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FATIGUE TECHNOLOGY INC.

StopCrackEX™

StopCrackEX® Manual 595069, Revision F
Enhanced Crack Arrest Hole Repair for
Bridges and Steel Structures

Part Number 2720-117

November 9, 2018

This Fatigue Technology Inc. (FTI) document is designed to provide specific instructions for personnel involved in repair of steel structures requiring the use of the Enhanced StopCrackEX Drill Stop Repair Process. A minimal training program is recommended prior to using the process. These instructions detail the procedure to be followed to ensure maximum effectiveness in retarding growth of cracks from drill stop repairs. The performance of this repair procedure can only be assured if the complete system of FTI tooling is used and these procedures are followed.

The information contained in this document is covered by U.S. patents. For more information, visit http://www.fatiguetech.com/patents.asp (StopCrackEX). FTI reserves the right to change the specifications or configurations of kits detailed in this manual as part of our ongoing technical and product improvement program.

WARNING: This document contains technical data, export of which is restricted by the Arms Export Control Act (Title 22, U.S.C., Sec 2751, et seq.) or the Export Administration Act of 1979, as amended (Title 50, U.S.C., App. 2401 et seq.). Violations of these export laws are subject to severe criminal penalties.

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Revision Log

Revision	Description	By	Date
--	Initial Release	LFR/TLI	12/18/2012
-A-	Added Section 7.0 Bushing Model Number Description. Changed wording of "handbook" to "manual" on cover page. Added reference to BTB-1533-B-0-.xxx bushings for use in higher yield strength structures in Section 3.1.	TLI/TMR	1/17/2013
-B-	Updated overflush bushing allowance in Section 3.4 from .050 to .250-inch.	TLI	2/28/2013
-C-	Updated overflush bushing allowance in Section 6.3 Step 9 from .050 to .250 inch. Added exception to overflush allowance to be .050-inch when using higher yield strength bushing in Sections 3.4 and 6.3 Step 9.	TLI	3/28/2013
-D-	Added Table 7.0-2 and updated Section 3.3 to include oversize bushings, tooling, and kits. Added Export Control statement to front cover.	TLI	10/8/2014
-E-	Complete rewrite of manual. Added new section 6.0 to include installing into vessel wall (Kiln), includes flanged bushings and interference pins to plug bushing. Section 6.4 added two more kits StopCrackEX-2A & -2B. Removed section 3.2, covered in section 2.0. Removed section 7.0, covered in 3.1 & 5.4	VWC	8/17/2018
-F-	Corrected part quantities in -2A & -2B kits. Added sentence "Price breaks may apply, contact FTI" in Note 1 of Tables 5.4-1 & 6.4-1.	VWC	11/9/2018

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1.0 INTRODUCTION

This manual specifies the required tooling and procedures for installation of Fatigue Technology Inc. (FTI) StopCrackEX® to arrest cracks in steel structures. The StopCrackEX process is an enhanced temporary drill stop repair.

FTI's StopCrackEX system has been adapted from the aerospace industry and is designed for use by maintenance personnel or contractors involved in the repair, maintenance, and preservation of steel structures. The process is simpler to apply and to install than typical drill stop procedures. It is not intended to be used as a permanent repair. StopCrackEX does not increase the residual strength of the overall structure. Tests have shown that StopCrackEX provides a significant improvement in crack arrest capability compared to traditional drill stops.

Notes:

1. Whenever a crack is discovered, an engineering assessment should be performed to determine whether a temporary drill stop repair is appropriate for the structure based on crack origin, crack length, and orientation to ensure the structure is capable of withstanding ultimate loads and that residual structural integrity requirements are not compromised.
2. The crack retardation performance of the StopCrackEX enhanced crack arrest hole repair procedure is dependent upon the length of the crack, applied loads, material properties, and structural geometry involved. While application of the StopCrackEX procedure to a typical fatigue crack will retard future crack growth when subjected to cyclic tensile loads, StopCrackEX will not improve the structural capability to withstand ultimate loads.
3. The patented StopCrackEX process does not replace traditional drill stops or crack arrest holes (CAH) drilled at the end of a visible crack to slow or arrest crack growth, but instead enhances the drill stop by using a proven technology to expand a bushing into the hole to greatly increase the probability that the crack will not re-initiate and continue to grow.

2.0 PROCESS OVERVIEW

StopCrackEX combines a correctly sized crack arrest hole (CAH) placed ahead of the visible crack tip, or adjacent to it, as explained in Section 3.4, with an initially clearance fit specially designed stainless steel bushing that is expanded radially into the hole using an expansion mandrel, as shown in Figure 2.0-1. Equipped with a StopCrackEX kit and a few minutes of instruction, an operator can quickly install a CAH at the end of the crack and cold expand the appropriate length StopCrackEX bushing into the hole. The length of the bushing is determined by the thickness of the web or member into which the bushing is being expanded. Figure 2.0-2 shows a StopCrackEX bushing installed ahead of a crack in a test coupon.

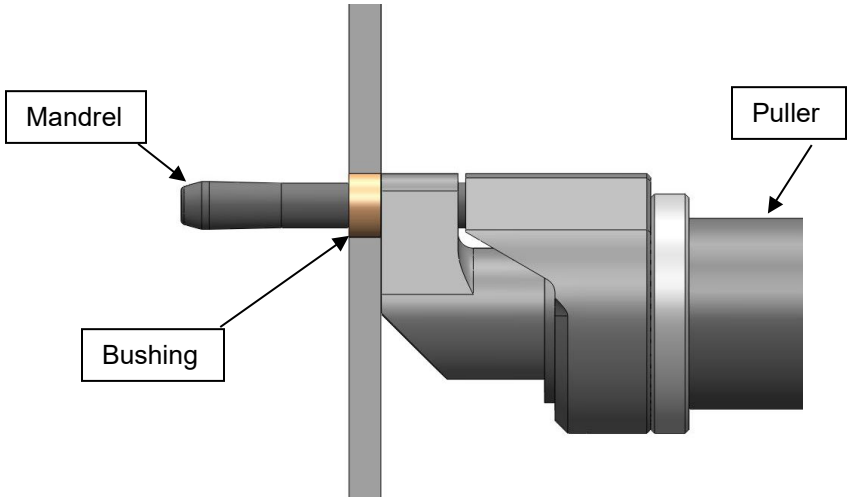

Figure 2.0-1
Expansion of Bushing into Hole

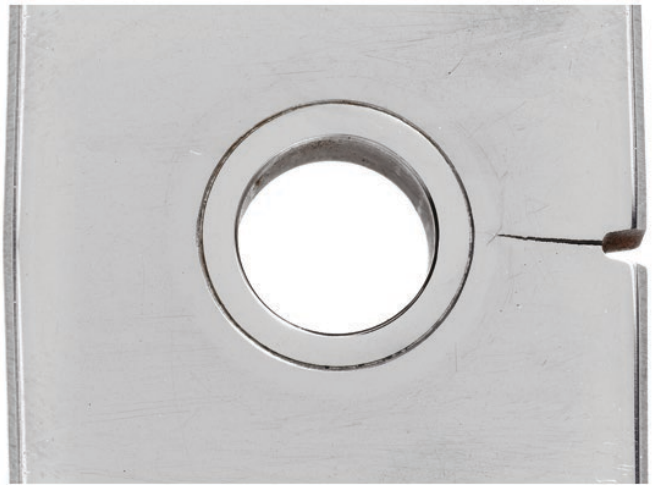

Figure 2.0-2
StopCrackEX Bushing Placed ahead of Crack Tip in a Test Coupon

The action of pulling the expansion mandrel through the bushing will expand the bushing radially into the hole at a very high interference fit, which will locally yield the surrounding material and induce a residual compressive stress around the hole through the thickness of the member as shown in Figure 2.0-3 (viewed through a special photoelastic coating). This beneficial residual stress will shield the hole from the bridge loads that drive the crack. Crack arrest is achieved by the combined beneficial residual stress induced in the material surrounding the hole by the cold expansion process and the resultant high interference fit of the bushing in the hole.

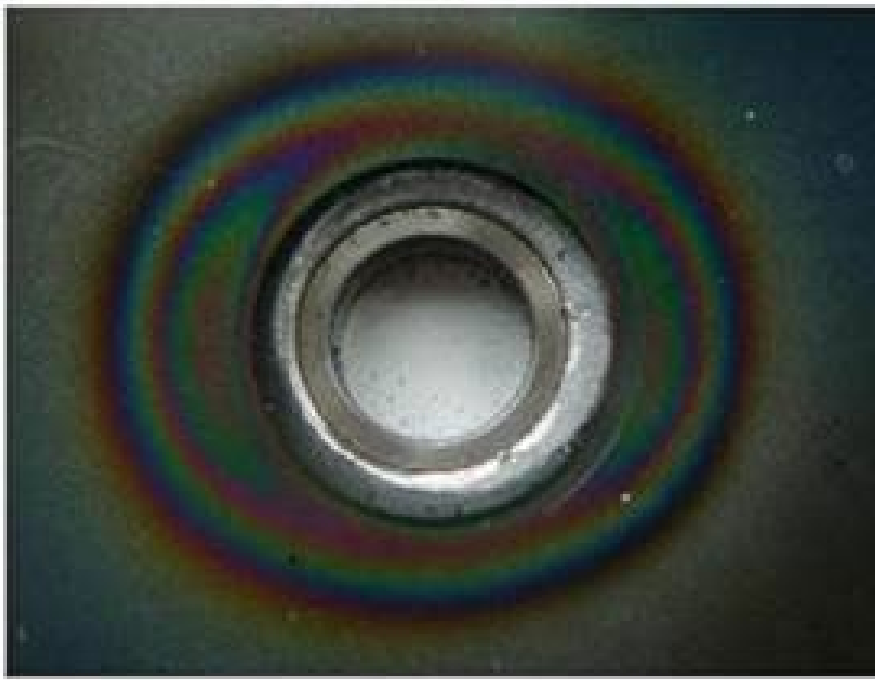

Figure 2.0-3
Residual Compressive Stress Field around a StopCrackEX Bushing
(Viewed through a Photoelastic Coating)

3.0 STEEL STRUCTURE PARAMETERS

3.1 Structure Material

The StopCrackEX system is designed for use in steel structures using A36 steel with maximum yield strength of 60 ksi. For higher-yield-strength steel structures, contact FTI with reference to our BTB-1533-B-X-.xxx bushing series. Higher-yield-strength bushings are required for these applications.

3.2 StopCrackEX Hole Size and Requirements

StopCrackEX bushings require a hole size of **.500 +.002/.000 inch** for proper installation. The correct size can be achieved and verified using the FTI-provided reamer(s) and hole check gage. The hole must be free of lubricants and debris. Paint, primer, or other coatings may be applied after bushing installation. If additional corrosion prevention is necessary, wet primer may be applied to the bore of the CAH prior to installation. Primer should be of low viscosity, as higher viscosity primer may interfere with the effectiveness of the StopCrackEX bushing installation.

In the event of an oversized starting hole, a contingency kit is available to step the hole up to .5156 +.002/.000 inch and install the oversize bushing. Table 5.4-1 and Table 6.4-2 details the kit contents and kit part number to order. Refer to Section 3.3 to determine which StopCrackEX Oversize Kit is required.

3.3 Structure Geometry at Crack Tip

For StopCrackEX to be properly installed, tooling clearance is required. There needs to be 18 inches of space in front of the crack tip away from the steel. Table 3.3-1 shows the two main StopCrackEX Kits based on the steel geometry and surrounding clearance.

Table 3.3-1
Two Main StopCrackEX Kits

Kit	Section	Pg.	Structure Geometry at Crack Tip
StopCrackEX-1	5	8	• Backside clearance (C) greater than .75 inch. • Steel thickness (t) less than 1.5 inches.
StopCrackEX-2	6	18	•Steel thickness (t) less than 3 inches.

StopCrackEX-1, Section 5, is the standard process for CAH installations. See Figure 3.4-1 for an example on an I-beam. This kit and installation method are for steel thickness up to 1.5 inches.

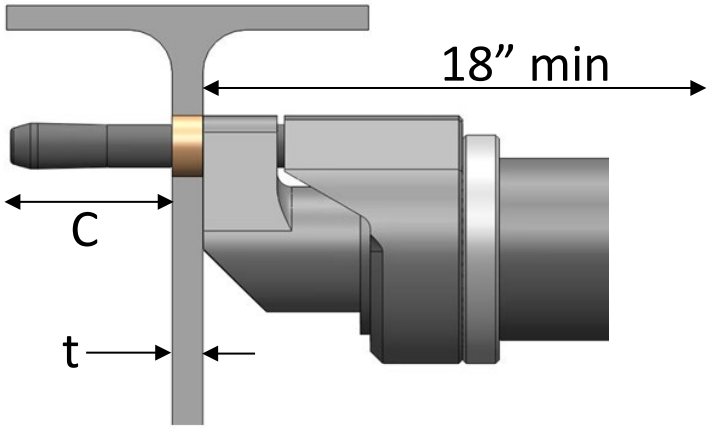

Figure 3.4-1
Side View of I-Beam with Puller

StopCrackEX-2, Section 6, is intended for CAH installations in thicker steel structures or those with little/no backside clearance. See Figure 3.4-2 for an example on a kiln, where the steel can be up to three inches thick with brick on the backside. This kit will include instruction on how to drill into the brick.

