401 Andover Park East
Seattle, Washington 98188-7605
USA (206) 246-2010

FATIGUE TECHNOLOGY INC.

StopCrackEX™

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

Part Number 2720-117

October 8, 2014

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 a pending U.S. Patent. This document and information contained within is proprietary to Fatigue Technology Inc (FTI). 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.

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

TABLE OF CONTENTS

FIGURES

TABLE OF CONTENTS (Continued)

1.0 INTRODUCTION

This manual specifies the required tooling and procedures for installation of Fatigue Technology Inc. (FTI) StopCrackEX to arrest cracks in steel bridges and 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 bridges and structures. The process is simple to apply and is quicker to install than some present 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 patent pending 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 stops 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 2.1, into which an initially clearance fit specially designed stainless steel bushing 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.

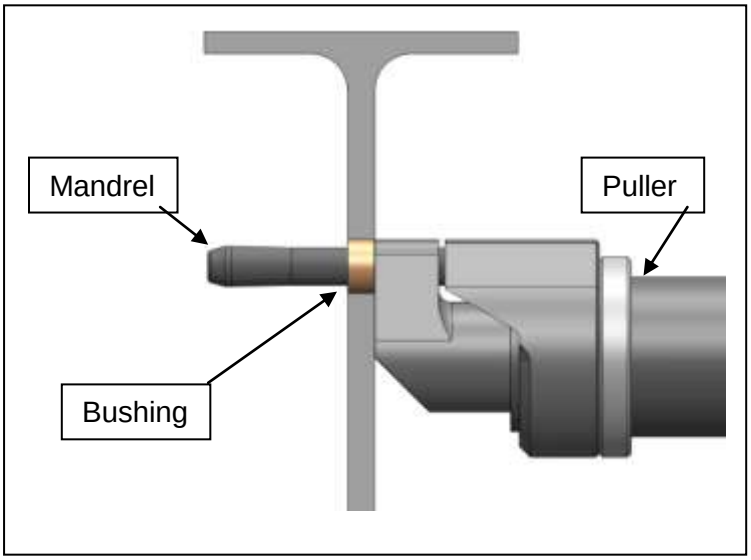


Figure 2.0-1
Expansion of Bushing into Hole

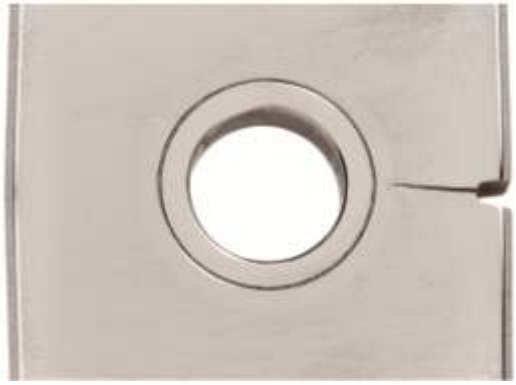


Figure 2.0-2
StopCrackEX Bushing Placed ahead of Crack Tip in a Test Coupon

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.

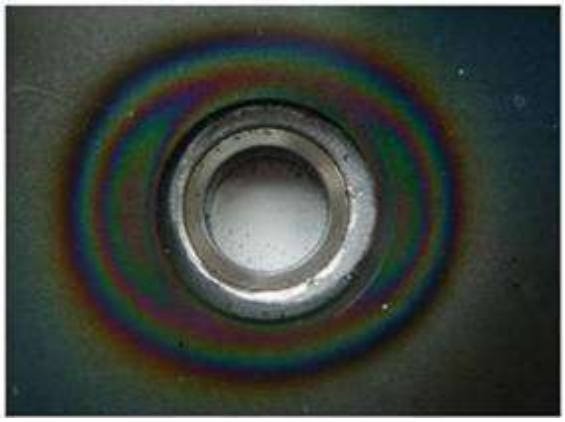


Figure 2.0-3
Residual Compressive Stress Field around a StopCrackEX Bushing
(Viewed through a Photoelastic Coating)

2.1 Location of Crack Arrest Hole for StopCrackEX

The procedure covers installation of StopCrackEX in two different cracking scenarios:
a. Cracks growing in the webs or flanges of steel beams as shown in Figure 2.1-1, and
b. Cracks growing along a weld or bend radius as shown in Figure 2.1-2.

