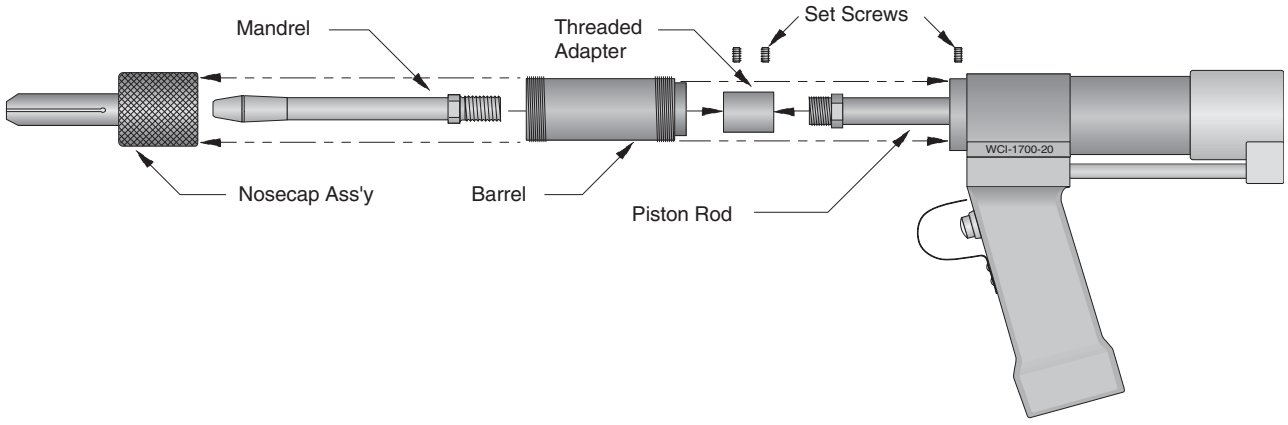


Figure 4-01 — Exploded View of Standard Puller Gun

4.6.1.1 Select the proper puller unit for the task.

4.6.1.2 Thread the mandrel completely into the threaded adapter of the puller unit. Note, when coldworking numerous holes, the set screw on the mandrel side of the threaded adapter must be tightened.

4.6.1.3 Slide the nosecap onto the mandrel, then thread the nosecap onto the barrel of the puller unit. Connect the puller hose fittings to the power unit and supply air line.

4.6.2 Procedures for assembling offset adapter coldworking system.

WARNING

Insure puller is disconnected from powerpak and/or shop air prior to assembling/disassembling tooling

4.6.2.1 Select the proper puller unit and offset adapter for the task.

4.6.2.2 Remove the threaded barrel from the puller unit. Remove the threaded adapter from the piston rod of the puller unit. Ref. Fig. 4-01.

4.6.2.3 Remove offset adapter cover for ease of installation.

4.6.2.4 Thread the offset adapter moveable arm onto the puller unit piston rod. Ref. Fig. 4-02.

4.6.2.5 After ensuring that the moveable arm is properly installed onto the piston rod, thread the offset adapter housing into the puller unit and lock in place with the jam nut. Ref. Fig. 4-02.

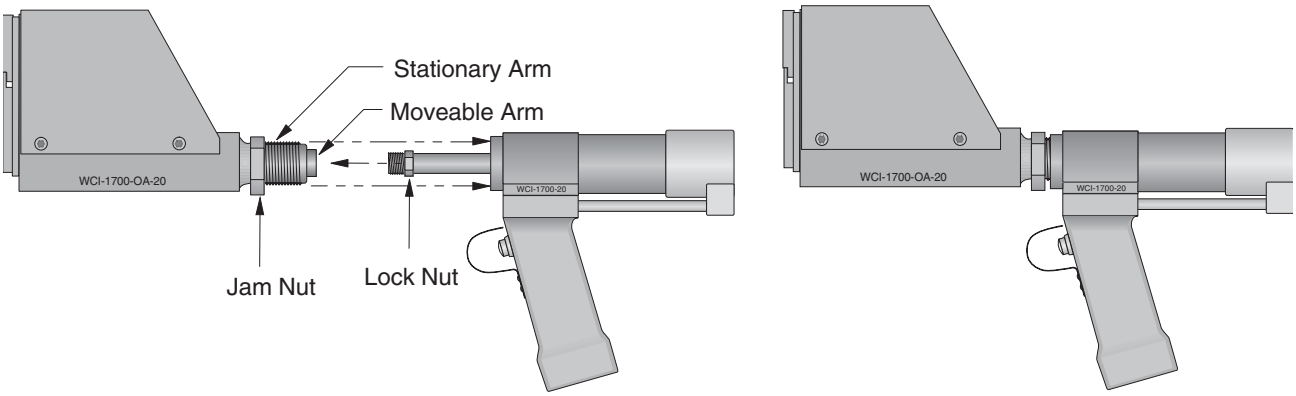


Figure 4-02 — Installing Offset Adapter on Puller Gun

4.6.2.6 Remove or loosen the two screws holding the nosecap backup plate onto the offset adapter. Ref. Fig. 4-03.

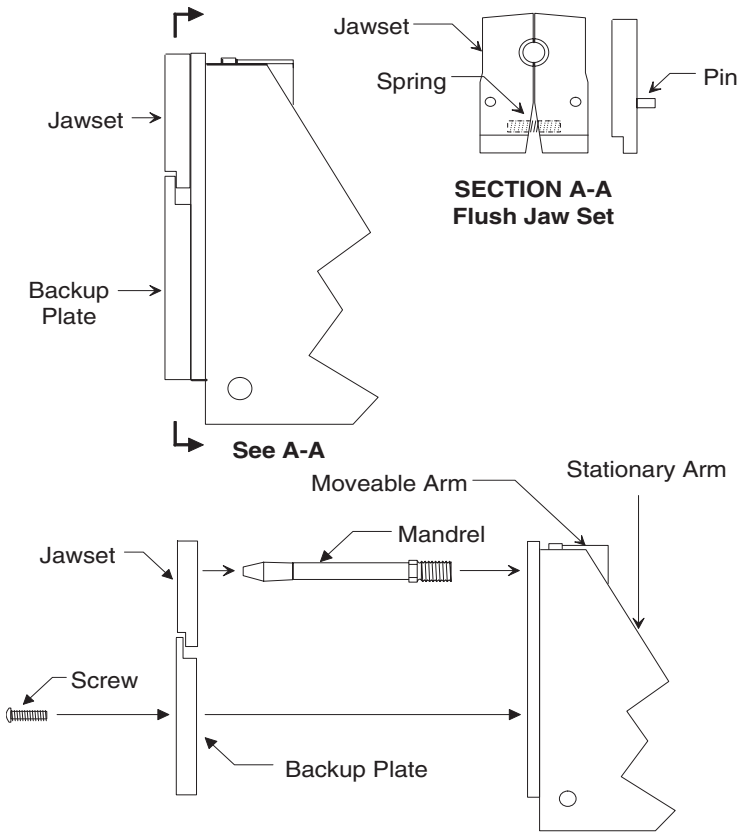


Figure 4-03 — Offset Adapter Jawset (guard not shown)

4.6.2.7 Select proper tooling.

4.6.2.8 Thread the mandrel completely into the offset adapter.

4.6.2.9 Ensure the spring is in place between the jawset halves before installation.

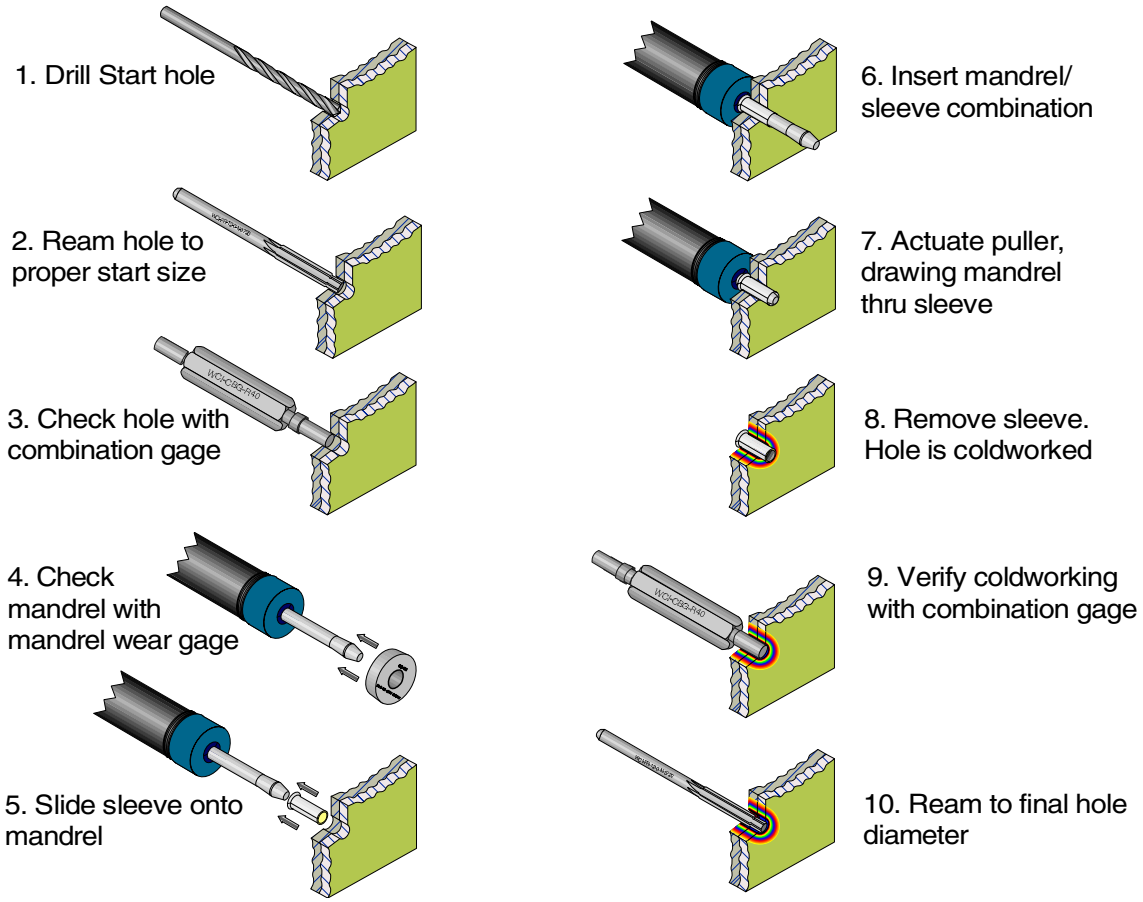
4.6.2.10 Slide the jawset, pin side first, onto the mandrel until flush against the offset adapter. Ensure the pins slide into the matching holes in the offset adapter housing.