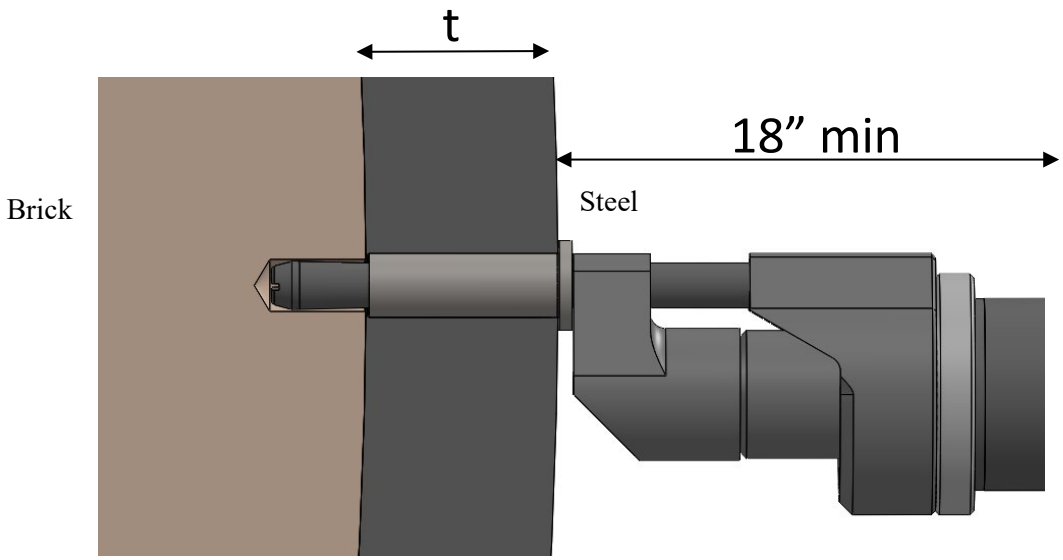

Figure 3.4-2
Side View of Kiln with Puller

3.4 Location of Crack Arrest Hole for StopCrackEX

The selection of the CAH depends on the location of the crack tip with surrounding features (such as welds, joints, fasteners, etc.). Finding the end of the crack tip is very important to the success of the StopCrackEX product. Using approved nondestructive inspection (NDI) technique, locate and mark the end of the crack.

The following two subsections will help you determine where to put the CAH in relation to the crack tip. The actual process is similar for both cases using StopCrackEX tooling.

3.4.1 Cracks Growing away from Features

In this case the CAH is placed 5/16-inch ahead of the crack tip with the center of the CAH located such that it will leave about 1/16-inch ligament between the end of the crack and the outer edge of the final CAH. With the nominal 1/2-inch hole, the center of the drill stop will be 5/16-inch ahead of the crack tip in line with the direction of the crack as shown in Figure 3.4-3 and Figure 3.4-4.

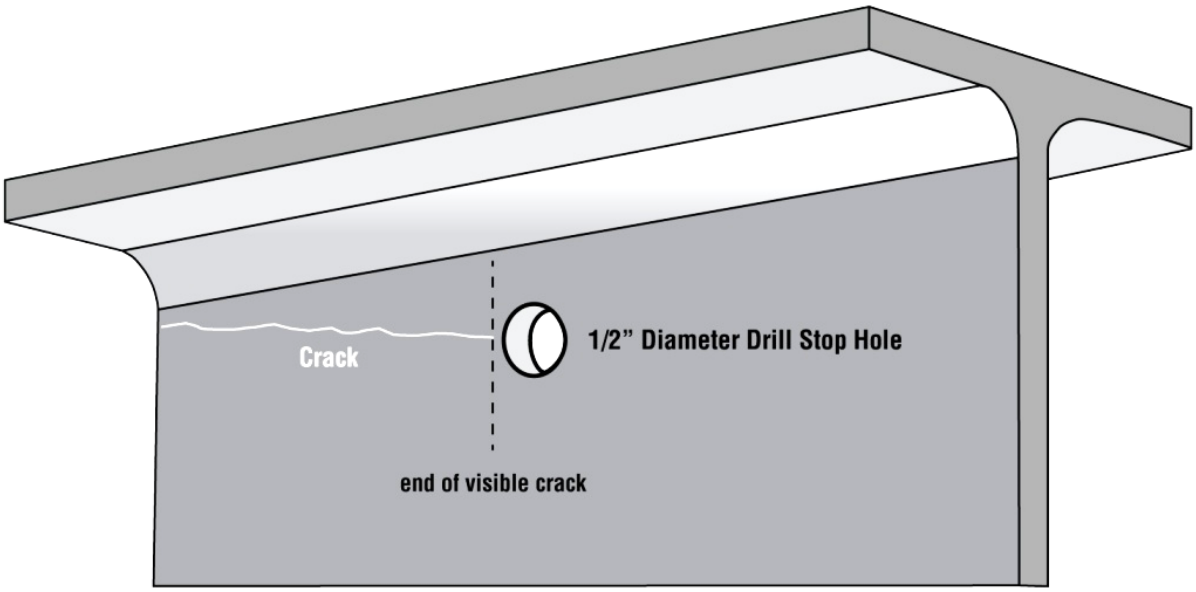

Figure 3.4-3
Crack Growing away from Features

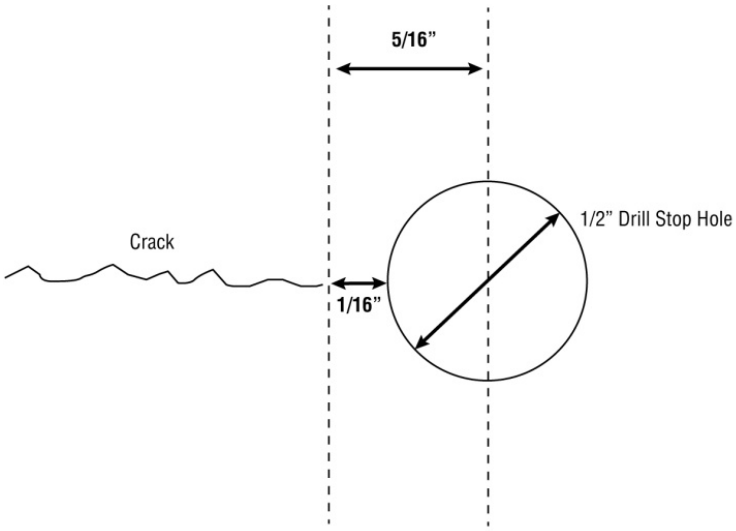

Figure 3.4-4
Crack Arrest Hole Placement for Crack away from Features

3.4.2 Cracks Growing along Features

In the case of a crack growing along a feature (such as a weld, joint, fastener, etc.) the location of the CAH is adjacent to the path of the crack and not directly ahead of the crack tip, as shown in Figure 3.4-5 and Figure 3.4-6 for the 1/2-inch StopCrackEX bushing. The purpose of this is to not cut into the weld (or joint, fastener, etc.) and compromise the strength of it. The center of the hole is such that the edge of the hole will be a tangent to the path of the crack with the crack tip in line with the edge of the hole as shown. The resultant residual compressive stress will close the crack tip and delay further growth of the crack.

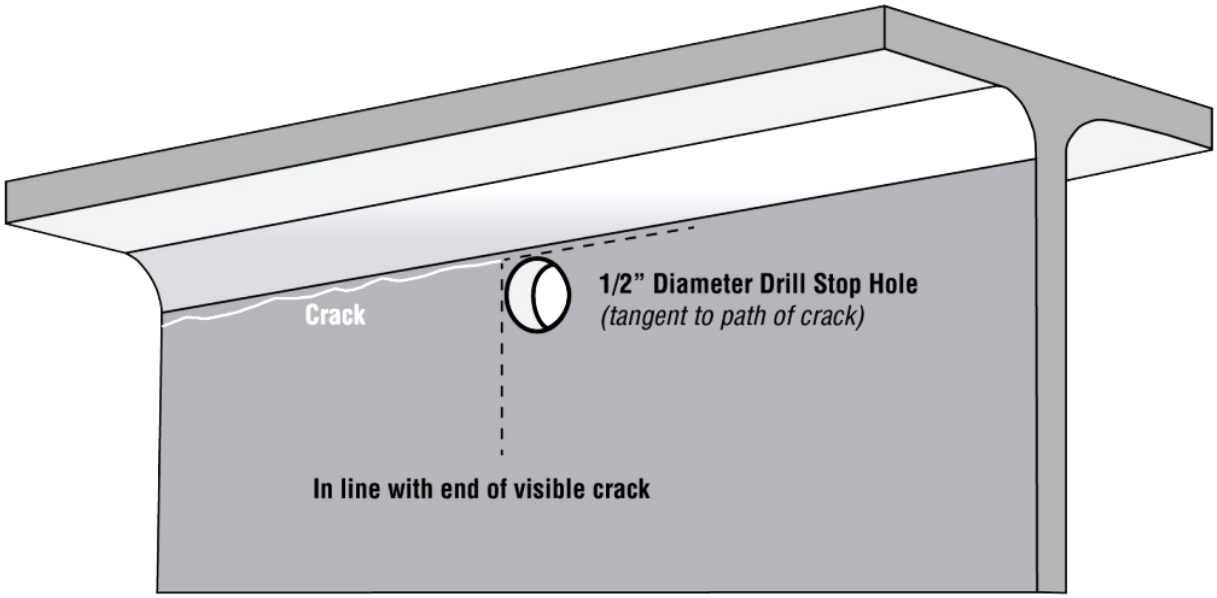

Figure 3.4-5
Crack Growing along Feature

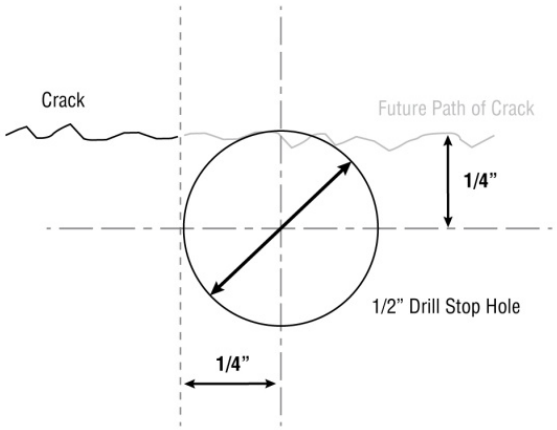

Figure 3.4-6
Location of Crack Arrest Hole for Crack along Feature

3.5 Edge Margin

Minimum edge margin is the ratio of the distance from the edge of the structure (e) to the diameter of the hole (D), as shown in Figure 3.5-1. Effective bushing installation and arresting crack growth is limited to e/D=1.

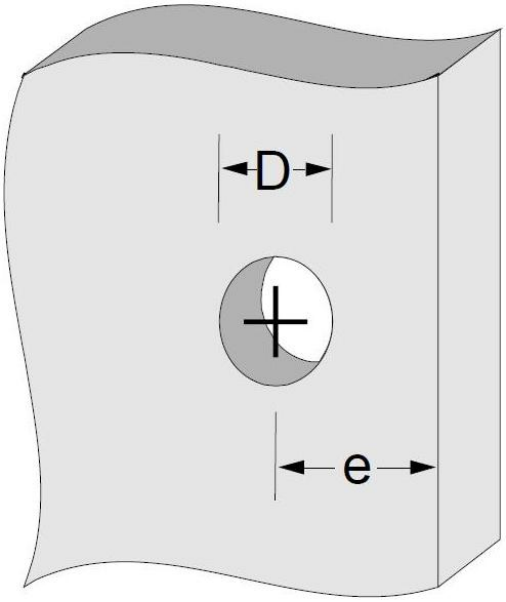

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Figure 3.5-1
Crack Arrest Hole Edge Margin

3.6 Hole Spacing

The StopCrackEX bushing requires a minimum 1.5D (D = diameter of hole) hole spacing to closest crack arrest hole, as shown in Figure 3.6-1.

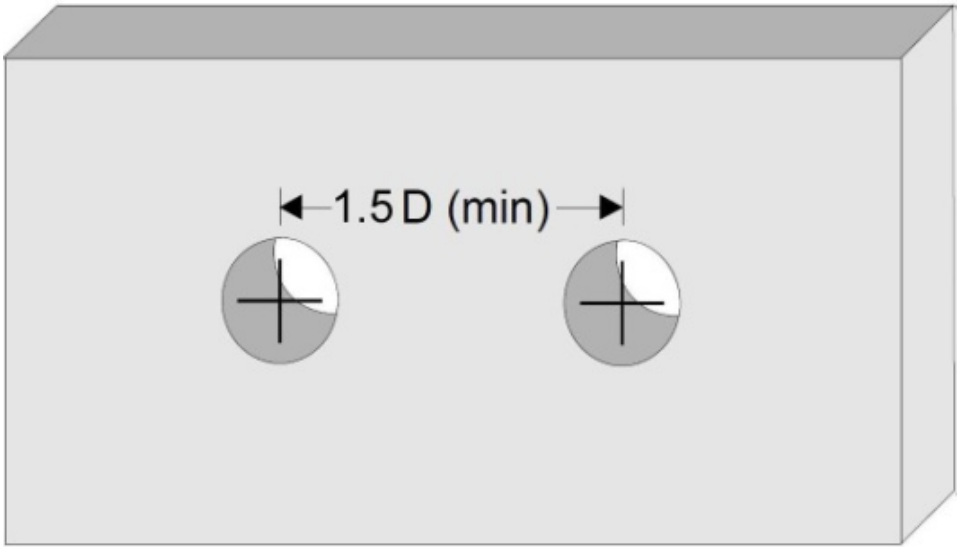


Figure 3.6-1
CAH Hole Spacing

4.0 SAFETY

StopCrackEX is designed as a complete and compatible tooling system designed to optimize the benefits of the cold expansion process that has been shown to improve the crack arrest capability of a CAH. The procedure described in this instruction should be followed to ensure correct bushing installation and the safety of the operator.

WARNING:
This tooling requires the use of very high hydraulic pressure to install the expanded bushing. Every attempt has been made to make FTI tooling as safe as possible; however, for operator safety, the following precautions must be followed:

- Wear safety glasses at all times during the hole drilling/reaming and the cold expansion process.
- Nobody should stand in front of the puller unit during the bushing installation processes.
- Disconnect the puller from the hydraulic hand pump or PowerPak whenever maintenance is being performed on the puller.
- Relieve the pressure in the hydraulic hand pump, disconnect air pressure from PowerPak, or disconnect power from the electric PowerPak whenever transporting the puller connected to either unit.
- Before operation of the puller, check that all connections, fittings, and caps are secure and tight.
- In the event of a ruptured or leaking hydraulic hose or a leaking hydraulic fitting on the puller, IMMEDIATELY RELEASE THE TRIGGER WHEN USING THE POWERPAK OR RELIEVE THE PRESSURE IN THE HAND PUMP. The PowerPak will return to the neutral position. Never use your hands to grasp a leaking hose under pressure. The force of escaping hydraulic fluid can cause serious injury. Only after the hydraulic pressure has been relieved in the hose should the source of the leak be investigated.
- Periodically inspect the hose for wear or damage that could cause failure of the hose and possibly result in injury.
- DO NOT attempt to disconnect the hydraulic hose while the hose is pressurized.
- DO NOT expose hoses to potential hazards such as extreme heat or cold, sharp surfaces, heavy impact, vehicular traffic, toxic materials or paints.
- DO NOT allow hoses to kink, twist, curl, or bend so tightly that the oil flow within the hose is blocked or reduced.
- DO NOT exceed 10,000 psi hydraulic pressure generated by the hand pump or PowerPak. Pressure beyond the rated capacities may result in personal injury.
- Periodically check the mandrel for wear, using the check gage provided, and DO NOT use mandrels that have been worn beyond their minimum allowable diameter.
- DO NOT use tools that have become worn or dull. Replace them with new parts having the same FTI model number.
- Keep cutting tools sharp and in good condition.