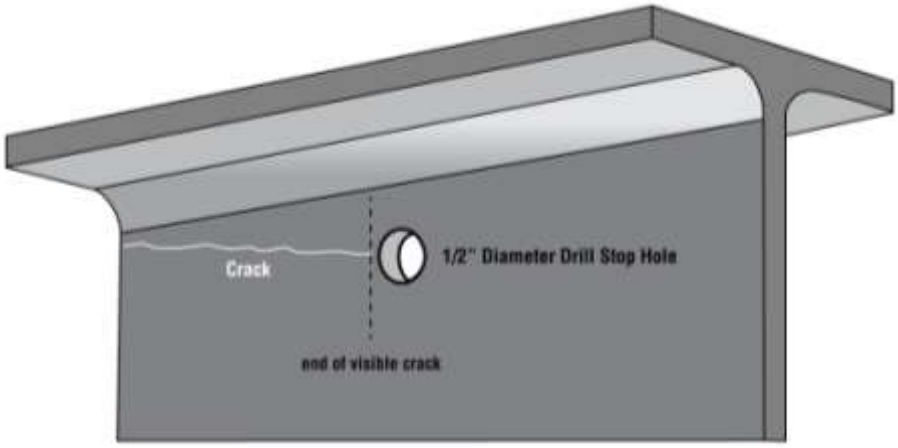


Figure 2.1-1
Crack in Flange or Web

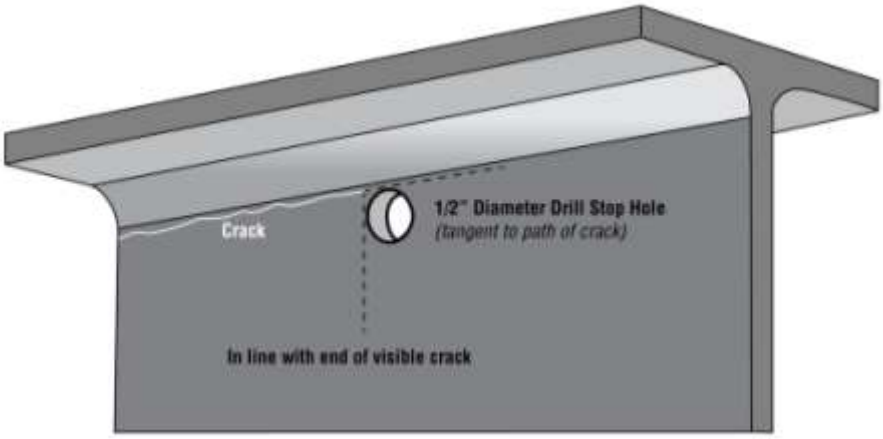


Figure 2.1-2
Crack Growing along Weld or Bend Radius

These two different cracks require different placement of StopCrackEX relative to the crack tip. The actual process is similar for both cases and includes the following steps using StopCrackEX tooling provided in the kit:

3.0 BRIDGE AND STEEL STRUCTURE PARAMETERS

3.1 Structure Material

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

3.2 Bushing Material

StopCrackEX bushings are stainless steel.

3.3 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 starting reamer and hole check gage. The hole needs to 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 7.0-2 details the kit contents and kit part number to order.

3.4 Structure Thickness and Bushing Length Selection

The maximum structure thickness allowed is currently one inch. Bushings lengths can be equal to the thickness of the structure and up to .250-inch overflush, with the exception of the higher yield strength bushings noted in Section 3.1, which are limited to .050-inch overflush. Trimming of bushing to the desired length before installation is acceptable if required. To avoid reducing the effectiveness of arresting crack growth, bushings should not be installed underflush.

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.

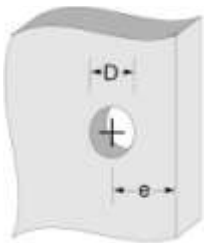


Figure 3.5-1
Crack Arrest Hole Edge Margin

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.