4.6.2.11 Install cover on offset adapter.

4.6.2.12 Install the backup plate using the two screws previously removed.

4.6.2.11 Connect puller to the power unit.

4.7 Coldworking Procedures Ref. Figure 4-04



Figurre 4-04 — Split Sleeve Coldworking Process (One Piece Mandrel)

4.7.1 Split sleeve coldworking is a tooling-critical process. The use of nonconforming or worn tooling will reduce fatigue life improvement or possibly result in extensive rework.

4.7.2 Drill, and/or ream existing hole to the start hole dimensions described for the particular toolset. After all drilling and reaming operations have been completed, clean the hole, removing all cutting fluid residue. The presence of any lubrication or cutting fluid may allow the split sleeve to slip during the coldworking operation. The pre-coldworked hole shall be free of all foreign materials present including, paint, sealant and metal particles.

4.7.3 Verify the start hole diameter using the correct start hole gage, or combination gage, supplied with each toolset. If the combination gage is not available, measure the hole using a telescoping ball gage and micrometer.

4.7.4 Using the mandrel wear gage, check mandrel wear by attempting to insert the mandrel into the wear gage. If the mandrel will insert into the gage, it is worn beyond limits. Verify that the mandrel and wear gage part numbers are correct.

4.7.5 Cycle the puller unit, drawing the mandrel completely into the nosecap. A mandrel not drawing into the nosecap sufficiently may be caused by a failure to thread the mandrel completely into the puller unit, or selection of incorrect mandrel length.

4.7.6 Select the proper split sleeve for the task, ie. flared, straight, or a combination of the two. Ensure that the sleeve length is a minimum of 1/32" longer than the material stackup. Stacked sleeves shall not have a separation within 1/16 inch of any faying surface. When stacking sleeves, the flared sleeve is installed first on the mandrel, and it is recommended that sleeve splits be aligned to facilitate their removal after coldworking. Ref. Fig. 3-02.

4.7.7 Slide the split sleeve onto the mandrel, until flush against the nosecap. Ref. Fig. 4-05.

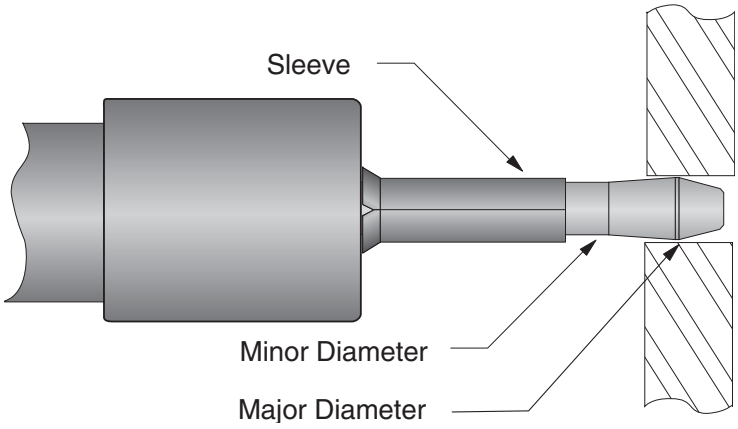


Figure 4-05 — Positioning Sleeve on Mandrel (dimensions exaggerated for clarity)

WARNING

Failure to meet this requirement may cause the tooling to experience a catastrophic failure, resulting in possible operator injury.

4.7.9 Insert the assembled tooling completely into the hole. Ensure that the nosecap is flush against the material to be coldworked. Nosecap shall be normal to the material surface. For surface to hole angles greater than 2°, beveled spacers may be used. Follow engineering directions for correct orientation of beveled spacers.

4.7.10 The hydraulic powerpak is preset to either 7,000 or 10,000 psi at the factory. It is strongly recommended that this setting not be adjusted lower. The powerpak will only provide the amount of pressure required to coldwork the hole. *Insufficient hydraulic pressure may prevent mandrel from pulling completely through the material.*

4.7.11 Coldwork the hole by actuating the puller unit.

4.7.12 Remove sleeve from hole and discard.

4.7.13 Many mandrels above 1" diameter are of two piece construction due to required mandrel geometry. Follow the instructions in figure 4-06 for using these mandrels.

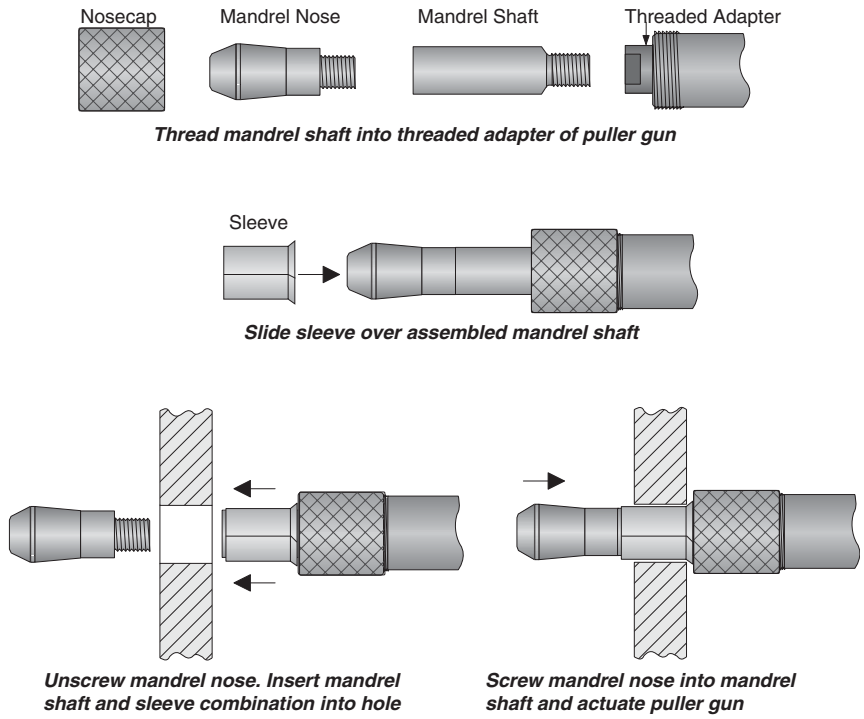


Figure 4-06 – Two Piece Mandrel

4.7.14 Verify coldworking operation utilizing the proper verification gage. If the verification gage is not available, the hole may be measured using a ball gage and micrometer. The measured values shall compare to the appropriate tables. When measuring the post-coldworked hole, measure away from the axial ridge. Ref Fig. 4-07.

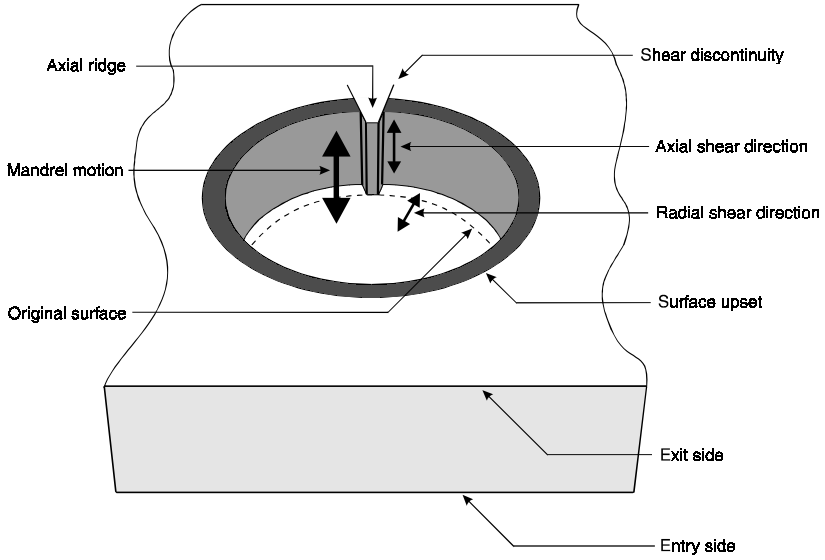


*Figure 4-07 — Axial Ridge. Note: measure hole **away** from ridge.*

4.7.15 For holes requiring postsizing, the non-cutting finish reamer pilot can function as a verification gage.

4.7.16 Ream to final hole size.

4.7.17 Countersink, if required.

5 CA Tooling— Titanium and High Strength Steel

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TABLE 5.01 CA Tooling
Titanium and High Strength Steel

STD TOOL CODE	FASTENER DIAMETER (1)		STARTING HOLE		MAX FINAL HOLE (2)	VERIFICATION GAGE
	Fraction	Decimal	Min	Max		
20	**1/8**	**0.125**	**0.110**	**0.112**	**0.1331**	**0.1125**
21	9/64	0.141	0.125	0.127	0.1513	0.1275
22	5/32	0.156	0.140	0.142	0.1694	0.1425
23	11/64	0.172	0.156	0.158	0.1888	0.1585
30	**3/16**	**0.190**	**0.170**	**0.172**	**0.2040**	**0.1725**
31	13/64	0.203	0.185	0.187	0.2220	0.1875
32	7/32	0.219	0.200	0.202	0.2400	0.2025
33	15/64	0.234	0.216	0.218	0.2592	0.2185
40	**1/4**	**0.250**	**0.231**	**0.234**	**0.2726**	**0.2350**
41	17/64	0.266	0.246	0.249	0.2903	0.2500
42	9/32	0.281	0.261	0.264	0.3080	0.2650
43	19/64	0.297	0.277	0.280	0.3269	0.2810
50	**5/16**	**0.312**	**0.287**	**0.290**	**0.3358**	**0.2920**
51	21/64	0.328	0.302	0.305	0.3533	0.3070
52	11/32	0.344	0.318	0.321	0.3721	0.3230
53	23/64	0.359	0.333	0.336	0.3896	0.3380
60	**3/8**	**0.375**	**0.348**	**0.351**	**0.4037**	**0.3530**
61	25/64	0.391	0.363	0.366	0.4211	0.3680
62	13/32	0.406	0.379	0.382	0.4396	0.3840
63	27/64	0.422	0.394	0.397	0.4570	0.3990
70	**7/16**	**0.438**	**0.409**	**0.412**	**0.4740**	**0.4160**
71	29/64	0.453	0.424	0.427	0.4890	0.4310
72	15/32	0.469	0.440	0.443	0.5050	0.4480
73	31/64	0.484	0.455	0.458	0.5200	0.4630
80	**1/2**	**0.500**	**0.470**	**0.473**	**0.5350**	**0.4780**
81	33/64	0.516	0.486	0.489	0.5510	0.4940
82	17/32	0.531	0.501	0.504	0.5660	0.5090
83	35/64	0.547	0.516	0.519	0.5810	0.5240