5.0 STOPCRACKEX-1

StopCrackEX-1, is intended for CAH installations in steel structures at or less than 1-inch thickness. A typical scenario is on an I-beam.

Confirm from Section 3.3 that this kit and installation method is correct for your application.

5.1 Preparation for StopCrackEX-1

5.1.1 Hole Preparation

The CAH center location has been determined as described in Section 3.4. Use of 1187-762 Center Punch is recommended prior to drilling pilot hole and will help initiate drilling at the correct location.

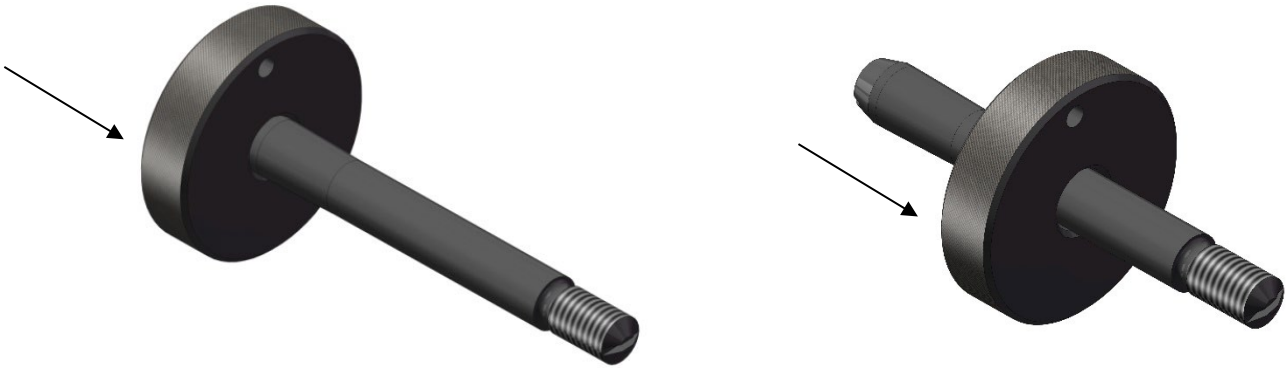
It is recommended to use a magnet mounted drill. These drills will hold their position when the drill bits are switched out. Hand power drills can be used but could result in non-circular holes. However, if the drilling process is started with a magnet mount drill, but then removed before hole completion, it is recommended to finish the step with a hand drill.

5.1.2 Steel Thickness

Knowing the thickness of the steel member at the crack location has two purposes: It will help with drilling the CAH as well as knowing what bushing needs to be used. Be sure to know which bushings are required and have on hand before drilling.

5.1.3 Tooling Preparation

Check the mandrel major diameter for wear. Insert the mandrel into the mandrel gage, opposite of the threaded end. If the mandrel is excessively worn and goes through the check fixture, discard the mandrel and select a new mandrel (Figure 5.1-1).



View 1
ACCEPTABLE

View 2
UNACCEPTABLE

Figure 5.1-1
Check Mandrel for Wear

5.1.4 Cycling Puller Unit

Always cycle the assembled puller unit and pump prior to use. This ensures the equipment is properly configured. If the mandrel does not return fully into the jaw, or the assembled equipment does not function properly, please contact FTI for assistance before working on your steel structure.

1. Assemble the puller and tooling, without a bushing, using the following steps as shown in Figure 5.1-2.
   i. Thread the lock ring onto the hydraulic puller.
   ii. Thread on the mandrel adapter and orient as desired.
   iii. Back the lock ring into the mandrel adapter until hand tight.
   iv. Thread jaw into the puller and align with the mandrel adapter.
   v. Take mandrel and slide through jaw and thread into mandrel adapter.

   The puller is now ready to use.

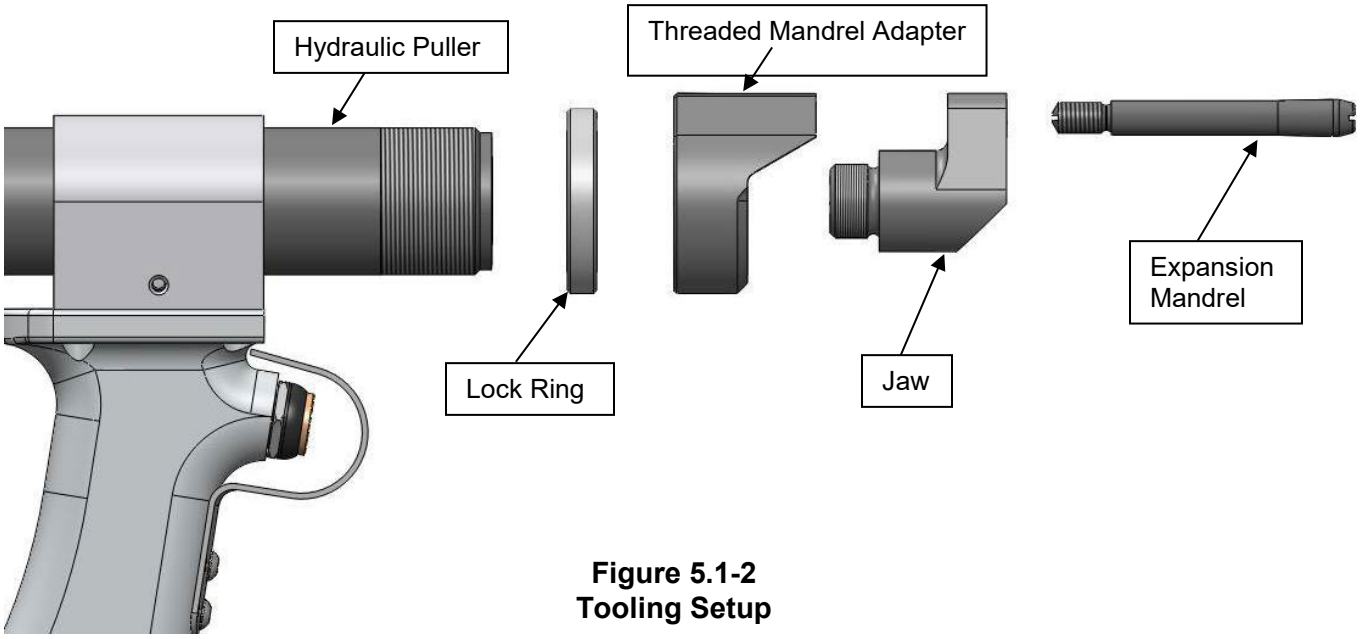


Figure 5.1-2
Tooling Setup

2. Attach the CP5-H-30-SCX Puller to the FTP-19 Hydraulic Hand Pump or the FT-E102 Electric PowerPak.

3. Cycle the puller to ensure the mandrel retracts fully inside the jaw.

5.2 Creating Crack Arrest Hole Procedure

5.2.1 Drilling Hole

1. Drill a pilot hole at the marked center using the Pilot Drill BTPD-1533-A-0 as shown in Figure 5.2-1.

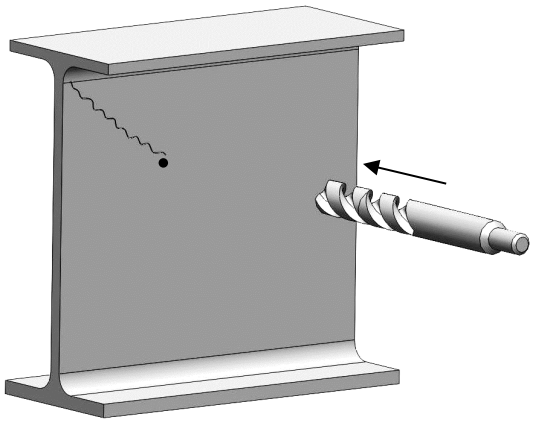


Figure 5.2-1
Pilot Hole Drilling

2. Using the Starting Drill BTSD-1533-A-0, drill hole through.

3. Using the Starting Reamer BTSR-1533-A-0, ream the hole to the final size and finish. Note: the non-cutting pilot on the reamer is sized to fit the hole produced by the starting drill, as shown in Figure 5.2-2. If required, clean the hole to remove excess cutting fluid/lubricant, chips, or debris.

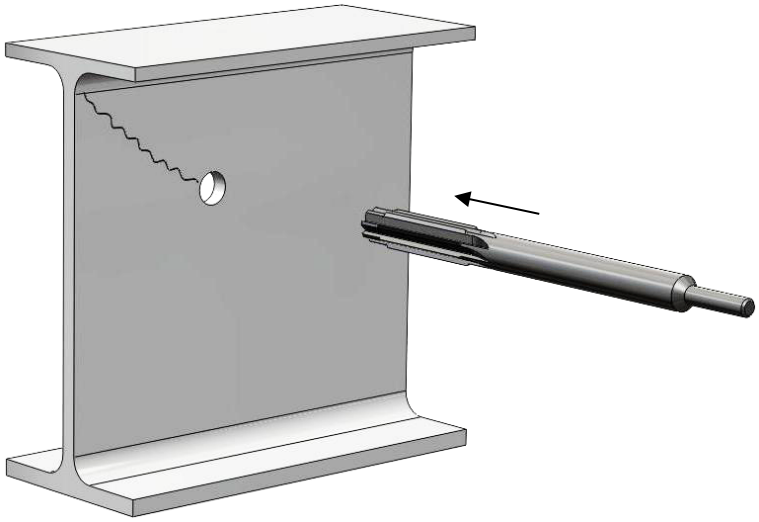


Figure 5.2-2
Pilot Hole Ream

5.2.2 Checking Hole

Verify the correct starting hole using the blade end of the combination gage BTCG-1533-A-0 as shown in Figure 5.2-3 and 5.2-4. Rotate gage 90 degrees to check for ovality. Note: If the starting hole is oversize, contact Fatigue Technology Inc.

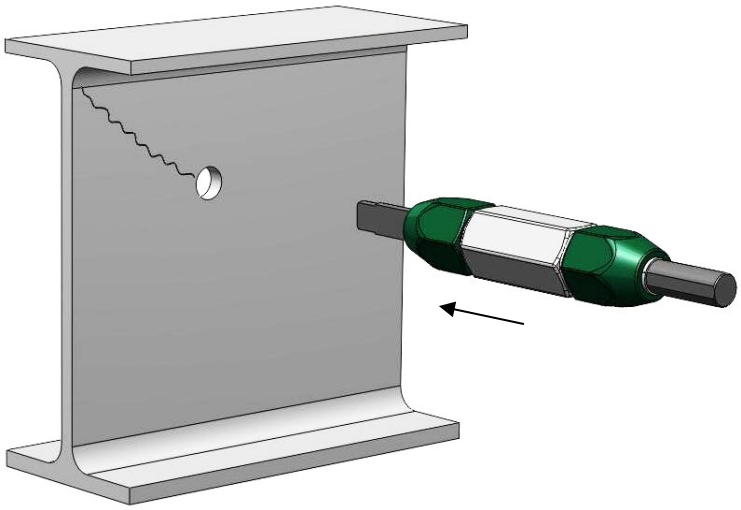
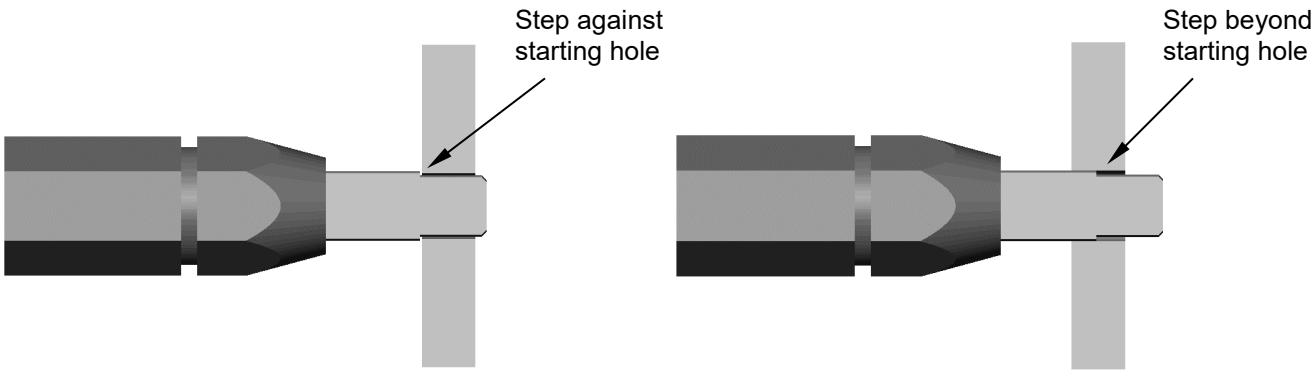


Figure 5.2-3
Hole Diameter Check



View 1
Starting hole within tolerance
ACCEPTABLE

View 2
Starting hole oversize
NOT ACCEPTABLE

Figure 5.2-4
Starting Hole Gage

5.3 StopCrackEX Installation Procedure

5.3.1 Structure Thickness and Bushing Length Selection

Determine the thickness of the material by measuring hole depth. A depth gage rule (1187-761) is provided in the basic kit for this purpose, shown in Figure 5.3-1.

Figure 5.3-1
Depth Gage

Select the correct length bushing or trim a bushing to match thickness of the material. Bushings provided in the kits are .25, .50, and .75 inches in length, see tooling list in Section 5.4.

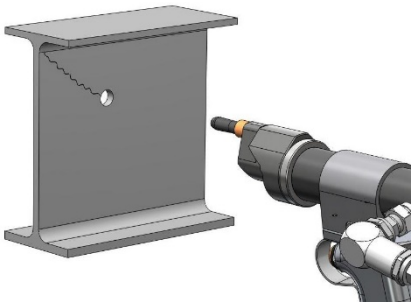
Note: The bushing may be overflush by up to .250 inch without compromising effectiveness, with the exception of the higher yield strength bushings noted in Section 3.1, which are limited to .050 inch overflush. Bushings should not be installed underflush to avoid reducing the effectiveness of arresting crack growth.