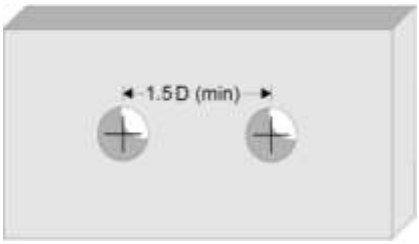


Figure 3.6-1
CAH Hole Spacing

4.0 TOOLING

All of the tooling required for StopCrackEX of 1/2-inch crack arrest holes is packaged in the kit (FTI-StopCrackEX-1A) shown in Figure 4.0-1. 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, the expansion mandrel, and a range of different length 1/2-inch diameter bushings, as well as process checking tools to verify the correct starting hole size, correct expansion of the bushing, and the wear condition of the mandrel. Tooling appropriate for other size crack arrest holes will be included at a later date.

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.

A complete list of the tooling contained in the FTI-StopCrackEX-1A Kit is in Table 7.0-1.

Figure 4.0-1
StopCrackEX Kit

5.0 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 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 ELECTRIC POWERPAK OR RELIEVE THE PRESSURE IN THE HAND PUMP. The electric 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 electric 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.

6.0 StopCrackEX INSTALLATION PROCEDURE

The tooling used in the StopCrackEX procedure is the same for both a crack growing in the base metal of a beam web or flange as well as for cracks growing along a weld or bend radius. The standard CAH used with the nominal StopCrackEX system is a 1/2-inch diameter hole. The difference between the two crack locations is the placement of the CAH with respect to the crack tip as detailed in the following paragraphs. Using approved nondestructive inspection (NDI) technique, locate and mark the end of the crack. The CAH will be located ahead of the crack tip as shown in Section 6.1.

6.1 Cracks in Web or Flange

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 6.1-1.