TABLE 5.01 (cont.) CA Tooling
Titanium and High Strength Steel

STD TOOL CODE	FASTENER DIAMETER (1)		STARTING HOLE		MAX FINAL HOLE (2)	VERIFICATION GAGE
	Fraction	Decimal	Min	Max		
90	**9/16**	**0.563**	**0.531**	**0.534**	**0.5960**	**0.5390**
91	37/64	0.578	0.547	0.550	0.6120	0.5550
92	19/32	0.594	0.562	0.565	0.6270	0.5710
93	39/64	0.609	0.577	0.580	0.6420	0.5860
100	**5/8**	**0.625**	**0.592**	**0.595**	**0.6570**	**0.6020**
101	41/64	0.641	0.608	0.611	0.6730	0.6180
102	21/32	0.656	0.623	0.626	0.6880	0.6330
103	43/64	0.672	0.638	0.641	0.7030	0.6490
110	**11/16**	**0.688**	**0.653**	**0.656**	**0.7180**	**0.6630**
111	45/64	0.703	0.669	0.672	0.7340	0.6800

1) For reference only. Actual hole diameters may vary due to engineering requirements

2) This is the maximum diameter hole that may be reamed, while retaining desired coldworking properties

6 CB Tooling— Aluminum, High Interference

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TABLE 6.01 CB Tooling
Aluminum and Mild Steel–High Interference

STD Tool Code	Starting Hole Diameter Min	Starting Hole Diameter Max	Final Hole Decimal Range (1) Min	Final Hole Decimal Range (1) Max	Max. Allow. Hole Size (2)	Boeing Max. Alow. Hole Size (3)
4-0-N	**0.113**	**0.115**	**0.1245**	**0.1399**	**0.1409**	***N/A***
4-1-N	0.128	0.130	0.1400	0.1554	0.1560	*N/A*
4-2-N (5-0-N) (4)	0.144	0.146	0.1555	0.1709	0.1760	*0.1720*
4-3-N (5-1-N) (4)	0.160	0.162	0.1710	0.1864	0.1920	*0.1880*
4-4-N	0.169	0.171	0.1890	0.1905	0.2026	*N/A*
6-0-N	**0.177**	**0.180**	**0.1865**	**0.1994**	**0.2130**	***0.2060***
6-1-N	0.192	0.195	0.1995	0.2149	0.2300	*0.2220*
6-2-N	0.209	0.212	0.2150	0.2304	0.2490	*0.2390*
6-3-N	0.225	0.228	0.2305	0.2464	0.2650	*0.2550*
8-0-N	**0.235**	**0.238**	**0.2465**	**0.2619**	**0.2790**	***0.2655***
8-1-N	0.251	0.254	0.2620	0.2774	0.2950	*0.2815*
8-2-N	0.266	0.269	0.2775	0.2929	0.3128	*0.2970*
8-3-N	0.283	0.286	0.2930	0.3089	0.3306	*0.3140*
10-0-N	**0.297**	**0.300**	**0.3090**	**0.3244**	**0.3490**	***0.3290***
10-1-N	0.313	0.316	0.3245	0.3399	0.3650	*0.3450*
10-2-N	0.328	0.331	0.3400	0.3554	0.3852	*0.3605*
10-3-N	0.344	0.347	0.3555	0.3714	0.3996	*0.3765*
12-0-N	**0.359**	**0.362**	**0.3715**	**0.3869**	**0.4190**	***0.3920***
12-1-N	0.375	0.378	0.3870	0.4024	0.4350	*0.4080*
12-2-N	0.391	0.394	0.4025	0.4179	0.4538	*0.4245*
12-3-N	0.406	0.409	0.4180	0.4339	0.4710	*0.4400*
14-0-N	**0.421**	**0.424**	**0.4340**	**0.4490**	**0.4860**	***0.4555***
14-1-N	0.437	0.440	0.4495	0.4699	0.5020	*0.4715*
14-2-N	0.450	0.453	0.4650	0.4804	0.5150	*0.4855*
14-3-N	0.465	0.468	0.4805	0.4959	0.5300	*0.5005*
16-0-N	**0.474**	**0.477**	**0.4960**	**0.5119**	**0.5390**	***0.5280***
16-1-N	0.490	0.493	0.5120	0.5274	0.5550	*0.5440*
16-2-N	0.505	0.508	0.5275	0.5429	0.5700	*0.5595*
16-3-N	0.521	0.524	0.5430	0.5579	0.5860	*0.5755*
18-0-N	**0.537**	**0.540**	**0.5580**	**0.5739**	**0.6020**	***0.5920***
18-1-N	0.553	0.556	0.5740	0.5894	0.6180	*0.6080*
18-2-N	0.568	0.571	0.5895	0.6049	0.6330	*0.6235*
18-3-N	0.583	0.586	0.6050	0.6209	0.6480	*0.6390*

TABLE 6.01 (cont.) CB Tooling
Aluminum and Mild Steel–High Interference

STD Tool Code	Starting Hole Diameter Min	Starting Hole Diameter Max	Final Hole Decimal Range (1) Min	Final Hole Decimal Range (1) Max	Max. Allow. Hole Size (2)	Boeing Max. Allow. Hole Size (3)
20-0-N	**0.597**	**0.600**	**0.6210**	**0.6364**	**0.6620**	***0.6562***
20-1-N	0.613	0.616	0.6365	0.6519	0.6780	*0.6719*
20-2-N	0.631	0.634	0.6520	0.6674	0.6960	*0.6875*
20-3-N	0.646	0.649	0.6675	0.6844	0.7110	*0.7040*
22-0-N	**0.659**	**0.662**	**0.6845**	**0.6999**	**0.7240**	***0.7188***
22-1-N	0.675	0.678	0.7000	0.7154	0.7400	*0.7344*
22-2-N	0.690	0.693	0.7155	0.7309	0.7550	*0.7500*
22-3-N	0.706	0.709	0.7310	0.7459	0.7710	*0.7657*
24-0-N	**0.718**	**0.721**	**0.7460**	**0.7614**	**0.7830**	***0.7812***
24-1-N	0.734	0.737	0.7615	0.7769	0.7990	*0.7968*
24-2-N	0.749	0.752	0.7770	0.7929	0.8140	*0.8125*
24-3-N	0.765	0.768	0.7925	0.8094	0.8300	*0.8281*
26-0-N	**0.782**	**0.785**	**0.8095**	**0.8249**	**0.8470**	***0.8437***
26-1-N	0.798	0.801	0.8250	0.8404	0.8630	*0.8594*
26-2-N	0.811	0.814	0.8405	0.8559	0.8760	*0.8750*
26-3-N	0.826	0.829	0.8560	0.8709	0.8910	*0.8906*
28-0-N	**0.841**	**0.844**	**0.8710**	**0.8864**	**0.9060**	***0.9062***
28-1-N	0.857	0.860	0.8865	0.9019	0.9220	*0.9218*
28-2-N	0.879	0.882	0.9020	0.9174	0.9440	*0.9420*
28-3-N	0.894	0.897	0.9175	0.9344	0.9590	*0.9575*
30-0-N	**0.901**	**0.904**	**0.9345**	**0.9499**	**0.9660**	***0.9910***
30-1-N	0.917	0.920	0.9500	0.9654	0.9820	*1.0067*
30-2-N	0.933	0.936	0.9655	0.9809	0.9980	*1.0230*
30-3-N	0.949	0.952	0.9810	0.9959	1.0140	*1.0390*
The following mandrels are all two piece, resulting in a two sided operation (5)						
32-0-N	**0.965**	**0.968**	**0.9960**	**1.0114**	**1.0468**	***1.0468***
32-1-N	0.981	0.984	1.0115	1.0269	1.0650	*1.0650*
32-2-N	0.997	1.000	1.0270	1.0424	1.0780	*1.0780*
32-3-N	1.013	1.016	1.0425	1.0579	1.1050	*1.1050*
36-0-N	**1.075**	**1.078**	**1.1210**	**1.1364**	**1.1700**	***1.1700***
36-1-N	1.091	1.094	1.1365	1.1519	1.1860	*1.1860*
36-2-N	1.107	1.110	1.1520	1.1684	1.2020	*1.2020*
36-3-N	1.123	1.126	1.1685	1.1844	1.2180	*1.2180*

TABLE 6.01 (cont.) CB Tooling
Aluminum & Mild Steel–High Interference

STD Tool Code	Starting Hole Diameter Min	Starting Hole Diameter Max	Final Hole Decimal Range (1) Min	Final Hole Decimal Range (1) Max	Max. Allow. Hole Size (2)	Boeing Max. Allow. Hole Size (3)
38-0-N	**1.136**	**1.140**	**1.1845**	**1.1999**	**1.2320**	***1.2320***
38-1-N	1.152	1.156	1.2000	1.2154	1.2480	*1.2480*
38-2-N	1.168	1.172	1.2155	1.2309	1.2640	*1.2640*
38-3-N	1.184	1.188	1.2310	1.2459	1.2800	*1.2800*
40-0-N	**1.199**	**1.203**	**1.2460**	**1.2614**	**1.2970**	***1.2970***
40-1-N	1.215	1.219	1.2615	1.2769	1.3130	*1.3130*
40-2-N	1.231	1.235	1.2770	1.2934	1.3290	*1.3290*
40-3-N	1.247	1.251	1.2935	1.3089	1.3450	*1.3450*
44-0-N	**1.316**	**1.320**	**1.3710**	**1.3864**	**1.4218**	***1.4218***
44-1-N	1.336	1.340	1.3865	1.4019	1.4375	*1.4375*
44-2-N	1.352	1.356	1.4020	1.4184	1.4531	*1.4531*
44-3-N	1.368	1.372	1.4185	1.4339	1.4687	*1.4687*
48-0-N	**1.427**	**1.431**	**1.4960**	**1.5114**	**1.5468**	***1.5468***
48-1-N	1.443	1.447	1.5515	1.5269	1.5625	*1.5625*
48-2-N	1.459	1.463	1.5270	1.5434	1.5781	*1.5781*
48-3-N	1.475	1.479	1.5435	1.5589	1.5937	*1.5937*
52-0-N	**1.559**	**1.563**	**1.6220**	**1.6374**	**1.6718**	***1.6718***
52-1-N	1.575	1.579	1.6375	1.6529	1.6875	*1.6875*
52-2-N	1.591	1.595	1.6530	1.6684	1.7031	*1.7031*
52-3-N	1.607	1.611	1.6685	1.6839	1.7187	*1.7187*
56-0-N	**1.696**	**1.700**	**1.7460**	**1.7614**	**1.8110**	***1.8110***
56-1-N	1.711	1.715	1.7615	1.7769	1.8260	*1.8260*
56-2-N	1.726	1.730	1.7770	1.7934	1.8420	*1.8420*
56-3-N	1.742	1.746	1.7935	1.8089	1.8575	*1.8575*

1) Select mandrel sizes for finished hole diameters in listed range. Under certain cicumstances, such as insufficient room for clean-up of coldworked hole, it is permissable to coldwork the hole as if the finished hole diameter was 1/64" smaller (i.e., smaller starting hole size, mandrel, etc.) and ream to the actual final hole size, provided the maximum allowable hole size is not exceeded.