Note: If additional corrosion protection is necessary, wet primer may be applied to the bore of the CAH prior to installation of the bushing. The area around the repair can also be primed and painted.

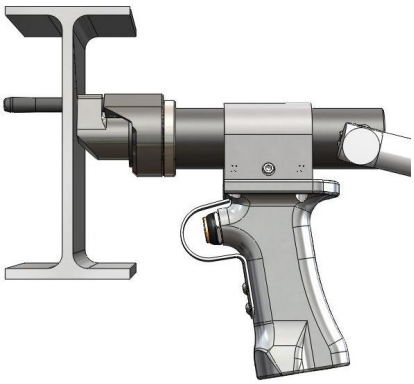
5.3.2 Bushing Installation

1. Using the following steps in Figure 5.3-2, cold expand the StopCrackEX bushing into the hole.

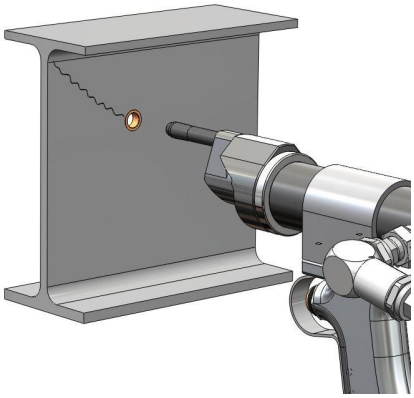
Place bushing(s) onto the back end of mandrel. Insert the mandrel through the jaw and thread into adapter.



Place mandrel and bushing into hole and hold nosecap firmly against structure.



Activate the puller by manually operating the hand pump or depressing the trigger to start the electric PowerPak.



The mandrel will pull through the bushing in the hole and cold expand the bushing into the surrounding material.

Figure 5.3-2
Bushing Cold Expansion Process

2. Verify cold expansion of bushing with plug gage end of the combination gage BTCG-1533-A-0 as shown in Figure 5.3-3. If the plug gage does not fit into bushing ID, then this installation has not been expanded properly. Here are a few possible scenarios:

   a. If a mandrel is excessively worn (goes through the gage), discard it and select a new one as outlined in Section 5.1.
   b. The steel material is not similar to A36 steel with yield strength under 60 ksi.
   c. The plug gage may be compromised and is out of calibration. If the plug gage was dropped it may have damaged the measuring ends.

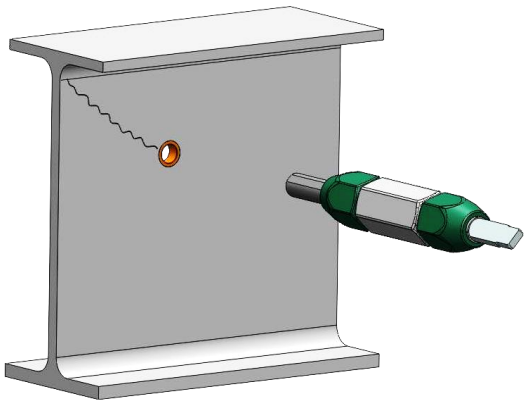


Figure 5.3-3
Bushing Cold Expansion Verification

3. Installation is now complete.

5.4 TOOLING OVERVIEW

The tooling required for StopCrackEX-1 of 1/2-inch diameter crack arrest holes is packaged in the kit (FTI-StopCrackEX-1A) shown in Figure 5.4-1. The basic kit includes a hydraulic puller unit that can be used with the hydraulic hand pump contained in the basic kit or with the optional electric PowerPak. Other tools are a nosecap and jaw assembly, two expansion mandrels, a range of different length 1/2-inch diameter bushings, and process checking tools to verify the correct starting hole size, correct expansion of the bushing, and the wear condition of the mandrel.

The StopCrackEX pre-lubricated stainless steel bushings are manufactured with the correct inside and outside diameters for the 1/2-inch CAH. Bushing lengths vary and should be selected from those provided in the kit corresponding to the thickness of the structure they are to be installed in. Oversize bushings are not included in the basic kit.

A complete list of the tooling contained in the FTI-StopCrackEX-1A Kit is in Table 5.4-1.

Figure 5.4-1
StopCrackEX-1A Kit

Table 5.4-1
StopCrackEX-1 Tools and Equipment

Quantity	Part Number	Description
Kit	**FTI-StopCrackEX-1A**	**StopCrackEX Standard Kit**
1	CP5-H-30-SCX	Hydraulic puller unit
1	FTP-19	Hand pump
1	6599-001	Tooling case assembly
1	1187-760	Flashlight
1	2720-117	Manual
1	FTI-StopCrackEX-Tools	Tooling sub-kit
1	FTI-StopCrackEX-CapAssembly-.50	Nosecap assembly sub-kit
1	FTI-StopCrackEX-Bush-.250	.250 inch bushings, 25 in box
1	FTI-StopCrackEX-Bush-.437	.437 inch bushings, 25 in box
1	FTI-StopCrackEX-Bush-.500	.500 inch bushings, 25 in box
1	FTI-StopCrackEX-Bush-.750	.750 inch bushings, 15 in box
Kit	**FTI-StopCrackEX-Tools**	**StopCrackEX Tooling Kit**
1	BTG-1533-A-0	Mandrel check gage
1	BTCG-1533-A-0	Combination Hole check gage
2	BTM-1533-A-0	Mandrel
2	BTPD-1533-A-0	Pilot drill .2500 inch
2	BTSD-1533-A-0	Starting drill .4844 inch
2	BTSR-1533-A-0	Starting reamer .5000 inch, piloted
1	1187-761	Depth gage
1	1187-762	Center hole punch
Kit	**FTI-StopCrackEX-1AOS**	**StopCrackEX Oversize Kit**
1	FTI-StopCrackEX-BushOS-A	Oversize Bushings
1	BTSR-1533-A-1	Oversize Starting Reamer .5156 inch
1	BTCG-1533-A-1	Oversize Hole Check Gage
Kit	**FTI-StopCrackEX-BushOS-A**	**Oversize Bushing Sub Kit**
5	BTB-1533-A-1-.250	.250 inch oversize bushing
5	BTB-1533-A-1-.500	.500 inch oversize bushing
5	BTB-1533-A-1-.750	.750 inch oversize bushing

Note:
1. Any part can be purchased within the kits of the noted quantities instead of purchasing entire kit. Price breaks may apply, contact FTI. Purchasing entire kit will include cases with cut out foam.
2. All bushing dimensions are lengths. Bushings diameters are either nominal or oversize as stated in Section 3.3.

6.0 STOPCRACKEX-2

StopCrackEX-2 is intended for CAH installations in thicker steel structures typically with no backside clearance. For example a kiln, where the steel can be up to three inches thick with brick on the backside.

Confirm from Section 3.3 that this kit and installation method is correct for your application.

Tools needed that are not provided in kit: magnet mount drill (recommended, not required), 3/8-inch masonry bit, and air hammer or sledge hammer.

6.1 Preparation for StopCrackEX-2

6.1.1 Hole Preparation

The CAH center location has been determined as described in Section 3.4. Use of 1187-762 Center Punch is recommended prior to drilling pilot hole and will help initiate drilling at the correct location.

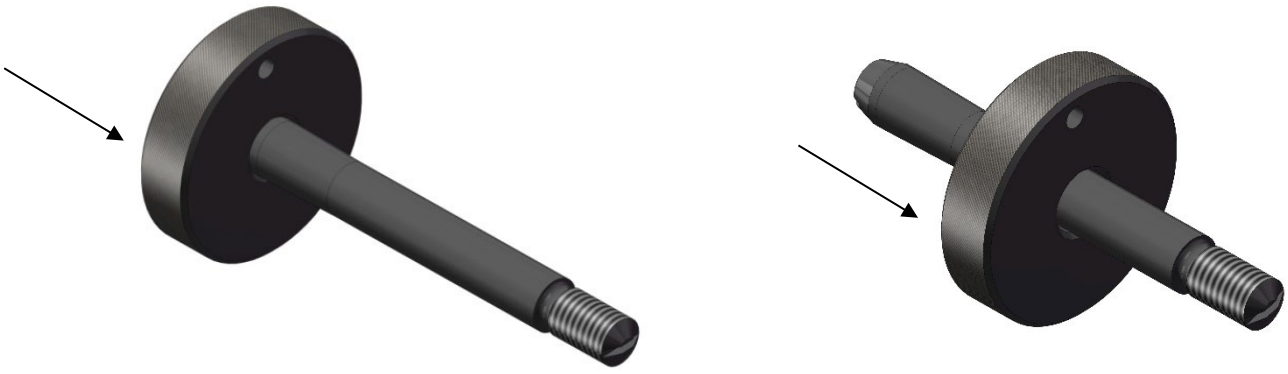
It is recommended to use a magnet mounted drill. These drills will hold their position when the drill bits are switched out. Hand power drills can be used but could result in non-circular holes. However, if the drilling process is started with a magnet mounted drill, but then removed before hole completion, recommend finishing the step with a hand drill.

6.1.2 Steel Thickness

Knowing the thickness of the steel member at the crack location has two purposes: It will help with drilling the CAH as well as knowing what bushing needs to be used. Be sure to know which bushings are required and have on hand before drilling.

6.1.3 Tooling Preparation

Check the mandrel major diameter for wear. Insert the mandrel into the mandrel gage, opposite of the threaded end. If the mandrel is excessively worn and goes through the check fixture, discard the mandrel and select a new mandrel (Figure 6.1-1).



View 1
ACCEPTABLE

View 2
UNACCEPTABLE

Figure 6.1-1
Check Mandrel for Wear

6.1.4 Cycling the Puller Unit

This ensures that your CP5-H-30-SCX puller unit and FTP-19 hand pump are ready for use. If you find an issue with the puller unit/pump/PowerPak after following this procedure, please contact FTI for assistance before working on your steel structure.

1. Assemble the puller and tooling, without bushing(s), using the following steps as shown in Figure 6.1-2.
   vi. Thread the lock ring onto the hydraulic puller.
   vii. Thread on the mandrel adapter and orient as desired.
   viii. Back the lock ring into the mandrel adapter until hand tight.
   ix. Thread jaw into the puller and align with the mandrel adapter.
   x. Take mandrel and slide through jaw and thread into mandrel adapter.

   The puller is now ready to use.

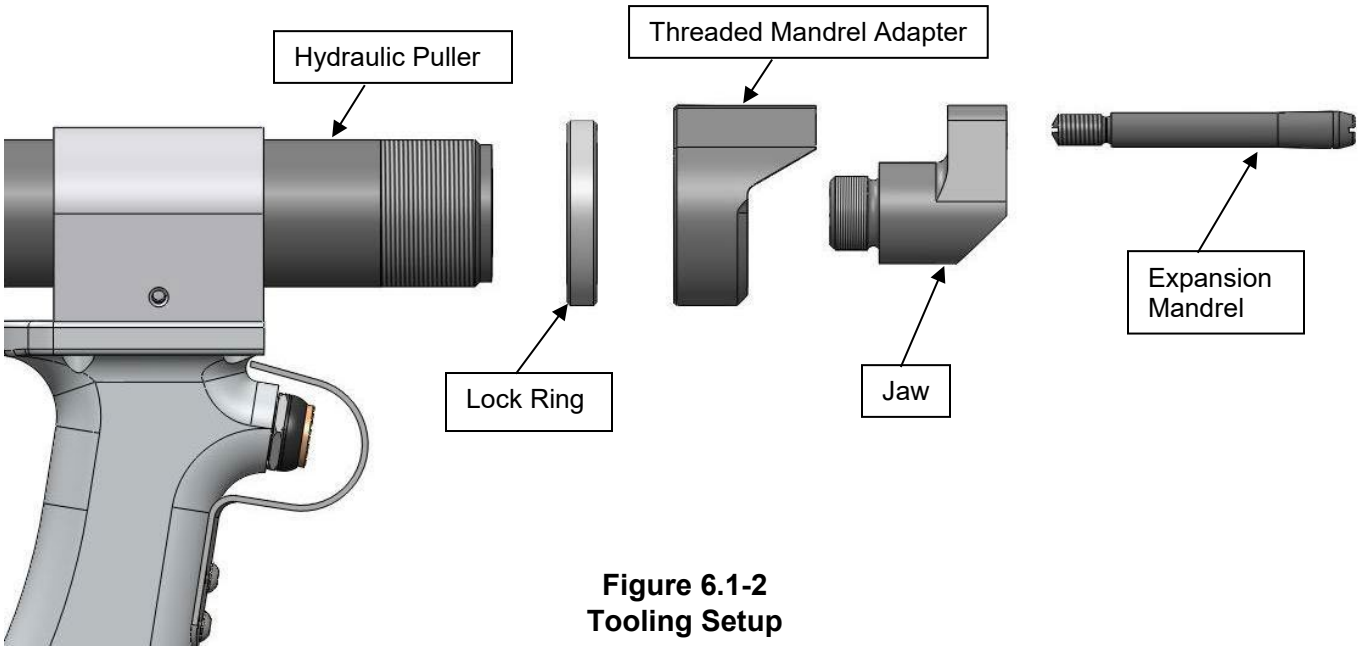


Figure 6.1-2
Tooling Setup

2. Attach the CP5-H-30-SCX Puller to the FTP-19 Hydraulic Hand Pump.

3. Cycle the puller to ensure the mandrel retracts fully inside the jaw.

Note: the FT-E102 Electric PowerPak can be used in place of the FTP-19 Hydraulic Hand Pump.

6.1.5 Cycling the Little Brute Puller Unit with Hydraulic PowerPak

Always cycle the assembled puller unit and pump prior to use. This ensures the equipment is properly configured. If the mandrel does not return fully into the jaw, or if the assembled equipment does not function properly, please contact FTI for assistance before working on your steel structure.

1. Assemble the puller and tooling, without bushing(s), using the following steps as shown in Figure 6.1-3.
   a. Thread the mandrel adapter onto the piston inside hydraulic puller, and hand tighten.
   b. Thread jaw into the puller hand tight.
   c. Take mandrel and slide through jaw and thread into mandrel adapter hand tight.