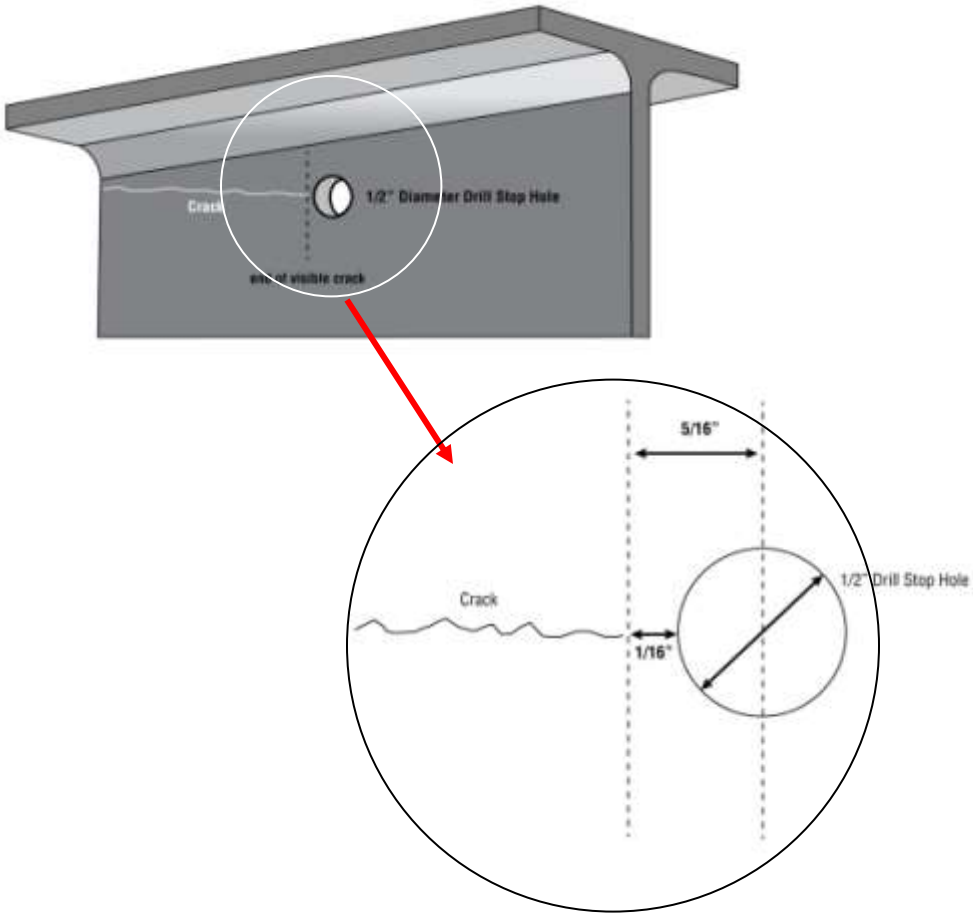


Figure 6.1-1
Crack Arrest Hole Placement for Crack in Web or Flange

6.2 Cracks Growing along a Weld or Bend Radius

In the case of a crack growing along a weld or bend radius, 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 6.2-1 for the 1/2-inch StopCrackEX bushing. The purpose of this is to not cut into the weld and compromise the strength of the welded joint. 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.

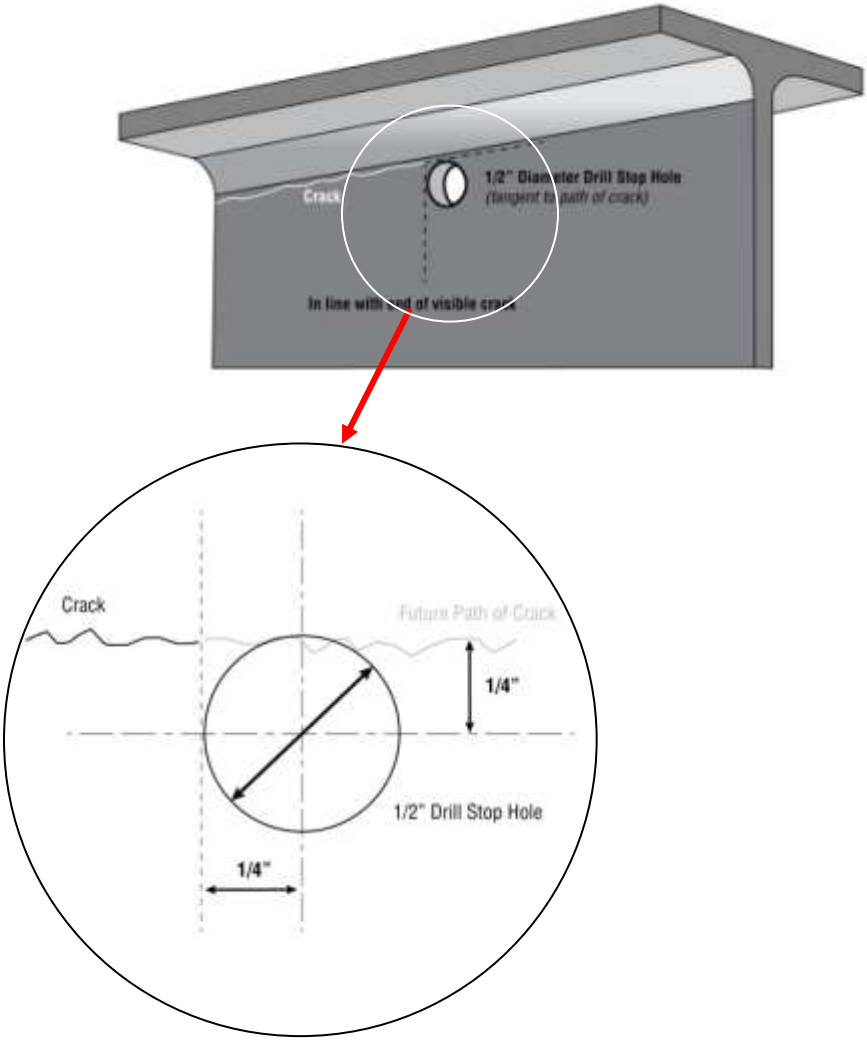


Figure 6.2-1
Location of Crack Arrest Hole for Crack along Weld or Bend Radius

6.3 Process Procedure

Once the location of the center of the StopCrackEX CAH has been determined in relation to the crack tip, proceed as follows:

1. Assemble the puller and tooling, without the bushing, using the following steps as shown in Figure 6.3-1.
   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 to lock in place.
   iv. Thread jaw into the puller and align with the mandrel adapter.
   The puller is now ready to use.