2) These figures meet and/or in some cases enhance most industry standard process specifications. It is permissable to ream the coldworked hole to the diameters listed, without re-coldworking.

3) When working to Boeing BAC 5973, it is permissable to ream the coldworked hole to the diameters listed, without re-coldworking.

4) Under Boeing 5973, a 5-0-N tool code is equivalent to a 4-2-N, while the 5-1-N is equivalent to a 4-3-N.

5) Tooling configuration and process parameters may vary due to OEM requirements.

7 CW Tooling— Aluminum, Low Interference

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TABLE 7.01 CW Tooling— Aluminum, Low Interference Bolts and Open Holes

MANDREL TOOL CODE	NOMINAL HOLE SIZE	START HOLE RANGE		FINISHED HOLE DIAMETER		VERIFICATION GAGE
B1267	**1/8**	**0.1225**	**0.1255**	**0.1267**	**0.1295**	**0.1265**
B1423	9/64	0.1381	0.1411	0.1423	0.1451	0.1421
B1580	5/32	0.1537	0.1567	0.1580	0.1608	0.1577
B1737	11/64	0.1694	0.1724	0.1737	0.1765	0.1734
B1894	**3/16**	**0.1850**	**0.1880**	**0.1894**	**0.1922**	**0.1890**
B2050	13/64	0.2006	0.2036	0.2050	0.2078	0.2046
B2206	7/32	0.2162	0.2192	0.2206	0.2234	0.2202
B2364	15/64	0.2319	0.2349	0.2364	0.2392	0.2359
B2520	**1/4**	**0.2475**	**0.2505**	**0.2520**	**0.2548**	**0.2515**
B2676	17/64	0.2631	0.2661	0.2676	0.2704	0.2671
B2833	9/32	0.2787	0.2817	0.2833	0.2861	0.2827
B2990	19/64	0.2944	0.2974	0.2990	0.3018	0.2984
B3145	**5/16**	**0.3100**	**0.3130**	**0.3145**	**0.3175**	**0.3140**
B3301	21/64	0.3256	0.3286	0.3301	0.3331	0.3296
B3458	11/32	0.3412	0.3442	0.3458	0.3488	0.3452
B3615	23/64	0.3569	0.3599	0.3615	0.3647	0.3609
B3771	**3/8**	**0.3725**	**0.3755**	**0.3771**	**0.3803**	**0.3765**
B3928	25/64	0.3881	0.3911	0.3928	0.3960	0.3921
B4083	13/32	0.4037	0.4067	0.4083	0.4117	0.4077
B4241	27/64	0.4194	0.4224	0.4241	0.4275	0.4234
B4396	**7/16**	**0.4350**	**0.4380**	**0.4396**	**0.4432**	**0.4390**
B4551	29/64	0.4506	0.4536	0.4551	0.4589	0.4546
B4708	15/32	0.4662	0.4692	0.4708	0.4746	0.4702
B4865	31/64	0.4819	0.4849	0.4865	0.4905	0.4859
B5020	**1/2**	**0.4975**	**0.5005**	**0.5020**	**0.5064**	**0.5015**
B5176	33/64	0.5131	0.5161	0.5176	0.5220	0.5171
B5332	17/32	0.5287	0.5317	0.5332	0.5376	0.5327
B5489	35/64	0.5444	0.5474	0.5489	0.5533	0.5484

TABLE 7.01 (cont.) CW Tooling— Aluminum, Low Interference Bolts and Open Holes

MANDREL TOOL CODE	NOMINAL HOLE SIZE	START HOLE RANGE		FINISHED HOLE DIAMETER		VERIFICATION GAGE
B5647	**9/16**	**0.5660**	**0.5630**	**0.5647**	**0.5691**	**0.5640**
B5803	37/64	0.5756	0.5786	0.5803	0.5847	0.5796
B5959	19/32	0.5912	0.5942	0.5959	0.6003	0.5952
B6116	39/64	0.6069	0.6099	0.6116	0.6160	0.6109
B6272	**5/8**	**0.6225**	**0.6255**	**0.6272**	**0.6316**	**0.6265**
B6429	41/64	0.6381	0.6411	0.6429	0.6473	0.6421
B6585	21/32	0.6537	0.6567	0.6585	0.6629	0.6577
B6742	43/64	0.6694	0.6724	0.6742	0.6786	0.6734
B6899	**11/16**	**0.6850**	**0.6880**	**0.6899**	**0.6943**	**0.6890**
B7055	45/64	0.7006	0.7036	0.7055	0.7099	0.7046
B7212	23/32	0.7162	0.7192	0.7212	0.7256	0.7202
B7369	47/64	0.7319	0.7349	0.7369	0.7413	0.7359
B7525	**3/4**	**0.7475**	**0.7505**	**0.7525**	**0.7571**	**0.7515**
B7681	49/64	0.7631	0.7661	0.7681	0.7727	0.7671
B7837	25/32	0.7787	0.7817	0.7837	0.7883	0.7827
B7995	51/64	0.7944	0.7974	0.7995	0.8041	0.7984
B8151	**13/16**	**0.8100**	**0.8130**	**0.8151**	**0.8197**	**0.8140**
B8307	53/64	0.8256	0.8286	0.8307	0.8353	0.8296
B8464	27/32	0.8412	0.8442	0.8464	0.8510	0.8452
B8621	55/64	0.8569	0.8599	0.8621	0.8667	0.8609
B8778	**7/8**	**0.8725**	**0.8755**	**0.8778**	**0.8824**	**0.8765**
B8934	57/64	0.8881	0.8911	0.8934	0.8980	0.8921
B9091	29/32	0.9037	0.9067	0.9091	0.9137	0.9077
B9248	59/64	0.9194	0.9224	0.9248	0.9294	0.9234
B9404	**15/16**	**0.9350**	**0.9380**	**0.9404**	**0.9452**	**0.9390**
B9560	61/64	0.9506	0.9536	0.9560	0.9608	0.9546
B9716	31/32	0.9662	0.9692	0.9716	0.9764	0.9702
B9874	63/64	0.9819	0.9849	0.9874	0.9922	0.9859
B10030	**1.0**	**0.9975**	**1.0005**	**1.0030**	**1.0078**	**1.0015**
B10187	1 1/64	1.0131	1.0161	1.0187	1.0235	1.0171
B10343	1 1/32	1.0287	1.0317	1.0343	1.0391	1.0327

TABLE 7.02 CW Tooling—
Aluminum, Low Interference
Hex Drive Bolts, Lockbolts and Rivets

MANDREL TOOL CODE	NOMINAL HOLE SIZE	START HOLE RANGE		FINISHED HOLE DIAMETER		VERIFICATION GAGE
Hex Drive Bolts & Lockbolts						
H1870	**3/16**	**0.1830**	**0.1860**	**0.187**	**0.190**	**0.1870**
H2000	13/64	0.1960	0.1990	0.200	0.203	0.2000
H2160	7/32	0.2105	0.2135	0.216	0.219	0.2145
H2470	**1/4**	**0.2430**	**0.2460**	**0.247**	**0.250**	**0.2470**
H2630	17/64	0.2590	0.2620	0.263	0.266	0.2630
H2780	9/32	0.2725	0.2755	0.278	0.281	0.2765
H3090	**5/16**	**0.3055**	**0.3085**	**0.309**	**0.313**	**0.3095**
H3250	21/64	0.3205	0.3235	0.325	0.328	0.3245
H3410	11/32	0.3355	0.3385	0.341	0.344	0.3395
H3710	**3/8**	**0.3670**	**0.3700**	**0.371**	**0.375**	**0.3710**
H3880	25/64	0.3840	0.3870	0.388	0.391	0.3880
H4030	13/32	0.3990	0.4020	0.403	0.406	0.4030
H4340	**7/16**	**0.4285**	**0.4315**	**0.434**	**0.438**	**0.4325**
H4500	29/64	0.4435	0.4465	0.450	0.453	0.4475
H4660	15/32	0.4600	0.4630	0.466	0.469	0.4640
Rivets						
R1280	**1/8**	**0.1245**	**0.1275**	**0.128**	**0.131**	**0.1285**
R1590	5/32	0.1555	0.1585	0.159	0.162	0.1595
R1900	**3/16**	**0.1865**	**0.1895**	**0.190**	**0.195**	**0.1905**
R2200	7/32	0.2160	0.2190	0.220	0.2245	0.2200
R2530	**1/4**	**0.2495**	**0.2525**	**0.253**	**0.257**	**0.2535**
R2830	9/32	0.2785	0.2815	0.283	0.286	0.2825
R3170	**5/16**	**0.3115**	**0.3145**	**0.317**	**0.3205**	**0.3155**
R3450	11/32	0.3410	0.3440	0.345	0.348	0.3450
R3780	**3/8**	**0.3725**	**0.3755**	**0.378**	**0.382**	**0.3765**
R4080	13/32	0.4035	0.4065	0.408	0.412	0.4075
R4410	**7/16**	**0.4340**	**0.4370**	**0.441**	**0.444**	**0.4380**