   The puller is now ready to use.

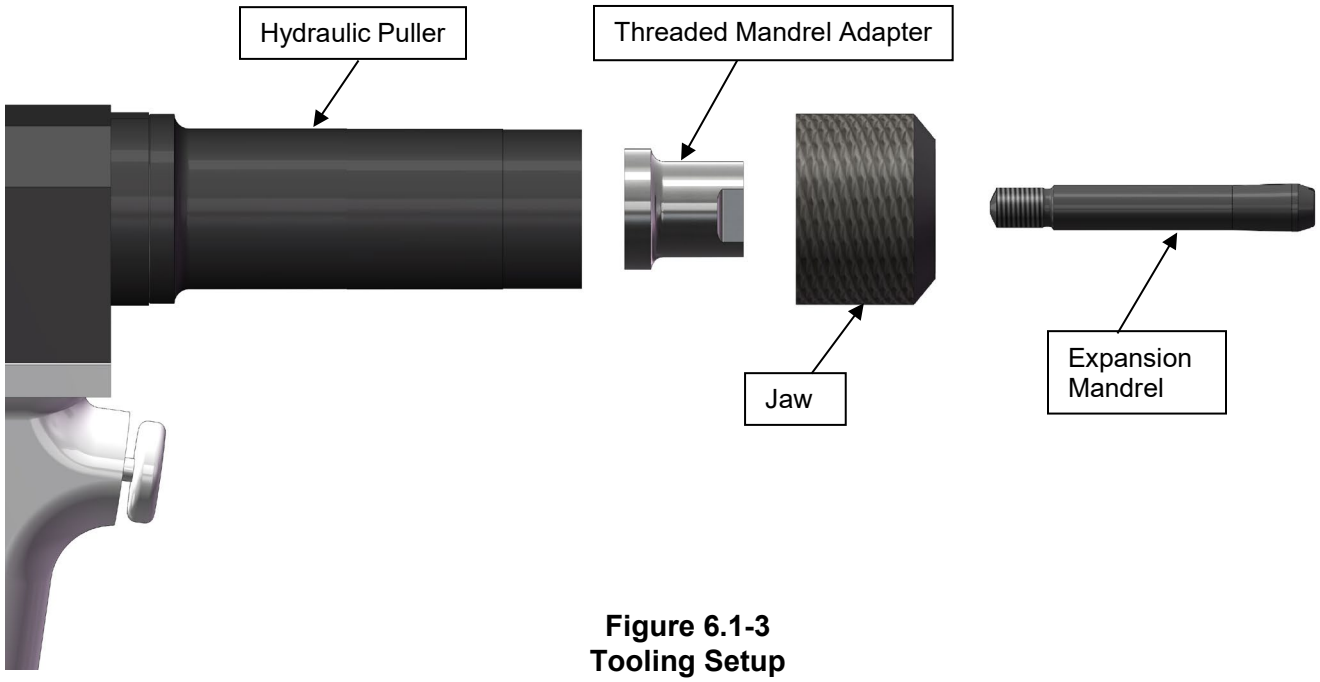


Figure 6.1-3
Tooling Setup

2. Attach pressured air hose to the FT-20 Hydraulic PowerPak. The required air pressure is 90-120 PSI and flow rate is 20 CFM.

3. Attach the LB-30 Puller to the FT-20 Hydraulic PowerPak.

4. Cycle the puller to ensure the mandrel retracts fully inside the jaw.

6.2 Creating Crack Arrest Hole Procedure

The figures used are a cut away from a curved vessel surface, where the grey is the steel surface and the brown is brick.

6.2.1 Drilling Hole

1. Use of 1187-762 Center Punch is recommended prior to drilling pilot hole.

2. Drill a pilot hole at the marked center position using Pilot Drill BTPD-1533-B-0 as shown in Figure 6.2-1. Drill until the drill point touches the brick.

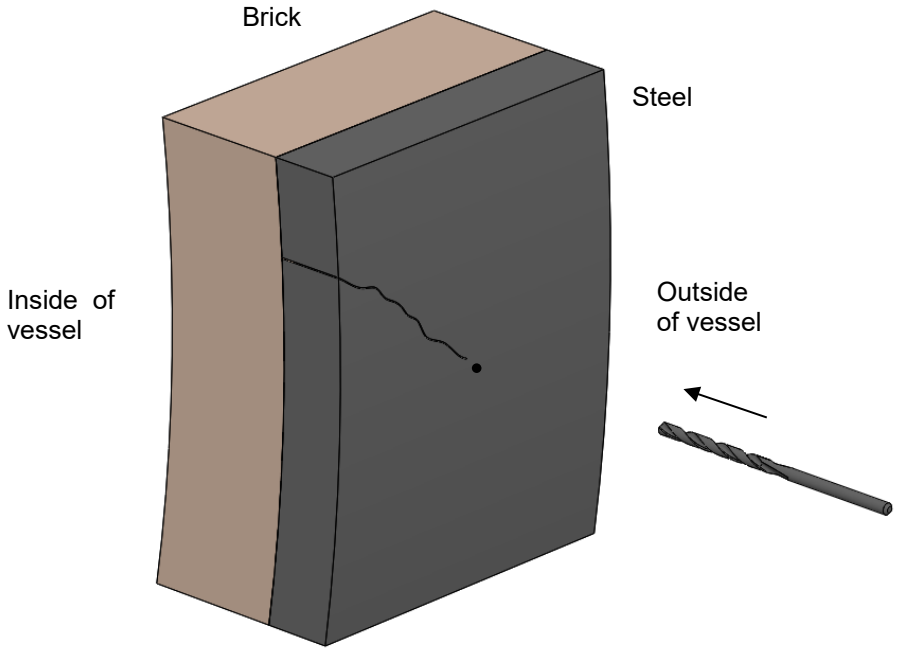


Figure 6.2-1
Drilling of Pilot Drill

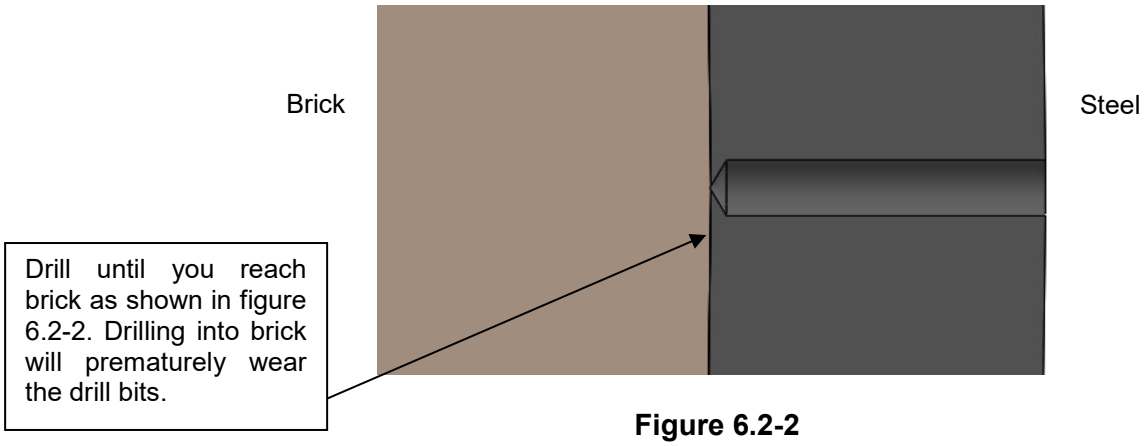


Figure 6.2-2
Cross Section of Pilot Hole

3. Using the Starting Drill BTSD-1533-B-0, drill hole through steel until the point goes just into brick as shown in Figure 6.2-3.

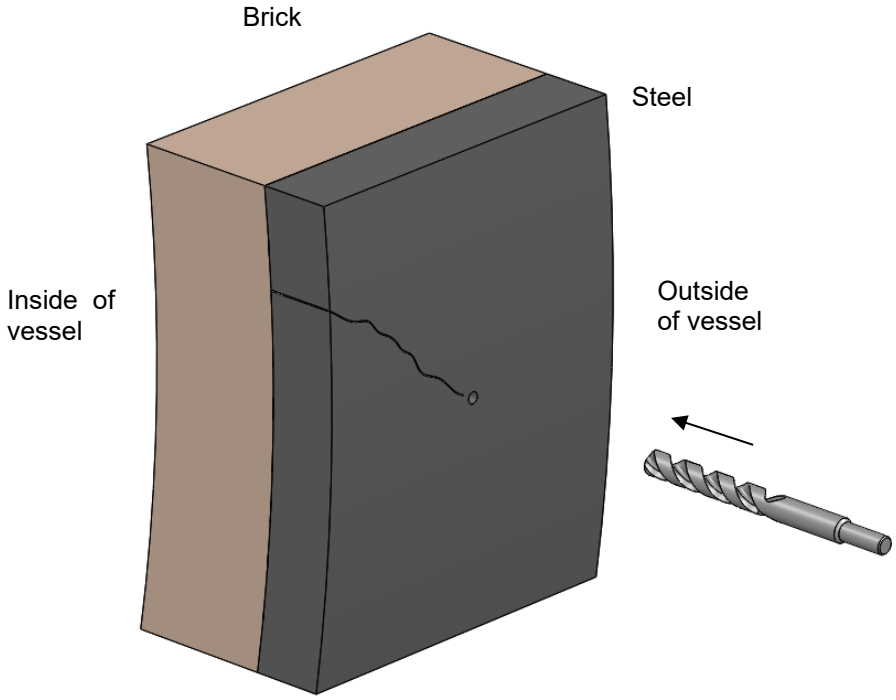


Figure 6.2-3
Drilling of Starting Drill

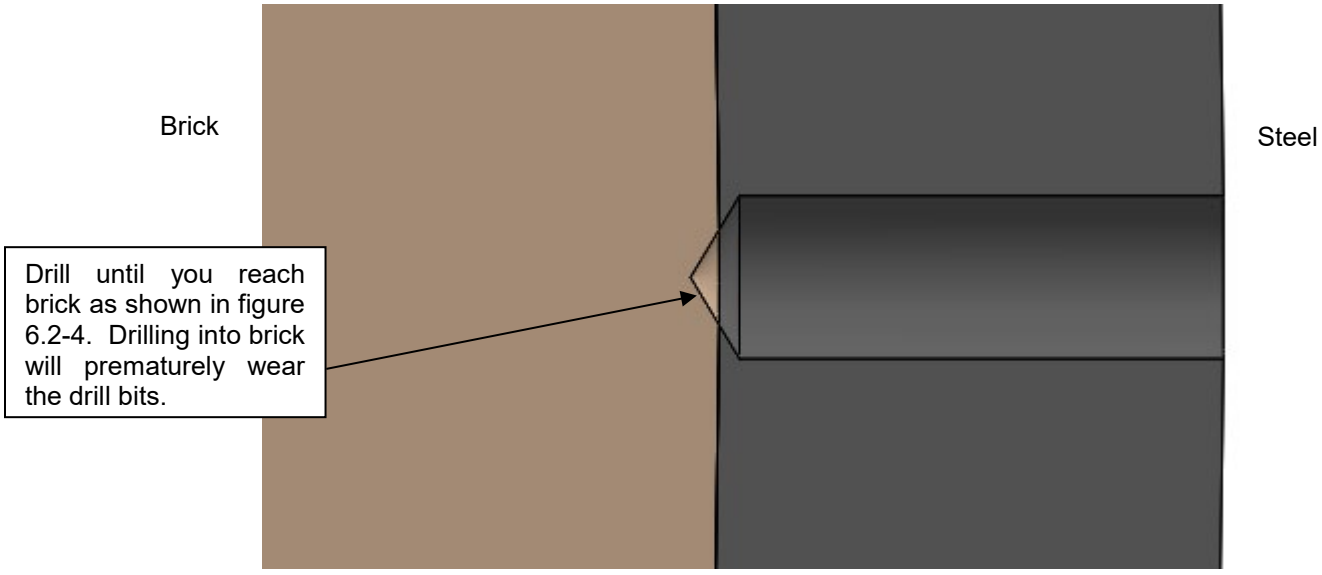


Figure 6.2-4
Cross Section of Starting Hole

4. The mandrel requires a backside clearance of at least .75 inches as shown in Figure 6.2-6. Use a 3/8-inch masonry bit (not sold with kits). If using the magnet mounted drill, complete the entire drilling operation to include the brick before moving the drill. A hammer drill may be required to drill through the brick.
    a. While drilling the brick it is important to not remove metal from the steel hole.
    b. DO NOT USE a 1/2-inch masonry bit, it will oversize the steel hole.
    c. Clean the hole to remove excess cutting fluid/lubricant, chips, or debris.