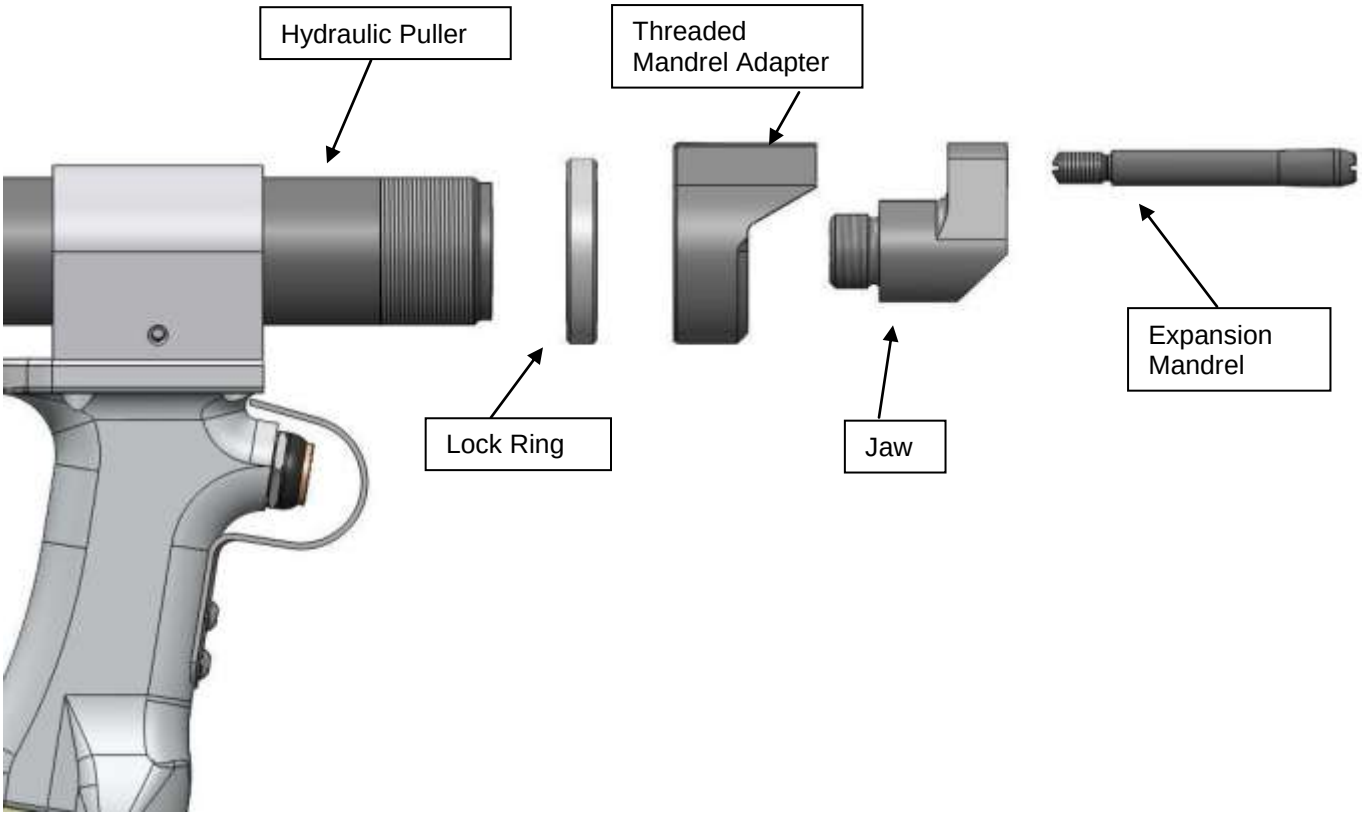


Figure 6.3-1
Tooling Setup

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.