8 Metric Tables–High Interference

TABLE 8.01 CB Tooling
Aluminum and Mild Steel–High Interference
Metric Units

STD Tool Code	Starting Hole Diameter Min	Starting Hole Diameter Max	Final Hole Decimal Range (1) Min	Final Hole Decimal Range (1) Max	Max. Allow. Hole Size (2)	Boeing Max. Alow. Hole Size (3)
4-0-N	**2.87**	**2.92**	**3.16**	**3.55**	**3.58**	***N/A***
4-1-N	3.25	3.30	3.56	3.95	3.96	*N/A*
4-2-N (5-0-N) (4)	3.66	3.71	3.95	4.34	4.47	*4.37*
4-3-N (5-1-N) (4)	4.06	4.11	4.34	4.73	4.88	*4.78*
4-4-N	4.29	4.34	4.80	4.84	5.15	*N/A*
6-0-N	**4.50**	**4.57**	**4.74**	**5.06**	**5.41**	***5.23***
6-1-N	4.88	4.95	5.07	5.46	5.84	*5.64*
6-2-N	5.31	5.38	5.46	5.85	6.32	*6.07*
6-3-N	5.72	5.79	5.85	6.26	6.73	*6.48*
8-0-N	**5.97**	**6.05**	**6.26**	**6.65**	**7.09**	***6.74***
8-1-N	6.38	6.45	6.65	7.05	7.49	*7.15*
8-2-N	6.76	6.83	7.05	7.44	7.95	*7.54*
8-3-N	7.19	7.26	7.44	7.85	8.40	*7.98*
10-0-N	**7.54**	**7.62**	**7.85**	**8.24**	**8.86**	***8.36***
10-1-N	7.95	8.03	8.24	8.63	9.27	*8.76*
10-2-N	8.33	8.41	8.64	9.03	9.78	*9.16*
10-3-N	8.74	8.81	9.03	9.43	10.15	*9.56*
12-0-N	**9.12**	**9.19**	**9.44**	**9.83**	**10.64**	***9.96***
12-1-N	9.53	9.60	9.83	10.22	11.05	*10.36*
12-2-N	9.93	10.01	10.22	10.61	11.53	*10.78*
12-3-N	10.31	10.39	10.62	11.02	11.96	*11.18*
14-0-N	**10.69**	**10.77**	**11.02**	**11.40**	**12.34**	***11.57***
14-1-N	11.10	11.18	11.42	11.94	12.75	*11.98*
14-2-N	11.43	11.51	11.81	12.20	13.08	*12.33*
14-3-N	11.81	11.89	12.20	12.60	13.46	*12.71*
16-0-N	**12.04**	**12.12**	**12.60**	**13.00**	**13.69**	***13.41***
16-1-N	12.45	12.52	13.00	13.40	14.10	*13.82*
16-2-N	12.83	12.90	13.40	13.79	14.48	*14.21*
16-3-N	13.23	13.31	13.79	14.17	14.88	*14.62*
18-0-N	**13.64**	**13.72**	**14.17**	**14.58**	**15.29**	***15.04***
18-1-N	14.05	14.12	14.58	14.97	15.70	*15.44*
18-2-N	14.43	14.50	14.97	15.36	16.08	*15.84*
18-3-N	14.81	14.88	15.37	15.77	16.46	*16.23*

TABLE 8.01 (cont.) CB Tooling
Aluminum and Mild Steel–High Interference
Metric Units

STD Tool Code	Starting Hole Diameter Min	Starting Hole Diameter Max	Final Hole Decimal Range (1) Min	Final Hole Decimal Range (1) Max	Max. Allow. Hole Size (2)	Boeing Max. Allow. Hole Size (3)
20-0-N	**15.16**	**15.24**	**15.77**	**16.16**	**16.81**	***16.67***
20-1-N	15.57	15.65	16.17	16.56	17.22	*17.07*
20-2-N	16.03	16.10	16.56	16.95	17.68	*17.46*
20-3-N	16.41	16.48	16.95	17.38	18.06	*17.88*
22-0-N	**16.74**	**16.81**	**17.39**	**17.78**	**18.39**	***18.26***
22-1-N	17.15	17.22	17.78	18.17	18.80	*18.65*
22-2-N	17.53	17.60	18.17	18.56	19.18	*19.05*
22-3-N	17.93	18.01	18.57	18.95	19.58	*19.45*
24-0-N	**18.24**	**18.31**	**18.95**	**19.34**	**19.89**	***19.84***
24-1-N	18.64	18.72	19.34	19.73	20.29	*20.24*
24-2-N	19.02	19.10	19.74	20.14	20.68	*20.64*
24-3-N	19.43	19.51	20.13	20.56	21.08	*21.03*
26-0-N	**19.86**	**19.94**	**20.56**	**20.95**	**21.51**	***21.43***
26-1-N	20.27	20.35	20.96	21.35	21.92	*21.83*
26-2-N	20.60	20.68	21.35	21.74	22.25	*22.23*
26-3-N	20.98	21.06	21.74	22.12	22.63	*22.62*
28-0-N	**21.36**	**21.44**	**22.12**	**22.51**	**23.01**	***23.02***
28-1-N	21.77	21.84	22.52	22.91	23.42	*23.41*
28-2-N	22.33	22.40	22.91	23.30	23.98	*23.93*
28-3-N	22.71	22.78	23.30	23.73	24.36	*24.32*
30-0-N	**22.89**	**22.96**	**23.74**	**24.13**	**24.54**	***25.17***
30-1-N	23.29	23.37	24.13	24.52	24.94	*25.57*
30-2-N	23.70	23.77	24.52	24.91	25.35	*25.98*
30-3-N	24.10	24.18	24.92	25.30	25.76	*26.39*
The following mandrels are all two piece, resulting in a two sided operation (5)						
32-0-N	**24.51**	**24.59**	**25.30**	**25.69**	**26.59**	***26.59***
32-1-N	24.92	24.99	25.69	26.08	27.05	*27.05*
32-2-N	25.32	25.40	26.09	26.48	27.38	*27.38*
32-3-N	25.73	25.81	26.48	26.87	28.07	*28.07*
36-0-N	**27.31**	**27.38**	**28.47**	**28.86**	**29.72**	***29.72***
36-1-N	27.71	27.79	28.87	29.26	30.12	*30.12*
36-2-N	28.12	28.19	29.26	29.68	30.53	*30.53*
36-3-N	28.52	28.60	29.68	30.08	30.94	*30.94*

TABLE 8.01 (cont.) CB Tooling
Aluminum and Mild Steel–High Interference

Metric Units

STD Tool Code	Starting Hole Diameter Min	Starting Hole Diameter Max	Final Hole Decimal Range (1) Min	Final Hole Decimal Range (1) Max	Max. Allow. Hole Size (2)	Boeing Max. Allow. Hole Size (3)
38-0-N	**28.85**	**28.96**	**30.09**	**30.48**	**31.29**	***31.29***
38-1-N	29.26	29.36	30.48	30.87	31.70	*31.70*
38-2-N	29.67	29.77	30.87	31.26	32.11	*32.11*
38-3-N	30.07	30.18	31.27	31.65	32.51	*32.51*
40-0-N	**30.45**	**30.56**	**31.65**	**32.04**	**32.94**	***32.94***
40-1-N	30.86	30.96	32.04	32.43	33.35	*33.35*
40-2-N	31.27	31.37	32.44	32.85	33.76	*33.76*
40-3-N	31.67	31.78	32.85	33.25	34.16	*34.16*
44-0-N	**33.43**	**33.53**	**34.82**	**35.21**	**36.11**	***36.11***
44-1-N	33.93	34.04	35.22	35.61	36.51	*36.51*
44-2-N	34.34	34.44	35.61	36.03	36.91	*36.91*
44-3-N	34.75	34.85	36.03	36.42	37.30	*37.30*
48-0-N	**36.25**	**36.35**	**38.00**	**38.39**	**39.29**	***39.29***
48-1-N	36.65	36.75	39.41	38.78	39.69	*39.69*
48-2-N	37.06	37.16	38.79	39.20	40.08	*40.08*
48-3-N	37.47	37.57	39.20	39.60	40.48	*40.48*
52-0-N	**39.60**	**39.70**	**41.20**	**41.59**	**42.46**	***42.46***
52-1-N	40.01	40.11	41.59	41.98	42.86	*42.86*
52-2-N	40.41	40.51	41.99	42.38	43.26	*43.26*
52-3-N	40.82	40.92	42.38	42.77	43.65	*43.65*
56-0-N	**43.08**	**43.18**	**44.35**	**44.74**	**46.00**	***46.00***
56-1-N	43.46	43.56	44.74	45.13	46.38	*46.38*
56-2-N	43.84	43.94	45.14	45.55	46.79	*46.79*
56-3-N	44.25	44.35	45.55	45.95	47.18	*47.18*

1) Select mandrel sizes for finished hole diameters in listed range. Under certain cicumstances, such as insufficient room for clean-up of coldworked hole, it is permissable to coldwork the hole as if the finished hole diameter was .4 mm (1/64 inch) smaller (i.e., smaller starting hole size, mandrel, etc.) and ream to the actual final hole size, provided the maximum allowable hole size is not exceeded.

2) These figures meet and/or in some cases enhance most industry standard process specifications. It is permissable to ream the coldworked hole to the diameters listed, without re-coldworking.

3) When working to Boeing BAC 5973, it is permissable to ream the coldworked hole to the diameters listed, without re-coldworking.

4) Under Boeing 5973, a 5-0-N tool code is equivalent to a 4-2-N, while the 5-1-N is equivalent to a 4-3-N.

5) Tooling configuration and process parameters may vary due to OEM requirements.

TABLE 8.02 CA Tooling
Titanium and High Strength Steel

Metric Units

STD TOOL CODE	Nominal Fastener	STARTING HOLE Min	STARTING HOLE Max	MAX FINAL HOLE (2)	VERIFICATION GAGE
20	**3.0**	**2.79**	**2.84**	**3.38**	**2.86**
21	4.0	3.18	3.23	3.84	3.24
22	4.0	3.56	3.61	4.30	3.62
23	4.0	3.96	4.01	4.80	4.03
30	**5.0**	**4.32**	**4.37**	**5.18**	**4.38**
31	5.0	4.70	4.75	5.64	4.76
32	5.5	5.08	5.13	6.10	5.14
33	6.0	5.49	5.54	6.58	5.55
40	**6.5**	**5.87**	**5.94**	**6.92**	**5.97**
41	7.0	6.25	6.32	7.37	6.35
42	7.0	6.63	6.71	7.82	6.73
43	7.5	7.04	7.11	8.30	7.14
50	**8.0**	**7.29**	**7.37**	**8.53**	**7.42**
51	8.5	7.67	7.75	8.97	7.80
52	9.0	8.08	8.15	9.45	8.20
53	9.0	8.46	8.53	9.90	8.59
60	**9.5**	**8.84**	**8.92**	**10.25**	**8.97**
61	10.0	9.22	9.30	10.70	9.35
62	10.5	9.63	9.70	11.17	9.75
63	11.0	10.01	10.08	11.61	10.13
70	**11.0**	**10.39**	**10.46**	**12.04**	**10.57**
71	11.5	10.77	10.85	12.42	10.95
72	12.0	11.18	11.25	12.83	11.38
73	12.5	11.56	11.63	13.21	11.76
80	**12.5**	**11.94**	**12.01**	**13.59**	**12.14**
81	13.0	12.34	12.42	14.00	12.55
82	13.5	12.73	12.80	14.38	12.93
83	14.0	13.11	13.18	14.76	13.31

TABLE 8.02 (cont.) CA Tooling
Titanium and High Strength Steel

Metric Units

STD TOOL CODE	Nominal Fastener	STARTING HOLE Min	STARTING HOLE Max	MAX FINAL HOLE (2)	VERIFICATION GAGE
90	**14.5**	**13.49**	**13.56**	**15.14**	**13.69**
91	14.5	13.89	13.97	15.54	14.10
92	15.0	14.27	14.35	15.93	14.50
93	15.5	14.66	14.73	16.31	14.88
100	**16.0**	**15.04**	**15.11**	**16.69**	**15.29**
101	16.5	15.44	15.52	17.09	15.70
102	16.5	15.82	15.90	17.48	16.08
103	17.0	16.21	16.28	17.86	16.48
110	**17.5**	**16.59**	**16.66**	**18.24**	**16.84**
111	18.0	16.99	17.07	18.64	17.27

1) For reference only. Actual hole diameters may vary due to engineering requirements

2) This is the maximum diameter hole that may be reamed, while retaining desired coldworking properties

9 CRACKARRESTOR—*Stop Drill Repair Procedures*

9.1 It is not uncommon for fatigue cracks to develop in airframes. A traditional interim repair has been to stop drill the crack, which involves drilling a hole at the tip of the crack to reduce the concentration of stress at the crack tip. Cracks often reinitiate at the stop drilled site due to missing the tip of the crack with the stop drilled hole.