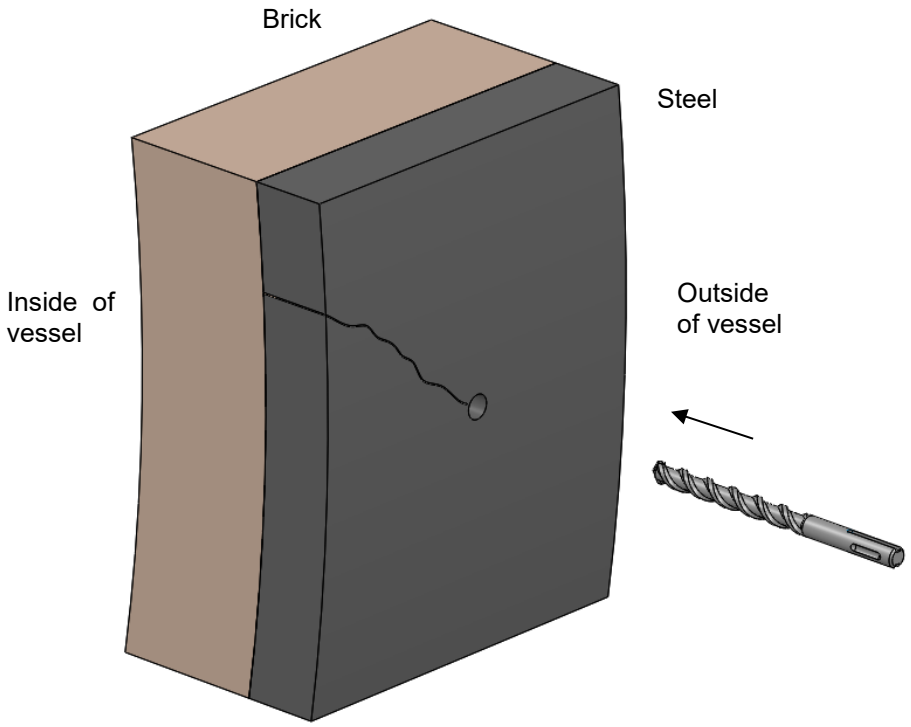


Figure 6.2-5
Drilling of Masonry Bit

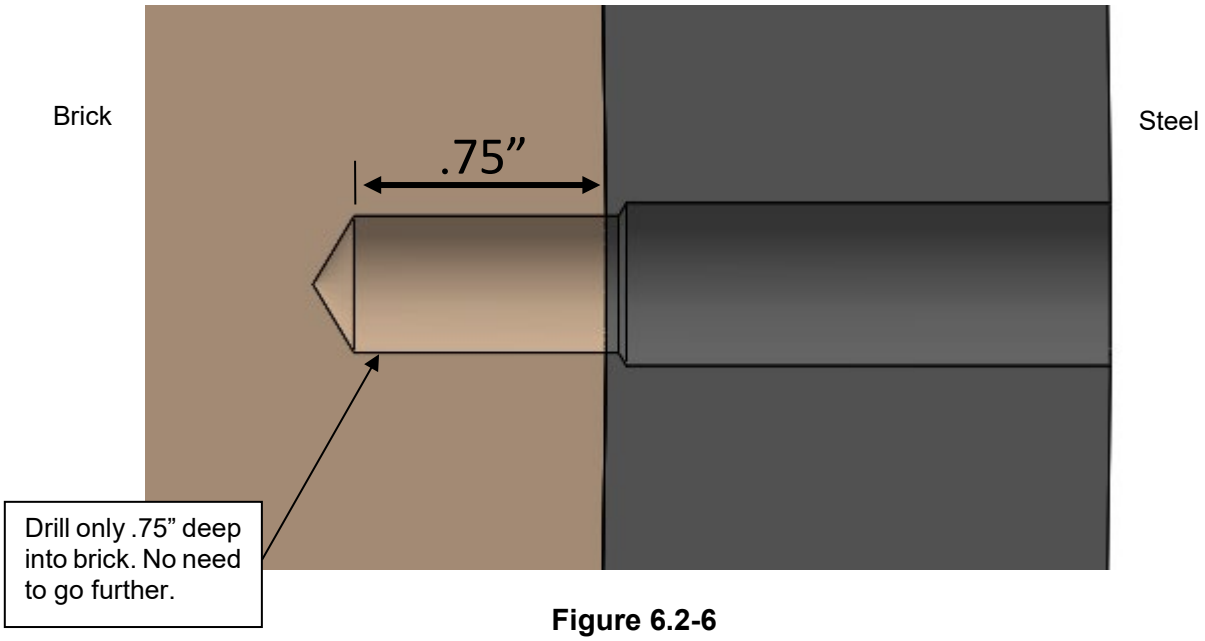


Figure 6.2-6
Cross Section of Masonry Hole

5. Using the Starting Drill BTSD-1533-B-0, chase hole entirely through steel as shown in Figure 6.2-7. This makes the hole uniform throughout steel.
    a. If the magnet mounted drill was removed, continue the drilling operations with a hand drill.

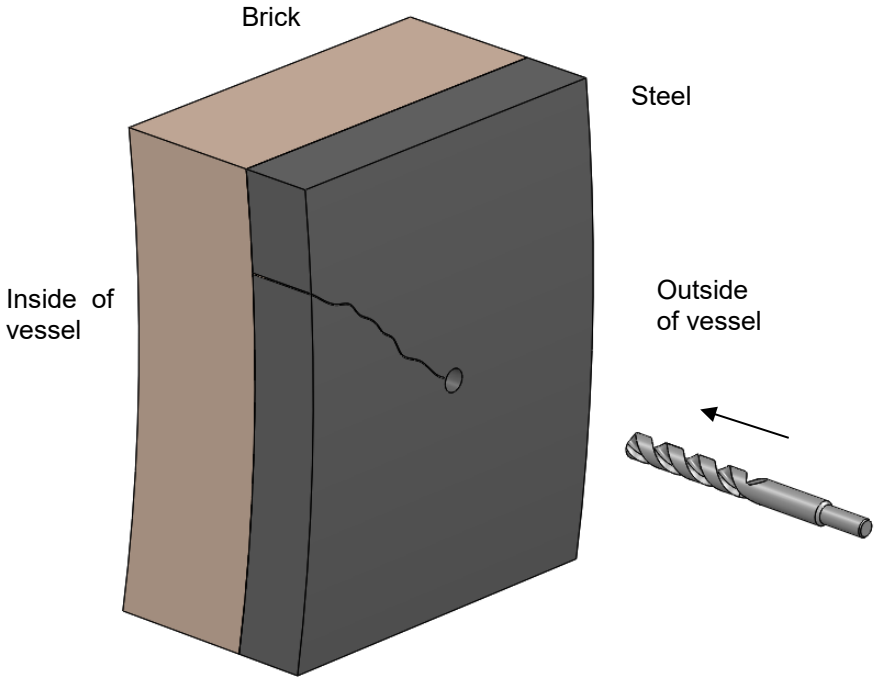


Figure 6.2-7
Drilling of Starting Drill

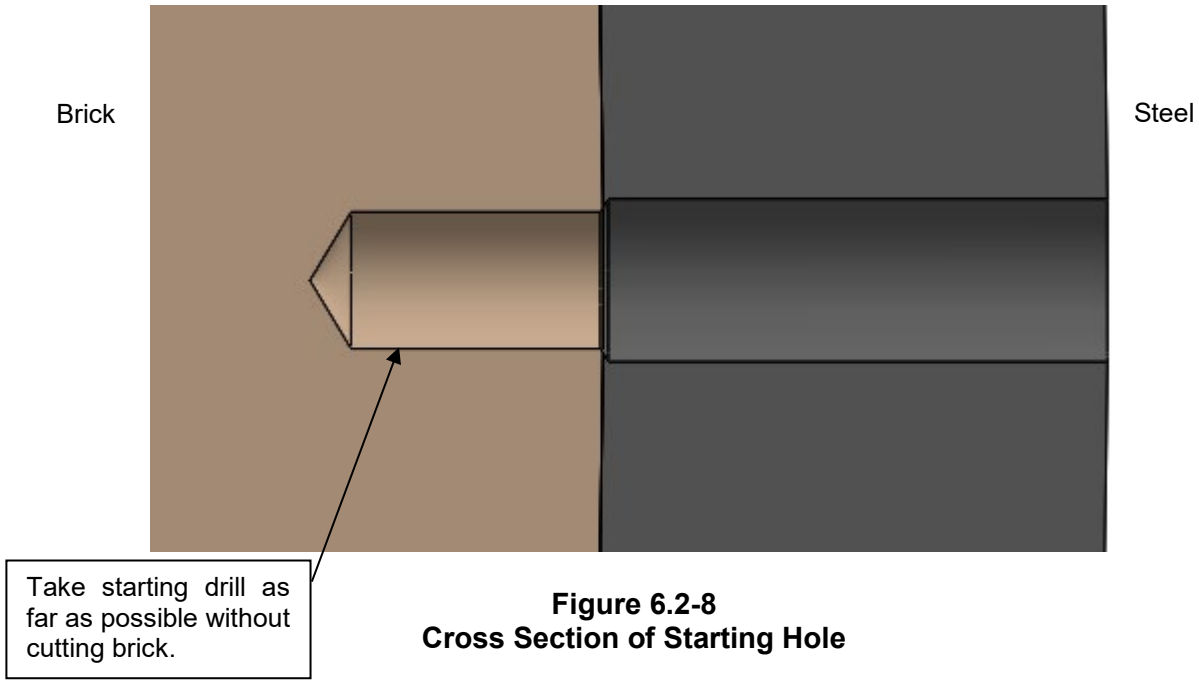


Figure 6.2-8
Cross Section of Starting Hole

6. Using the Starting Reamer BTSR-1533-B-0, ream the hole. Stop drilling when the end of the piloted reamer reaches the end of the steel.
   i. The non-cutting pilot on the reamer is sized to fit the hole produced by the starting drill, as shown in Figure 6.2-9. This piloted reamer is essential for cutting a perfect circular hole for StopCrackEX. Do not skip usage of this Starting Reamer during the process.

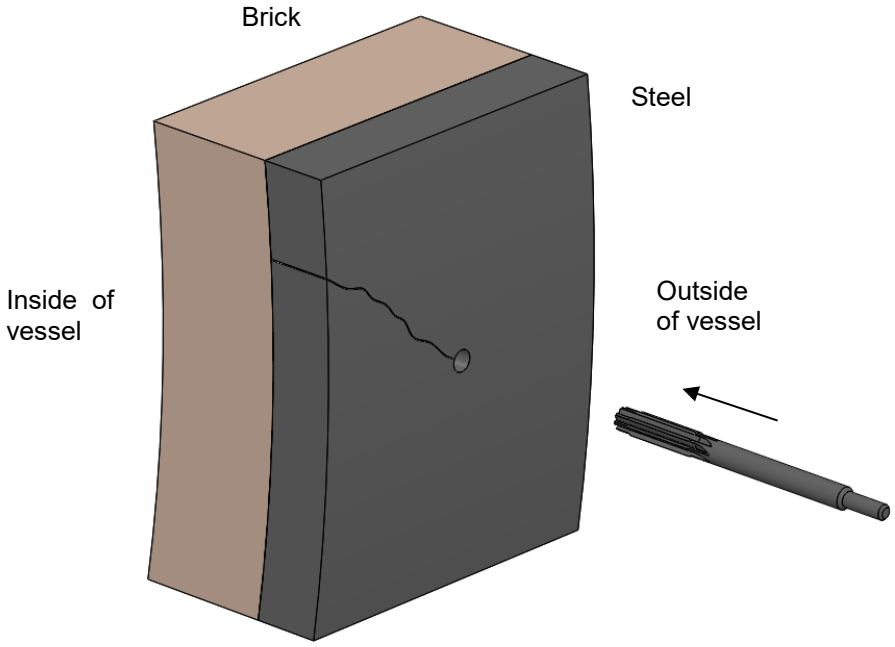
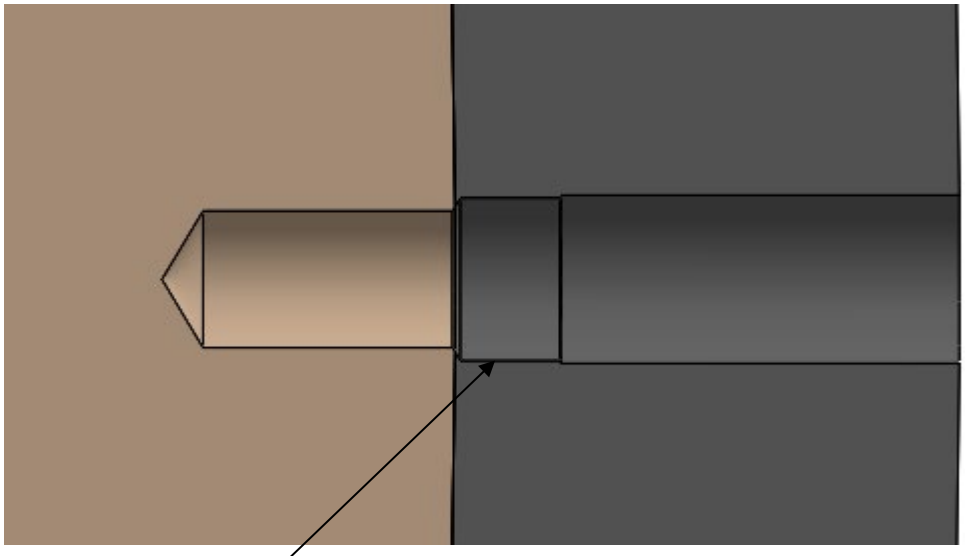


Figure 6.2-9
Reaming of Starting Reamer



Starting reamer will not cut down through to brick because it has pilot.

Figure 6.2-10
Cross Section of Starting Reamer

7. Using the Spiral Reamer BTRS-1533-B-0, complete reaming up to the masonry as shown in Figure 6.2-11. Stop drilling when the end of the spiral reamer reaches the masonry.