4. Drill a pilot hole at the marked center position using the Pilot Drill BTPD-1533-A-0. Use of 1187-762 Center Punch is optional prior to drilling pilot hole.

5. Using the Starting Drill BTSD-1533-A-0, drill starting hole as shown in Figure 6.3-2.

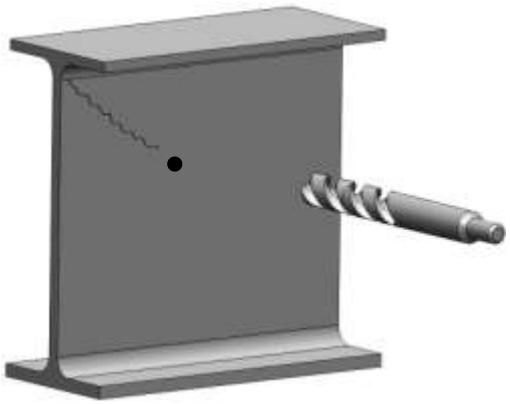


Figure 6.3-2
Starting Hole Drilling

6. Using the Starting Reamer BTSR-1533-A-0, ream the hole to the correct 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 6.3-3. If required, clean the hole to remove excess cutting fluid/lubricant.

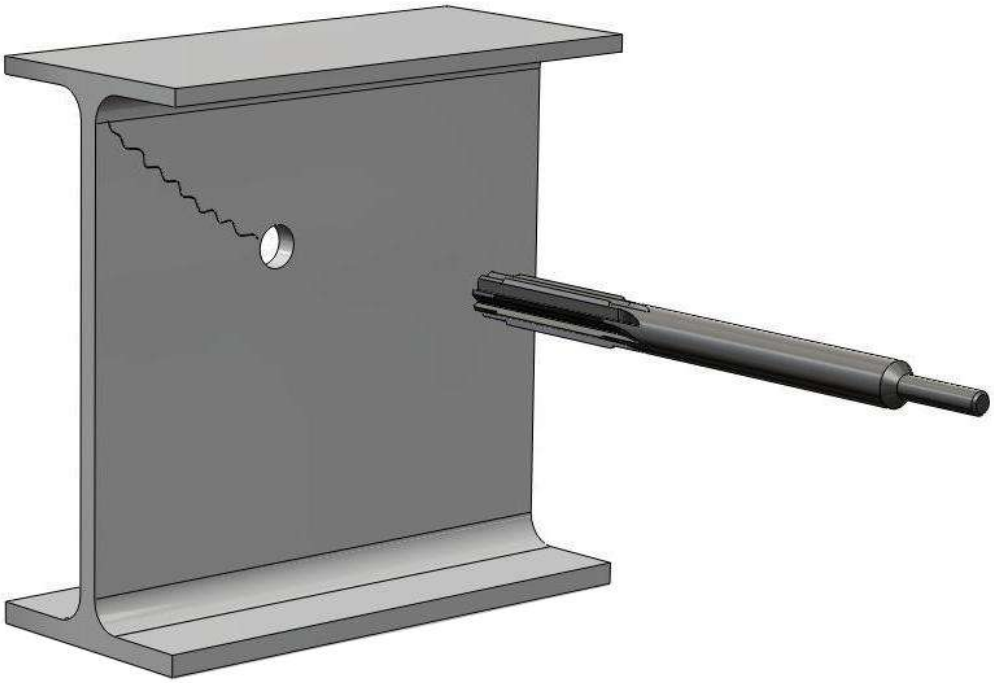


Figure 6.3-3
Pilot Hole Ream

7. Verify the correct starting hole using the blade end of the combination gage as shown in Figure 6.3-4. Rotate gage 90 degrees to check for ovality. Note: If the starting hole is oversize, contact Fatigue Technology Inc.