9.1.1 The ***CRACKARRESTOR*** system significantly enhances the stop drill process by cold expanding the stop drilled hole. Coldworking the stop drilled hole greatly enhances the chances that the very tip of the crack becomes protected in the zone of compressive residual stress induced around the stop drilled hole.

9.2 Process the Hole

9.2.1 Determine the desired final hole diameter.

9.2.1.1 Use a $^{3}/_{16}$ inch final hole diameter for material thicknesses of $^{3}/_{16}$ inch or less.

9.2.1.2 For material thickness greater than $^{3}/_{16}$, utilize a $^{1}/_{4}$ inch final hole diameter.

9.2.2 Using table 9-01, select the tooling needed to process the hole diameter.

9.2.3 Utilizing approved Non-Destructive Inspection (NDI) methods, determine the location of the end of the crack. Drill the pilot hole, utilizing the tooling provided in the tool set.

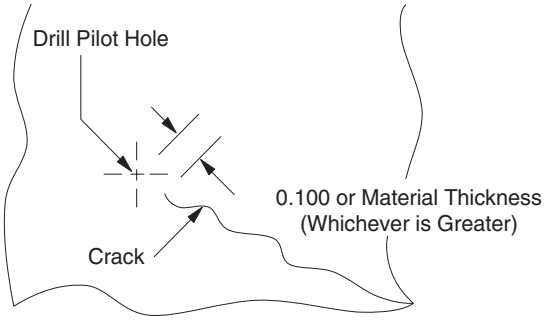

Figure 9-01 — Crack Length > 0.200"

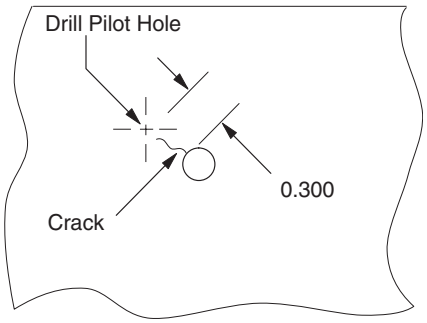

Figure 9-02 — Crack Length < 0.200"

9.2.3.1 For crack lengths greater than 0.200 inch, the center of the pilot hole shall be located either 0.100 inch, or one material thickness, ahead of the observed crack tip, whichever is greater. Ensure hole is within 2° of normal to the surface. See Fig. 9-01.

9.2.3.2 For crack lengths less than 0.200 inch, the center of the pilot hole shall be located 0.300 inch from the point of crack origin. See Fig. 9-02.

9.2.4 Ream the pilot hole to the start hole diameter utilizing the starting reamer included with the tool set.

9.2.5 Verify starting hole using combination go-no go gage.

NOTE

An oversize start hole is cause for rejection. Process the hole using the next larger tool set.

9.2.6 Inspect hole, using appropriate NDI procedures, to verify there is no cracking in the hole on the opposite side from the initial crack indication. ***If a crack exists, reject the hole.*** Ream oversize and repeat the procedure.

9.2.7 Clean the hole, removing all cutting fluid residue. The pre-coldworked hole should be free of any foreign material or residue.

9.3 Assemble Tooling

9.3.1 Unscrew the nosecap assembly from the puller body. Ref. Fig 9-03.

9.3.2 Extend the internal piston to the end of the unit by turning the end nut counterclockwise with the provided $^{5}/_{8}$" ratchet wrench.

9.3.3 Screw the proper mandrel into the threaded adapter finger tight.

9.3.4 Slide the proper nosecap assembly over the mandrel and screw onto the puller body.

9.3.5 Select the proper sleeve, and slide it onto the mandrel, flared end first. It must fit snug against the nosecap assembly. Ref. Fig 9-03

9.4 Coldwork the Hole

9.4.1 Insert the assembled tooling completely into the hole.

9.4.2 Ensure that the nosecap is flush against the material to be coldworked. The nosecap must be normal to the material surface. For surface angle greater than 2°, beveled spacers may be used. Contact Engineering for proper beveled spacer orientation.

9.4.3 Orient the sleeve/puller so that the sleeve split is toward the crack origin.

9.4.4 Coldwork the hole by turning the end nut in a clockwise direction with the ratchet wrench. This will draw the mandrel through the sleeve, thereby expanding the hole.

9.4.5 Ensure that the mandrel is completely through the sleeve and remove the puller unit.

9.4.6 Remove the sleeve from the hole and discard.

9.4.7 Using the final hole reamer from the appropriate tool set, ream the hole. Note that there are separate reamers provided for rivet and interference fit bolt applications.

9.4.8 Install appropriate fastener

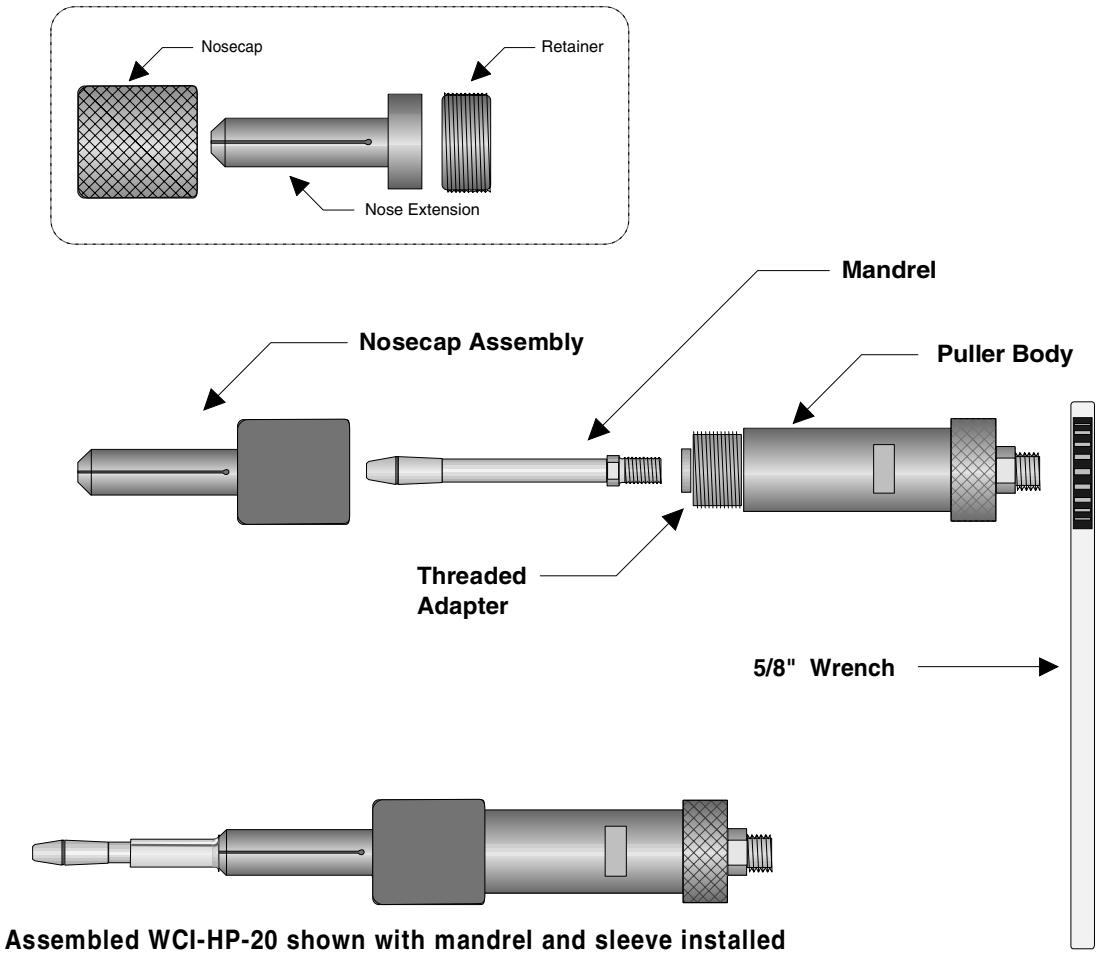

Figure 9-03 — Assembling the WCI-HP-20 Hand Puller

Table 9-01 *CrackArrestor* Start and Final Hole Diameters

Desired Final Hole Size	Tool Code	Start Hole Diameter		Finish Reamer Diameter	Fastener Type
		Min	Max		
3/16	A30	0.170	0.172	0.1875	Rivet
				0.1845	Interference Fit Bolt (1)
1/4	A40	0.231	0.234	0.2500	Rivet
				0.2470	Interference Fit Bolt (1)
17/64	A41	0.246	0.249	0.2656	Rivet
				0.2626	Interference Fit Bolt (1)

(1) Hi-Lok or Equivalent

Table 9-02 *CRACKARRESTOR* Tooling

QTY	PART NUMBER	DESCRIPTION
3/16" Nominal Tooling Set		
4	WCI-SD-A30	Start Drill
2	WCI-SR-A30	Start Reamer
1	WCI-CBG-A30	Combination Gage
1	WCI-CAM-A30-1-35-V2	Mandrel
50	WCI-CAS-A30-16F	Split Sleeves, Flared
1	WCIS-WG-A30	Mandrel Wear Gage
2	WCI-FR-A30-1875	Final Reamer (for 3/16" Aluminum Rivet)
2	WCI-FR-A30-1845	Final Reamer (for 3/16" Interference Fit Bolt)
1/4" Nominal Tooling Set		
4	WCI-SD-A40	Start Drill
2	WCI-SR-A40	Start Reamer
1	WCI-CBG-A40	Combination Gage
1	WCI-CAM-A40-1-35-V2	Mandrel
50	WCI-CAS-A40-16F	Split Sleeves, Flared
1	WCIS-WG-A40	Mandrel Wear Gage
2	WCI-FR-A40-2500	Final Reamer (for 1/4" Aluminum Rivet)
2	WCI-FR-A40-2470	Final Reamer (for 1/4" Interference Fit Bolt)
17/64" Oversize Tooling Set		
2	WCI-SR-A41	Start Reamer
1	WCI-CBG-A41	Combination Gage
1	WCI-CAM-A41-1-35-V2	Mandrel
50	WCI-CAS-A41-16F	Split Sleeves, Flared
1	WCIS-WG-A41	Mandrel Wear Gage
2	WCI-FR-A41-2656	Final Reamer (for 17/64"" Aluminum Rivet)
2	WCI-FR-A41-2626	Final Reamer (for 17/64" Interference Fit Bolt)
Capital Tooling		
1	WCI-HP-20	Hand Puller
1	WCI-1700NE-A3031-20F	3/16" Extension Nosecap Assembly
1	WCI-1700NE-A4041-20F	1/4" and 17/64" Extension Nosecap Assembly
Documentation		
2	WCI-CA-RP	Repair Procedures
2	WCI-CA-ROF	Reorder Forms

10 Maintenance & Repair Toolkits

CR Tooling

CB Tooling

10.1 CR TOOLING

10.1.1 CR Tooling is used to enhance structural repairs performed at the repair facility. This tooling must be assembled and used in accordance to procedures outlined in section 4.