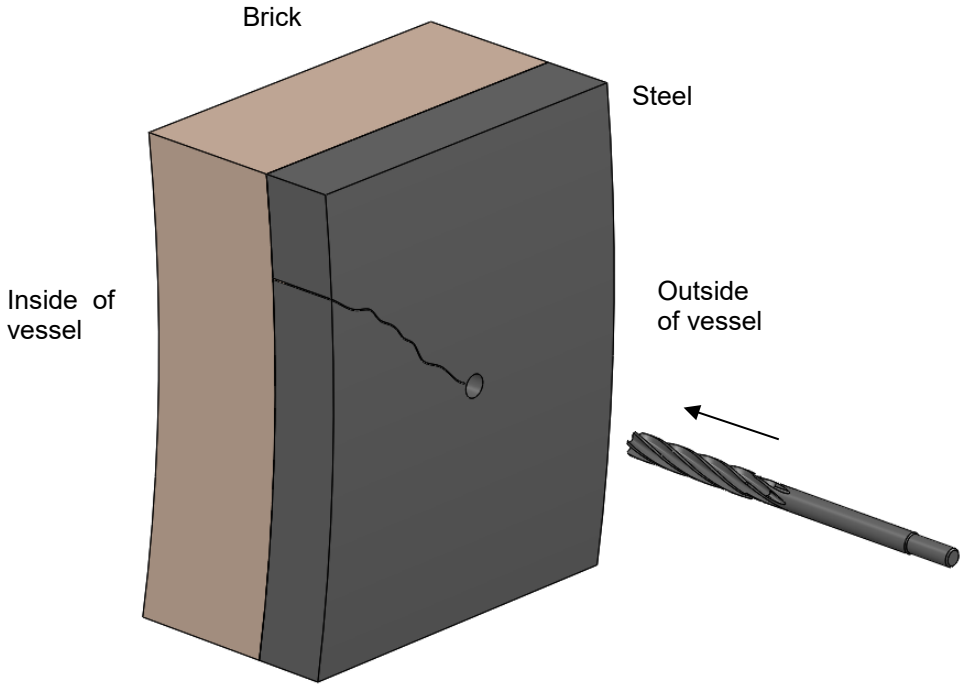


Figure 6.2-11
Reaming of Spiral Reamer

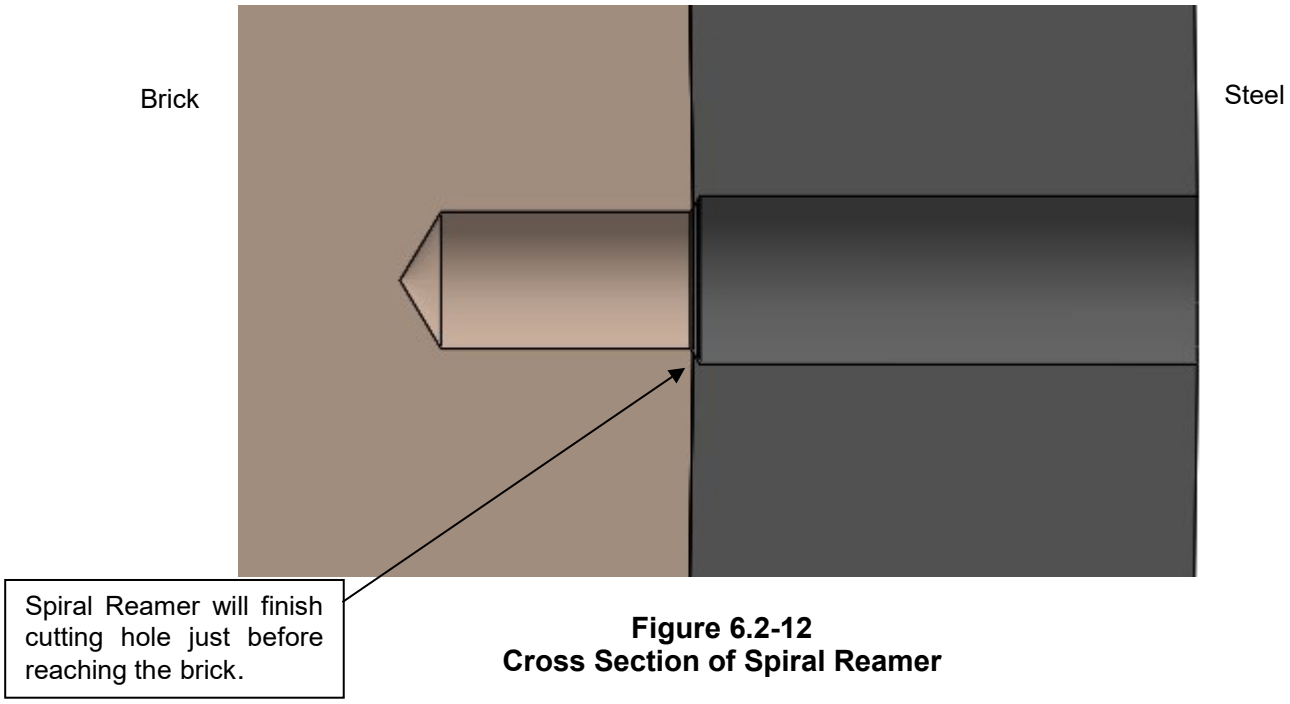


Figure 6.2-12
Cross Section of Spiral Reamer

6.2.2 Checking Hole

1. Verify the starting hole is to size using the blade end of the combination gage BTCG-1533-A-0 as shown in Figure 6.2-13 and 6.2-14. Rotate gage 90 degrees to check for ovality.
   a. If the starting hole is oversize, a contingency kit is included for this purpose. Start with Section 6.2.1 Step 6 with oversize tooling FTI-StopCrackEX-2OS.

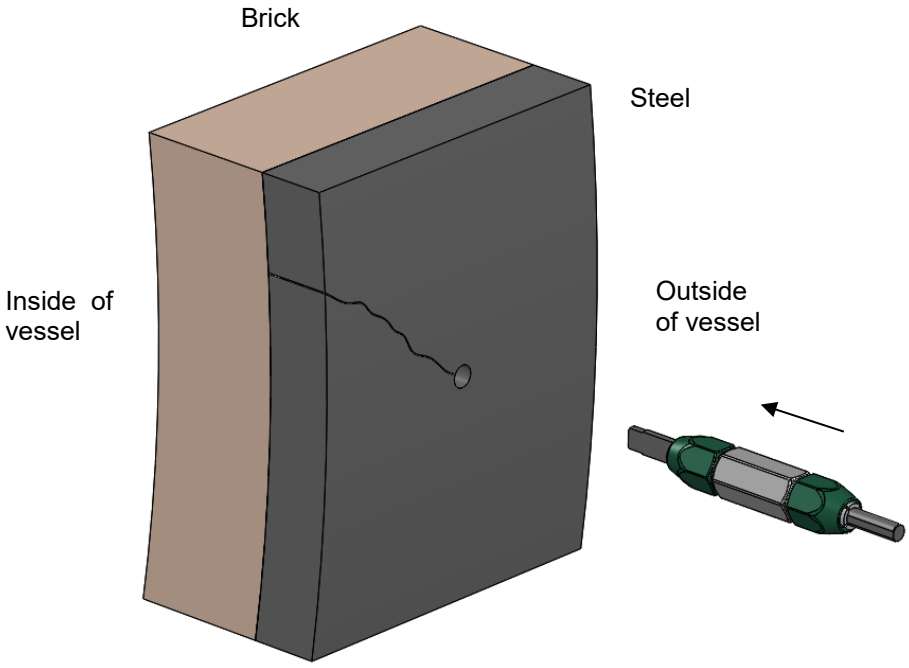
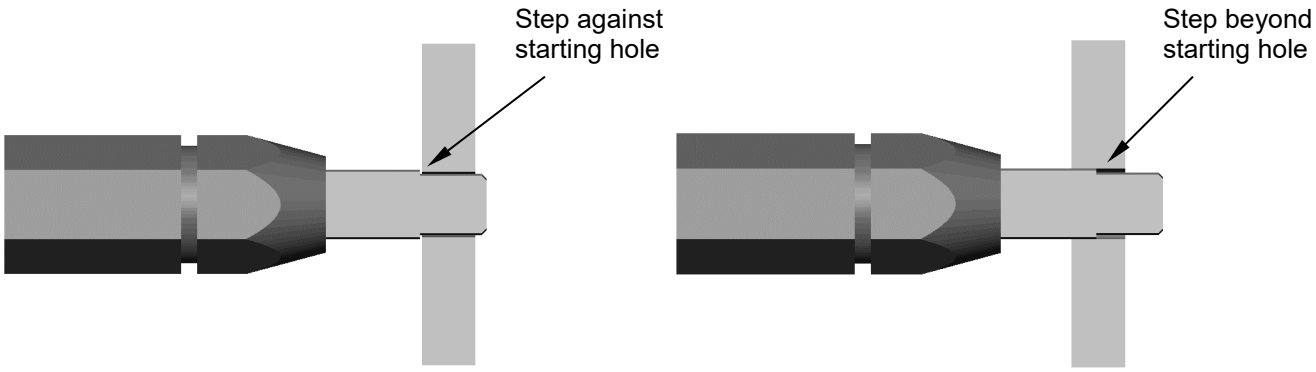


Figure 6.2-13
Hole Diameter Check



View 1
Starting hole within tolerance
ACCEPTABLE

View 2
Starting hole oversize
NOT ACCEPTABLE

Figure 6.2-14
Starting Hole Gage

6.3 StopCrackEX Installation Procedure

6.3.1 Structure Thickness

Determine the thickness of the material CAH drilled. Measure depth of hole with BTSG-1533-A-0 depth pin gage as shown in Figure 6.3-1. In this figure, the steel is 1-1/2 inches thick.

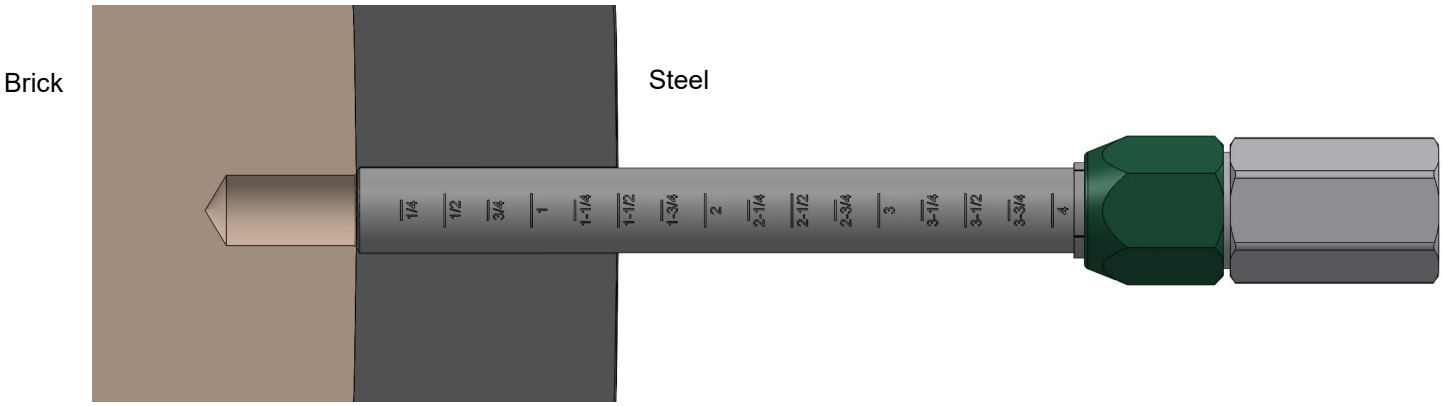


Figure 6.3-1
Hole Depth Measurement

6.3.2 Bushing Configuration

For steel thickness less than 1.5 inches, Table 6.3-1 below indicates which series of bushings are to be stacked together to match to thickness of the material.

Table 6.3-1
Bushing Configuration under 1.50 inch

Steel Thickness	.500 Flanged Bushing FTI-StopCrackEX-BushFL-.500	.250 Bushing FTI-StopCrackEX-Bush-.250	.500 Bushing FTI-StopCrackEX-Bush-.500	.750 Bushing StopCrackEX-Bush-.750
.250		1		
.500	1			
.750	1	1		
1.00	1		1	
1.25	1			1

For steel thickness between 1.50 – 3.00 inches, Table 6.3-2 below indicates which series of bushings are to be stacked together to match to thickness of the material.

Table 6.3-2
Bushing Configuration over 1.50 inch

Steel Thickness	1.50 Flanged Bushing FTI-StopCrackEX-BushFL-1.50	.250 Bushing FTI-StopCrackEX-Bush-.250	.500 Bushing FTI-StopCrackEX-Bush-.500	.750 Bushing StopCrackEX-Bush-.750
1.50	1			
1.75	1	1		
2.00	1		1	
2.25	1			1
2.50	1		2	
2.75	1		1	1
3.00	1			2

Note:

1. If the steel thickness is in-between sizes listed in the tables it is recommended to round up to the nearest thickness. (Ex. 2.125 thick material would use bushings for a 2.25 steel thickness.) Alternatively, the bushing can be trimmed to size.
2. The longest straight bushings should always be on the bottom of the hole adjacent to the brick.
3. Flanged bushings are not required at front of hole, but during pin installation straight bushings could be pushed out of place.
4. If additional corrosion protection is necessary, wet primer may be applied to the bore of the CAH prior to installation of the bushing. The area around the repair can also be primed and painted.

6.3.3 Bushing Installation

1. Clean the hole to remove excess cutting fluid/lubricant, chips, or debris.
2. Using the following steps in Figure 6.3-2, cold expand the StopCrackEX bushing(s) into the hole.

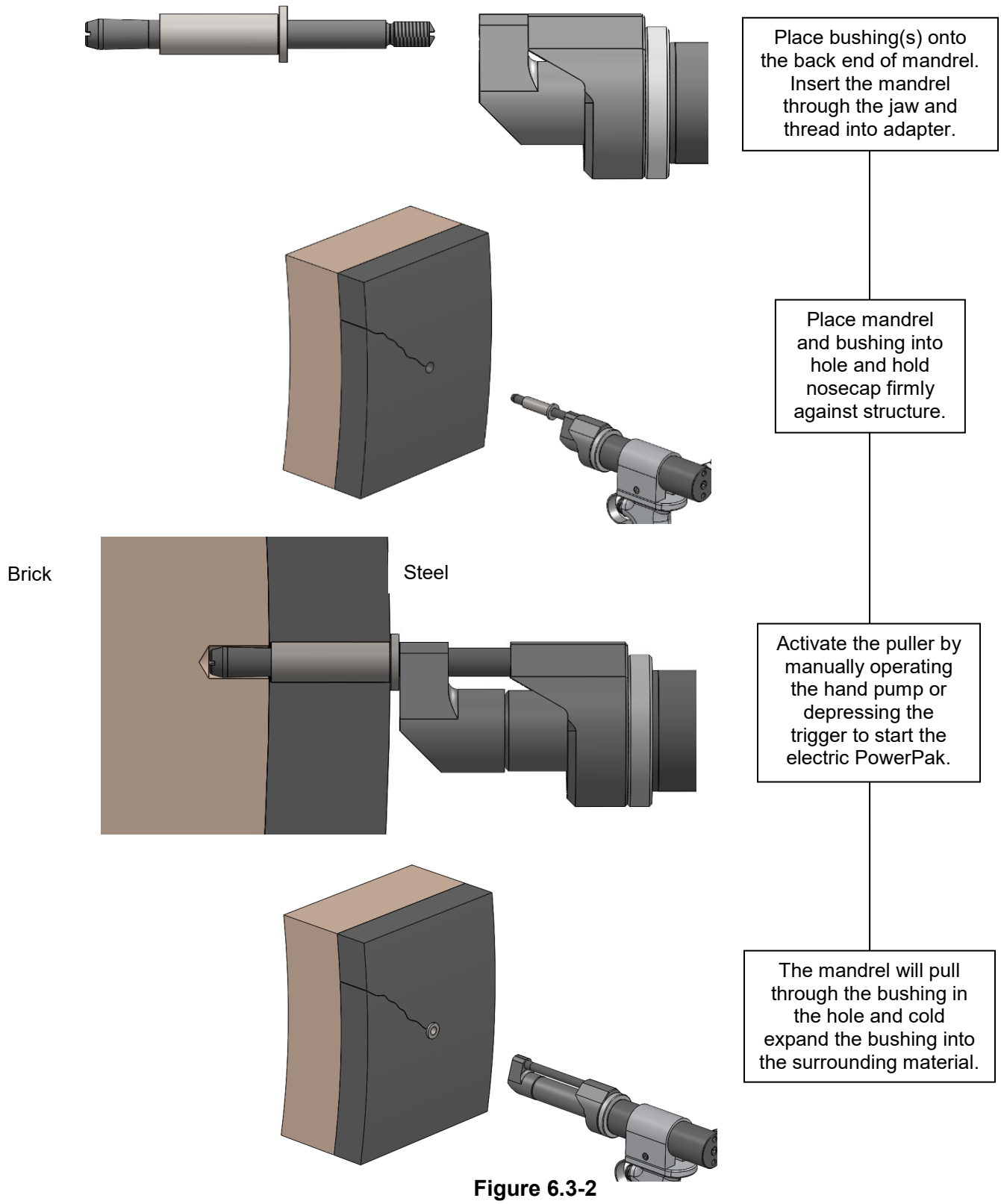


Figure 6.3-2
Bushing Cold Expansion Process

3. Verify cold expansion of bushing with plug gage end of the combination gage BTCG-1533-A-0 as shown in Figure 6.3-3. If the plug gage does not fit into bushing ID, then this installation has not been expanded properly. Here are a few possible scenarios:
   a. If a mandrel is excessively worn (goes through the gage), discard it and select a new one
   b. The steel material is not similar to A36 steel with yield strength under 60 ksi.
   c. The plug gage may be compromised and is out of calibration. If the plug gage was dropped it may have damaged the measuring ends.