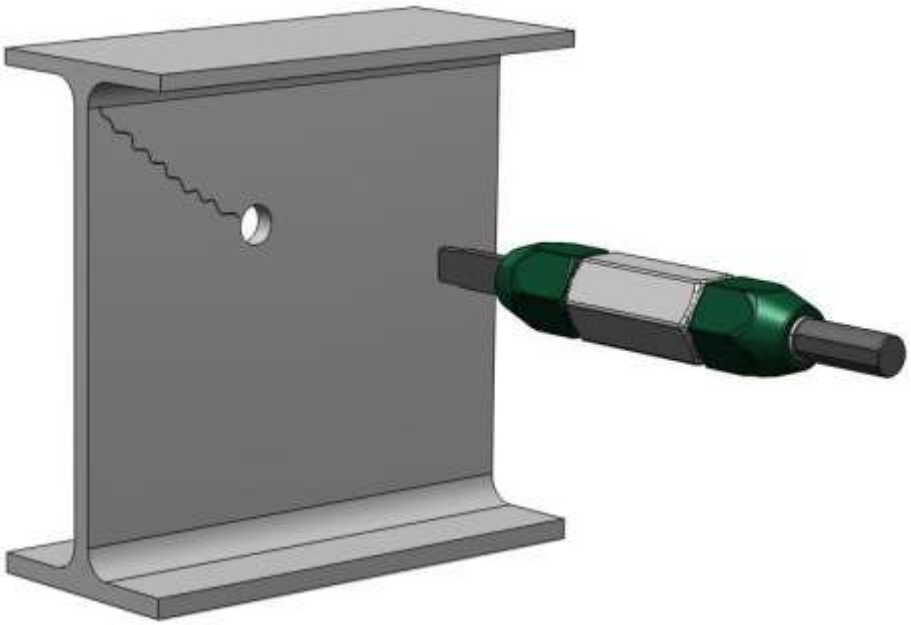


Figure 6.3-4
Hole Diameter Check

8. Determine the thickness of the material in which the crack is located (T). A depth gage rule is provided in the basic kit for this purpose, 1187-761.

9. Select the correct length bushing or trim a bushing to match to thickness of the material. Note: The bushing may be overflush by up to 0.250 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.

10. Check the mandrel major diameter for wear. Insert the mandrel into the mandrel gage. If the mandrel is excessively worn and goes through the check fixture, discard the mandrel and select a new mandrel (Figure 6.3-5).

View 1
ACCEPTABLE

View 2
UNACCEPTABLE

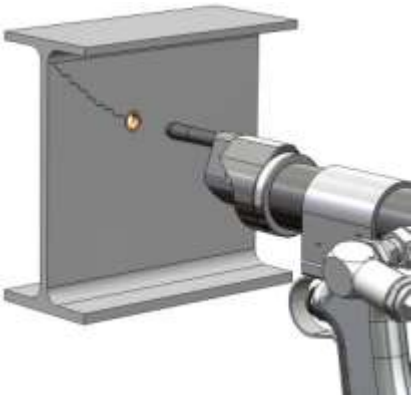
Figure 6.3-5
Check Mandrel for Wear

11. Using the following steps in Figure 6.3-6, cold expand the StopCrackEX bushing into the hole.

Place bushing 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 6.3-6
Bushing Cold Expansion Process

12. Verify cold expansion of bushing with the plug gage end of the combination gage as shown in Figure 6.3-7.

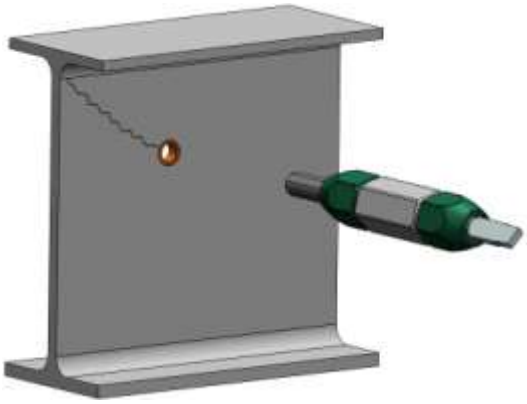


Figure 6.3-7
Bushing Cold Expansion Verification

13. Installation is now complete.

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.