10.1.2 Instructions for using the tables found in Section 10.

10.1.2.1 Compare the measured existing hole diameter with the values found in Table 10-01. If the measured value is less than the maximum shown in the table, follow the chart to the far right which will indicate the correct tool code (tool set) for use.

NOTE

It will be necessary to ream a $^{17}/_{64}$ inch existing hole to $^{9}/_{32}$ inch required pilot diameter prior to beginning the coldwork procedure.

10.1.2.2 Table 10-02 provides the hole/fastener diameters for each tool set. The post coldworked hole may be reamed to the diameter reflected in the “Final Hole Dia. – Max Allowable” column of the table, without re-expansion of the hole.

NOTE

Do not exceed the maximum hole diameter value when reaming the coldworked hole. Exceeding this value will remove the beneficial zone of compression negating any fatigue enhancements.

10.1.2.3 Table 10-03 provides a detail listing of tooling provided in each tool set. After determining the correct tool code from Table 10-01, refer to Table 10-03 for a listing of tools needed to perform the coldworking task.

NOTE

The coldworking task will require the use of either standard, or offset tooling, depending upon the geometry of the application. For additional information, see paragraph 2.12 for access restriction.

10.1.2.4 Assemble the tooling and coldwork the hole per section 4.

10.2 CB TOOLING

10.2.1 CB tooling kits are used to enhance structural repairs performed during a depot level modification. This tooling must be assembled and used in accordance to procedures outlined in Section 4. Two standard CB kits are provided, the CWORK-1 for existing hole sizes from $^{5}/_{32}$" to $^{3}/_{8}$", and the CWORK-3 for exisiting holes between $^{13}/_{32}$" and $^{7}/_{8}$".

10.2.2 Instructions for using the tables found in Section 10.

10.2.2.1 Compare the measured existing hole diameter with the values found in Tables 10-04 or 10-05 (CWORK-1 and CWORK-3 respectively). If the measured value is less than the maximum shown in the table, follow the chart to the left which will indicate the correct tool code (tool set) for use.

NOTE

Using the 14-0-N tooling for a $^{7}/_{16}$ inch diameter hole involves a minimal (0.004 inch) ream alowance between the coldworked hole and the final hole diameter. Exercise extreme care when reaming the final hole.

10.2.2.2 The post coldworked hole may be reamed to the maximum diameter reflected in the far right of the table, without re-expansion of the hole.

NOTE

Do not exceed the maximum hole diameter value when reaming the coldworked hole. Exceeding this value will remove the beneficial zone of compression negating any fatigue enhancements.

10.2.2.3 After determining the correct tool code from Tables 10-04 and 10-05, refer to Tables 10-06 and 10-07 for a listing of tools needed to perform the coldworking task.

NOTE

The coldworking task will require the use of either standard, or offset tooling, depending upon the geometry of the application. For additional information, see paragraph 2.12 for access restriction.

10.2.2.4 Assemble the tooling and coldwork the hole per section 4.

TABLE 10.01 CR TOOL CODE SELECTION

EXISTING HOLE DIAMETER (1) (2)		REQUIRED PILOT HOLE DIA (3)	FINAL FASTENER HOLE DIA	TOOL CODE (2)
Fraction	Maximum			
5/32	0.164	0.157	0.187	R30
3/16	0.194	0.187	0.219	R32
13/64, 7/32	0.224	0.219	0.250	R40
1/4	0.255	0.250	0.281	R42
17/64, 9/32	0.285(4)	0.281	0.312	R50
5/16	0.317	0.312	0.344	R52
21/64, 11/32	0.347	0.344	0.375	R60
3/8	0.378	0.375	0.406	R62

1) If hole is countersunk, and countersink nosecap is unavailable, process the hole using the next larger tool code

2) Selected tool code may be used for any existing hole diameter which is less than the specified maximum

3) -0.000 / +0.005 inch.

4) It will be necessary to ream 17/64" existing hole diameter to 9/32" required pilot hole diameter before performing coldwork procedure

TABLE 10.02 CR HOLE/FASTENER DIAMETERS

TOOL CODE	PILOT HOLE DIA (1)	START HOLE DIA		APPROX. HOLE DIA AFTER EXPANSION (2)	FINAL HOLE DIA (3)		RECOMMEND FASTENER (HI-LOK)	RECOMMENDED FINAL HOLE DIA	
		Min	Max		Min Allowable	Max Allowable		Min	Max
R30	0.157	0.169	0.171	0.173	0.178	0.207	0.1890	0.186	0.189
R32	0.187	0.199	0.202	0.205	0.210	0.239	0.2177	0.215	0.218
R40	0.219	0.229	0.232	0.236	0.241	0.270	0.2490	0.246	0.249
R42	0.250	0.260	0.263	0.268	0.273	0.301	0.2802	0.277	0.280
R50	0.281	0.290	0.293	0.299	0.304	0.348	0.3115	0.308	0.311
R52	0.312	0.322	0.325	0.332	0.337	0.380	0.3427	0.340	0.343
R60	0.344	0.352	0.355	0.363	0.368	0.411	0.3740	0.371	0.374
R62	0.375	0.383	0.386	0.394	0.399	0.442	0.4052	0.402	0.405

1) -0.000/+0.005

2) ±0.002", dependent upon hole diameter, alloy and heat treatment

3) Expanded hole may be enlarged to maximum allowable diameter without re-expansion of hole

TABLE 10.03 CWORK-2B KIT CONTENTS (CR TOOLING)

EXPENDABLE TOOLING SET (1)	QTY (2)	TOOL CODE/TOOL SET NUMBER R30 CWRK-R30	R-32 CWRK-R32	R40 CWRK-R40	R42 CWRK-R42
START DRILL (3)	2	WCI-SD-R30	WCI-SD-R32	WCI-SD-R40	WCI-SD-R42
START REAMER	2	WCI-SR-R30	WCI-SR-R32	WCI-SR-R40	WCI-SR-R42
COMBINATION GAGE	1	WCI-CBG-R30	WCI-CBG-R32	WCI-CBG-R40	WCI-CBG-R42
MANDREL GAGE	1	WCIS-WG-R30	WCIS-WG-R32	WCIS-WG-R40	WCIS-WG-R42
FINAL HOLE GAGE	1	WCI-FHG-1860-1890	WCI-FHG-2150-2180	WCI-FHG-2460-2490	WCI-FHG-2770-2800
MANDRELS					
EXTENSION	2	WCI-CRM-R30-1-35	WCI-CRM-R32-1-35	WCI-CRM-R40-1-35	WCI-CRM-R42-1-35
OFFSET	1	WCI-CRM-R30-1-20	WCI-CRM-R32-1-20	WCI-CRM-R40-1-20	WCI-CRM-R42-1-20
SLEEVES, FLARED	100	CRS-R30-16F	CRS-R32-16F	CRS-R40-16F	CRS-R42-16F
FINISH REAMER	2	WCI-FR-R30-1860	WCI-FR-R32-2150	WCI-FR-R40-2460	WCI-FR-R42-2770
NOSECAPS					
EXTENSION	1	WCI-1700NE-R30-20F	WCI-1700NE-R32-20F	WCI-1700NE-R40-20F	WCI-1700NE-R42-20F
OFFSET	1	WCI-1700-OAJ-R30	WCI-1700-OAJ-R32	WCI-1700-OAJ-R40	WCI-1700-OAJ-R42

		R50 CWRK-R50	R-52 CWRK-R52	R60 CWRK-R60	R62 CWRK-R62
START DRILL (3)	2	WCI-SD-R50	WCI-SD-R52	WCI-SD-R60	WCI-SD-R62
START REAMER	2	WCI-SR-R50	WCI-SR-R52	WCI-SR-R60	WCI-SR-R62
COMBINATION GAGE	1	WCI-CBG-R50	WCI-CBG-R52	WCI-CBG-R60	WCI-CBG-R62
MANDREL GAGE	1	WCIS-WG-R50	WCIS-WG-R52	WCIS-WG-R60	WCIS-WG-R62
FINAL HOLE GAGE	1	WCI-FHG-3080-3110	WCI-FHG-3400-3430	WCI-FHG-3710-3740	WCI-FHG-4020-4050
MANDRELS					
EXTENSION	2	WCI-CRM-R50-1-35	WCI-CRM-R52-1-35	WCI-CRM-R60-1-35	WCI-CRM-R62-1-35
OFFSET	1	WCI-CRM-R50-1-20	WCI-CRM-R52-1-20	WCI-CRM-R60-1-20	WCI-CRM-R62-1-20
SLEEVES, FLARED	100	CRS-R50-16F	CRS-R52-16F	CRS-R60-16F	CRS-R62-16F
FINISH REAMER	2	WCI-FR-R50-3080	WCI-FR-R52-3400	WCI-FR-R60-3710	WCI-FR-R62-4020
NOSECAPS					
EXTENSION	1	WCI-1700NE-R50-20F	WCI-1700NE-R52-20F	WCI-1700NE-R60-20F	WCI-1700NE-R62-20F
OFFSET	1	WCI-1700-OAJ-R50	WCI-1700-OAJ-R52	WCI-1700-OAJ-R60	WCI-1700-OAJ-R62

1) For restricted access situations, the kit includes the Offset Adapter, Offset Mandrels and Offset Nosecaps

2) Indicates the quantity of tooling in each expendable tooling set. If more than 100 holes of any one size need to be processed, it will be necessary to order additional split sleeves.

3) Starting Drill is required for new holes only.