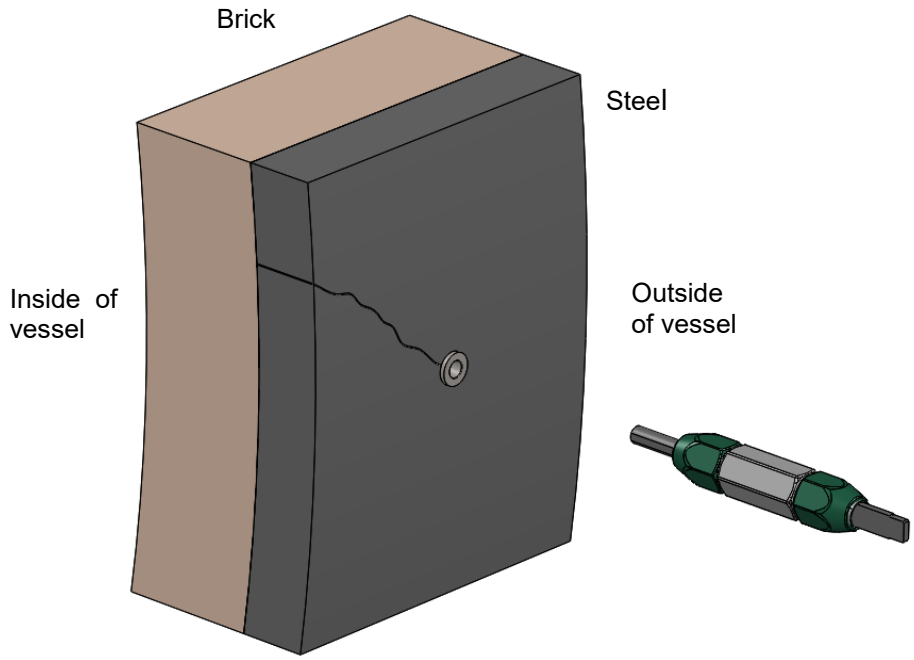


Figure 6.3-3
Bushing Cold Expansion Verification

4. Installation is now complete.

6.3.4 Optional Pin Installation through Bushing

Interference pins are provided in StopCrackEX-2 kits. These interference pins are press-fit into the bushings to plug the hole. These pins are used in applications where sealing between steel surfaces is required. (Ex. Installing StopCrackEX in a kiln wall and preventing leakage through bushing.)

There are different length interference pins based on the steel thickness. Use the table below to select the correct length pin.

Table 6.3-3
Interference Pin Selection

Steel Thickness	Pin
≤ .750	FTI-StopCrackEX-Pin-.750
.750 - 1.50	FTI-StopCrackEX-Pin-1.50
1.50 - 2.25	FTI-StopCrackEX-Pin-2.25
2.25 - 3.00	FTI-StopCrackEX-Pin-3.00

Each pin is designed at a diameter. This is for optimal installation forces. Use of longer pins in shorter thicknesses is not recommended because the pin may fall out under certain circumstances (Ex. steel high temperature cycling).

1. Insert pin with pilot end into bushing. The piloted end has a marking "DN". This helps start the pin alignment properly.

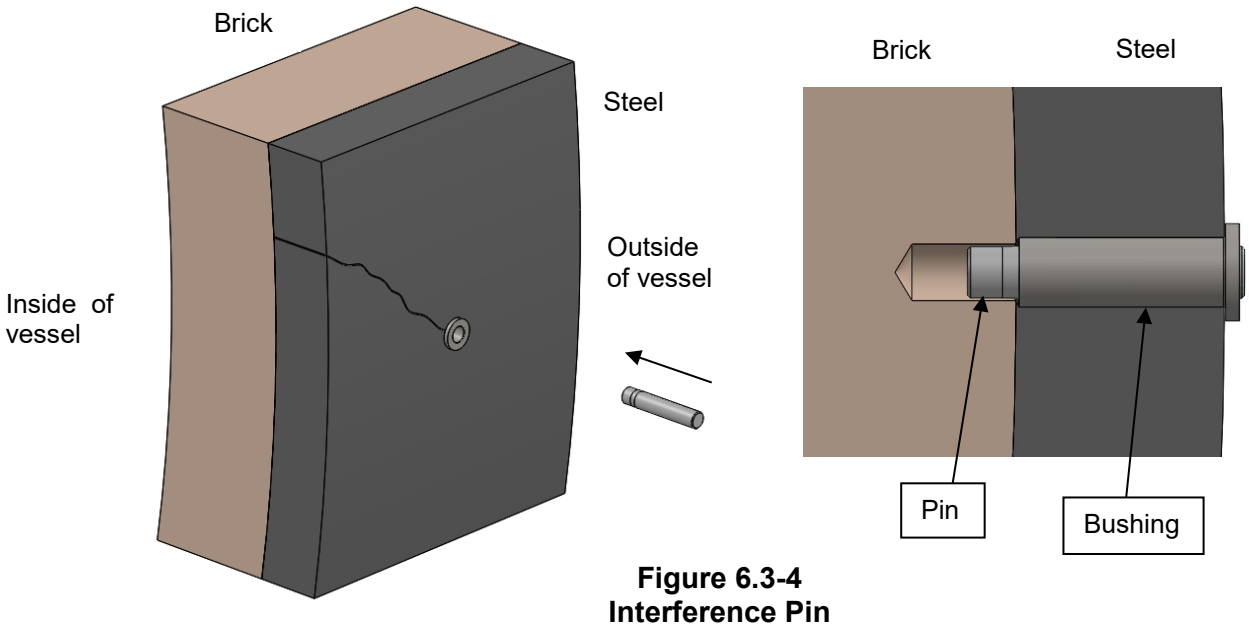


Figure 6.3-4
Interference Pin

2. Press pin into bushing as shown in Figure 6.3-3. The pins for each size (.75, 1.50, 2.25, and 3.00) are intended to be installed flush against the flange of the first bushing. Use air hammer or sledge hammer to drive pins until they stop. Do not hammer pins excessively if pins stop moving. Be aware that pin end can "mushroom" on excessive driving, preventing complete installation into bushing. Overflush pins are acceptable and pins may be trimmed if desired.

   Note: If additional corrosion protection is necessary, the steel pin can to be primed and painted.

6.4 TOOLING OVERVIEW

The tooling required for StopCrackEX-2 of 1/2-inch diameter crack arrest holes is packaged in the kits (FTI-StopCrackEX-2A or FTI-StopCrackEX-2B) shown in Figure 6.4-1. The first kit (-2A) includes a hydraulic puller unit that can be used with the hydraulic hand pump contained in the basic kit or with the optional electric PowerPak. The second kit (-2B) includes the hydraulic Little Brute puller and PowerPak, which requires pressured air. Other tools include a nosecap and jaw assembly, expansion mandrel, and process checking tools to verify the correct starting hole size, correct expansion of the bushing, and the wear condition of the mandrel. Consumable tooling includes a range of different length 1/2-inch diameter bushings and interference pins for plugging the bushing.

The StopCrackEX pre-lubricated stainless steel bushings are manufactured with the correct inside and outside diameters for the 1/2-inch CAH. Bushing lengths vary and should be selected from those provided in the kit corresponding to the thickness of the structure they are to be installed in. See Section 6.3.2 for determining bushing lengths needed. Oversize bushings are included in the basic kit.

A complete list of the tooling for both StopCrackEX-2 Kits are available in Table 6.4-1 on the next page. The Oversize Tooling Kit list is in Table 6.4-2.

Figure 6.4-1
StopCrackEX-2A Kit

Table 6.4-1
StopCrackEX-2 Tools and Equipment

Quantity	Part Number	Description
	FTI-StopCrackEX-2A	**Steel Vessel Crack Repair Kit**
1	CP5-H-30-SCX	Hydraulic puller unit
1	FTP-19	Hand pump
1	6599-002	Tooling case assembly
1	1187-760	Flashlight
1	2720-117	Manual
1	FTI-StopCrackEX-CapAssy-.50	Nosecap assembly sub-kit
1	FTI-StopCrackEX-Tools-2	Tooling sub-kit
2	FTI-StopCrackEX-BushFL-.500	.500 inch flanged bushings, 15 in box
2	FTI-StopCrackEX-BushFL-1.50	1.50 inch flanged bushings, 10 in box
1	FTI-StopCrackEX-Bush-.250	.250 inch bushings, 25 in box
1	FTI-StopCrackEX-Bush-.500	.500 inch bushings, 25 in box
1	FTI-StopCrackEX-Bush-.750	.750 inch bushings, 15 in box
1	FTI-StopCrackEX-Pin-.750	.750 inch pins, 20 in box
2	FTI-StopCrackEX-Pin-1.50	1.50 inch pins, 10 in box
1	FTI-StopCrackEX-Pin-2.25	2.25 inch pins, 15 in box
1	FTI-StopCrackEX-Pin-3.00	3.00 inch pins, 15 in box
1	FTI-StopCrackEX-2OS	Oversize sub-kit
	FTI-StopCrackEX-2B	**Steel Vessel Crack Repair Kit w/ powered hydraulics** [+]
1	LB-30	Little Brute
1	FT-20	PowerPak
1	6599-003	Tooling case assembly
1	1187-760	Flashlight
1	2720-117	Manual
1	BTL-1533-B-0	Nosecap
1	FTI-StopCrackEX-Tools-2	Tooling sub-kit
2	FTI-StopCrackEX-BushFL-.500	.500 inch flanged bushings, 15 in box
2	FTI-StopCrackEX-BushFL-1.50	1.50 inch flanged bushings, 10 in box
1	FTI-StopCrackEX-Bush-.250	.250 inch bushings, 25 in box
1	FTI-StopCrackEX-Bush-.500	.500 inch bushings, 25 in box
1	FTI-StopCrackEX-Bush-.750	.750 inch bushings, 15 in box
1	FTI-StopCrackEX-Pin-.750	.750 inch pins, 20 in box
2	FTI-StopCrackEX-Pin-1.50	1.50 inch pins, 10 in box
1	FTI-StopCrackEX-Pin-2.25	2.25 inch pins, 15 in box
1	FTI-StopCrackEX-Pin-3.00	3.00 inch pins, 15 in box
1	FTI-StopCrackEX-2OS	Oversize sub-kit
	FTI-StopCrackEX-Tools-2	**StopCrackEX-2 Tooling Kit**
1	BTG-1533-A-0	Mandrel check gage
1	BTCG-1533-A-0	Combination hole check gage
2	BTM-1533-A-0-2.25L	Mandrel
1	1187-762	Center hole punch
2	BTPD-1533-B-0	Pilot drill .2500 inch
2	BTSD-1533-B-0	Starting drill .4844 inch
2	BTSR-1533-B-0	Starting reamer .5000 inch, piloted
2	BTRS-1533-B-0	Reamer Spiral .5000 inch
1	1187-761	Depth gage
1	BTSG-1533-A-0	Depth pin gage

Table 6.4-2
StopCrackEX-2 Oversize Tools and Equipment

Quantity	Part Number	Description
	FTI-StopCrackEX-2OS	**StopCrackEX-2 Oversize Kit**
1	FTI-StopCrackEX-BushOS-2A	Oversize Bushings
1	BTSR-1533-B-1	Oversize Starting Reamer .5156 inch piloted
1	BTRS-1533-B-1	Oversize Reamer Spiral .5156 inch
1	BTCG-1533-A-1	Oversize Hole Check Gage
	FTI-StopCrackEX-BushOS-2	**Oversize Bushing Sub Kit**
1	FTI-StopCrackEX-BushFLOS-.500	.500 inch flanged oversize bushings, 10 in box
1	FTI-StopCrackEX-BushFLOS-1.50	1.50 inch flanged oversize bushings, 5 in box
1	FTI-StopCrackEX-BushOS-.250	.250 inch oversize bushings, 5 in box
1	FTI-StopCrackEX-BushOS-.500	.500 inch oversize bushings, 5 in box
1	FTI-StopCrackEX-BushOS-.750	.750 inch oversize bushings, 5 in box

Note:

1. Any part can be purchased within the kits of the noted quantities, instead of purchasing the entire kit. Price breaks may apply, contact FTI. Purchasing entire kit will include cases with cut out foam.
2. All bushing and pin sizes are lengths. Bushings and pins are either nominal or oversize.
3. All drills and reamers are for a 3/8-inch chuck.
4. [+] FTI-StopCrackEX-2B Kiln Standard Kit requires air pressure (90 – 120 psi) at recommended 20 CFM.