7.0 BUSHING MODEL NUMBER DESCRIPTION

Figure 7.0-1 shows how the model number is determined.

Figure 7.0-1
StopCrackEX Bushing Model Number

A complete list of the tooling for StopCrackEX is available in Table 7.0-1 on the next page.

Table 7.0-1
StopCrackEX Drill Stop Repair Tools and Equipment
(Kit # FTI-StopCrackEX-1A)

Quantity	Part Number	Description
	FTI-StopCrackEX-1A	**StopCrackEX Basic Kit**
1	CP5-H-30-SCX	Hydraulic puller unit
1	FTP-19	Hand pump
1	6599-001	Equipment and tooling case assembly
1	1187-760	Flashlight
1	2720-117	Manual
1	FTI-StopCrackEX-Tools	Tooling sub-kit
1	FTI-StopCrackEX-Cap Assembly - .50	Nosecap assembly sub-kit
1	FTI-StopCrackEX-Bush - .250	Plastic storage case including 25 bushings
1	FTI-StopCrackEX-Bush - .437	Plastic storage case including 25 bushings
1	FTI-StopCrackEX-Bush - .500	Plastic storage case including 25 bushings
1	FTI-StopCrackEX-Bush - .750	Plastic storage case including 15 bushings
	FTI-StopCrackEX-Tools	**StopCrackEX Tooling Kit**
1	BTG-1533-A-0	Mandrel check gage
1	BTCG-1533-A-0	Hole check gage
2	BTM-1533-A-0	Mandrel
2	BTPD-1533-A-0	Pilot drill 1/4-inch with 3/8-inch chuck attachment
2	BTSD-1533-A-0	Starting drill .4844 inch with 3/8-inch chuck attachment
2	BTSR-1533-A-0	Starting reamer .5000 inch with 3/8-inch attachment
1	1187-761	Depth gage
1	1187-762	Center hole punch
*	**FTI-StopCrackEX-Cap Assembly - .50**	**Puller Nosecap Assembly Sub-Kit**
1	CP5OC-8-SCX	Nosecap
1	CP5TA-16-SCX	Threaded mandrel adapter
*	**FTI-StopCrackEX-Bush - .250**	**Bushing Sub-Kit**
25	BTB-1533-A-0-.250	1/2-inch diameter bushing .250 inch length
1	1187-757	Plastic storage case
*	**FTI-StopCrackEX-Bush - .437**	**Bushing Sub-Kit**
25	BTB-1533-A-0-.437	1/2-inch diameter bushing .437 inch length
1	1187-757	Plastic storage case
*	**FTI-StopCrackEX-Bush - .500**	**Bushing Sub-Kit**
25	BTB-1533-A-0-.500	1/2-inch diameter bushing .500 inch length
1	1187-757	Plastic storage case
*	**FTI-StopCrackEX-Bush - .750**	**Bushing Sub-Kit**
15	BTB-1533-A-0-.750	1/2-inch diameter bushing .750 inch length
1	1187-757	Plastic storage case

Note: * Respective size bushings can be purchased in kits of the noted quantities by ordering this part number**.**

Table 7.0-2
StopCrackEX Oversize Kit Tools and Equipment
(Kit # FTI-StopCrackEX-1AOS)

Quantity	Part Number	Description
	FTI-StopCrackEX-1AOS	**StopCrackEX Oversize Kit**
1	FTI-StopCrackEX-BushOS-A	Oversize bushings
1	BTSR-1533-A-1	Oversize Starting Reamer .5156 inch with 3/8-inch attachment
1	BTCG-1533-A-1	Oversize Hole Check Gage
	FTI-StopCrackEX-BushOS-A	**Oversize Bushing Sub Kit**
5	BTB-1533-A-1-.250	1/2-inch diameter oversize bushing .250 inch length
5	BTB-1533-A-1-.500	1/2-inch diameter oversize bushing .500 inch length
5	BTB-1533-A-1-.750	1/2-inch diameter oversize bushing .750 inch length