Each CWORK-2B Kit Contains:

Eight Tooling Sets Above
Puller Unit - WCI-1700-20
Offset Adapter - WCI-1700-OA-20
Power Pak - WCI-20
Stop Drill Kit - CrackArrestor WCI-CAK-1A
Four Drawer Mobile Cabinet

TABLE 10.04 HOLE SPECIFICATIONS—CWORK-1 TOOLKIT

TOOL CODE	EXISTING HOLE DIA. (1) (2)	START HOLE DIAMETER		FINAL FASTENER / HOLE DIAMETER		MAX. ALLOW HOLE DIAMETER (3)
	Fraction	Min	Max	Minimum	Maximum	
4-4-N	5/32	0.169	0.171	0.18900	0.1905	0.2026
6-2-N	3/16	0.209	0.212	0.2150	0.2304	0.2390
8-0-N	7/32	0.235	0.238	0.2465	0.2619	0.2655
8-2-N	1/4	0.266	0.269	0.2775	0.2929	0.2970
10-0-N	9/32	0.297	0.300	0.3090	0.3244	0.3290
10-2-N	5/16	0.328	0.331	0.3400	0.3554	0.3605
12-0-N	5/8	0.359	0.362	0.3715	0.3869	0.3920
12-2-N	3/8	0.391	0.394	0.4025	0.4179	0.4555

1) Contact West Coast Industries if existing hole is countersunk.

2) Selected tool code may be used for any existing hole diameter which is less than specified maximum

3) Expanded hole may be enlarged to the maximum allowable diameter without coldworking

TABLE 10.05 HOLE SPECIFICATIONS—CWORK-3 TOOLKIT

TOOL CODE	EXISTING HOLE DIAMETER (1) (2)		START HOLE DIAMETER		FINAL FASTENER / HOLE DIAMETER		EXPANDED HOLE DIAMETER (4)	MAXIMUM ALLOWABLE HOLE DIA (5)
	Fraction	Maximum	Min	Max	Nominal	Maximum		
14-0-N	13/32	13/32 (0.410)	0.421	0.424	7/16 (3)	1/2	0.431	0.505
16-0-N	7/16	15/32 (0.469)	0.474	0.477	1/2	9/16	0.486	0.567
18-0-N	1/2	17/32 (0.531)	0.537	0.540	9/16	5/8	0.550	0.630
20-0-N	9/16	37/64 (0.587)	0.597	0.600	5/8	11/16	0.612	0.692
24-0-N	5/8	45/64 (0.708)	0.718	0.721	3/4	13/16	0.736	0.817
28-0-N	3/4	13/16 (0.831)	0.841	0.844	7/8	15/16	0.862	0.942
30-0-N	7/8 (6)	57/64 (0.891)	0.901	0.904	15/16	1	0.923	1.005

1) Contact West Coast Industries if existing hole is countersunk.

2) Selected tool code may be used for any existing hole diameter which is less than specified maximum

3) Using 14-0-N tooling for 7/16" hole diameter involves a minimal (0.004") ream allowance between the coldworked hole and the final hole diameter. Exercise care when final reaming the hole.

4) Approximately ±0.003.

5) Expanded hole may be enlarged to maximum allowable diameter without re-expansion of hole.

6) Contact WCI for further information regarding holes greater than 7/8".

TABLE 10.06 CWORK-1 KIT CONTENTS (CB TOOLING)

EXPENDABLE TOOLING SET	QTY	TOOL CODE/TOOL SET NUMBER			
		4-4-N CBMK-4-4-N	6-2-N CBMK-6-2-N	8-0-N CBMK-8-0-N	8-2-N CBMK-8-2-N
START DRILL	2	WCI-SD-4-4-N	WCI-SD-6-2-N	WCI-SD-8-0-N	WCI-SD-8-2-N
START REAMER	2	WCI-SR-4-4-N	WCI-SR-6-2-N	WCI-SR-8-0-N	WCI-SR-8-2-N
COMBINATION GAGE	1	WCI-CBG-4-4-N	WCI-CBG-6-2-N	WCI-CBG-8-0-N	WCI-CBG-8-2-N
MANDREL GAGE	1	WCIS-WG-4-4-N	WCIS-WG-6-2-N	WCIS-WG-8-0-N	WCIS-WG-8-2-N
MANDREL	1	WCI-CBM-4-4-N-1-20	WCI-CBM-6-2-N-1-20	WCI-CBM-8-0-N-1-20	WCI-CBM-8-2-N-1-20
MANDREL	2	WCI-CBM-4-4-N-1-35	WCI-CBM-6-2-N-1-35	WCI-CBM-8-0-N-1-35	WCI-CBM-8-2-N-1-35
SLEEVES, FLARED	100	CBS-4-4-N-16F	CBS-6-2-N-16F	CBS-8-0-N-16F	CBS-8-2-N-16F
EXTENSION NOSECAP	1	WCI-1700NE-0601-20F	WCI-1700NE-0623-20F	WCI-1700NE-0801-20F	WCI-1700NE-0823-20F
O.A. NOSECAP	1	WCI-1700OAJ-0601F	WCI-1700OAJ-0623F	WCI-1700OAJ-0801F	WCI-1700OAJ-0823F
FINISH REAMER	2	WCI-FR-4-4-N-1860	WCI-FR-6-2-N-2150	WCI-FR-8-0-N-2460	WCI-FR-8-2-N-2770
FINAL HOLE GAGE	1	WCI-FHG-1860-1890	WCI-FHG-2150-2180	WCI-FHG-2460-2490	WCI-FHG-2770-2800

EXPENDABLE TOOLING SET	QTY	TOOL CODE/TOOL SET NUMBER			
		10-0-N CBMK-10-0-N	10-2-N CBMK-10-2-N	12-0-N CBMK-12-0-N	12-2-N CBMK-12-2-N
START DRILL	2	WCI-SD-10-0-N	WCI-SD-10-2-N	WCI-SD-12-0-N	WCI-SD-12-2-N
START REAMER	2	WCI-SR-10-0-N	WCI-SR-10-2-N	WCI-SR-12-0-N	WCI-SR-12-2-N
COMBINATION GAGE	1	WCI-CBG-10-0-N	WCI-CBG-10-2-N	WCI-CBG-12-0-N	WCI-CBG-12-2-N
MANDREL GAGE	1	WCIS-WG-10-0-N	WCIS-WG-10-2-N	WCIS-WG-12-0-N	WCIS-WG-12-2-N
MANDREL	1	WCI-CBM-10-0-N-1-20	WCI-CBM-10-2-N-1-20	WCI-CBM-12-0-N-1-20	WCI-CBM-12-2-N-1-20
MANDREL	2	WCI-CBM-10-0-N-1-35	WCI-CBM-10-2-N-1-35	WCI-CBM-12-0-N-1-35	WCI-CBM-12-2-N-1-35
SLEEVES, FLARED	100	CBS-10-0-N-16F	CBS-10-2-N-16F	CBS-12-0-N-16F	CBS-12-2-N-16F
EXTENSION NOSECAP	1	WCI-1700NE-1001-20F	WCI-1700NE-1023-20F	WCI-1700NE-1201-20F	WCI-1700NE-1223-20F
O.A. NOSECAP	1	WCI-1700OAJ-1001F	WCI-1700OAJ-1023F	WCI-1700OAJ-1201F	WCI-1700OAJ-1223F
FINISH REAMER	2	WCI-FR-10-0-N-3080	WCI-FR-10-2-N-3400	WCI-FR-12-0-N-3710	WCI-FR-12-2-N-4020
FINAL HOLE GAGE	1	WCI-FHG-3080-3110	WCI-FHG-3400-3430	WCI-FHG-3710-3740	WCI-FHG-4020-4050

Each CWORK-1 Kit Contains:

Eight Tooling Sets Above

Puller Unit - WCI-1700-20

Power Pak - WCI-20 (Optional: WCIS-10000)

Offset Adpapter - WCI-1700-OA-20

Four Drawer Mobile Cabinet

TABLE 10.06 CWORK-3 KIT CONTENTS (CB TOOLING)

EXPENDABLE TOOLING SET (1)	QTY (2)	TOOL CODE/TOOL SET NUMBER 14-0-N CBMK-14-0-N	16-0-N CBMK-16-0-N	18-0-N CBMK-18-0-N	20-0-N CBMK-20-0-N
START DRILL (3)	2	WCI-SD-14-0-N	WCI-SD-16-0-N	WCI-SD-18-0-N	WCI-SD-20-0-N
START REAMER	2	WCI-SR-14-0-N	WCI-SR-16-0-N	WCI-SR-18-0	WCI-SR-20-0-N
COMBINATION GAGE (4)	1	WCI-CBG-14-0-N	WCI-CBG-16-0-N	WCI-CBG-18-0-N	WCI-CBG-20-0-N
MANDREL GAGE	1	WCIS-WG-14-0-N	WCIS-WG-16-0-N	WCIS-WG-18-0-N	WCIS-WG-20-0-N
MANDREL	2	WCI-CBM-14-0-N-2-30	WCI-CBM-16-0-N-2-30	WCI-CBM-18-0-N-2-30	WCI-CBM-20-0-N-2-30
SLEEVES, STRAIGHT	50	CBS-14-0-N-16S	CBS-16-0-N-16S	CBS-18-0-N-16S	CBS-20-0-N-16S
FLUSH NOSECAP	1	WCI-1800N-14S	WCI-1800N-16S	WCI-1800N-18S	WCI-1800N-20S

		24-0-N CBMK-24-0-N	28-0-N CBMK-28-0-N	30-0-N CBMK-30-0-N
START DRILL (3)	2	WCI-SD-24-0-N	WCI-SD-28-0-N	WCI-SD-30-0-N
START REAMER	2	WCI-SR-24-0-N	WCI-SR-28-0-N	WCI-SR-30-0-N
COMBINATION GAGE (4)	1	WCI-CBG-24-0-N	WCI-CBG-28-0-N	WCI-CBG-30-0-N
MANDREL GAGE	1	WCIS-WG-24-0-N	WCIS-WG-28-0-N	WCIS-WG-30-0-N
MANDREL	2	WCI-CBM-24-0-N-2-30	WCI-CBM-28-0-N-2-30	WCI-CBM-30-0-N-2-30
SLEEVES, STRAIGHT	50	CBS-24-0-N-16S	CBS-28-0-N-16S	CBS-30-0-N-16S
FLUSH NOSECAP	1	WCI-1800N-24S	WCI-1800N-28S	WCI-1800N-30S

1) The CWORK-3 tooling kit which augments the CWORK-2B repair kit, includes the seven expendable tooling sets given in this table, as well as a WCI-1800 puller unit, and the WCI-20 powerpak

2) Indicates the quantity of tooling included in each expendable tooling set. If more than 50 holes of any one size are to be processed, it will be necessary to order additional split sleeves

3) Starting drill is required for new holes only

4) Combination Gage checks start hole diameter and verifies coldworking

Each CWORK-3 Kit Contains:

Seven Tooling Sets Above
Puller Unit - WCI-1800-30
Power Pak - WCI-20 (Optional: WCIS-10000)
Four Drawer Mobile Cabinet